MILITARY PYROTECHNICS

THE HISTORY AND DEVELOPMENT OF MILITARY PYROTECHNICS

BY

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ILLUSTRATED

WITH AN HISTORICAL INTRODUCTION

BY

MARVIN DANA

IN THREE VOLUMES

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PLATE I.

No. 1.

The Artificers (from an old French wood-cut).

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

INTRODUCTION.

This publication has been prepared under the direction of the Ordnance Department to be used as a basis for the instruction of officers and civilians in the art of manufacturing military pyrotechnics.

Such a publication was found necessary, due to the lack of any written information on the subject and the inability to secure men trained in the art.

These volumes—Volume I, History and Development of Pyrotechnics; Volume II, Manufacture of Pyrotechnics; and Volume III, A Study of the Chemicals Used in the Manufacture of Pyrotechnics—were compiled under the direction of Henry B. Faber, dean of the pyrotechnic schools established during the World War, with an historical introduction by Marvin Dana. Acknowledgment is made to the various ordnance officers and civilians, teachers and students of the Pyrotechnic School, as well as the manufacture of pyrotechnics, all of whom contributed to a greater or less degree in the furnishing of the necessary information and scientific data on which these works are based.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ORDNANCE,
Washington, May 31, 1919.

No. O. O. 461/3341.
From: Chief, Trench Warfare Division.
To: The Chief of Ordnance.
Subject: Textbook on Military Pyrotechnics.

1. During the period of participation of the United States in the World War, the requirements for military pyrotechnics increased at a more rapid rate than productive capacity. This condition was foreseen but could not be immediately remedied by the creation of new manufacturing facilities. Pyrotechnics remains as one of the few "crafts" of our industrial life. No literature exists. Knowledge of the art has been handed down from generation to generation, and is confined to but a handful of skilled operators. The prewar industry had been expanded to the limit. Withdrawal of skilled operators from producing plants in order to form a nucleus for newer organizations would have been disastrous. The only remaining solution was to proceed immediately with the education of new operators.

2. With this end in view, an Ordnance School of Military Pyrotechnics was authorized. The services of Mr. Henry B. Faber as dean of the school were secured. Some 45 students taken from various walks of life were then apprenticed to the various manufacturing plants. Each student confined his activities to some one or more specific phases of the work. From the technical diaries of these students, Mr. Faber and his assistants extracted such data as would make a complete and well-correlated textbook for the use of the organizations of the additional plant facilities to be created.

3. The manuscript of this work was practically completed at the signing of the armistice, but was not published owing to the immediate reduction of requirements. Time no longer being pressing, Mr. Faber was authorized to in-

crease the scope of the work so as to make its usefulness broader than was originally intended. The manuscript as it stands to-day covers the entire field of pyrotechnics and opens promising lines of research and development. It is recommended that this work be published by the Ordnance Department with funds still remaining from the allotment made to cover the cost of the Ordnance School of Military Pyrotechnics. The necessary authority has been obtained from the Office of the Chief of Staff (O. O. 461/2997 Miscl.). Should an emergency again arise, this book would be of priceless value.

4. It is not, however, solely with this end in view that publication is suggested. Present conditions do not indicate that material improvements in the art may be expected from within the fireworks industry. It is therefore believed that interest in the subject must be stimulated in other directions and that a judicious distribution of this work among libraries and technical institutions would open up fields of research from which much good might reasonably be expected.

E. J. W. Ragsdale,
Lieut. Col. Ordnance Department, U. S. A.
Chief, Trench Warfare Division.

[First indorsement.]

O. O. 461/3341.
Office, Chief of Ordnance, June 2, 1919.
To: Chief, Trench Warfare Division.

1. The publication by the Ordnance Department of the Textbook on Military Pyrotechnics as above referred to is approved.

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

PREFACE.

No adequate history of pyrotechny has been written. Such a volume would indeed require the work of a lifetime on the part of its author; not for the actual writing, but for the gathering of materials. These would have to be sought very painstakingly in libraries scattered here and there throughout the world—passages of cursory reference in old texts of Latin and Greek and the Oriental tongues.

For the ancients gave no place to pyrotechny as a theme apart. Their narratives that have to do with the art are only haphazard *obiter dicta.*

In the pages that follow an attempt has been made to present the subject briefly, yet with due attention to its origins, its historical progress, and its present-day importance. Developments due to the World War have aroused a new appreciation of the vast possibilities here offered to achievement; not merely for purposes of spectacular entertainment, or the grim needs of battle, but also for vital attainments in the industrial activities of our complex civilization.

And the first preparation for the work of the future is a knowledge of what has already been accomplished in the past.

PART I.

GENERAL SURVEY.

CHAPTER I.

INTRODUCTORY.

Pyrotechny is the art of fire. This is the literal meaning; a definition so broad that it relates the art to almost every variety of human activity.

It might even be applied justly to describe the operations of the Creator throughout His cosmos.

For, in that sacrament which we call fire, flame is the outward and visible sign of an inner grace—heat. And the universe has its genesis in heat; heat terrific, inconceivable. So stupendous is the truth we know that we dare not even guess concerning the quality of that infinite flame which burns at the heart of God, wherein the cosmic fire has its source. The enormous activity of heat gives its highest known expression in the temperature of the constellation Argo, which is calculated by astronomers to be 30,000° centigrade. The Piscian temperature, the nearest to that of our own period, is 5,000° centigrade. And somewhere amid the æons there is one tiniest speck of time with a temperature between the boiling and the freezing points. In that fleeting moment in the history of the universe—a moment measured by man in cycles of millions of years—organic life comes into being; to endure briefly, soon to vanish utterly.

We may well marvel over the miracles of transmutation wrought by heat's magic when we consider the simplicity of those materials that assume protean forms of infinite variety under the impulse of changing temperatures. Hydrogen, oxygen, nitrogen, carbon, calcium, magnesium, iron, sodium, and silicon constitute sea water and air, and, too, the substance of our own bodies. And these same elements line the spectra of the hottest stars.

The art of fire touches man more intimately than does any other art; for it is his very life. The Troglodyte realized the truth, just as does the most enlightened scientist of to-day. Primitive humanity gave all honor to that flaming orb which we call the sun; hailed it as the generous giver, the single source whence every variety of earthly life draws its being—just as the race of this present age recognizes, in the far-flung radiant energy of the heavenly light, the vital causation for all earthly processes. An instinctive understanding set the face of the first man toward the east, that he might adore the daily miracle of the dawn.

In the beginning man made the sun a god and worshiped, and he worshiped as well the god's sign and agent, fire. On every altar blazed those lights kindled by the priests, to be reverenced by the devout. The priesthood wrote the scroll of mysteries in letters of flame.

The divine quality of fire made it also the constant familiar of each magician, whether his magic were white or black.

In due time the sorcerers turned from incantations to distillations. Wizards became alchemists, seeking madly for the secret of transmuting baser metals into gold. But fire was still the familiar spirit to give its tireless aid throughout all researches.

The alchemist was metamorphosed into the chemist, into the scientist. And with the new learning came new uses for fire, that most subtle among the ancient elements, with resources inexhaustible and eternal. To-day, the whole fabric of our civilization would crash into hopeless chaos were the countless busy flames of industry to be extinguished.

The art of fire is indeed the supreme art; for fire is at once the universal slave, the universal master.

