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HISTORY OF MILITARY PYROTECHNICS IN WORLD WAR

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MILITARY PYROTECHNICS.

This handbook is issued with the understanding that it shall at all times be given the care accorded confidential information; that no portion of it shall be published by paraphrase or otherwise, and that it shall be returned to the office of the Chief of Ordnance when the person to whom it is issued leaves the military service of the United States.

The facts have been collected by W. N. Dickinson from the official records, cablegrams, and reports, and have been supplemented by information obtained from officers in the several branches of the military establishment, whose services were rendered both in the United States and with the American Expeditionary Forces.

The matter included in the present pamphlet was originally compiled in conjunction with the "History of Trench Warfare Matériel" and references to it will be found in that history.

For convenience in publication and in use, it has been separated into the present form.

C. C. WILLIAMS,
Maj. Gen., Chief of Ordnance, U. S. A.

CONTENTS.

	Page.
CHAPTER I. Pyrotechnics	5
CHAPTER II. Production of pyrotechnics	29
APPENDIX:	
Tactical use of foreground illumination	37
List of reference publications	40

PHOTOGRAPHS.

	Faces page.
Flag and signal rockets	16
Testing incendiary rocket	16
Types of signal cartridges, 25 mm. and 35 mm	18
Very signal pistol, with cartridge	20
Very pistol and cartridge	20
Types of Ordnance signal lights	22
Smoke torch	23
Airplane flare, Mark I	24
One day's output of flare bombs for the Signal Corps	24
Michelin parachute flare	25
Michelin parachute, bomb and container	25
Illuminating bomb, Mark I	26
Incendiary drop darts, airplane type	26

MILITARY PYROTECHNICS.

Chapter I.

PYROTECHNICS.

Military pyrotechnics are employed for communication and illumination.

In the former of these two uses, they play their part in the great system of understanding on the basis of which modern warfare is waged. While included within the trench warfare matériel, pyrotechnics are employed also in open warfare, and both from the ground and from planes in the air.

In an unobtrusive corner in the National Museum in Washington is a large war map, brilliantly lighted and confronted by four conference chairs. On this map are lines and tabs indicating the entire Western Front with the positions of the several armies on both sides of the line at the time of the signing of the armistice. Indicated thereon are the headquarters, the reserve units, and the distribution of the troops on the fighting front by divisions. This represents the concentration of information as to the disposition of the various divisions, as obtained by telegraph, telephone, and by dispatches.

Apart from the reserves, it represents the information which was constantly being gathered through the intermediate channels from the fighting front. This front might consist of long lines of trenches, open country, woods, mountains, or waterways. The front might be quiet or in vigorous action, and the difficulties of establishing and maintaining contact for immediate communication varied with the degree of action, with weather conditions and the time of night or day. In time of movement instant information was of the utmost importance. On it depended the opportunity for surprise, knowledge of the need for support or the necessity for change in plans. Battle without chaos is dependent upon complete understanding and it is this understanding only which prevents chaos. The information to establish this understanding was conveyed by ground telegraph, wireless telegraph, telephone, buzzerphone, written dispatches, messengers on cycles and motor cycles, Cavalry riders, runners, electric flashlights or other lights or projectors using either intermittent flashes or color, reflection of the sun in mirrors, whistles, horns, bugles, message grenades, flag signals, arm movements, dogs, carrier pigeons, photographs, messages dropped from airplanes, panels laid on the ground and observed from airplanes, and pyrotechnics.

It was necessary that the information be transmitted from the front to the rear, from the rear to the front, and laterally between units cooperating in the same action. Observation posts, balloons, airplanes, and practically every part of the field were involved in this necessity for communication. Reliance could not be placed upon one method only of communication, as any one method might be rendered impotent. Wires might be cut, a balloon or an airplane brought down, messengers killed or cut off, and observation posts destroyed. One of the principles in warfare is that an observation post which is not fired upon is not necessarily one which has not been located. It is indeed considered best to leave unmolested stations which have been located in order that the enemy may not construct others better protected or disguised. It often happens that these stations are not destroyed until the day when it will be really advantageous to deprive the enemy of their use, as in the case of attack.

In the forward areas a complete understanding must exist between each Infantry unit on the front and its supporting Artillery, the Air Service, Trench Mortar batteries, the Chemical Warfare units, the sappers who are about to explode mines, and with the plans and operations of the units immediately adjoining. As actions are now planned and carried out, the establishment of uniform time for the setting of watches to permit of the carrying out of orders on exact schedule is of the utmost importance. With troops widely scattered through a labyrinth of trenches, shell holes, woods, ravines, and protected positions, this establishment of time must take place, in so far as possible, from a single source and at a moment sufficiently close to the major operation to reduce to a minimum any errors resulting from variation in the functioning of individual timepieces. If this complete understanding is not had, units fail to cooperate or may be subjected to the fire of their own artillery, or the artillery, machine gun, or mortar fire of adjoining units.

This whole subject of communication and intercommunication is treated broadly under the tactical instructions in "Liaison for all Arms."

Pyrotechnics are visible (more or less) either by night or by day, with the exception that those with yellow or red smoke and flag rockets can not always be seen to advantage at night. Their meaning may be conveyed by the form, color, or numerical distribution of burst. When used as ground signals it will be observed that they are more liable to be employed in the very forefront of the action at a time when seconds count and when the lives of many men or the success of an individual movement depends upon their proper functioning. When it is recalled that these pyrotechnics when in the possession of forward units may be carried through trenches knee-deep in water, through a deluge of rain, or across marshy country, it

will be clear that their protection from dampness is imperative. They may be fired at night, and more frequently are fired at night than by day, and their distinguishing markings therefore should be readily determinable by touch as well as by sight. One signal means one thing and another signal means another thing, and the wrong signal would convey incorrect information and cause confusion and might bring disaster. Protection from dampness and clear marking are features to be dwelt upon.

Signal rockets may be sent up from carefully aimed troughs or tubes, or may be sent up without fixtures of any kind, and a difference in the course of the rocket might bring the burst over a unit different from that by whom it had been discharged, or at a point which would cause confusion in the mind of the watcher as to the unit to which the signal applied. For this reason it was necessary in our own pyrotechnics to take a lesson from the French and attach a smoke tracer to rockets, which, while it lessened the height to which the rocket could be thrown, indicated the source from which the rocket had been sent.

The question of height also has a bearing upon the chance of confusing the signals discharged from ground units and from airplanes, which may burst along substantially the same line of front, but whose meaning is intended for different watchers and for different purposes, hence the establishment of different altitudes of burst for ground and airplane signals.

When friendly and enemy front lines are in close proximity, it is manifestly difficult and frequently impossible for watchers to determine whether rockets sent up have emanated from a friendly or from an enemy source, and hence the frequent change in the types of rockets employed by troops on different nights.

Under favorable conditions, ground pyrotechnics may establish an understanding with friendly airplanes or artillery, indicate position of units which may or may not be cut off from other means of communication, call for a barrage, give warning of a gas attack, indicate that ammunition is running low, that friendly artillery shell are raining on our own troops, or convey practically any other information that may be agreed upon in the code.

From the trenches where the ground signal pyrotechnics were most frequently employed, apart from establishing communication with airplanes and lining out the position, their use was practically confined to signaling from the front to the rear, and the code was finally confined to very few signals. This was due to the uncertainty in the determination of the unit from which the signal emanated, the lack of certainty of proper functioning of the signal as a result of chemical or physical changes in the signal, and the practice of the enemy of observing the signal and then repeating that signal at

different parts of his or near-by lines for the purpose of confusing our signal officers. Military pyrotechnic signals have a place, but for use along an entrenched front with the enemy close at hand there are distinct practical limitations to their employment.

While the outline of forward positions is perhaps more frequently indicated by means of panels laid upon the ground and observed by friendly airplanes, such outline of position may be indicated by the burning of Bengal flares—position lights—or by the use of signal cartridges discharged from Very pistols or VB signal projectors employed with rifles.

Pyrotechnics also have their use in providing a sudden illumination at night over an area which it is desired to guard against surprise attack or in revealing an enemy who may be effecting a movement or operation under the cover of darkness.

Smoke torches, which also come under the head of pyrotechnics, may be employed for concealment of the movements or operations of friendly troops.

Military pyrotechnics are also employed largely in the air service for the direction of planes, the establishment of communications with forward ground units or with watchers, for purposes of illumination, for the establishment of understanding with the home field as to whether it is clear for night landing, and by means of wing tip flares for providing temporary illumination of the ground at night to permit of landing.

For use from airplanes the signals usually are discharged from Very pistols, and frequent use of the Very pistol is also made in discharging pyrotechnic signals from the ground.

GENERAL NARRATIVE.

Prior to the present conflict, the following pyrotechnics had been developed for the United States Army: Rockets by the Signal Corps; position lights by the Engineering Corps; Frankford Arsenal rifle illuminating grenades by the Army Ordnance Department; and the Very pistol cartridge, which was in production by the Navy and which had been issued in very limited quantities to the Signal Corps of the Army.

The rockets employed by the Signal Corps were red, green, white, yellow smoke, and sequence rocket (since discarded), all with parachute. The comparatively small elevation attained by these rockets was between 200 and 400 feet, and the colors were indistinct and the functioning uncertain.

The white hand position light, which had been developed by the Engineering Corps, would burn for about one minute with a candlepower of 12,000.

The Frankford Arsenal rifle grenade, illuminating, was both unsatisfactory and costly.

The Very pistol cartridge, manufactured by the Navy and issued in small quantities to the Signal Corps, was No. 10 gauge. About 3,000,000 cartridges had been manufactured, and hence the manufacturers were in possession of the necessary molds and had obtained experience in producing the Very star. The formula of the composition used by the Navy was not, however, considered stable by the Army Ordnance Department, and the degree of visibility of the cartridge was regarded as unsatisfactory.

In addition to the above there had been more or less developed a smoke torch for signaling purposes, a 35-millimeter cartridge for purposes of aviation signaling, the airplane flare, and the wing tip flare.

In the design of the smoke torch, the British type had been followed and some minor changes made to meet the requirements of the American chemical market.

The 35-millimeter cartridge and its pistol were adopted from the French program and included a variety of signals which were to be used in the Aviation Service.

The airplane flare was to be used from an airplane, illuminating the underlying terrain, and required much experimental work. The type was a slightly modified French Michelin flare.

The wing tip flare is attached to the wings of an airplane, and is used as an illuminant to facilitate night landing. It takes its name from its location on the lower side of the wings of an airplane. The origin of the design was the Holt landing flare adopted by the British.

It will appear that pyrotechnics were to be furnished both for ground work and for the Air Service.

For the use of American troops in France, the early supply of pyrotechnics was obtained abroad.

It was not until September 27, 1917, by General Order No. 128, that the design of all signaling and illuminating devices of a pyrotechnic nature was assigned to the Army Ordnance Department.

On March 28, 1918 (cablegram 796–5H), Gen. Pershing cabled directing that the entire French system of pyrotechnics be adopted. The following signals were therefore adopted:

Signal star rocket, Mark I, white, 1, 3, and 6 stars	2 pounds, 20 inches long.
Signal star rocket, Mark I, red, 1, 3, and 6 stars	
Signal star rocket, Mark I, green 1, 3, and 6 stars	
Signal parachute rocket, Mark I, red	
Signal parachute rocket, Mark I, green	
Signal parachute rocket, Mark I, white caterpillar	
Signal parachute rocket, Mark I, red caterpillar	
Signal parachute rocket, Mark I, green caterpillar	
Signal parachute rocket, Mark I, yellow smoke	
Signal parachute rocket, Mark I, flag	
Signal parachute rocket, Mark I, red smoke	
Signal illuminating rocket, Mark I, white parachute	

164404—20——2

VB star cartridge, Mark I, white, 1, 3, and 6 stars	$4\frac{1}{2}$ inches to 7 inches long; 0.7 to 0.9 pound.
VB star cartridge, Mark I, red, 1, 3, and 6 stars	
VB star cartridge, Mark I, green, 1, 3, and 6 stars	
VB parachute cartridge, Mark I, white	
VB parachute cartridge, Mark I, red	
VB parachute cartridge, Mark I, green	
VB parachute cartridge, Mark I, white caterpillar	
VB parachute cartridge, Mark I, red caterpillar	
VB parachute cartridge, Mark I, green caterpillar	
VB parachute cartridge, Mark I, yellow smoke	
Very star cartridge, Mark I, 25-mm., white, 1, 3, and 6 stars	6 inches long; 0.2 to 0.4 pound.
Very star cartridge, Mark I, 25-mm., red, 1, 3, and 6 stars	
Very star cartridge, Mark I, 25-mm., green, 1, 3, and 6 stars	
Very parachute cartridge, Mark I, 25-mm., white	6 inches long; 0.4 pound.
Very parachute cartridge, Mark I, 25-mm., red	
Very parachute cartridge, Mark I, 25-mm., green	
Very parachute cartridge, Mark I, 25-mm., white caterpillar	
Very parachute cartridge, Mark I, 25-mm., red caterpillar	
Very parachute cartridge, Mark I, 25-mm., green caterpillar	
Very parachute cartridge, Mark I, 25-mm., yellow smoke	
35-mm. signal cartridge, Mark I, aviation, white, 1, 2, 3, and 6 stars	4 inches to 6 inches long; 0.5 to 0.6 pound.
35-mm. signal cartridge, Mark I, aviation, red, 1 and 6 stars	
35-mm. signal cartridge, Mark I, aviation, white caterpillar, parachute	
35-mm. signal cartridge, Mark I, aviation, yellow smoke, parachute	
35-mm. signal cartridge, Mark I, aviation, yellow, 1 and 6 stars	
35-mm. signal cartridge, Mark I, aviation, message	
35-mm. signal cartridge, Mark I, aviation, red smoke, parachute	
35-mm. signal cartridge, Mark I, aviation, changing color—red to green	
35-mm. signal cartridge, Mark I, aviation, changing color—red to white	
35-mm. signal cartridge, Mark I, aviation, changing color—green to red	
35-mm. signal cartridge, Mark I, aviation, changing color—green to white	
35-mm. signal cartridge, Mark I, aviation, changing color—white to red	
35-mm. signal cartridge, Mark I, aviation, changing color—white to green	
35-mm. signal cartridge, Mark I, aviation, green, 1 and 6 stars	
Wing tip flare, Mark I, white and red	4 inches long, 0.6 pound.
Airplane flare, Mark I	4 feet long, 36 pounds.
Position light, Mark I, white, ground	3 inches long, 0.4 pound.
Position light, Mark I, red, ground	
Position light, Mark I, green, ground	
Position light, Mark II, white, hand	10 inches long, 0.8 pound.
Smoke torch, Mark I	6 inches long, 0.4 pound.