CHAPTER II.

FIRE IN RELIGION AND MYTHS.

The most desultory inspection of primitive religions shows that worship of the sun and of fire was universal. The truth is curiously illustrated by the fact that even our word "Devil" literally means the "Shining One" (the sun), from a Sanskrit root.

In its origin, the word "Devil" had no evil significance. It remains to-day the word for god in the Gypsy tongue, which is closely akin to the original Aryan. *Deva* means god in Sanskrit. When Zoroaster taught, ages ago, he condemned as evil the god then worshiped by the Persians, and thus *Deva* came to be regarded as a wicked deity. The Sanskrit root-forms are *div* and *dyu*, each meaning "to shine." From the form *div*, *Deva* is derived; from the form *dyu*, *Dyaus* is derived. These are the sources of the word for god in many, even most languages. Among such derivations are *theos* in Greek, *diewas* in Lithuanian, *deus* in Latin, *dieu* in French, *dios* in Spanish and *dio* in Italian. The Teutonic variants are similarly derived, such as Teüfel, diuval, djöfull, djevful, and the like. The Greek *Zeus* is from the Sanskrit *Dyaus*, to which the word *Jupiter* also owes its origin. In the Rigveda, Dyaus is the god whose glory is the brightness of the heavens. He is called also *Dyaus Pitri*, which signifies God the Great Ancestor of All. It is this latter appellation that is transformed directly into the word *Jupiter*—literally, *Zeus* the Father. In old German, *Zio* is the name given to the god of day, where the significance is precisely that of the original Aryan. We have the form represented in Anglo-Saxon by the word Tuesday, which was first written Tiwsdaeg, the day of *Zeus*.

It is in truth strange that the God whom we worship and the Devil whom we should shun, both take their names from the same source—that source whence all religions drew their first inspiration. The clear teaching is that there was a universal worship of the sun-god by primitive man, together with a constant employment of fire as the god's sign and instrument. In the infancy of our race, the conception of religion attributed the origin of all good, even of all life, to the sun. This crude and instinctive appreciation of truth has been wholly justified by the findings of modern science.

It was inevitable that the spectacular glory of the lightning should have profoundly impressed primitive man, and should have caused him to regard it as divinely hurled from heaven to earth by the god, for good or for evil, according to his mood. And not lightning alone. Every formation of fire reflected in some measure the splendor and the power of the god. A favorite legend of all peoples had to do with the gift of fire to mortals. The Hindu story is so old that it employs the most ancient method of kindling a flame, by use of the fire stick. This device consisted of two cords attached to a pointed stick in such a manner that, while one was being unwound, the other was being wound up. It was operated with the point of the stick resting on a disk of wood. By alternately pulling on the two cords, the stick was twirled so rapidly that the friction of its point against the disk produced fire. Count Rumford verified the efficacy of the contrivance in his experiments. It is known that it was formerly used in America over the whole extent of the continents, both north and south. It is still employed in South Africa, Australia, Sumatra, and among the Veddahs of Ceylon. According to the Sanskrit, the gods, *Devas*, and the spirits of evil, *Asuras*, made a truce in order to work together with the fire drill. They took Mount Mandara for the stick and the Great Serpent, *Sasha*, for the cord. The *Devas* pulled at the snake's tail; the *Asuras* at its head; and from the crest of the mountain first blazed the lightning.

Another form given to the name of the mountain is Manthara. With a prefix, the word gives *pramantha*, which is the Sanskrit word for a fire drill. Philologists have traced to this word the name of Prometheus, that Titan who, according to Greek mythology, stole from heaven its sacred fire for the use of man.

Agni, one of the Hindu divinities, was designated the god of gods, and he was specifically the ruler over all fires, whether of earth or of heaven. It is from this name that the Latin gets its word for fire, *ignis*. The sacred narrative concerning Agni is consistent, for it declares that he himself was born a babe from the friction of two fire sticks.

Indra, who became identified as the sun god, is of particular importance still in the Hindu pantheon, and the holy writings give much space to tales of his battles to overcome Vitra, darkness.

In the north, there was no less worship of fire. The Norse Frodi was a god of fire. The quern, or mill, which is conspicuous among the myths concerning him, was actually his fire drill. His symbol was the sun, and after that the lightning and all other forms of flame. Thor, also, ruled especially over fire. Now, it is a fact that fire, in the symbolism of natural religions, is intimately connected with passion. This truth is indicated in the cases of both Agni and Thor, who were gods, not only of fire, but also of marriage. The popular acceptance of Thor's divinity in this regard is witnessed by the old English superstition that makes Thursday, Thor's day, the luckiest of the week on which to wed. Another example is afforded on our own continent. Catequil was worshiped in Peru as the god of fire. And he it was who, as the god of lightning, threw down to earth the thunderstones. These were small, round pebbles, which were very highly regarded by the people as fetishes, endowed with magical virtues for inspiring love. Hermes, in one phase, was a fire god, and the Caduceus that distinguished him was in fact a fire wand.

The Druids worshiped Be-al, the life of all, a deity essentially the same as the Phœnician Ba-al. They looked on the sun and fire as symbols of the god. One of their two great annual festivals, which was celebrated on May 1, was called *Beltane*, meaning "the fire of god." The other festival was held on November 1. The name of this, *Samh-in*, signifies the fire of peace. At the time of this second festival, all the fires in the houses were extinguished, to be afterward set burning anew by means of torches kindled at the sacred flame. In their worship of the sun and of fire, the Druids included the offering of human sacrifices, which were burned within curiously contrived inflammable cages.

In Greek mythology, great importance was given to fire as the supreme gift of heaven to man. To Prometheus and Epimetheus, two brothers who were Titans, was entrusted the creation of man and of the animals. Epimetheus did the active work of creation, under the superintendence of Prometheus. But Epimetheus fashioned the animals first, and gave to them all his gifts, so that, when it came to the point of creating man, he had nothing left for a dower. He confessed his plight to Prometheus, who, with the help of Minerva, ascended to heaven, where he lighted his torch at the chariot of the sun, and thence brought down the divine flame to earth. With this gift of fire, man was rendered superior to all animals; for by it he could fashion weapons with which to subdue the fiercest beasts. Moreover, fire gave him the means by which to shape tools for tilling the earth, and for use in all arts. Finally, by the gift of Prometheus, man gained power to overcome the rigors of climate, to bid defiance to cold.

The Greeks gave highest honors to Athena, or Minerva, as queen of the air. She might well be regarded as the patron deity of pyrotechny, since she was not only queen of the air, but also queen of fire. Ruskin points out that Athena was queen of that fire which is in human hearts, and manifests as courage and endurance. Athena was worshiped by the arts of fire, and all flaming devices were fittingly symbols of her. The rocket, had it been known to classical Greece, might have been interpreted, in her behalf, as brave to dare the unknown dark, to mount with all energy until its very life was at an end, and, with its last breath, to set on fire that burden which it has carried aloft, in order that, even after its own passing, a new glory should be spread in the heavens.

Among other distinguished Greek divinities, intimately concerned with this sort of worship, were Hephæstus, lord of fire of the hand, and Apollo, lord of fire of the brain.

From the multiplicity of deities reverenced by the Romans, we may note particularly the goddess Vesta, on the altar of whose temple in the Forum burned perpetually the sacred fire brought by Æneas from Troy. The sanctity of this flame is attested by the fact that it remained constantly attended by 80 virgins, vowed to chastity; among whom, any violation of their trust was punished by the offenders being buried alive. Once extinguished, the fire could be relighted only by the Pontifex Maximus himself, who used for that purpose the ancient fire drill. The esteem in which the worship of Vesta was held is shown by the historical record that the temple of the goddess in the Forum was the last to yield before the rising power of Christianity.

The influence of fire worship crept into most of the heroic legends. Thus, in the tale of the Chimæra slain by Bellerophon mounted on Pegasus, it is declared that the monster was fashioned after the manner of a lion and a goat in its fore parts, but that it had the form of a dragon in its hinder parts, and that it breathed forth a destroying fire.

Jason, seeking the Golden Fleece, received the promise of it from Æetes, on condition that he should plow with the fire-breathing bulls, which were brazen hoofed. The Latin poet tells that the fire streaming from the bulls' nostrils burned up the herbage as they passed, and that the sound was like the roaring of a furnace, while the smoke ascended in a dense cloud, like that caused by the pouring of water on quicklime.

So of the mystical bird of the Heliopolis priests:

After 500 years of life, the Phœnix, according to Ovid, prepared for death, and at the same time for new life, by building a special nest in an oak tree, or palm. In the nest, he made a funeral pyre, decked with cinnamon, spikenard and myrrh. In the flames of this fire, the bird was consumed; but it presently arose out of the ashes to a new life of 500 years.. According to some writers, there was a difference between the identities of the old bird and the new. In such case, the young bird carried the remains of its parent, inclosed within an egg of myrrh, to Heliopolis, there to receive sacred ministrations from the priests of the sun.

The Cockatrice, or Basilisk, as usually described, had the form of the ordinary barnyard fowl, but wore a crown on its head instead of a comb. The creature was so dreadful that even the serpent fled from its approach, and its glance caused instant death. It was supposed to take its origin from the egg of a cock, hatched by a toad, or serpent, or some form of saurian.

TABLE DES ESSAIS

Qui ont indiqué la meilleure proportion pour composer la Poudre.

NUMEROS DES ESSAIS.	MATIERES Dont on a composé les Poudres d'essai.									DEGRÉS DE FORCE *à l'éprouvette.*
	SALPETRE.			CHARBON.			SOUFRE.			
	Essais pour connoître si l'on peut faire de la poudre sans soufre, & quelle est la quantité de charbon qui peut donner le plus de force au salpêtre.									
	liv.	onc.	gr.	liv.	onc.	gr.	liv.	onc.	gr.	
1 . .	1	0	0	0	1	0	0	0	0	. 0 Fuse sans explosion.
2 . .	1	0	0	0	2	0	0	0	0	. 3 Fait explosion.
3 . .	1	0	0	0	3	0	0	0	0	. 5
4 . .	1	0	0	0	3	4	0	0	0	. 7
5 . .	1	0	0	0	4	0	0	0	0	. 9
6 . .	1	0	0	0	4	4	0	0	0	. 8
7 . .	1	0	0	0	5	0	0	0	0	. 6
	Le numéro 5 ayant donné le degré le plus fort, on a ajouté du soufre à la dose de ce numero, pour connoître si cette matiere peut en augmenter la force & jusqu'à quelle quantité.									
8 . .	1	0	0	0	4	0	0	0	4	. 11
9 . .	1	0	0	0	4	0	0	1	0	. 15
10 . .	1	0	0	0	4	0	0	1	4	. 14
11 . .	1	0	0	0	4	0	0	2	0	. 12
	Le numéro 9 ayant donné le degré le plus fort, on a essayé de retrancher du charbon sans diminuer le soufre, jugeant que la poudre en seroit plus forte, & il s'est trouvé qu'elle a augmenté de force jusqu'au numéro 13.									
12 . .	1	0	0	0	3	4	0	1	0	. 16
13 . .	1	0	0	0	3	0	0	1	0	. 17
14 . .	1	0	0	0	2	4	0	1	0	. 14
15 . .	1	0	0	0	2	0	0	1	0	. 10
	Comparaison du numéro 13 avec les proportions qui en approchent le plus, pour s'assurer que la dose de ce numéro est la plus forte.									
16 . .	1	0	0	0	3	0	0	1	4	. 15
17 . .	1	0	0	0	3	0	0	0	4	. 13
18 . .	1	0	0	0	2	0	0	2	0	. 13
19 . .	1	0	0	0	2	4	0	1	4	. 14
	Autre comparaison du numéro 13 avec les poudres faites suivant les proportions les plus en usage en Europe & en Chine.									
	POUDRE D'EUROPE.									
20 . .	1	0	0	0	2	$5\frac{1}{3}$	0	2	$5\frac{1}{3}$	. 11
	POUDRE DE CHINE.									
21 . .	1	0	0	0	3	0	0	2	0	. 14

Table of powder tests.

There was only a single method of destroying the Basilisk. This was by means of a mirror. While scrupulously avoiding the gaze of the animal, the hunter employed his skill to catch that same gaze in a mirror, whereby it would be reflected back against the Basilisk itself, which would then be instantly destroyed by the lethal power of its own eyes.

The ancients were awed also by various natural phenomena of a fiery sort. Their superstition was not limited to lightning, but extended to other manifestations, which were regarded with mingled reverence and fear. The ignis fatuus, or will-o'-the-wisp, is merely a luminous meteor, usually pale blue, the gaseous emanation from rotting vegetable or animal matter, which is sometimes seen over marshes or graveyards. This was universally regarded as a ghostly visitant of malign import. Indeed, the spread of knowledge does not yet by any means suffice to remove the popular dread of this seemingly uncanny apparition, and many a yokel hies him homeward in quaking terror after sight of the noiselessly flitting wraith of flame.

On the other hand, St. Elmo's fire was of old esteemed a good omen, though most fearful to look on. This is in reality an electrical manifestation (like the brush discharge from a machine), which occurs when the electricity of a low-lying cloud combines with that of the earth to make displays as luminous globes at the ends of pointed objects, especially if metallic. The St. Elmo from whom the phenomenon takes its name was probably St. Erasmus, patron saint of mariners from Calabria, Sicily, and Spain. The display was commonly called the fire of Castor and Pollux.

On our own continent, the sun and fire were worshiped from times primeval. The cult of the Mayas was essentially Egyptian, and their influence molded also the religion of the later Aztecs. Thus, Viracocha, among the Quichuas, was the god of day, while the place of his daily rising was definitely determined as Lake Titicaca.

The Sioux have a legend as to the origin of fire. According to this, the gift was bestowed on mankind by a friendly god, who, under the guise of a panther, struck sparks by the impact of his claws on flint as he scampered up a hill.

Other Indian traditions give the source of fire as Michabo, the Great Hare, who was the god of all the Algonquins, the Powhatans of Virginia, the Lenni Lenape of the Delaware, and the Ottawas of the north. He was the god of the solar life. The name is from *michi*, great, and *wabos*, white or hare. Michabo was god of the dawn, battling always against the darkness, even as Ormuzd battled against Ahriman. Here, among the aboriginees of our land, was the same old worship of sun and light and flame, the same sacred story of the sun's endless warfare against the night.

These few instances must suffice to illustrate the universality of fire-worship and sun-worship among the early pagans. There remains for brief consideration that Christian religion on which our modern civilization is founded.