35-mm. signal pistol, Mark I, aviation	10 inches long, 2 pounds.
Very signal pistol, 25-mm., Mark IV	8 inches long, 2 pounds.

The adoption of the French pyrotechnic system necessitated the change from the No. 10 gauge Very pistol to the 25-millimeter Very pistol.

On April 1, 1918, a letter from the Trench Warfare Division of the American Expeditionary Forces specified the quantity requirements as then viewed to complete the year 1918. In this letter appeared the statement:

> Negotiations are in progress for the purchase from the French of six months' supply from April 1, and the indications are that our demands will be granted and that a further supply sufficient for the balance of the year will also be available from the French if it should be necessary.

Following the decision to adopt the entire French system of pyrotechnics, the preparation of drawings and specifications for manufacture in the United States to correspond with the French system of pyrotechnics was delayed due to the lack of information in the United States of the French requirements of design and details of manufacture. No French drawings nor specifications, and but few samples had been received. Following a number of requests, further samples were received and drawings and specifications were completed shortly thereafter.

Until the middle of the summer of 1918, the status of the pyrotechnic supply program was considered satisfactory. However, during August and September of 1918, the new requirements to June, 1919, were issued, and it became immediately evident that existing facilities were inadequate to produce the large quantities required, involving some 128,000,000 pieces, to be delivered at the rate of approximately 430,000 per diem.

A survey of production possibilities was made, and, based upon the results, the Trench Warfare Board submitted recommendations to the Chief of Ordnance on September 26, 1918, covering the development of the existing private plant facilities in the United States to handle the more complex pyrotechnic items and the erection of Government plants to manufacture the simpler items. The armistice was signed before these recommendations were approved. The Plant Facilities Section also considered the erection of two or more pyrotechnic assembly plants.

In anticipation of the approval of the above recommendations, and realizing the urgent necessity for experienced pyrotechnic operators, the Plant Facilities Section established the Ordnance Pyrotechnic Schools in New York under the direction of Henry B. Faber. Student units were established at the various pyrotechnic factories and extensive research and development was undertaken.

It was not until after this latter date that the Chemical Research Branch of the Trench Warfare Section was established—on October 24, 1918. The lateness of this date will indicate the condition with respect to the scientific treatment of the pyrotechnics problem. At that time it was stated that the most pressing problem for the consideration of the Chemical Research Branch was that of suitable specifications for the chemicals to be employed in the manufacture of military pyrotechnics. It appeared that no work of this character had been previously undertaken by anyone connected with the Ordnance Department and investigation and inquiry soon developed that neither the British, French, nor Italian military authorities had made such study.

Apparently the first logical step was to consult with the manufacturers of pyrotechnics and to use the information thus obtained for the formulation of a tentative draft of specifications to tide over the pressing emergency. It was planned that an extensive chemical investigation should be made with respect to each chemical having a part in the manufacture of pyrotechnic material to ascertain the degree of purity required, the amount of moisture permissible, and the best degree of fineness in grade.

Visits were made to several of the more important plants which were manufacturing pyrotechnic material for the Government and conferences were held with the men best qualified to give information. It was plainly evident that none of the fireworks manufacturers had a real chemical control of their manufacturing processes. At one or two plants some slight attempt was occasionally made to exercise some degree of chemical control, but, inasmuch as none of the manufacturers purchased their chemicals on specifications or appeared to understand the chemistry involved in the functioning of the finished product, such attempts were naturally not fruitful. It was stated by one of the most intelligent men interviewed that he always tested the chemicals by tasting them.

It was the practice of each fireworks manufacturer to buy his chemicals from the same source year after year; his only specification was that the chemical in question "must be the same as that previously furnished." It appears that the manufacturers of the chemicals had learned to know the needs and idiosyncrasies of each of their clients among the fireworks manufacturers and had supplied different grades of material to the different fireworks manufacturers although the chemicals were to be used for the same purpose by each.

The need for chemical control in the manufacture of military pyrotechnics was illustrated by a concrete example: Previous to the war, arsenic disulphide, known in the trade as "red Saxony arsenic" and used for the production of yellow smoke, was imported from Europe. The war resulted in the cutting off of importation and the

use of domestic material became necessary. Trouble at once developed. It was found that to obtain a given volume of smoke, the employment of about 50 per cent more of the chemical was necessary, but why this increase was necessary was not known to the fireworks manufacturers. Trouble of another and very serious nature developed. The workmen using material frequently became badly poisoned. In spite of this, no case had developed in which a chemical analysis was resorted to by the fireworks manufacturers. An Army Ordnance Department chemist made an analysis of the material and found that it contained from 45 to 50 per cent of white arsenic (arsenic trioxide), while the "red Saxony arsenic," formerly employed, and which had been obtained from abroad, was a naturally occurring mineral (realgar), was very pure, and only required grinding to the proper degree of fineness in order to suitably prepare it for its purpose.

The greatest difference of opinion was encountered as regards the permissible quantity of various impurities in the chemicals. Apparently no detailed study of tolerances had been made. It was well known that the presence of small quantities of sodium salts was very harmful in strontium or barium salts, as the yellow produced by the incandescent vapor of metallic sodium degrades other colors: but the actual quantity which was permissible without serious degradation of color was not known. The same may be said regarding the presence of calcium strontium salts or of calcium and strontium in barium salts. The question of the permissible amount of moisture was also one which required more adequate information. All fireworks manufacturers were agreed that moisture should be avoided, and some of them specified that the chemicals furnished them should be dry; yet upon receipt the kegs were opened and allowed to stand open in a humid atmosphere possibly weeks before using. To offset the influence of the atmospheric moisture taken up by the chemicals, it was the practice of the mixer to add other ingredients. At some of the plants the chemicals were kept dry, or were dried before mixing. and the resulting products from these plants were much more uniform in quality.

The moisture content of the chemicals is naturally dependent on the hydroscopicity of the salt itself or of the impurities contained therein. This again brings up the question of allowable impurities For example, a quantity of calcium chloride, which might have no serious effect on the color produced by a strontium salt, might make the mixture so hydroscopic as to render it practically useless. Calcium and magnesium salts, because of their hydroscopic nature, are especially to be avoided and are impurities which are likely to occur in the other salts used. Detailed studies as to the tolerances with respect to these impurities have not been made.

The next question which engaged attention was that of the possibility of substitution or provision for choice of material for use in the manufacture of pyrotechnics with a view to reducing cost and providing against embarassment in the event of a scarcity of some element developed. The highest grade of shellac is costly and if it developed that a lower grade could be used to equal advantage, considerable saving would be effected. The function of shellac is to furnish a suitable binder and control the rate of combustion. The heat produced volatilizes and dissociates the salts which give color to the flame. The shellac employed must necessarily contain no substitutes which would degrade the color of the flame. Some years ago, the Board of Explosives forbade the use of chlorate and shellac mixture in the manufacture of railway fuzes, believing them to be dangerous. This mixture is used together with flame coloring material in position lights, etc., and some of the fireworks manufacturers did not concur in the opinion held by the Board of Explosives. The manufacturers of railway fuzes used mixtures of potassium perchlorate and sulphur in place of chlorate and shellac. Inquiry developed that the immediate substitution of perchlorate would be impossible for a large pyrotechnic program but that the production of perchlorate could be rapidly increased.

But one concern in the United States was manufacturing this material in quantity and practically its whole production was being used by the manufacturers of railway fuzes. While within a few months the production of perchlorate could be increased to provide practically any quantity desired, it was found that extended study should be made first as to the necessity and desirability of the substitution of the perchlorate mixture.

Specifications were compiled and were regarded as being sufficiently rigid for the use of chemicals to be used for military pyrotechnics. Conference with the manufacturers of chemicals led to the belief that the specifications as laid down were reasonable and that no particular difficulty would be encountered in obtaining material of the required purity.

Reference was made to work done by the Chemical Warfare Service at the American University in connection with the signal smokes which had been developed by them and which were believed to be particularly good.

The pyrotechnic schools were disbanded November 30, 1918, but Mr. Faber, with a small corps of assistants, continued the preparation of records of the investigation and work done by engineers and students, and a file of valuable data relating to plant facilities, types of factories, development of and references to formulæ is on file in the Trench Warfare Section for future reference. (File 319.12/17.)

The feeling was expressed that the whole question of military pyrotechnics was one deserving of scientific development. No ex-

tensive research along these lines had been conducted and completed, and the expressed opinion considered the advisability of a Government pyrotechnic laboratory and arsenal to permit of the many problems involved being studied and the solutions embodied in definite drawings and specifications.

A large work of three volumes on pyrotechnic production is now nearing completion.

While the requirements had been very largely increased during August of 1918, a still further increase in these requirements had later been estimated, and the requirement sheets embodying these later increases were about to be issued just as the armistice was signed.

The following table will indicate the requirements in force as of the date of the signing of the armistice and data with reference to the major items of pyrotechnics available then and later:

Principal items in pyrotechnics.

Item.	Total requirements.	Requirements to Nov. 1, 1918.	Ordered in the U. S.	Ordered from abroad.[1]	Floated from U. S.	Completed in U. S. to Nov. 11, 1918.	Total completed in U. S.
Rockets, signal star, Mark I:							
White, 6 stars	1,145,186	363,563				[2] 437,101	
3 stars	1,144,009	362,386					
1 star	1,144,009	362,386					
Red, 6 stars	1,145,186	363,563					
3 stars	1,144,009	362,386					
1 star	1,144,009	362,386					
Green, 6 stars	1,099,588	335,680					
3 stars	1,118,539	354,631					
1 star	1,118,539	354,631					
Rockets, signal parachute, Mark I:							
Red caterpillar	1,368,530	413,854	255,000				5,000
White caterpillar	1,369,707	415,031	255,000				5,000
Green caterpillar	1,368,530	413,854	255,000				5,000
Red	386,506	159,326	106,024				109,159
Green	401,006	173,826	117,904		2,800		120,535
Yellow smoke	1,135,115	361,132	63,000		53,700		96,539
White illuminating	2,689,293	822,060	159,000		2,000		188,522
Flag	610,923	194,803	45,000				6,461
Amber			5,750				5,760
Rockets, signal, old style:							
Yellow smoke			36,100				36,100
Red			71,976		32,200		71,976
Green			60,096		57,175		60,096
Amber			35,697		31,000		36,062
Golden rain, Mark I			1,553				1,553
Cartridges, VB star, Mark I:							
White, 6 stars	1,638,572	483,832	95,000			[3] 110,000	101,120
3 stars	1,641,900	484,798	95,000				95,174
1 star	2,437,292	715,672	145,000				145,000
Red, 6 stars	673,452	203,692	40,150				40,150
3 stars	720,044	217,216	40,000				40,000
1 star	1,562,028	461,514	90,000				90,270
Green, 6 stars	673,452	203,692	40,000				40,000
3 stars	673,452	203,692	40,000				40,000
1 star	317,356	100,330	20,000				20,408
Cartridges, VB parachute, Mark I:							
White	3,573,320	1,043,520	200,000				205,117
Red	2,867,784	838,728	165,000				167,508
Green	2,867,784	838,728	165,000				165,210
White caterpillar	582,208	183,932					
Red caterpillar	488,264	148,048	30,000				30,000
Green caterpillar	488,264	148,048	30,000				30,234
Yellow smoke	405,064	123,888	20,000				0

[1] Impossible to determine quantity ordered and delivered until details of final settlement are received.
[2] Includes all types of rockets.
[3] Includes all types of VB cartridges.

Principal items in pyrotechnics—Continued.