And now, once again, we find that the Bible, too, is replete with incidents based on the vast importance of fire as symbol and agent, whether divine or demoniac, whether the white glory of heaven or the crimson flares of hell. The record runs from the first book of the Pentateuch to the Revelation of St. John the Divine. At the very outset, God said, "Let there be light, and there was light."

It is related in Genesis that, after the expulsion of the original sinners from Paradise:

"He placed at the East of the Garden of Eden Cherubims and a flaming sword which turned every way to keep the way of the tree of life."

For the guidance of the chosen ones, a cloud of smoke went before them by day and a pillar of fire by night. In His wrath against the cities of the plain, Sodom and Gomorrah, God utterly destroyed them by a rain of fire. In His love for the saint, God carried up Elijah from earth to heaven in a chariot of fire. On the Ark of the Covenant, the presence of Jehovah was made visible by a white flame, the Shekinah. And, too, the Burning Bush proclaimed His Being in the holy place on the mount.

Nor are such examples, and the many like them, limited to the books of the Hebrew Scriptures. The Greek text of the New Testament abounds in analogous instances. In the Acts of the Apostles, it is said, concerning the Day of Pentecost:

"And there appeared unto them cloven tongues like as of fire. and it sat upon each of them."

The Apocalypse overflows with such allusions to the symbolism of fire:

"His eyes were as a flame of fire * * * And he had in his right hand seven stars * * * and his countenance was as the sun shineth in his strength."

"And out of the throne proceeded lightnings and thunderings and voices, and there were seven lamps of fire burning before the throne which were the seven spirits of God."

"And another angel came and stood at the altar having a golden censer, and there was given unto him much incense, that he should offer it with the prayers of all the saints upon the golden altar which was before the throne. And the smoke of the incense which came with the prayers of the saints ascended up before God within the angel's hand. And the angel took the censer and filled it with fire of the altar, and cast it into the earth, and there were voices and thunderings and lightnings and an earthquake."

It was natural that primitive man should exalt fire above the others of the four elements; for it chiefly was a thing to be sought for, to be tended, to be loved, to be feared. It was significant of God's beauty and glory; but, too, of His wrath against sin. An ancient fear led man to dread the destruction of the world by fire. It is a curious fact that our own astronomers warn us of the possibility that some time another heavenly body may come into collision with our earth, involving both in annihilation, consuming them instantaneously in a flaming fury, a celestial holocaust.

The hearth has always been, and is still, the heart of the home, the altar for family worship.

The priests early played on the instinctive reverence of the people for sun and flame, and taught of a mystical potence in the countless sacred fires that glowed everywhere on the altars of the world. The part taken by the priesthood, and by those directly developed from it, the magicians and the alchemists, now demands our attention.

CHAPTER III.

PRIESTCRAFT AND PYROTECHNY.

From earliest times, the ministrations of the priesthood have been concerned, to either a greater or less extent, with fire. Throughout the ritual of all churches from ancient ages to modern, the flames on the altars have been significant of spiritual truth cherished by the faithful. In the burnt offerings, the consuming of the sacrifice on the altar was by fire, which served as the symbol of the god thus propitiated and worshiped. Always, the spectacular value of flame was highly esteemed and consistently cultivated by the priests, for the sake of its effect in arousing the emotions of the devout. Sacred flames played a conspicuous part in the temple worship of all nations throughout the past. The Levitical priesthood made fire the visible interpreter of holy teaching. The prevalence and endurance of fire in connection with religion is well illustrated even to-day by the ceremonial observances of the Roman Catholic Church. The lighting of the candles on the altar, or the extinguishing of them, is a vital part of various services. Sometimes, as in the Tenebræ, the contrasting effects of light and darkness are used with powerful effect to sway the mood of the worshipers. And always, in the chancel of every church, the highest or the humblest, shows softly that rosy radiance of a flame which symbolizes the actual presence of God within the Host on the altar.

As we consider the Jewish religion, we are impressed by the fact that the symbolism of fire is carried out, not only in the public worship, but in the ritual observances that still are distinctive of every orthodox Jewish household. There, the burning of candles is an essential part of those ministrations in which the priest, according to the ancient manner, is the head of the family. And it is curious to note that the relation of fire to religion is carried beyond the merely spectacular, is made to include also the practical use of fire on the hearth, which is lighted or extinguished in accordance with religious observances.

It was inevitable, from the prominence of fire in the beginnings of religion, that the priests should especially cultivate a knowledge far beyond that of the people. They early learned details in the management of flame that gave a supernatural seeming to many altar fires. Moreover, all the learning thus gathered by the priests was jealously guarded by them. Almost at the outset they took advantage of their station, as ministers of the divine, to claim for themselves abilities beyond those possessed by the ordinary man. The mastery of fire played a very important part in substantiating their claims to supernatural power.

We should do wrong to underestimate the knowledge attained by the priests of olden time. It is not to be doubted that they gathered and held a considerable body of learning, which included no small measure of detailed information in matters concerning fire. It must be remembered that, until modern days, all of the world's learning was in the possession of the priesthood. The physical work of the world, including the waging of war, was left to others, but whatever there was of art and science through the ages was gained and held by the priestly caste of every nation. That such learning was in many respects considerable, even at a most remote period historically, may be understood by a little consideration of the Egyptian priests. From what may be learned in one direction, it is fair to conclude that the Egyptians possessed a variety of knowledge both exact and extensive. As to a single detail in connection with them, we have the testimony of the pyramids. As to their learning in other particulars, we are unable to find a precise record, but the testimony offered by the pyramids has endured through the ages, so that to-day our study of it gives us definite information as to the progress of these ancients in one scientific field. It is fair to conclude that their learning in other directions also was not of a sort to be despised. The special reasons influencing them to a study of fire must undoubtedly have resulted in no mean knowledge. From the nature of the case, we are unable to determine precisely the extent of their learning, but we should err in regarding it as negligible; in fact, we are able to prove their possession of some erudition concerning combustibles by our research in another direction, to which attention will be given further on.

What is thus directly known of the Egyptians, at the time of the building of the Great Pyramid, is known indirectly concerning the priesthood of that age in other places scattered over the earth. For the wisdom of the Egyptians included within itself all that there was of learning in this age. And, too, that same wisdom was diffused throughout the world. The Egyptian culture spread everywhere, and carried broadcast its esoteric teachings.