Item.	Total requirements.	Requirements to Nov. 1, 1918.	Ordered in the U. S.	Ordered from abroad.	Floated from U. S.	Completed in U. S. to Nov. 11, 1918.	Total completed in U. S.
Cartridges, Very parachute 25 mm.:							
White	1,969,246	695,192	.....	.....	.....	.....	.....
Red	1,509,594	464,755	.....	.....	.....	.....	.....
Green	1,509,594	464,755	.....	.....	.....	.....	.....
White caterpillar	3,481,434	1,037,110	.....	.....	.....	.....	.....
Red caterpillar	3,959,002	1,175,731	.....	.....	.....	.....	.....
Green caterpillar	3,959,002	1,175,731	.....	.....	.....	.....	.....
Yellow smoke	2,682,714	805,270	.....	.....	.....	.....	.....
Cartridges, Very star, 25 mm.:							
White, 1 star	6,781,497	1,955,272	100,000	.....	.....	.....	0
Red, 1 star	1,884,345	573,802	100,000	.....	.....	.....	0
Green, 1 star	1,884,345	573,802	100,000	.....	.....	.....	0
Red, 6 stars	3,327,033	992,564	.....	.....	.....	.....	.....
3 stars	3,327,033	992,564	.....	.....	.....	.....	.....
Green, 6 stars	3,327,033	992,564	.....	.....	.....	.....	.....
3 stars	3,327,033	992,564	.....	.....	.....	.....	.....
Wing tip flares, Mark I:							
White	497,450	486,400	56,082	.....	20,000	70,000	47,882
Red	497,450	486,400	56,082	.....	13,000		41,283
Airplane flare, Mark I	83,228	76,092	65,083	.....	.....	2,100	8,000
Position lights, Mark I (ground):							
White	2,883,123	892,251	305,000	.....	10,798	.....	150,002
Red	2,315,779	754,791	575,000	.....	49,823	[1] 1,187,532	482,017
Green	2,315,779	754,791	380,000	.....	19,856	.....	275,417
Position lights, Mark II (hand), white	2,981,823	990,951	863,000	.....	481,827	.....	813,034
Smoke torch, Mark I	3,328,000	956,000	500,000	.....	.....	31,000	188,102
Rifle lights, Mark I, old style, white	.....	.....	320,000	.....	.....	55,000	55,000
Signal lights, Mark I, old style:							
White	.....	.....	29,000	.....	.....	.....	0
Red	.....	.....	143,000	.....	.....	.....	55,000
Green	.....	.....	143,000	.....	.....	.....	55,000
Signal lights, Mark II, for Mark III pistols:							
White	.....	.....	1,000,000	.....	.....	[2] 2,661,008	994,360
Red	.....	.....	1,000,000	.....	.....	.....	884,780
Green	.....	.....	1,000,000	.....	.....	.....	720,348
Signal pistols:							
Mark III, 10-gauge	.....	.....	20,460	.....	.....	.....	20,460
Mark I, 35-mm	.....	.....	29,669	.....	.....	.....	1
Mark IV, 25-mm	194,680	97,016	166,719	.....	.....	.....	25,066

[1] Includes all types of position lights.
[2] Includes all types of signal lights.

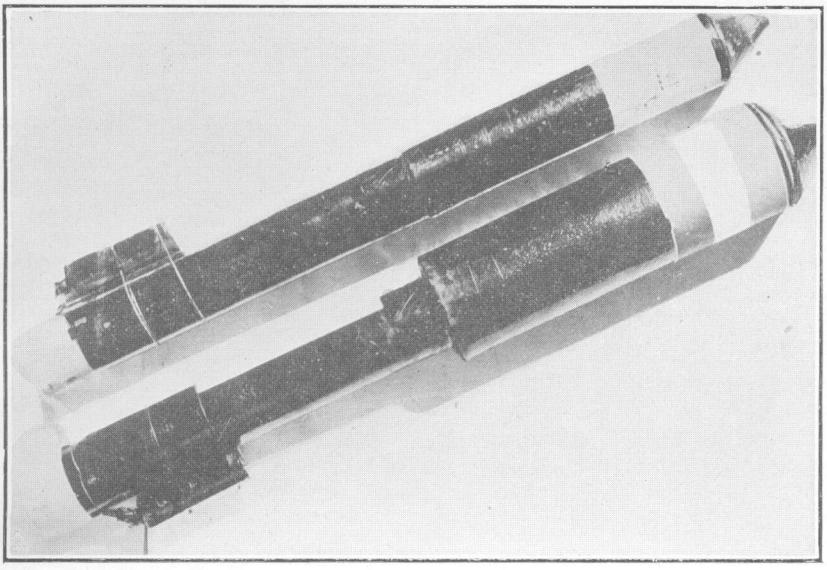
NOTE.—Columns relating to completions and flotations may be considered more or less as of armistice date, as cancellations became effective shortly thereafter.

COURSE OF DEVELOPMENT AND MANUFACTURE.

In the improvement of the rockets which were used by the Signal Corps, signal rockets Mark I and Mark II were developed and proved to possess 95 per cent efficiency in functioning and performance. This marked a distinct improvement over the rockets previously employed, and the new rockets also attained a height of 800 to 1,200 feet as compared with a height of 200 to 400 feet with the old rockets. The new rockets burned approximately one minute. Under Mark I were included the red and green rockets, and in addition a rocket known as the "golden rain" type, which had been substituted for the white rocket previously employed. This golden rain type in turn gave way to a rocket with an amber star.

Later direction from France, however, led to the abandoning of this type in favor once more of a white rocket to be used for illuminating

PLATE 1a.



FLAG AND SIGNAL ROCKETS. TRENCH WARFARE SECTION, ORDNANCE DEPARTMENT, TOURS, FRANCE.

PLATE 2a.

TESTING INCENDIARY ROCKET AT MILITARY AVIATION FIELD, MINEOLA, L. I., NEW YORK, 1917.

as well as for signaling. Originally the day rocket using yellow smoke was designated "Signal Rocket Mark II."

The above references to efficiency and height attained, which are gathered from an Ordnance Department record, were doubtless based upon tests made under favorable conditions, for another Trench Warfare Division report confines the heights reached to 650 or 800 feet, and in conversation with a Signal Corps officer, who had been in France with the First Division, he called attention to the fact that 1,200 feet would be over twice as high as the Washington Monument; that he had seen rockets in service at the front, both of French make and of American make, that certainly none of them had reached the maximum height stated, and that his impression was that none of them had reached half that height. Regarding the matter of efficiency, he called attention to the catalytic action of certain chemicals employed in pyrotechnics, which caused deterioration. When questioned concerning the change from the golden rain type of rocket to the amber star, in the face of the general contention that it was more reliable to adhere to form rather than color in differentiation between signals, he stated that the change was probably made after it had been found that disintegration due to catalytic action within the rocket would cause a change in the form of the burst. Apart from yellow smoke, which was used mainly by headquarters, red, white, and green were the only colors employed.

In connection with rockets, position lights, and smoke torches, an ignition disk is provided with each piece, and on tearing off the protective band this ignition disk is made available to be rubbed by hand on a friction quick match, attached to the fuze, to cause the piece to function.

The VB signal cartridge was fired from a rifle grenade discharger attached to an infantry rifle. A .30 caliber blank cartridge was, however, used in the rifle, and this cartridge was taped onto each VB signal cartridge and detached at the time of use. The cartridges were marked for ready identification either by day or by night. At the beginning of our operations in France the organizations which used the VB signal cartridge encountered difficulty in its operation due to the fact that the blank rifle cartridge attached to the VB signal cartridge of French manufacture was the 8-millimeter cartridge, which did not fit the American rifle; hence it was necessary either to use French rifles or to extract the bullet from the American caliber .30 service cartridge before the signals could be used. The marking of the cartridges was in French and this caused trouble in identifying the different signals. Many misfires occurred due to the percussion cap in the French VB signal cartridge not being placed central with the firing pin, or placed too far away to be struck by the the firing pin inside of the signal cartridge, and in many cases when

164404—20——3

the cartridge did function, the parachute would fail to open. According to an Ordnance Engineering Division report received from overseas, there was a difference of opinion as to the desirable height of flight of this type of signal. On misty nights the signal would function above the mist and could not be seen, and in hilly terrain the signal would not function high enough to be seen on clear nights. To remedy this difficulty a blank cartridge with a heavy charge and a separate blank cartridge with a light charge could be developed. Contrary to reasoning with reference to the rockets, concerning the necessity for determining their source, it was specified that this VB signal must leave no trail of sparks, as such trail would aid the enemy in locating the position of the man who fired it. Experimental samples of the American manufactured VB cartridges, with blank cartridges attached, were received in France a few weeks before the armistice was signed, and in these the percussion cap of the signal cartridge was exploded by the pressure of the gases from the discharge of the rifle cartridge instead of by a firing pin as is used in the French type.

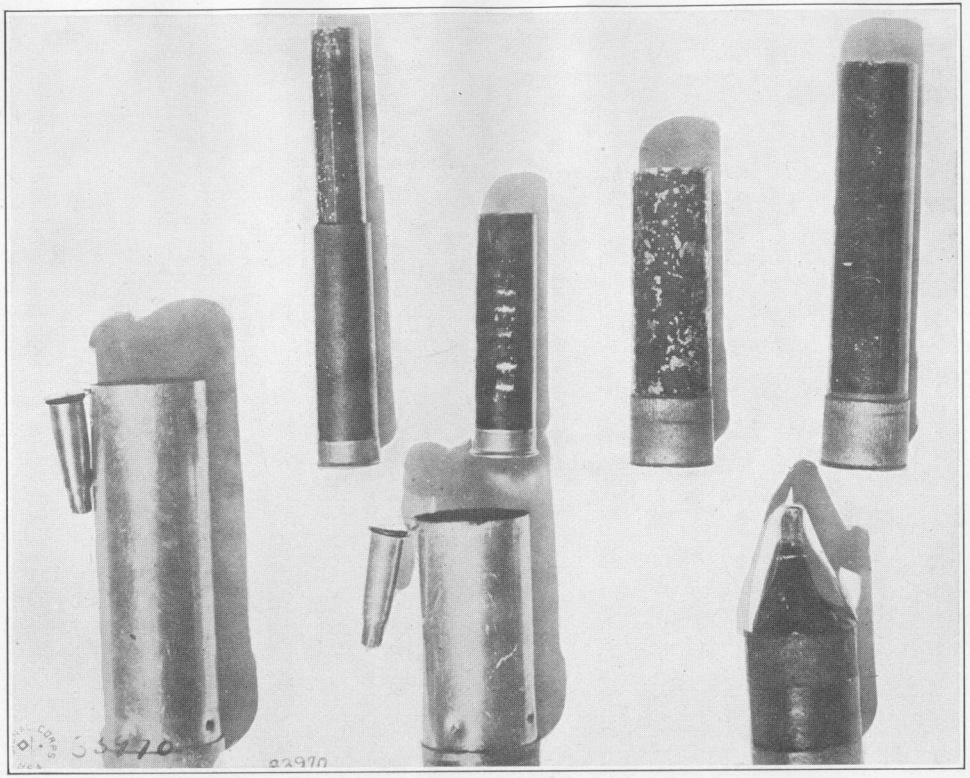
Signal light Mark I was designed to be used in conjunction with the VB discharger and the Army rifle for signaling purposes by the Infantry. The light functioned satisfactorily but the American Expeditionary Forces would not accept the device, as there was a trail of sparks from the signal when it was fired. As these signals were used only at night this would enable the enemy to locate the man firing the signal. The VB discharger Mark I, developed from the French design, was therefore adopted instead of the rifle light, as the VB cartridge signal did not leave a trail of fire.

The rifle light Mark I is a development from the Frankford Arsenal rifle grenade, illuminating, and was designed to be thrown from a VB rifle discharger. It contains an illuminating pellet, suspended by a parachute and burning 20 seconds with from 40,000 to 60,000 candlepower. The parachute was of such size as to suspend the illuminant at practically the point of burst until consumed and the cost of the new cartridge was less than one-fourth that of the Frankford Arsenal type.

This is a matter of nomenclature of a development of about November, 1917, on the same work order with signal light Mark I. The specimen retained of the signal light was produced by the Nixon Fulgent Products Co. and that of the rifle light by the Unexcelled Manufacturing Co.

CARTRIDGES FOR 25-MILLIMETER VERY PISTOL (PYROTECHNICS).

These cartridges were used in conjunction with the 25-mm. Very pistol Mark IV for signaling purposes by troops. Sixteen types of these cartridges were authorized, including signals both with and with-



TYPES OF SIGNAL CARTRIDGES 25 MM. AND 35 MM.

In the upper type the propelling charge is a part of the cartridge. In the lower type the propelling charge is separately contained. In the lower right of the photo is a signal light. Trench Warfare Section, Ordnance Department, Tours, France.

out parachute. Orders were placed in the United States for 300,000 of the cartridges, but at such a late date that none were produced. The cartridge case of the 25-mm. cartridge not being of the standard American size none of the shotgun cartridge manufacturers desired to produce the paper-cartridge case. Contracts were therefore awarded for metal cartridge cases and apparently these were entirely satisfactory. It was in cablegram 1005–6A of April 27, 1918, that we were advised by the American Expeditionary Forces that the No. 10 gauge size of signal cartridge appeared to be too small for signal work, and it was their belief that it would be necessary for us to develop the 25-mm. or 1-inch size.