Thus, the hidden learning was cherished alike by the priesthood in that lost Atlantis of which Plato tells, and by the temple ministers of the Mayas on our own continent. The ruins at Stonehenge, too, are witnesses as to the prevalence of Egyptian culture. These remains were used by the Druids, but their construction long antedated that form of worship. They were the work of Neoliths, who were sun worshipers, using fire as the chief symbol of their deity. It is a significant fact that the ruins, crude as they are, display considerable knowledge of astronomy on the part of the builders; and this, together with other peculiarities of construction, identify the fragments as evidences of the Egyptian cult. There is a circle of earthwork, which has a diameter of 300 feet. Within this earthwork is a circle of trilithons. These consist, each, of two upright stones, one of them being laid across the top ends of the other two. A single circle, having a diameter of 100 feet, includes 30 of these trilithons. And within this circle there is a group of blue stones. It is to be observed that these latter are not of a sort native to the British Isles. The blue stones are carefully arranged in a horseshoe formation, which is made of five huge trilithons. Within the horseshoe stand 10 monoliths. A clue to the prime purpose of this primitive temple is afforded by the horseshoe formation, in the matter of its opening; for this faces exactly to the sunrise at the time of the summer solstice. The Druids found the place ready to their hand, and used it for the purposes of their own sun worship and of their sacrifices by fire.[1]

In their devotion to the fire used in religious rites, the priests came, little by little, to learn many secrets concerning the nature and operations of the element. The knowledge of such activities was utilized by them for the mystification of the people. In short, the priestly control of fire in various ways was made to serve as justification for a claim to miraculous powers on the part of the ministers of religion. The priests made pretentions to the possession of divine abilities, delegated to them by the god of whom they were the representatives, and the credulous populace readily admitted such claims, supported as they were by inexplicable phenomena. The people saw the altar fire kindled at a mere word spoken by the minister, saw it flash into flames that changed color miraculously, saw it die at another command; and the worshipers reverently gave homage to the priest, who thus displayed his possession of supernatural powers. By varying flames and the narcotic fumes of incense, the priests showed themselves, as it seemed, truly the ambassadors of the god, masters of his symbol and agent, the flame.

From this point, there was needed only a brief progression to the practice of magic in all its forms. It is necessary to appreciate the fact that the art of fire, in its origins, was vitally dependent on the growth and prevalence of magic in the ancient days.

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[1] Many antiquarians have been reluctant to admit that the Druids offered up human sacrifices in their worship. Nevertheless, the testimony in this regard leaves little room for doubt. Roman writers, contemporary with the Druids, give the statement of eyewitnesses to Druidic rites in which human beings were burned alive as offerings to the fire-god.

CHAPTER IV.

ARTS OF MAGIC AND ALCHEMY.

We have already defined pyrotechny as the art of fire. But, while this is the literal meaning of the word, its application is too broad to satisfy our further needs in a consideration of the subject.

Pyrotechny has been commonly defined as the art of producing pleasing scenic effects by means of fire. This interpretation of the word is wholly unsatisfactory, since it fails to include a large and important portion of pyrotechnic activities. For example, there was no intention of producing merely a pleasing scenic effect in those contrivances which were named "murdering marrons." On the contrary, they were designed specifically to work injury against an enemy, and the worse the havoc wrought, the better their object was achieved. On the other hand, the definition is equally inapplicable to devices of a pyrotechnic sort intended for life-saving purposes at sea. It is necessary, then, to formulate a definition of pyrotechny that shall be sufficient to cover all varieties used in the past, as well as those familiar to us in the present, and also that undoubtedly large number of new and valuable inventions to be produced in the future.

The simplest possible definition that seems complete may be given thus:

Pyrotechny is the art of aërial fire.

This definition limits the art to products visible in the air; but is broad enough to include a very wide range of activities. It is thus differentiated from the concerns of such fires as we employ ordinarily in the home and factory, and elsewhere, for purposes of comfort and industrial accomplishment.

Moreover, we find a particular justification for the new definition in the matter of those origins of the art having a religious character. And the definition is, likewise, peculiarly applicable in the next stage of our consideration, which has to do with those developments of the art of fire due to the growth of magic.

Many varieties of substances possess a lively tendency, under suitable conditions, to combine with oxygen, and to do this with such violence as to yield products that are both hot and luminous to an intense degree. This is the manner in which fire generally comes into being. In the matter of ordinary burning, the dependence for a sufficient supply of oxygen is on the air. But there exist certain solid substances containing oxygen in combination with other elements, from which substances the oxygen may be released so readily, and to such an extent, as to result in combustion of extraordinary energy. Ages ago, the priests discovered some among the number of such substances, and in these discoveries pyrotechny had its beginning. But the work of the priesthood in this direction was taken up and carried much further by innumerable magicians, who began to flourish almost at the dawn of history, and have continued with varying fortunes even till to-day.

In the very earliest times of which there exists any historical record, religion and magic became well-nigh inextricably mingled. This was the case in ancient Babylonia, Chaldea, and Egypt. The priests commonly practiced the various arts of sorcery and necromancy, and served in addition as soothsayers. Later on, the magicians formed a class by themselves, apart from religious ministrations. But, both before and after this separation, they were actively concerned with fire, in its various aspects, as playing an important part in their ceremonial observances. Just as fire was of value to the priest, so, too, it was of value to the enchanter. It presently became, indeed, of much more importance to the wizard than ever it had been to the priest. When the magician desired to summon to his aid an elemental spirit, or sought to call forth from the shades some ghostly visitant, his first preparation for the spell was the drawing of a circle, or other geometrical figure, within which to stand while uttering his incantations. And it was necessary that this circle, or pentagram, or other figure, should be outlined in fire by lights burning at measured distances along the circumference, or in the angles. The fires might be either brilliantly illuminating, or merely glowing, and giving forth clouds of smoke. Such fumes were of particular potency when the magician desired to secure an effect on other persons present with him. For this purpose, the materials employed were often of a sort to make the smoke narcotic in its effect. It was frequently, also, of great service in illusions of the eye.

Magic, as historically known, comprises five divisions. These are the black, which is evil in its designs and in the instruments by which it is effected; the white, which is beneficent in its scope and in its agencies; the natural, which employs physical means of a kind not commonly known; the celestial, which seeks to attain its ends through planetary control; the goetic, which gains any desired power by compact with the devil—a variety of magic once much esteemed by the unscrupulous, and still not by any means abandoned.

It is principally with natural magic that the history of pyrotechny has to do. The magician strove to gain a mastery over fire, and so gradually came into possession of a knowledge far beyond that held by the generality of folk. This result was inevitable from the prominence of fire in the innumerable operations of magic. The fact of such secret learning is amply attested by many records. The literature of magic is large, and elaborate in its details. It is not fitting in this place to make any extensive survey of such literature. It is sufficient to refer, for example, to the writings of Benvenuto Cellini, who, in his descriptions of necromancy, lays special stress on the burning of fires and on the smoke clouds given out from the flames. Indeed, the methods of sorcery have changed but little with the passing of the centuries. We have in our own country to-day the cult of Voodoo, that barbaric faith imported with slavery from Africa, and here developed into something even worse than its own evil source. Some years ago, a Voodoo assembly in New Orleans was raided by the police. The record shows that about 100 women were present in the hall, dancing, unclad, with frantic violence, while the high priestess (Mama-loi) droned her incantations. Because Voodoo is a form of serpent worship, the hall contained a number of snakes, which lay coiled on silver platters, swinging their heads to the rythm of the music. And, too, there was, as always in such scenes, the fire. On the hearths in each corner of the room glowing coals sent upward great columns of a perfumed smoke that served to stimulate to wildest extravagance the antics of the devotees. * * * Thus, in our own land and time, the magical fires are still burning, even as they have been burning constantly throughout the ages.

It would be folly to suppose that the early magicians were merely fools or charletans. As a matter of fact, they were of many sorts. Some deluded themselves; some deluded others: but many were actually men of learning, ambitious students who sought in every way possible to increase their stores of wisdom. It was this class of investigators that, in the pursuit of natural magic, laid the foundations of a true science. As a rule, such men of ambition were lured on by that universal dream of the ancient learning, the transmutation of metals. One and all, they were seeking the philosopher's stone, that mighty substance which, at a touch, should dissolve baser metals into the original elements, and refashion them into gold.