SIGNAL LIGHT MARK II (VERY).

In connection with the Very pistol cartridge, which had been issued by the Navy to the Signal Corps, the composition was not considered stable by the Army Ordnance Department nor was the degree of visibility considered satisfactory and hence new specifications were provided by the Ordnance Department. This new cartridge was known as "Signal Light Mark II." This signal was used by the Navy before the present war and adopted by the Army. Total weight approximately 1 ounce. Used in conjunction with Very signal pistol model Mark III by the Infantry. Contracts were awarded and large quantities made but the signals were abandoned on instructions from the American Expeditionary Forces, as it was decided that our signal cartridges should be the same size as the French so that signals could be interchangeable between troops.

CARTRIDGE FOR 35-MILLIMETER SIGNAL PISTOL (PYROTECHNICS).

This cartridge was used for signaling purposes in aviation in conjunction with the 35-millimeter signal pistol (aviation). Twenty different types of 35-millimeter cartridges were authorized in the pyrotechnics program but no contracts were awarded, as before the production was started in the United States the caliber was changed to 25 millimeters. In general it may be said that the cartridges for use in the same pistol, while of the same caliber, were not all of the same length; in fact, the ends of some of the cartridges would extend far beyond the muzzle of the pistol. The difference in length was due to the quantity of pyrotechnic material which was called for by the type of signal for which the cartridge was used; that is, the length of the caterpillar or the number of stars. For aviation work it was not necessary to have any considerable amount of propelling charge in the cartridge, as the altitude was provided for by the plane being in the air, and it was only necessary to propel the signal a

short distance clear of the plane. For Very pistol cartridges to be used from the ground, however, a stronger propelling charge was necessary in order to provide for the functioning of the signal at the proper altitude.

In a letter dated September 19, 1919, from the Engineering Division of the American Expeditionary Forces regarding these cartridges, the point is brought out that at that time the French were using a signal burning first in one color and then changing to another color and that the adoption of this changing type was not known to the American Expeditionary Forces until it was actually in service. The thought expressed by the American Expeditionary Forces was that there was a chance that one of the colors might not function and that thus the proper signal would not appear and a serious misunderstanding might result. This brings to mind the reference to the uncertainty in the operation of some of the military pyrotechnics through catalytic action, and possibly through dampness, as referred to in a previous part of this chapter.

VERY SIGNAL PISTOL, MARK III.

This pistol was used by the Navy prior to the present war, and was adopted by the Army. It was used by the Infantry in conjunction with the signal light Mark II (Very). A contract was awarded to the Remington Arms Co., Bridgeport, Conn., for the manufacture of a quantity of these pistols but on receipt of word from the American Expeditionary Forces that the signal cartridges should be of the same size as the French, the contract for these pistols was canceled, and the 25-millimeter Very pistol, Mark IV, was adopted to supersede it. Some of the No. 10 gauge Mark III pistols had been shipped abroad but were returned to this country and were used for training purposes.

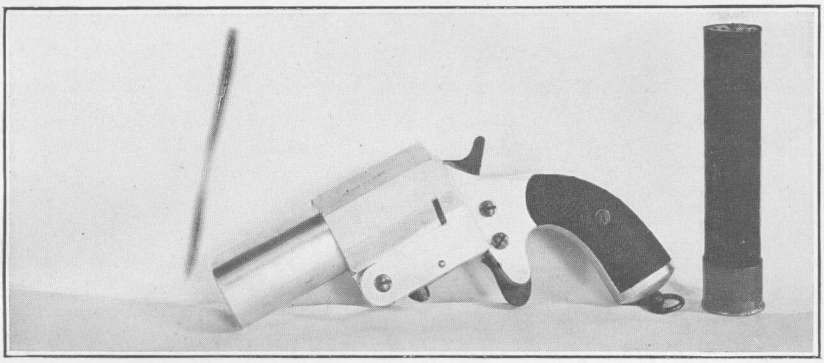
25-MILLIMETER VERY PISTOL, MARK IV.

This pistol was used by our Infantry for signaling purposes. There were no particular difficulties encountered in production and the number ordered and produced are indicated in the table dealing with production.

25-MILLIMETER VERY PISTOL, FRENCH MODEL 1917.

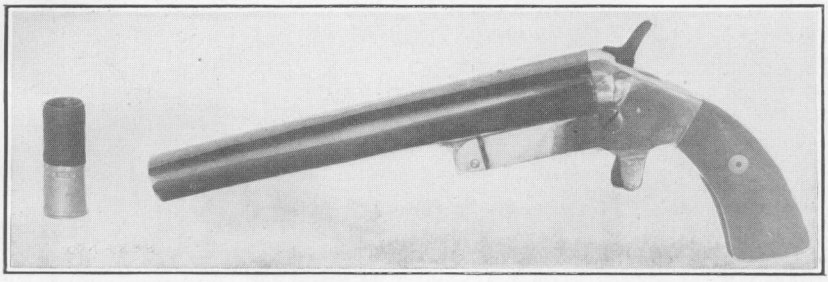
This pistol was used for signal work and is the latest type designed by the French. In Weekly Letter of September 7, 1918, from the Ordnance Department at Washington to the American Expeditionary Forces, attention was called to a pamphlet which had been received from France regarding this model and particularly to the radically different grip, the longer barrel of steel instead of brass, and other minor changes as compared with the 25-millimeter Very pistol, Mark IV, then in production. The thought was advanced that possibly

PLATE 4a.



VERY SIGNAL PISTOL, WITH CARTRIDGE. FOR USE FROM AIRPLANE FOR COLORED FLASH SIGNALS, ETC.

PLATE 5a.



VERY PISTOL AND CARTRIDGE.

the powerful recoil of the pistol made necessary a different construction and a different grip and that a greater range was desired, thus accounting for the length of the barrel. It was requested that a definite statement be made whether or not it was desired to put the new French model into production, and reply of October 3 stated that the new French model had not been tested and that they were not in a position to state that it was superior to the one which was already in production in the United States. They recommended, however, that tests be made here, and if the new model proved superior to a marked degree that it be put into production as soon as existing contracts on the older design were completed. In both of these letters the new design was referred to as that of 1918. Tests were made and the opinion was expressed that it was not as satisfactory a pistol as the Mark IV, as the locking mechanism worked too hard and the trigger-pull was too great. No production was started.

35-MILLIMETER SIGNAL PISTOL, MARK I (AVIATION).

This pistol was used by aviators to fire signal cartridges. Contracts for 29,669 were awarded to the Dohler Die Casting Co., Brooklyn, N. Y., the Hammond Typewriter Co., New York City, and the Parker Bros. Gun Co., Meriden, Conn. One pistol was produced. Prior to the introduction of this pistol, we had no pistol for aviation work and adopted the French design. The American design was satisfactory except for the firing pin and firing-pin spring. In connection with this a different type of hammer is desirable to eliminate the necessity for placing the hammer at half cock in order to load the pistol.

35-MILLIMETER SIGNAL PISTOL, MARK II (AVIATION).

This pistol is the same as the 35-millimeter signal pistol, Mark I (aviation), except that the French design is followed more closely in detail. It was proposed to use the above title to identify the new drawings which would be used in the manufacture of sand-cast aluminum parts instead of die cast, as had been used in the 35-millimeter signal pistol, Mark I. The die-cast pistol proved successful, so this project was abandoned.

35-MILLIMETER SIGNAL PISTOL (BRASS).

Five sample pistols of French design were received from abroad. This pistol was designed by the French to take the place of the 35-millimeter signal pistol, Mark I, but information was received to the effect that no improvement was apparent, and an experimental order placed in the United States for the manufacture of 20 of the brass pistols was canceled.

35-MILLIMETER SIGNAL PISTOL, MARK III (AVIATION).

This project was authorized under this nomenclature for the copy of a new French model, but word being received from abroad that certain defects in the 35-millimeter signal pistol, Mark I, had been eliminated, it was the opinion that the Mark I pistol was a better design than the Mark III, and hence no further action was taken in this project.

POSITION LIGHT, MARK I, WHITE, RED, AND GREEN (GROUND).

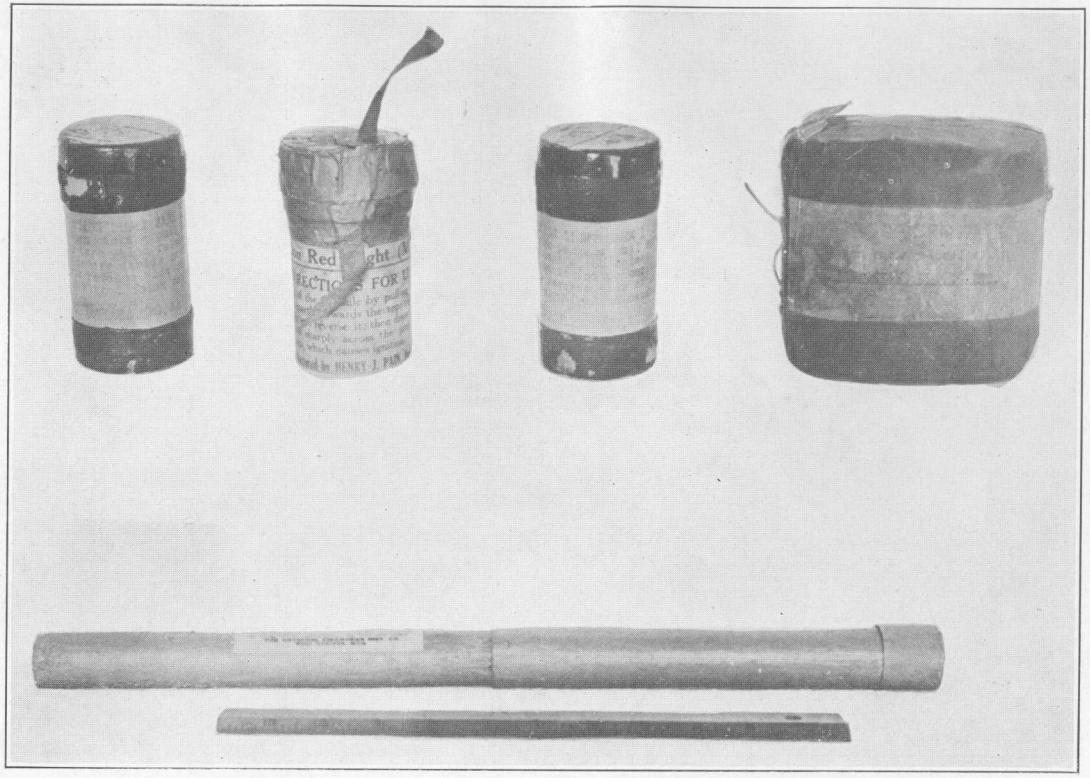
Steps were taken to develop a ground position light, but during the experimental stage a modified form of the British ground flare was adopted. The device, which was later independently perfected by the Ordnance Department, is known as "Position light, Mark I, ground." There are three types—white, red, and green. Each type burns about a minute. The white is of about 5,000 candle power; the red, about 1,400, and the green, about 1,200. These are regarded as superior to any other known pyrotechnic devices of the kind.

This is a development of the position light of the Engineering Corps and of the British ground flare. It weighs from 4¼ to 5¼ ounces, varying with the color. Its use is in conjunction with troop movements. It is provided with a friction igniter and when ignited is placed or thrown upon the ground. As in the case of the hand position lights, they were also used at times by airplane squadrons for marking the landing field at night.

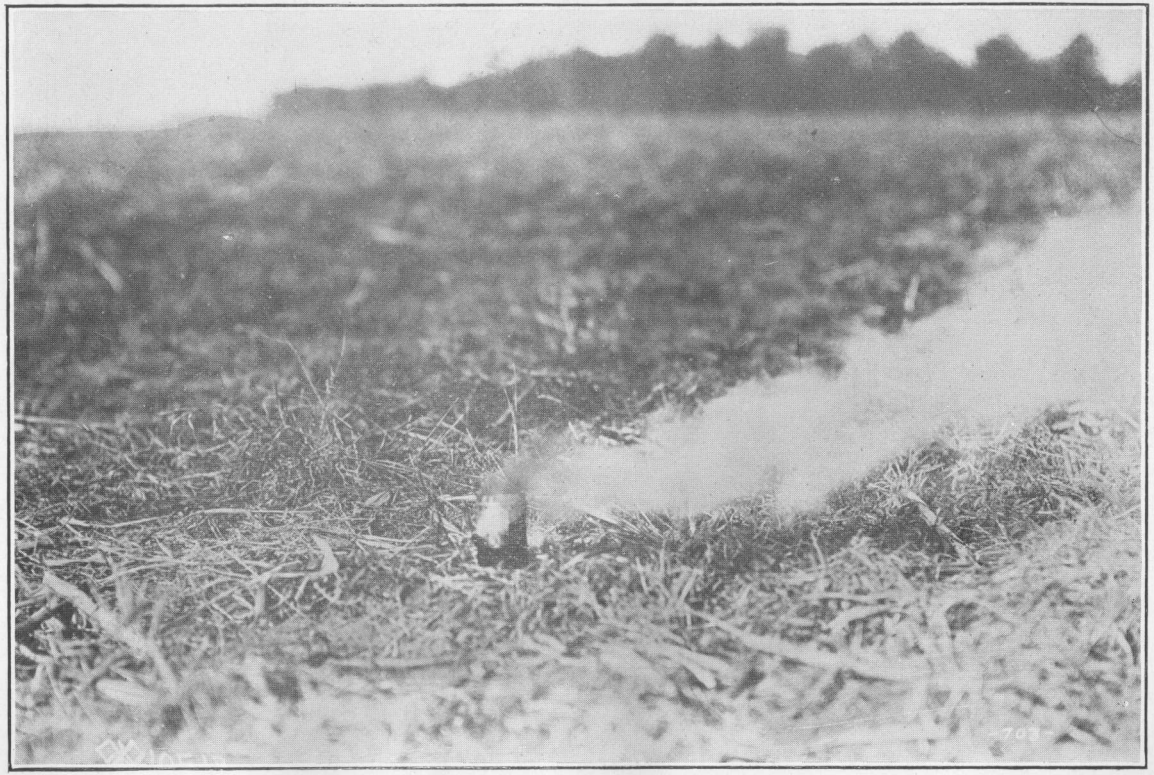
Smoke torch, type "S," adopted by our forces was used both as a signal and for producing a smoke screen. It is of British manufacture and was not manufactured in the United States. It burns for approximately five minutes, giving a dense yellow smoke. The smoke composition is packed in a metal case approximately 3¾ inches in diameter, and about 6 inches long, and is ignited by a friction striker. The size and weight were carefully considered in the design of this torch, due to the fact that it was necessary for the soldier to carry it. Samples of two types were sent to the United States and both were considered satisfactory by our troops.

SMOKE TORCH, MARK I.

Of the types of pyrotechnics, which were more or less developed in our service at the outbreak of the war, the American smoke torch was arranged like the British type, which had been followed, to burn from 2½ to 3 minutes. It gave out, however, a considerably larger volume of smoke, as compared with the samples received here, and, later, on cable advice from the American Expeditionary Forces, the burning time was increased to 4 minutes, and the design and chemical



TYPES OF ORDNANCE SIGNAL LIGHTS. POSITION LIGHT MARK I (ABOVE). POSITION LIGHT MARK II.



SMOKE TORCH.

formula adopted resulted in smoke torch, Mark I. The smoke torch, Mark I was manufactured in the United States and was in quantity production when the armistice was signed.

Holt wing tip flares, which were used by our air squadron, were of British manufacture. The flare is ignited by means of an electric squib imbedded in the upper end of the flare and connected to a switch in the fuselage of the plane. Two types of these flares were used; one giving a red mist-penetrating tinge, and the other a white light. Much difficulty was encountered in the use of these flares through the failure of the electric squib to function. Instead of using two to a plane to insure illumination for night landing, the aviators were using six and eight to a plane.

The American adaption, known as the *wing tip flare, Mark I,* was also made with the white light and with the red tinge, and while laboratory results of 22,000 to 25,000 candlepower were obtained, difficulty encountered in connection with the quality of the chemicals obtainable at the time resulted in production requirements being reduced to a minimum of 12,000 candlepower for the white flare and a minimum of 6,000 candlepower for the red tinge flare. The burning time was 1 minute.

Airplane flare, Mark I, modeled after the Michelin illuminating bomb, was designed for use in aviation work to illuminate the country which the aviator desired to bomb and also occasionally for landing purposes. It consists of a thin sheet-metal cylinder, about 4 feet long and 4 inches in diameter, provided with guiding fins at the tail of the cylinder a small metal revolving vane at the nose, and two projecting buttons for providing means for attachment to a releasing device for providing means for attachment to a releasing device located underneath the wings of the plane. The cylinder contains an igniting device, an expelling charge, an inner case containing the illuminating compound, and a silk parachute connected by cords to the inner case. The mounting of the vaned wheel consists of a brass stud or shaft passing through the nose carrying on its inner end the ignition striker. This stud or shaft, instead of having a smooth bearing through the nose piece, is threaded for a portion of its length, and is likewise provided with a flat surface, and a cotter pin hole at that part of the shaft which is exterior to the nose piece.

During shipment and handling a cotter pin passing through the hole in the shaft prevents the firing pin striking the ignition surface. On being mounted on the plane the cotter pin is removed and the flare is attached by means of the attachment buttons provided to a releasing device on the lower side of the wing, and, in so attaching, the flat surface on the shaft of the vaned wheel is inserted in a clip which prevents the shaft from turning. At such time as the aviator desires to release the flare, he operates from the fuselage the mechanical connection to

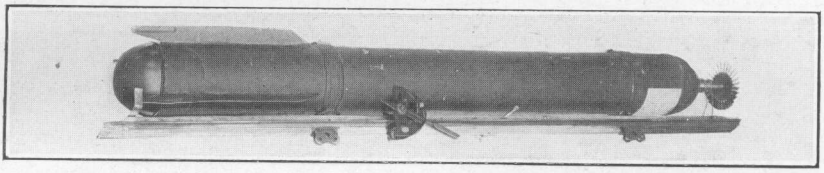
the releasing device, and the cylinder then drops free from the plane and the vaned wheel commences to turn as a result of the action of the impinging of the air against it, as would be the case with a windmill or pinwheel. In so revolving, the shaft advances on the thread in its bearing until its roughened inner end is forced into friction contact with the quick match which ignites the expulsion charge. Ordinarily this occurs when the flare casing has dropped about 200 or 300 feet below the plane. On the ignition of the expulsion charge, the inner case, together with the parachute, is expelled from the outer case at the guiding vane end of the cylinder and the illuminating charge in the inner case is ignited. The parachute opens and the burning illuminant is thus suspended and permitted to slowly descend toward the earth.

The above is a description of the manner in which the flare is designed to function. Its total weight is about 36 pounds. It is the best flare of this character that has thus far been developed, but it is not an entirely satisfactory device. Its successful functioning is dependent upon a train of action and the failure of any part to function affects the successful operation. It is felt that the entire firing mechanism should be changed to insure more positive action of the firing pin. A clockwork time mechanism has been developed and will probably receive further consideration. Some difficulty has been experienced in the ignition of the illuminant due to the first fire breaking away from the illuminant when the parachute has opened. It is felt that some parachute failures are bound to occur, due either to the parachute not opening properly or to the breaking of the suspension cords. In the present device no means is provided for an adjustable fuze.

The airplane flare of American design was designed to burn about 7 minutes with from 225,000 to 350,000 candlepower, as compared with a burning time of 6 minutes and 55 seconds and a candlepower of 190,000 in the French Michelin type.

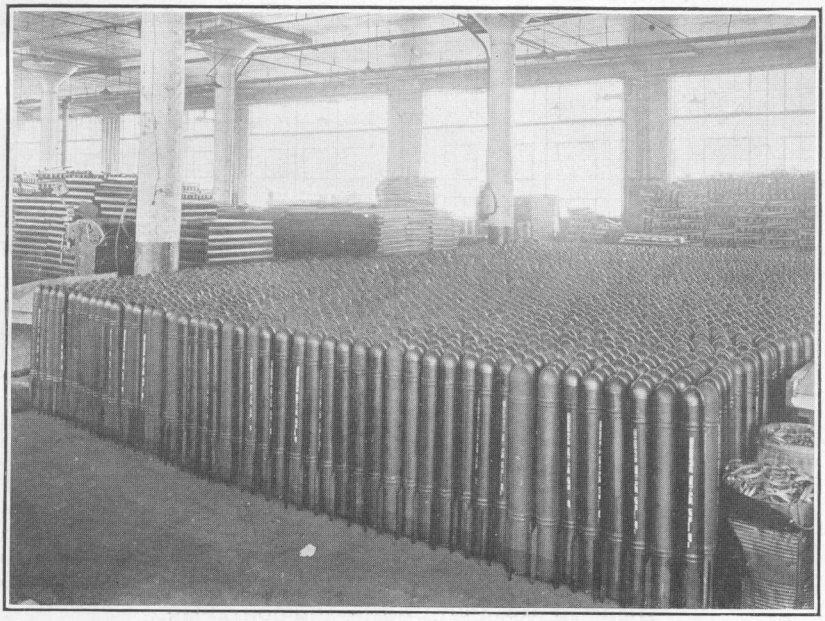
The airplane flare Mark II is an adaptation of the French Bourges illuminating flare and is used in conjunction with night observation from airplanes. It was designed to be thrown from the airplane by the pilot or the observer and is employed in an emergency and as an auxiliary to airplane flare Mark I. The French flare is cylindrical in shape, with a length of 20 inches and a diameter of $2\frac{3}{4}$ inches. The illuminant is suspended by a cloth parachute which is from 3 to 4 feet in diameter. A time fuze is provided which can be set to the number of seconds desired by the aviator. In operation the flare is dropped from the airplane by the aviator or observer and is caused to function by pulling a small string attached to the firing mechanism. The experimental work was carried on by the pyrotechnic laboratory of the Ordnance Department, and it did not go beyond the experimental

PLATE 8a.



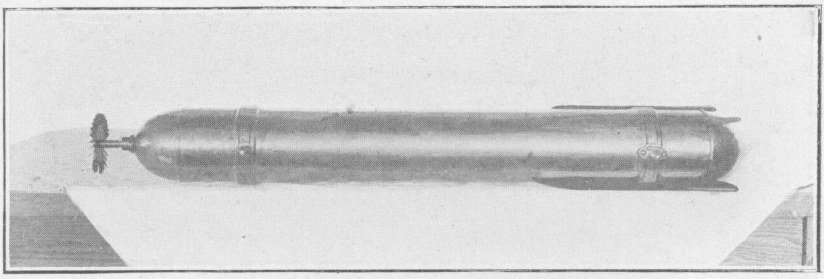
AIRPLANE FLARE MARK I.

PLATE 9a.



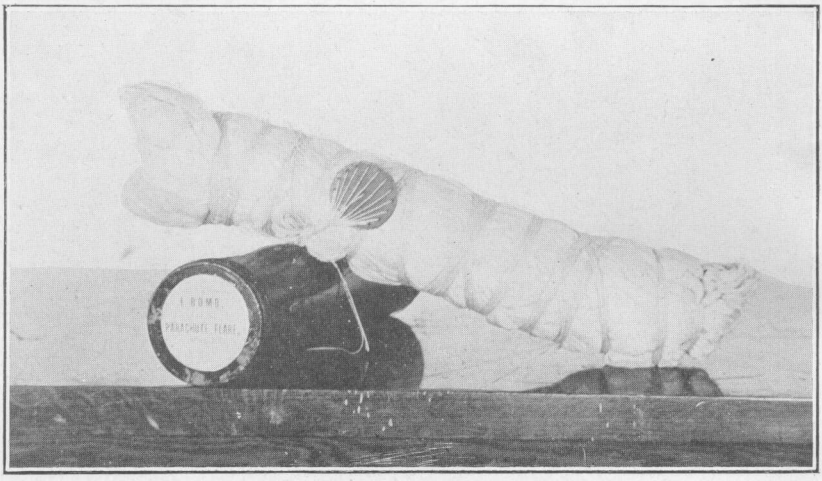
ONE DAY'S OUTPUT OF FLARE BOMBS FOR THE SIGNAL CORPS.

PLATE 10a.



MICHELIN PARACHUTE FLARE..

PLATE 11a.



MICHELIN PARACHUTE, BOMB, AND CONTAINER.

stage. Apart from the tests for candlepower, the experimental work was confined to different forms of firing mechanisms, along the lines of standard ignition, the grenade type of ignition, and clockwork and friction types of ignition. The illuminating composition made up at the pyrotechnic laboratory had a burning time of 3 minutes and developed a candlepower of 110,000.

In the French manufacture this Bourges flare is considerably smaller than the Michelin flare from which with wing tip flare, Mark I, was adapted, and has a time fuze which arms it to function much nearer the ground and it is in much greater favor with the aviators than the Michelin flare. A dozen Bourges flares can be carried in the fuselage of the plane while only 2 or 3 Michelin flares can be carried, and these must be suspended from the Michelin releasing mechanism underneath the wings or the fuselage. The Bourges flare is fired by the aviator jerking a cord at the instant he throws the flare clear of the plane. This cord releases the firing pin which is under compression. The firing pin strikes a cap which ignites a time fuze. The objectionable feature of this flare is that the fuze is always armed and recommendation was made that safer firing mechanism be developed. It was suggested that the Bourges flare with a yellow or mist-penetrating light be developed, as this would greatly aid night flying in the zone in which the squadron was operating. The timing arrangement of the fuze should have a greater range. Drawings, specifications, and samples were sent to the United States with a request that they be put into production immediately.

SMOKE MESSAGE TUBE (AIRPLANE).