Just as the magician was evolved out of the priest, so the alchemist was evolved out of the magician; and the work of the alchemist, despite its vagaries, was the beginning of physical science.

The first and last endeavor of the alchemists, always, was to discover the philosopher's stone, by the magic of which every substance it touched might be changed into gold. Though their object was of this chimerical sort, their investigations in striving to attain it were so painstaking and so extensive that slowly, through passing centuries, they accumulated great stores of learning, which prepared the way for a later and saner science.

In the course of time, the work of the alchemists developed into a quest for the alkahest. This was an imaginary universal solvent, with a potence such that it would disintegrate anything with which it came in contact. Afterward, the alchemists concentrated their desire on the philosopher's stone under a new guise, the magisterium, by a touch of which all other metals might be transmuted into gold. Moreover, the magisterium was supposed to possess powers more subtle than any ever attributed to the philosopher's stone; for it was believed that it could exert control over all or-

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ganic structures, thus healing diseases, or even restoring life to a dead body. A somewhat later development of a similar idea among the alchemists led to extravagant visions of an elixir vitæ. The wide influence which this dream exerted over the minds of men is historically witnessed in our own country by the wanderings of Ponce de Leon, in his search for the fountain of youth * * *. Thus, the ancient fancy is brought measurably close to us and to our own time.

The greatest legendary name in alchemy is that of Hermes Trismegistus. He stands as the personification of the early Egyptian culture, which was, in fact, the world culture of that age. Whatever there was of knowledge in those days was comprehended within the term Hermetic philosophy. That knowledge was carefully kept secret, its possession strictly limited to the chosen few, the adepts. It was an esoteric learning, and, as such, penetrated throughout the world. The wisdom was, indeed, so jealously guarded that the word hermetic supplies us with an adjective indicative of absolute secrecy.

The first alchemist of whom we have definite record was Gebir, an Arab, identified by the authorities of his own race as Jabir ibn Hayan, who flourished at Cufa near the end of the ninth century of our era. He was credited with the authorship of numerous volumes, both Arabic and Latin, which treated alchemical subjects. A careful examination of the evidence, however, seems to show that the Latin works were not written by him, but by later authors seeking the prestige of the great seer's name.

Albertus Magnus, who won world-wide and lasting repute as an alchemist, was a Dominican friar of Germany, living in the thirteenth century. He was probably the inventor of amalgam, although this discovery has been attributed also to St. Thomas Aquinas, his pupil.

Another distinguished alchemist was Raymond Lully, who was born on the island of Majorca, in 1235. He was the first to dissolve gold.

The greatest of the alchemists, in many ways, was Roger Bacon, the Englishman, who lived in the latter part of the thirteenth century. He was a Franciscan friar, devoted to the acquisition of every sort of learning. Naturally, considering the age in which he lived, he gave himself over chiefly to alchemical researches. His religious convictions, however, were strong enough to prevent his dabbling in sorcery after the fashion of most alchemists. Although he believed in astrology and the philosopher's stone, he openly and consistently flouted the practice of magic, whether white or black. "The Admirable Doctor," as he came to be called, was esteemed for his learning, but he raised up enemies by unsparing denunciations of current evils, which he did not hesitate to attack even within the church itself. He was for a time lecturer at Oxford University, but soon became embroiled with the authorities, who unjustly accused him of operations in magic. He was eventually imprisoned in Paris, and was forbidden to write. The attention of Pope Clement IV., however, had been attracted to the learned monk, and he expressed a desire to examine Bacon's works. It was in response to the request that the "Opus Majus" was written. This was sent to Clement, who, after a careful study of the volume, secured the release of the prisoner and his return to Oxford as a lecturer. Nevertheless, the experiences undergone by him had in nowise chastened the monk's fighting spirit. He promptly attacked the iniquities that prevailed within his own order, with the result that the general of the Franciscans placed all his writings on the Index Expurgatorius, and he was cast into prison a second time, where he remained for 10 years. He was finally released and permitted to return to Oxford, but he died only two years afterward. He is celebrated not only for the wideness of his learning, but for the scientific exactness of his methods in the laboratory. He invented the magnifying glass and a rectified calendar.

The latest of the great alchemists was Paracelsus, as he is commonly known, although he was baptized Philippus Aureolus Theophrastus Bombastus von Hohenheim. He was a Swiss physician, born in 1493. After a period of wandering as a student, he became the town physician at Basel, where he also lectured in the university. After two years, however, he left his chair in the university, by reason of serious differences which arose between him and the magistrates of the city. Thereafter, for a dozen years, he continued a wandering life, but eventually settled in Salzburg, where he died at the age of 48. The man had next to nothing in the way of morality, but he possessed a genius for research. It was he who first laid emphasis on the doctrine that all the life processes are chemical, and that, in consequence, each and every remedy for disease must be sought in chemistry. In his own practice as a physician he introduced many remedies of a chemical sort. He was, too, the discoverer of hydrogen. He was always an enthusiastic alchemist, but his mental clarity enabled him to divert much alchemical learning, which was wholly useless as such, into other directions where it might become available for scientific purposes. He was charletan of the charletans, but he had a splendid mind, which he employed in able accomplishment. He has been called the sublime drunkard of Hohenheim. The appellation is just, both as to the drunkard and the sublime.

As a scientific chemistry slowly evolved, alchemy, as was inevitable, fell into disrepute. Its false pretensions were derided, first by the few, then by the many, until the general opinion was that expressed by *Surly* in Ben Johnson's "Alchemist," who declares:

> That alchemy is a pretty kind of game,
> Somewhat like tricks o' the cards, to cheat a man
> With charming.

The followers of chemical science, in their rejection of alchemical absurdities, resolved firmly to accept nothing save those things physically proven in their tests. The new spirit was definitely announced by Boyle in 1681, in his book entitled "The Skyptical Chymist." Henceforth, the attitude was to be one of utter skepticism toward anything not demonstrated in the laboratory.

Yet, chemistry never quite abandoned, in their entirety, the fascinating dreams of the alchemists. As late as 1811, Davy wrote:

"It is the duty of the chemist to be bold in pursuit * * *. He must recollect how contrary knowledge sometimes is to what appears to be experience * * *. To inquire whether the metals be capable of being decomposed and composed is a grand object of true philosophy."

Four years later came Faraday's declaration:

"To decompose the metals, to reform them, and to realize the once absurd notion of transmutation are the problems now given to the chemist for solution."

As late as 1912, Duncan, in The New Knowledge, says: "The alchemist became the chemist, and the chemist has become the alchemist."

Thus, by devious ways through a progress of ages, the art of fire has brought about that perfection of scientific labor which we know as chemistry. And now, in its turn, chemistry becomes the minister of pyrotechny, the art of aërial fire—for those important developments already begun, and for those others destined to multiply amazingly in the future.

CHAPTER V.

OUTLINES OF HISTORY.