The message cartridge for the 35-millimeter pistol (aviation) was to some extent used for sending information such as reconnaissance reports, maps, etc., from the airplane to the land force. This cartridge did not have sufficient capacity to meet the requirements of our air squadron. The aviators improvised a type of message tube consisting of a tin can with a cloth streamer, and this worked out satisfactorily with the exception that it did not have a smoke tracer. The idea of the smoke tracer is to aid the watcher on the ground in locating the message after it has reached the ground, and its smoke must be of such color that it can be distinguished from the smoke of bombs or shell. To attract attention before dropping the message, the aviator would blow a whistle or a horn, or in some cases, would fire a few shots from his machine gun in order to attract attention to the message which was about to be released. Tentative drawings were prepared by the Engineering Division of the American Expeditionary Forces of a smoke message tube having a message-carrying capacity 8 inches long by 2 inches in diameter and providing for the ignition of the smoke composition which was located in a compartment in one

end of the tube by means of a Mark II offensive hand grenade bouchon without the detonator.

Work was also being carried on in the United States in the development of a smoke message tube when the armistice was signed.

OFFENSIVE GRENADE FLARE.

The object of this grenade was to replace the Very signals used in aviation, it being much simpler and easier to throw one of these grenades from the plane than to load and fire a pistol. It was developed at the Ordnance pyrotechnic laboratory and the tests conducted with experimental grenades indicated that they could be manufactured to function equally as well as the Very cartridges. The unsatisfactory feature lies in the fact that the star may be blown back onto the plane, as the direction in which the star is expelled can not be controlled. The matter was in an experimental stage at the time of the armistice.

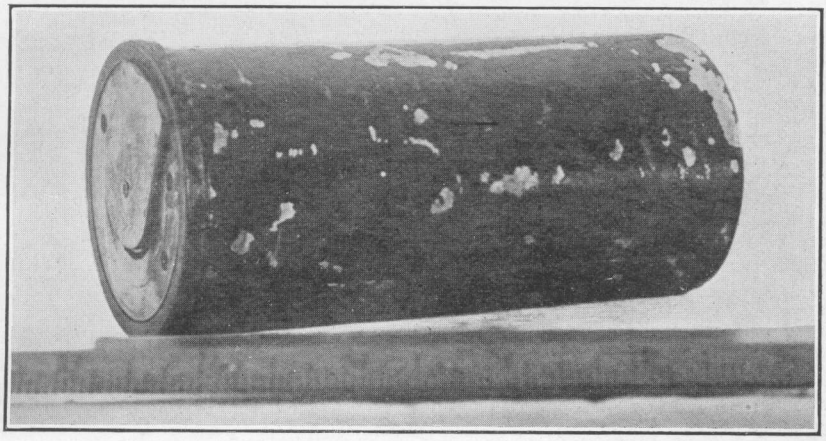
ILLUMINATING BOMB AND GUN, MARK I.

This was an experimental project to provide an illuminating shell of greater range than the rocket. The shell was loaded with a single illuminating star and a 36-inch parachute. The illuminating composition was designed to burn about 20 seconds, giving a candlepower of 60,000 or more. The shell was to burst about 350 feet from the ground and the fuze to give a maximum range of 1,500 feet. The project was not carried beyond the experimental stage, and it was decided to use the Stokes' mortar and modify the Stokes' shell for illuminating purposes.

DROPPING DEVICE FOR INCENDIARY DARTS.

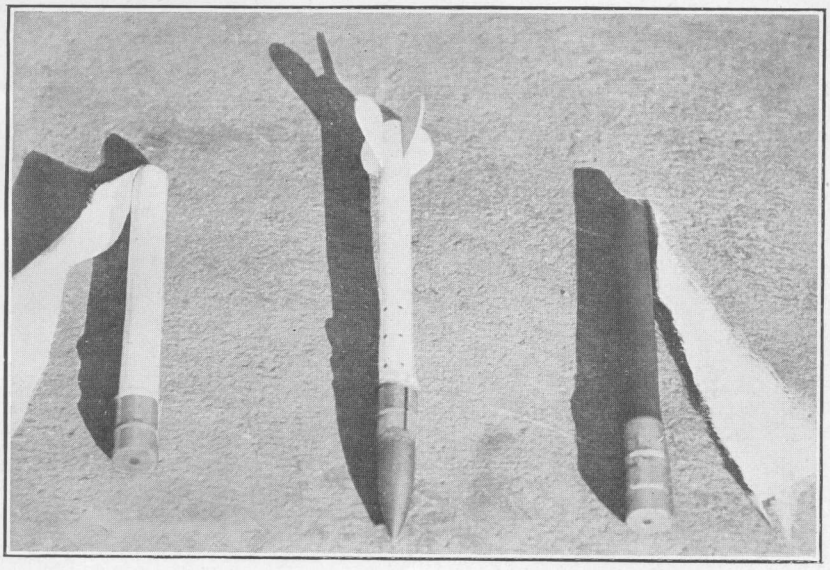
The purpose of this device was to provide a means for the carrying of incendiary darts by airplanes and the dropping of them upon objects which could be set on fire. The project was in the experimental stage at the signing of the armistice. The device was designed to be attached to the standard bomb-carrying device of D. H.–4 airplanes, using the standard release mechanism. A safety device was incorporated in the loading bucket and precluded the possibility of the darts becoming ignited while in the dropping device. The device is pivoted on trunnions at one end, and when released swings about these trunnions in a vertical downward arc, which is retarded slightly at the point when the dropping bucket is pointing directly downward, thus allowing the darts to be spilled. The retardation is then relieved and the remaining momentum of the device, together with the wind pressure due to the movement of the airplane, completes the movement and the empty bucket swings up under the wing of the airplane, where it is caught and held by suitable latches. The value of the device has not yet been demonstrated.

PLATE 12a.



ILLUMINATING BOMB, MARK I.

PLATE 13a.



INCENDIARY DROP DARTS, AIRPLANE TYPE.

The darts to be carried by this device were the incendiary darts, Mark I; the bucket being loaded with 61 darts. The assembled weight loaded was approximately 60 pounds, of which weight 25 pounds represented the weight of the darts.

The incendiary dart, Mark I, was between 11 and 12 inches in length and about 1 inch in diameter. It consisted of a tube containing an incendiary mixture, a nose with striker and cap to ignite the mixture on impact with the ground, and a stabilizer to insure the dart traveling nose downward when released from a plane. In the experiments a cloth stabilizer was at first employed and later a vaned paper stabilizer was used. The basic idea was to provide a dart which on striking the ground would send a radial shower of flame several feet high for the purpose of igniting grain fields or other readily ignitable objectives.

The Mark I incendiary dart was constructed to permit the carrying of large quantities of darts in an airplane, it being considered that as many as 1,000 darts might be carried at one time in a large plane and that it would be possible to scatter the incendiary units over a considerable area. A quantity of darts were sent to France but they were condemned there as not being suitable for the purpose. Those are doubtless fully reported upon by the Chemical Warfare Service.

At the time that the United States was ready to initiate its manufacturing program, only three or four plants were available for quantity production; one of the manufacturing companies having just been organized.

The tabulation immediately preceding will in general indicate the quantity orders placed, and for the presentation of contract details the "History of Production of Pyrotechnics," prepared by the Trench Warfare Division of the Army Ordnance Department and submitted on January 3, 1919, is reproduced.

CHAPTER II.

HISTORY OF THE PRODUCTION OF PYROTECHNICS.

SIGNAL ROCKETS.

JANUARY 3, 1919.

The first contract was let to Unexcelled Manufacturing Co., New York, on December 1, 1917. Quantity production started in January. On May 13, 1918, the Engineering Division changed specifications to conform to French types. This radical change made it necessary for manufacturers to alter their plans considerably. Production of old style signal rockets was as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Mark II. Yellow smoke:				
Unexcelled Manufacturing Co	G1121-424TW	Nov. 30, 1917	20,000	20,000
Henry J. Paine	G1191-440TW	Nov. 27, 1917	10,000	10,000
Unexcelled Manufacturing Co	P3274-1128TW	Feb. 22, 1918	6,000	6,000
Henry J. Paine	P3574-1236TW	Mar. 1, 1918	100	100
Total			36,100	36,100
Mark I. Golden rain:				
Unexcelled Manufacturing Co	G1121-424TW	Nov. 30, 1917	1,188	1,188
Henry J. Paine	G1193-442TW	Nov. 27, 1918	365	365
Total			1,553	1,553
Mark I. Amber:				
Unexcelled Manufacturing Co	G1121-424TW	Nov. 30, 1917	8,812	8,812
Henry J. Paine	G1193-442TW	Nov. 27, 1917	9,635	10,000
Unexcelled Manufacturing Co	P3273-1127TW	Feb. 22, 1918	17,250	17,250
Total			35,697	36,062
Mark I. Red:				
Unexcelled Manufacturing Co	G1121-424TW	Nov. 30, 1917	20,000	20,000
National Fireworks Co	G1190-439TW	Nov. 27, 1917	7,500	7,500
Henry J. Paine	G1193-442TW	Nov. 27, 1917	22,500	22,500
Unexcelled Manufacturing Co	P3275-1127TW	Feb. 22, 1918	4,976	4,976
Total			54,976	54,976
Grand total			128,326	128,691

The changes in design of signal rockets which started on May 13, 1918, were put into effect at the different manufactories as rapidly as possible. Samples were submitted by the manufacturers to meet the requirements. Quantity production on the new types started the latter part of July. Production accepted by Government inspectors up to December 8, 1918, was as follows:

Article and firm.	Cuntract No.	Date.	Contracted for.	Completed.
Mark I. Red:				
Unexcelled Manufacturing Co.	P3273–1127TW	Feb. 22, 1918	28,024	16,000
National Fireworks Manufacturing Co.	P14553–2441TW	Sept. 4, 1918	50,000	11,000
Unexcelled Manufacturing Co.	P15167–2504TW	Sept. 19, 1918	25,000	17,000
Henry J. Paine	P15484–2538TW	Sept. 26, 1918	20,000	17,000
Total			123,024	61,000
Mark I. Green:				
Unexcelled Manufacturing Co.	P3273–1127TW	Feb. 22, 1918	25,904	25,904
National Fireworks Manufacturing Co.	P14553–2441TW	Sept. 4, 1918	50,000	8,000
Unexcelled Manufacturing Co.	P15167–2504TW	Sept. 19, 1918	25,000	25,000
Henry J. Paine	P15484–2538TW	Sept. 26, 1918	20,000	18,000
Total			120,904	76,904
Mark I. Amber:				
Unexcelled Manufacturing Co.	P3273–1127TW	Feb. 22, 1918	5,750	5,750
Mark I. Yellow smoke:				
Unexcelled Manufacturing Co.	P3274–1128TW	Feb. 22, 1918	24,000	24,000
Henry J. Paine	P3574–1236TW	Mar. 1, 1918	39,900	39,900
Total			63,900	63,900
Mark I. White:				
Unexcelled Manufacturing Co.	P3273–1127TW	Feb. 22, 1918	29,000	29,000
Henry J. Paine	P3556–1233TW	Mar. 4, 1918	35,000	35,000
National Fireworks Manufacturing Co.	P14553–2441TW	Sept. 4, 1918	50,000	1,000
Unexcelled Manufacturing Co.	P15167–2504TW	Sept. 19, 1918	25,000	25,000
Henry J. Paine	P15484–2538TW	Sept. 26, 1918	20,000	20,000
Total			159,000	110,000
Grand total			472,578	317,562

In order to aid production the Government started to furnish paper parachutes to manufacturers in September, 1918. Some of these were imported from Japan and some sewed in this country. The contracts let with the production to December 12, 1918, were as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
28-inch domestic sewed: Japan Paper Co.	P14841–2476TW	Sept. 12, 1918	31,700	31,700
28-inch imported: Japan Paper Co.	P14841–2476TW	....do.....	27,000	27,000
28-inch domestic sewed: Japan Paper Co.	P15282–2512TW	Sept. 21, 1918	95,000	95,000
28-inch imported: Japan Paper Co.	P15282–2512TW	....do.....	25,000	23,000
28-inch domestic sewed: Japan Paper Co.	P15405–2532TW	Sept. 24, 1918	1,000,000	230,000
Do	P15551–2548TW	Sept. 25, 1918	28,700	28,700
Total			1,205,400	435,400
32-inch imported: Japan Paper Co.	P15282–2512TW	Sept. 21, 1918	90,000	90,000
32-inch domestic sewed: Japan Paper Co.	P16310–2657TW	Oct. 9, 1918	630,000	170,000
32-inch imported: Japan Paper Co.	P16418–2671TW	Oct. 15, 1918	1,000,000	90,000
32-inch domestic sewed: Japan Paper Co.	P17797–2815TW	Nov. 6, 1918	400,000	77,700
Total			2,120,000	427,700
34-inch imported: Lewis Nixon	P15402–2529TW	Sept. 24, 1918	103,000	103,000
36-inch imported: Japan Paper Co.	P16961–2716TW	Oct. 22, 1918	210,000	187,500
Flag imported: Japan Paper Co.	P15791–2472TW	Sept. 11, 1918	5,000	5,000
Do	P16314–2661TW	Oct. 5, 1918	40,000	.....
Total			45,000	5,000
Grand total			3,683,400	1,158,600

POSITION LIGHTS.

The first contract for position lights was for the hand type, Mark II, let to Henry J. Paine on December 19, 1917. The first produc-

tion passing Government inspection was the first part of February, 1918. Contracts for the hand type, Mark I, were first let the early part of March, 1918, and by the middle of May quantity production was passed Government inspection. It was necessary for several changes in specifications to be made. The most radical of which were made June 14, 1918, covering formulæ, time of burning, and candlepower. Since that time, the manufacturers adapted their production to the new specifications as rapidly as their samples could be made to pass the necessary tests. Considerable trouble was encountered, but by August 1 the Mark II hand-type position lights had reached a steady maximum quantity production. The Unexcelled Manufacturing Co. were not able to reach quantity production on the ground type Mark I until September, 1918. In the meantime, however, the Nixon Fulgents Product Co. were able to turn out their contract complete by July 20, 1918. The contracts let and production accepted by Government inspection up to December 12, 1918, are as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Mark II. Hand, white:				
Henry J. Paine	G1192-441TW	Nov. 27, 1917	50,000	50,000
Unexcelled Manufacturing Co	G1274-472TW	Dec. 8, 1917	50,000	50,000
Do	P3280-1134TW	Feb. 22, 1918	485,000	485,032
Henry J. Paine	P15487-2541TW	Sept. 24, 1918	27,000	27,000
Unexcelled Manufacturing Co	P15554-2549TW	Sept. 27, 1918	30,000	30,000
Essex Specialty Co	P16250-2651TW	Oct. 10, 1918	50,000	.....
Henry J. Paine	P3557-1234TW	Mar. 4, 1918	165,000	165,000
Total			857,000	807,032
Mark I. Ground, white:				
Unexcelled Manufacturing Co	P3275-1128TW	Feb. 22, 1918	132,000	132,002
Lewis Nixon	P3856-1291TW	Mar. 8, 1918	18,000	18,000
Unexcelled Manufacturing Co	P15792-2569TW	Sept. 26, 1918	50,000	.....
Essex Specialty Co	P16250-2651TW	Oct. 10, 1918	100,000	.....
Total			300,000	150,002
Mark I. Ground, red:				
Unexcelled Manufacturing Co	P3275-1129TW	Feb. 22, 1918	330,000	330,017
Lewis Nixon	P3656-1291TW	Mar. 8, 1918	45,000	45,000
Do	P13417-2345TW	Aug. 12, 1918	45,000	45,000
Unexcelled Manufacturing Co	P15792-2569TW	Sept. 26, 1918	50,000	50,000
Essex Specialty Co	P16250-2651TW	Oct. 10, 1918	100,000	12,000
Total			570,000	482,017
Mark I. Ground, green:				
Unexcelled Manufacturing Co	P3275-1129TW	Feb. 22, 1918	198,000	74,017
Lewis Nixon	P3656-1291TW	Mar. 8, 1918	27,000	27,000
Unexcelled Manufacturing Co	P15792-2569TW	Sept. 26, 1918	50,000	.....
Essex Specialty Co	P16250-2651TW	Oct. 10, 1918	100,000	.....
Total			375,000	101,017
Grand total			12,102,000	1,540,068

RIFLE LIGHTS MARK I, SIGNAL LIGHTS MARK I, AND VB CARTRIDGES.

Production was well under way on contract for 2,000,000 rifle lights, Mark I, and signal lights, Mark I, when on June 13, 1918, the Engineering Division notified us that these articles would have to be

completely changed to the French types. Production was stopped. The French types are known as VB star and parachute cartridges, of which there are about 20 types. Quantity production on these types started about October 15, 1918. The contracts let and production accepted by Government inspection up to December 12, 1918, are as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Rifle light, Mark I, white:				
Unexcelled Manufacturing Co	P3271-1125TW	Feb. 22, 1918	265,000	(1)
Lewis Nixon	P3856-1291TW	Mar. 8, 1918	55,000	55,000
Signal lights, Mark I, green:				
Unexcelled Manufacturing Co	P3272-1126TW	Feb. 22, 1918	88,000	(1)
Lewis Nixon	P3856-1211TW	Mar. 8, 1918	55,000	55,000
Mark I, red:				
Unexcelled Manufacturing Co	P3272-1126TW	Feb. 22, 1918	88,000	(1)
Lewis Nixon	P3856-1291TW	Mar. 8, 1918	55,000	55,000
Total			606,000	165,000
VB parachute:				
Lewis Nixon	P3856-1291TW	Mar. 8, 1918	610,000	53,040
VB star cartridge:				
Lewis Nixon	P3856-1291TW	Mar. 8, 1918	605,000	174,420
Total			1,215,000	227,460

[1] Canceled.

SIGNAL LIGHTS, MARK II, VERY.

On January 3, 1918, contracts were let for Remington Arms Co. U. M. C. for 1,000,000 signal lights, Mark II, except stars, and to the National Fireworks Distributing Co., for 1,000,000 stars. These contracts were completed and production well under way on 2,000,000 more, when on May 18 we were notified that the 10 gauge pistol, the ammunition for which is the signal lights, Mark II, would be replaced by the 25 mm. French type pistols. Production was stopped immediately. The contracts let with production accepted by Government inspection up to December 12, 1918, are as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Red, Mark II:				
Remington Arms Co	G1802-636TW	Jan. 2, 1918	333,000	307,800
Do	P2473-871TW	Feb. 1, 1918	667,000	576,980
Total			1,000,000	884,780
White, Mark II:				
Remington Arms Co	G1802-636TW	Jan. 2, 1918	334,000	330,400
Do	P2473-871TW	Feb. 1, 1918	666,000	615,480
Total			1,000,000	945,880
Green, Mark II:				
Remington Arms Co	G1802-636TW	Jan. 2, 1918	333,000	294,600
Do	P2473-871TW	Feb. 1, 1918	667,000	425,748
Total			1,000,000	720,348
Grand total			3,000,000	2,551,008

VERY CARTRIDGES, 25 MM.

Contracts were let first for 25-mm. Very cartridges on August 17, 1918. The primed metal cartridge cases were made by one manufacturer and sent to a fireworks plant to be loaded. The Government furnished primers, silk parachutes, metal parts, and in order to facilitate production, it was intended to furnish the loading plant all component parts. Production was well under way on component parts when the armistice was signed. Contracts let with production accepted by Government inspectors to December 12, 1918, were as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
1 star, red: National Fireworks Co	P15172-2506TW	Sept. 19, 1918.	100,000	0
1 star, white: National Fireworks Co	P15172-2506TW	do	100,000	0
1 star, green: National Fireworks Co	P15172-2506TW	do	100,000	0
Total			300,000	
Cartridge cases: Empire Art Metal Co	P13873-2372TW	Aug. 21, 1918.	2,000,000	836,010
No. 4 commercial primers: Winchester Repeating Arms Co	P15519-2543TW	Sept. 27, 1918.	25,000,000	4,760,000
24-inch silk parachutes:				
New England Corset Co	P17024-2727TW	Oct. 24, 1918.	500,000	0
Rose Bros. & Co	P15187-2508TW	Sept. 20, 1918.	100,000	65,600
Total			600,000	65,000
Metal star containers: Art Metal Works	P16105-2630TW	Oct. 3, 1918.	5,200,000	10

SMOKE TORCHES.

On June 25, 1918, contract was let for 500,000 smoke torches. The first production was not satisfactory, but after several experiments were made, a successful mixture was accomplished. An improvement was made in the tin can. Production accepted by Government inspectors up to December 12, 1918, was as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Smoke torches: Nixon Fulgent Products Co	P10700-2114TW	June 25, 1918.	500,000	110,000

WING-TIP FLARES.

The first contract was let August 27, 1918, to Henry J. Paine for 20,000 red and 20,000 white wing tip flares. Considerable delay was caused making a mixture that would give the proper time of burning. A contract was let on June 1, 1918, to Nixon Fulgent Products Co., who were able to meet the specifications. A successful formula was given to Henry J. Paine so that production could proceed without further delay. The contracts let with production accepted by Government inspectors up to December 12, 1918, are as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Mark I. red:				
Henry J. Paine	P8741-1971TW	May 27, 1918	20,000	0
Lewis Nixon	P9062-1990TW	June 1, 1919	36,083	36,083
Total			56,083	36,083
Mark I. white:				
Lewis Nixon	P9062-1990TW	June 1, 1919	36,082	36,082
Henry J. Paine	P8741-1971TW	May 27, 1918	20,000	8,000
Total			56,082	44,082

AIRPLANE FLARES.

On May 29, 1918, a contract was let to the Nixon Fulgent Products Co. for assembling of 50,000 airplane flares. The metal casing or bomb, was let to Edward G. Budd Manufacturing Co., Philadelphia, on June 5, 1918. The Government also furnished silk for the parachutes and contracted for the making of the parachutes. Considering the large amount of detail involved, good progress was made in securing silk for the parachutes, making of the parachutes, and the making of metal cases. It was necessary to make several changes in the loading or assembling before the flares would function properly. The contracts let with production accepted by Government inspectors up to December 12, 1918, are as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Silk for airplane flares:				
Cheney Bros	P11934-2222TW	July 16, 1918	75,000	75,000
D. G. Dery (Inc.)	P12144-2340TW	do	200,000	147,153
Stehli Silk Corporation	P11894-2209TW	do	101,000	101,000
Sanquoit Silk Co	P11935-2223TW	do	42,000	38,705
Louis Roessel & Co	P11932-2220TW	do	75,000	40,279
Schwarzenbach, Huber Co	P9251-2006TW	June 4, 1918	30,000	30,000
	P9369-2019TW	June 6, 1918	50,000	50,000
	P9923-2059TW	June 13, 1918	50,500	50,500
	P10387-2084TW	June 21, 1918	[1] 25,000	25,000
	P10965-2134TW	June 28, 1918	112,500	112,500
	P11367-2160TW	July 6, 1918	450,000	394,428
	P13567-2354TW	Aug. 15, 1918	75,000	75,000
Duplan Silk Corporation	P11933-2221TW	July 16, 1918	[1] 100,000	92,171
Total			[1] 1,386,000	1,231,728
Parachutes for airplane flares:				
Duplan Silk Corporation	P8912-1982TW	June 5, 1918	1,000	1,000
Follmer, Clogg Co	P9960-2061TW	do	1,785	1,785
	P13629-2358TW	Aug. 16, 1918	2,000	2,000
	P14890-2482TW	Sept. 13, 1918	25,000	13,400
	P12161-2245TW	July 18, 1918	300	[2]
Jacob Gerhardt Co	P13787-2370TW	June 17, 1918	1,500	1,500
	P16313-2660TW	Oct. 13, 1918	10,000	6,094
	P10964-2133TW	June 28, 1918	1,800	1,800
Total			44,385	27,579
Metal cases for airplane flares: Edw. G. Budd Manufacturing Co.	P9321-2009TW	June 5, 1918	65,083	41,020
	P17796-2814TW	Nov. 1, 1918	[2]	
Assembling and loading:				
National Fireworks Co	P17584-2788TW	Oct. 30, 1918	15,000	[2]
Lewis Nixon	P8913-1983TW	June 29, 1918	50,083	3,600
Total			65,083	3,600

[1] Yards. [2] Canceled.

HISTORY OF THE PRODUCTION OF SIGNAL PISTOLS.

VERY SIGNAL PISTOLS, MARK III, 10-GAUGE.

The Remington Arms U. M. C. Co. was given contracts for 35,000 10-gauge Very signal pistols, of which 20,460 were completed when it was decided to change to the 25-mm. Very pistols, Mark IV. Production accepted by Government inspectors up to December 12, 1918, is as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Mark III, 10-gauge:				
Remington Arms Co	G720-382TW	Nov. 13, 1917	12,500	12,500
	P5871-1176TW	Apr. 13, 1918	22,500	7,960
Total			35,000	20,460

25-MM. VERY PISTOLS, MARK IV.

On August 5, 1918, contracts were let for 135,000 25-mm. Very pistols, of which 15,000 have been passed by Government inspectors December 12, 1918:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
25-mm., Mark IV:				
A. H. Fox Gun Co	P13029-2302TW	Aug. 5, 1918	33,057	4,193
National Tool & Manufacturing Co	P13030-2303TW	do	75,000	0
Scott & Fetzer Machine Co	P13031-2304TW	do	30,000	7,750
National Tool & Manufacturing Co	P16311-2658TW	Oct. 13, 1918	28,662	0
Total			166,719	11,943

35-MM. VERY PISTOLS, MARK I, AVIATION.

Thirty-five-mm. pistols, Mark I, aviation, were contracted for the last of August, 1918. Production was well under way when the armistice was signed. Production accepted by Government inspection up to December 12, 1918, is as follows:

Article and firm.	Contract No.	Date.	Contracted for.	Completed.
Die cast parts:				
Dohler Die Casting Co.—				
Handles	P13578-2355TW	Aug. 16, 1918	31,152	5,258
Barrels	P13578-2355TW	do	31,152	4,931
Sides	P13578-2355TW	do	31,152	6,193
Locking piece	P13578-2355TW	do	31,152	4,347
Finished pistols:				
Hammond Typewriter Co	P13325-2330TW	Aug. 10, 1918	15,000	0
Parker Bro	P14453-2431TW	Aug. 29, 1918	14,669	0
Total finished pistols			29,669	0

APPENDIX.