As has been said, the secret learning of the Egyptians in earliest times was distributed among the wise men of the world. That this learning was notable concerning the movements of heavenly bodies is witnessed by the Great Pyramid, which has endured through the ages as a visible proof. Moreover, there is a tradition, carefully preserved, that tells of the knowledge thus possessed by, and restricted to, the chosen few. Since the truth of the tradition is supported by ample evidence in one direction, it is not unreasonable to give it credence in other respects. From the nature of the case, it is impossible that anything should survive to render such other testimony positive, like that afforded in the case of the pyramid. But we may be sure that the priests and magicians of Egypt, in the earliest days, gained a very appreciable mastery of the art of fire. They became, doubtless, skilled in that phase of natural magic which was so intimately concerned in their control over the people. Such knowledge was always, of course, zealously guarded, just as were all the esoteric teachings of religion. The method of secrecy survived, to a greater or less extent, through the whole period of history. Thus, for example, even as late as the beginning of our Christian era, Christ explained that His parables contained hidden meanings, for the understanding of the disciples alone, while the apparent lesson in each story was sufficient for the vulgar. So, the possessors withheld from popular knowledge in ancient times their discoveries concerning the nature and activities of fire. The adepts soon acquired definite information as to many combustible substances, from which they could produce flames of extraordinary violence with an ease seemingly miraculous; and, too, they secured a fair control over color effects in fire.

By these means, they kept to themselves a vast advantage both in religious prestige and in magical practices.

It has been generally believed that the Chinese were the inventors and first exploiters of pyrotechny, the art of aërial fire. This belief is natural enough in view of the fact that the Chinese records of fireworks antedate any others. But it must be remembered that the primitive culture radiating from Egypt penetrated into the Celestial Kingdom, and the later Chinese developments had their actual source in such diffusion of knowledge.

It is possible that the secret learning was carried from the populous southern part of China toward India by way of the Bramahputra Basin, through Assam into Bengal, and thus to Calcutta and Benares. But it is quite probable that the Hindu adepts received their instructions directly from Egyptian sources, without any intermediary assistance on the part of the Chinese. It is worthy of note in this connection that, while the development of pyrotechny for purposes of spectacular display developed somewhat similarly in China and India, the Hindus employed the art also in contriving war weapons of a sort utterly unknown by their more peaceful neighbors.

Attention should be given also to the fact that, through long ages, China and India were practically alone in the cultivation of pyrotechny. The Egyptian culture passed, and, save for monuments in stone, the land of its birth no longer showed any least trace of the ancient learning. Only a few vestiges of it survived in China and India, through all the vicissitudes of changing dynasties.

These nations were never progressive. Oriental apathy has been consistently demonstrated in every succeeding epoch. The history of pyrotechny offers no exception. The Chinese people placidly amused itself during centuries with firecrackers; mandarins were entertained by spectacular effects of a more pretentious sort in colored fire; scenic displays were frequent at the courts of rajah and maharajah.

It was the power of Rome that brought a new energy and glory to the art of aërial fire. This was not due to any machinations of priests or sorcerers. It was caused directly by the enterprise of the race, which came to dominate the world, and sought and took to itself every variety of luxury and art—all that should make for fullness of life. Just as the Roman legions brought home Chinese silks, more precious than their weight in gold—so precious, indeed, that the Roman matrons raveled them out and wove them again in thinner fabrics—just as the returning conquerors bore with them treasures in jewels from India, so the expeditionary forces carried homeward with them from the Orient a new knowledge of the art of fire. This novel learning was seized on with eagerness for the entertainment of emperor and populace alike. Exhibitions of fireworks, which included set pieces, were given in the Circus as early as the reign of the Emperor Augustus, and afterward during the reigns of Carinus and Diocletian. One of the more elaborate displays so excited the admiration of a Latin poet that he composed verses in celebration of it. From the writings of the age we are informed that it was customary to use, for the more imposing effects, a framework that was movable and fitted with adjustable parts, by means of which variously colored fires might be set in motion.

The overthrow of the empire in the west put a definite end to the Roman development of pyrotechny. The interval of inactivity continued for nearly half a thousand years.

In the meantime, the single development of pyrotechny, concerning which we have any dependable record, was the Greek fire. Some account of this will be given in a separate chapter.

The Crusaders came into contact with the Greek fire, and by bitter experience gained an increased knowledge of combustibles, with which they returned to Europe. The introduction of gunpowder was the direct result, and, somewhat less directly, a new activity in the art of aërial fire. It would seem that something of the old Roman spirit revived in Italy, for pyrotechny there was especially cultivated. The Florentines particularly were alert and efficient in their pyrotechnic operations. Siena, too, acquired no small renown for complicated displays. Various feast days of the church were distinguished by vivid presentations in flame of some sacred story, appropriate to the saint it was desired to honor.

The figures employed in portraying these legends were usually of heroic size, sometimes gigantic. They were fashioned of plaster, covering a wooden frame which was afterward removed. There was provided, also, a high platform to serve as pedestal for each figure. These platforms were mounted on wheels, so that their positions could be shifted by means of ropes and pulleys, to suit the action of the story. In addition, the scene was embellished by a system of pipes, arranged for the purpose of throwing forth either balls of colored fire, or streams of flame. The figures themselves were so equipped that fire might issue from mouth or eyes or nostrils, and that the blades of swords, spears, battle-axes, or other weapons, which were brandished, might be of living flame. Especially imposing fiery pageants were characteristic in celebration of the Feast of the Assumption, and, too, that in honor of St. John. These were conspicuous during a period of a full century or more.

Then, gradually, for some reason not wholly clear, the Italian enthusiasm for this species of religious entertainment waned. It finally died out altogether. There remained, nevertheless, a degree of devotion to fireworks as a spectacular method of entertainment, and elaborate displays continued to be given on the occasion of various state festivities. These were particularly prominent as a part of the popular rejoicings over the election of a Pope, and again at the time of his coronation.

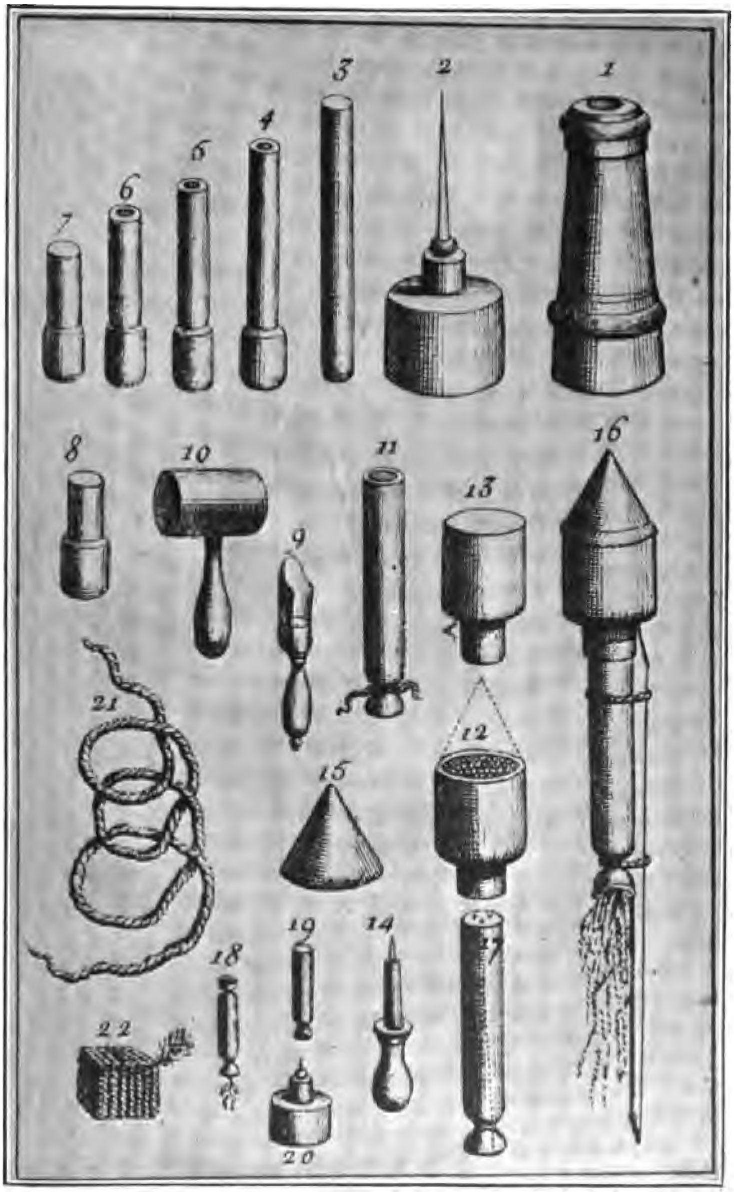
But, while Italy tended toward abandonment of the art, a new impulse drove it to increased activity in the more northern nations, in Germany, and more especially in France and England.