TACTICAL USE OF FOREGROUND ILLUMINATION.

The illumination of the foreground is effected by several means, but the most effective is the searchlight.

TACTICAL USE OF SEARCHLIGHTS.

Considerations.—Depending upon whether the searchlight is used for reconnoitering the dispositions made by the enemy or for combating him, it takes part in the work of exploration or in the action itself. Apart from these two methods of employment, there exists hardly a means of utilizing it with a tactical object. The searchlight is the most effective auxiliary of fire at night. It surprises the enemy, blinds him, and renders him visible, under conditions which depend principally on the hygrometric condition of the air, the diameter of the searchlights, and on the angle of site. By its unforeseen appearance it contributes in delaying and in hindering the advance, and directly to nullify, the intentions of the assailant. The surprise is prepared by the securing of data of prominent points of the terrain during daytime, by means of a special oscillation and inclination device which permits of instantly directing the beam on the point marked.

Independently of the moral effect produced by the surprise, that caused by the dazzling power of the rays prevents the adversary from aiming and firing under good conditions, since it completely prevents him from observing and estimating distances. Furthermore, advance on the searchlight is very difficult. Oscillating illumination (change of direction of the beam from left to right and from right to left) or intermittent (light alternating with obscurity) causes loss of orientation and direction; horses are seized with panic, intrenching has to be suspended, and the enemy is often obliged to discontinue all movement.

* * * * * * *

Moonlight does not reduce as much as would be thought the use of the searchlight, the illuminating power of the searchlight being far greater than that of a full moon. There results an increase of visibility when the searchlight enters into operation. Field searchlights can furnish in normal weather the visibility of the naked eye, and consequently the vulnerability of the adversary at the following distances:

1. *Chemical light apparatus.*—Owing to their low illuminating power these apparatus can operate only with the use of a cylindrical beam. The useful range of these searchlights for the discovery of a group is at from 150 to 200 meters with the naked eye and 250 meters with a field glass. The width of the front illuminated by these apparatus is about 10 meters.

2. *Electric light apparatus.*—Thirty-six-inch electric searchlight, cylindrical beam: Group personnel, with naked eye 1,400 meters; with field glass 2,000 meters; isolated personnel, with naked eye 800 meters; with field glass 1,200 meters. With divergent beam: Group personnel, with naked eye 700 meters; with field glass 800 meters.

Sixteen-inch electric searchlight, cylindrical beam: Group personnel, with naked eye 800 meters; with field glass 1,400 meters; isolated personnel, with naked eye 600 meters; with field glass 800 meters. With divergent beam: Group personnel, with naked eye 500 meters; with field glass 600 meters.

Twenty-four-inch electric searchlight was also available, and later, searchlights up to 60 inches in diameter were available; but these later large types were more particularly designed for use in the rear areas for aircraft detection and illumination.

The distances above mentioned give the degree of visibility of the different diameters of field searchlights, supposing the illuminated troop to be standing and dressed in gray or light blue, the shining parts of the equipment being covered with cloth. At the kneeling position the visibility decreases by one-half; it decreases in still greater portions at the lying position.

* * * * * * *

Light and yellow colors appear white in the luminous beam, green appears yellowish; troops in white and very dark uniforms are easy to discover, for they are well detached

in the luminous beam; gray and light blue uniforms are difficult to distinguish on a green background.

The flashes of arms, tools, buttons, visors of caps render a command very visible. Lights from fires and lanterns are rather difficult to see when they are in the luminous beam.

A fine rain considerably diminishes the range of the searchlight; fog completely checks its action. The same applies to smoke.

Against the dazzling light the only protection is to wear black glasses.

Lowering of visors and leafy branches carried in front give but mediocre results and have the disadvantage of allowing the troops to be discovered by flashes. The eyes of horses appear in the beam like phosphorescent lights.

GENERAL PRINCIPLES ON THE USE OF SEARCHLIGHTS.

* * * * * * *

Long-range searchlights can be employed for the following purposes:

1. Support exploration and contribute to reconnoitering of the terrain.
2. Illuminate objects for fire.
3. Facilitate the march of columns.
4. Mask the movements of friendly troops.
5. Blind enemy searchlights.
6. Blind the adversary.
7. Deceive the enemy by feints.
8. Produce an effect of demoralization.
9. Illuminate work of all kinds.
10. Insure communication between distant detachments and secure for signaling.
11. Aviation.

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ILLUMINATE OBJECTS FOR FIRE.

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Artillery fire.—As soon as the object has been discovered, the commander of the battery has the fire prepared for such object, the beam of the searchlight remaining unmasked as little as possible, so as not to draw the fire of the enemy. On firing the salvo the searchlight unmasks for the time necessary for observing the fire and, if required, following the object.

Infantry fire (rifle or machine gun).—

Rifle.—

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A searchlight engaged should not retire, even under a menacing pressure of the assailant, unless it receives order from the commanding officer of the troops to which it is assigned, the natural role being to illuminate to the last moment.

Machine gun.—

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The machine guns open fire each time the object is illuminated by the luminous beam.

FACILITATE THE MARCH OF COLUMNS.

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The searchlight can also illuminate a line of march, the troops marching in the shade by side of the beam.

Owing to the very sensible contrast between the shade and the light, it is difficult to observe, through the luminous beam, what is passing beyond. Searchlights can therefore be used to establish a sort of luminous screen, behind which the enemy can see nothing. For this purpose one or more searchlights are employed, which are placed more or less to the flank according to circumstances.

This method is employed particularly on flat terrain, but is not practicable in broken country or in mountainous country, since the searchlight has to be installed at the same height as the objects to be masked, and the enemy must not be able to discover them by passing above or below the luminous beam.

Another method, but one of delicate application, consists in moving the luminous beam before a troop advancing, to prevent the enemy discovering it.

Blinding the adversary.—It is impossible for troops in face of a searchlight beam to distinguish anything in the direction of the searchlight or in the neighboring directions. It is therefore possible to approach very closely to an enemy blinded in this manner without being seen, and cases may occur in which an attack with the bayonet can be immediately carried out. This effect is increased if the searchlight be oscil-

lated from side to side, and if a succession of violent contrasts be produced by shutting off the light and reestablishing it several times in succession. Troops marching under these conditions generally lose direction and get in disorder. This effect is still more marked with mounted troops.

Deceiving the enemy by feints.—The searchlights having been adjusted and put in action, the attention of the enemy is drawn in their direction, and this is taken advantage of to make a surprise attack from the opposite side.

Effects of demoralization.—The Russians are greatly in favor of this, for they noted these effects at the siege of Port Arthur. At night the men are in a state of nervous tension. When the luminous beam is thrown on them they are dazzled and think they are perceived by the enemy. This fear increases, for they are conscious of being unable to defend themselves, and thus feel their destruction imminent.

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Communication between detachments—Signaling.—At night the luminous beam is visible at very great distances (12 to 62 miles,) according to its strength.

For signaling, the Morse signals or conventional signals are used. Another method consists in projecting the luminous beam on the clouds. Its trace is seen from a great distance (43½ to 50 miles).

In daytime the searchlight can replace the heliograph; in this case it has to be oriented.

Aviation.—According to aviators it appears that the zone lighted by the divergent lens is sufficient to enable a belated aeroplane to land without too great difficulty.

METHOD OF USE.

It is much more difficult to employ searchlights judiciously in an attack than in defense, for, while the defender will endeavor to explore and minutely search all the terrain in front of him, the assailant will seek obscurity to execute his movements and obtain surprise effects.

DISTRIBUTION OF SEARCHLIGHTS.

The conditions of a good distribution are that each zone of terrain be illuminated with sufficient intensity. It is according to this rule that, in certain foreign armies, the number of searchlights necessary is calculated at the rate of 1 for each 1,000 yards of front.

Searchlights are preferably employed in groups of two each—one for searching for objects, the other for keeping them illuminated and enabling the fire on them to be properly directed. It is thus possible to continue searching the terrain.

ACTION OF THE SEARCHLIGHT.

For searching the terrain it is necessary to operate by alternating light and obscurity, in order that an enemy can not see the beam coming upon it and have the time to avoid it. One should also operate by "bounds," the searchlight remaining unmasked only for the time necessary to allow the observers to see well the illuminated sector. A continuous illumination attracts the fire of the enemy infantry and artillery and facilitates their aim. By means of the sighting device for height and direction fixed on each searchlight, it will be easy to direct the beam instantaneously on a given point that has been marked during daytime. When troops are reported the surprise by the light and the surprise by the fire should be as simultaneous as possible; the adversary remains illuminated as long as the troops covering him with fire consider useful.

The use of the light of a searchlight as a rallying signal at the moment of shock and even during the action is to be condemned, for the friendly troops will almost always be illuminated the same as the enemy.

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To embarrass adverse ranging on the searchlight the same can be raised or lowered, varying the intensity of the light by combining changes and variations with periods of obscurity. In this manner changes of position of the searchlight can be simulated.

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The best position for observing is about 40 meters on the flank and a few meters to the rear of the searchlights.

If, in order to observe better, the officer observer has to advance, he will select a position situated at a lower height than that of the searchlight, so as to be always below the beam.

In case of necessity the officer observer may observe from the position of the searchlight, but must place himself below the cone of light.

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The observer should impress himself with the idea that the illumination of targets will be the most important task of the searchlight. The dazzling, which in certain cases may produce a considerable effect, will be but secondary.

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The illumination of the foreground by means other than searchlights is accomplished by various contrivances.

Among those most often used are:

Portable lights (automobile headlights), usually electric, using storage batteries.

Rockets shaped like a cartridge, 6 inches long and 1 inch in diameter, fired from a sort of sawed-off shotgun, the light burning about 20 to 30 seconds.

Rockets, a good deal like those used for fireworks, fired from a tube and burning about three minutes.

Flares thrown to the front and so weighted as to stick in the ground upon landing, burning for varied lengths of time.

Rockets which are attached to parachutes and burn as they slowly descend.

Very lights, which burn about one minute.

Bengal flares.

Balls made of a magnesium compound which are lighted and then thrown to the front, burning about two minutes.

Ordinary torches or lanterns backed with reflectors.

Bonfires built by advance sentinels and lighted by them as they withdraw under pressure of the enemy.

These and other contrivances are used for the illumination of the immediate foreground and are effective at ranges from 50 to 300 yards. Some of the lights may be so arranged as to be tripped and lighted by the enemy as he approaches, or may be lighted by men in listening posts. They are of value only in illuminating the ground for the use of rifle and machine gun fire, and mainly are of use in defense only.

Their tactical use is governed by the condition and extent of the area to be illuminated and the amount of illumination desired or possible, especial effort being made to keep the enemy in the light and one's own troops as much as possible in the shadow.

The time, method, and extent of illumination by means of the above-mentioned methods is a tactical question to be decided by the immediate commanders.

It is to be observed that the agents employed in the illumination of the foreground will be largely governed by the conditions. A searchlight throwing a steady beam or intermittent flashes can be readily located by the enemy and will draw artillery fire. With a circular beam, for distance projection, its area of illumination is limited to the diameter of the beam of light. On terrain which is level or sloping toward the enemy positions, it will illumine friendly positions as well as enemy positions.

The position of chemical searchlights located near the front lines may be changed more readily than large electric searchlights, owing to the lighter equipment.

Flares illumine the general surroundings, rather than the specific objective.

Torches thrown out in front of the lines by hand illumine for a short period only, but additional torches can be thrown out if required.

Illuminating bombs are preferable to rockets, in that the trailing sparks of a rocket give indication prior to the bursting of the illuminating element, and thus give warning which may permit of enemy concealment prior to the burst.

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INDEX.

	Page.
Cartridges:	
25 mm. Very pistol	18
35 mm. signal pistol	19
VB signal	17
Flares:	
Airplane, Mark I	23
Airplane, Mark II	24
Holt wing tip	23
Michelin	25
Offensive grenade	26
Wing tip, Mark I	23
Illuminating bomb and gun, Mark I	26
Illumination, tactical use of foreground	37
Incendiary dart, Mark I	27
Incendiary dart, dropping device for	26
Items of pyrotechnics	9
Lights:	
Rifle, Mark I	18
Signal, Mark I	18
Signal, Mark II	19
Manufacturing methods	11–15
Pistols:	
Signal, 35 mm	21
Very, Mark IV, 25 mm	20
Very, French model 1917, 25 mm	20
Position lights, Mark I	22
Pre-war status	8–9
Production chart	15
Production:	
Airplane flares	34
Wing tip flares	33
Paper parachutes	30
Position lights	30
Rifle lights	31
Signal lights	31–32
Signal rockets	29
Smoke torch	33
Very cartridges	33
VB cartridges	32
Very signal pistol	35
Pyrotechnic schools	11, 14
Reference publications	40
Requirements	15
Rockets:	
Signal, Marks I and II	16
Golden rain	16
Smoke message tube	25
Smoke torch	22