In these two countries, the fifteenth century witnessed a remarkable growth of pyrotechny for scenic effects, and this activity continued and increased during the centuries that followed.

It is interesting to note that the Eve of St. John was celebrated with ornate splendor of fire in the British Isles, and in France as well, just as it had been in Italy. But these celebrations in the northern countries were continued long after the passing of the Italian. Indeed, this festival, as distinguished by fire display, still shows some traces of survival to-day in the more remote portions of the British Isles.

The coming of gunpowder brought in its train a considerable interest as to the composition and operation of various combustible substances. The ordnance department of the Government of Great Britain, for example, early took over the active work in pyrotechny. Experiments were made in the manufacture of fireworks, and the successful results of these were offered to the public by the Government on various occasions for general rejoicing. Under the new auspices, displays of fireworks served for secular, rather than religious, festivities. Both in France and in England, pyrotechnic productions enjoyed the approval of the court as well as of the people. They were made a prominent part in many of the masques and in the presentation of historical panoramas. On the occasion of a royal marriage, the gaiety of the people was enhanced by the setting off of fireworks in great quantities. The formal pieces arranged for such productions were often most elaborate. National legends were drawn on to afford material that might be effectively interpreted in terms of fire. The artisans displayed remarkable cunning in contriving means to heighten the illusions. The arts of the Italians were appropriated and applied by the workers in other countries. The method of constructing figures of plaster on wooden frames was commonly used, and complicated mechanical appliances were devised, to give to the various persons and monsters of the scene movements having a semblance of life. Considerable attention was given also to the setting in which the events of the drama were presented. Romantic and fantastic tales of enchanted castles—wherein uncouth beasts threatened to consume hero or heroine, or both, with fiery breath—were common subjects for the exercise of the fireworkers' skill. On the Continent especially, classical myths were frequently made the theme of such spectacles. There was, of course, no end to the possibilities for pyrotechnic treatment in these fabulous stories. They gave the producer choice between the glories amid which the gods disported themselves on Olympus, or the uncanny horrors of mysterious caverns in infernal regions. Thus, the opportunity for extravagant scenes was limited only by the ingenuity and imagination of the designer. Naturally, at the outset, the effects secured were not only bizarre: they were lamentably crude. In the course of time, however, an artistic sense developed, and this kept pace with progress in the art of aërial fire.

PLATE II.



The French were particularly devoted to Greek mythology in the subjects chosen for intricate pageants. But the British always remained especially interested in their own national narratives of heroic exploits. St. George and the Dragon were a never-failing delight, alike to the builder of the show and to the assembly regaled by its production. Boadicea, too, had her place as the central figure of martial achievements pictured in flame. In similar fashion, those giants of Flemish legend, whose grotesque effigies are still carried in procession through the towns of Belgium, were favorite characters for presentation by the pyrotechnist in Liége and Antwerp. There was also, in some instances on the Continent, a clever intermingling of pagan stories and Christian doctrines, by which the fables of the ancients were diverted into allegories to illustrate church teachings, and were thus set forth as fiery spectacles for the entertainment and instruction of the people.

The development of pyrotechny was continued, in the various countries, under Government auspices and control down to our own times. Many and great improvements were made, both in the matter of the materials employed and in the effects secured, until the displays came to be marked by beauty, rather than by the grotesqueness of former days. The popular liking for entertainments of this character increased in proportion to the improvement manifested in the productions. But the Government limited its entertainments to occasions for general rejoicing, such as a royal marriage, or a state triumph to celebrate some notable victory in war. The liking of the populace for these shows was unsatisfied by the number of the festivals. Private enterprise realized the opportunity here offered for the commercial exploitation of pyrotechny. About the middle of the nineteenth century, companies were capitalized in England and other countries for the manufacture of fireworks, and also for their regular display at certain times and places. Resorts to which admission was charged thus sprang into being, and their immediate popularity justified the highest hopes of the producers. In England, Vauxhall early attained an extraordinary vogue, which it maintained unabated for years. Ranelagh, too, was successful in the same sort of entertainment. The fame of the Crystal Palace, for both the beauty and variety of its exhibitions, is familiar to the present generation. Similarly, in the United States, private enterprise has been both active and successful in developing this form of entertainment. Numerous summer resorts depend on the art of aërial fire as a principal means toward the pleasure of their patrons. Such displays are also often offered by civic authorities on special occasions. Thus, the Fourth of July is celebrated throughout the land, alike in tiniest hamlet and mightiest city, by pyrotechnic splendors for the delighting of the people.

For the sake of completeness in this historical sketch, a brief reference must be made to some phases in the art of aërial fire that have no concern with purposes of spectacular entertainment.

The rocket—that most curious projectile, complete in itself, needing neither cannon nor gun to launch its flight—was doubtless as fascinating to its discoverers as it is to-day to those engaged with it. Its possibilities as a weapon were early appreciated and developed. The Hindus, for example, employed war rockets against British troops at the time of the mutiny. No garniture of stars or balls or serpents was carried by these rockets, to be discharged at the termination of flight. They were designed strictly for offensive purposes. The charge was contained in a section of bamboo cane, and this was headed with a cap of metal, from which a sharp point protruded. The sides of the bamboo were pierced with little pipes, from which, during the burning of the charge, flames issued. Since the metal point would hold the rocket fast to any structure with which it came in contact, the contrivance served admirably as an incendiary agent. But it was, too, no mean weapon to wound or slay. For this purpose, the Hindus so aimed it that it should make almost an horizontal flight.

In the latter part of the eighteenth century and the beginning of the nineteenth, there was great activity on the part of those enthusiastic over pyrotechnic devices as war instruments. A rocket corps even was made a part of the British Army. Rocket missiles were used against Americans in the Revolutionary War, and they were frequently employed in battles on the Continent of Europe. This period witnessed also many other inventions for military use, such as the carcasse, the murdering marron, the pyrophore, and the like. These will be described fully in a subsequent chapter.

This development gradually ceased, as the great improvements in other departments of ordnance rendered it essentially ineffective, by comparison.

But another variation in the use of rockets was destined to no such ignominious conclusion. The value of this means for signaling at night was realized. Rockets soon became a necessary part in the equipment of all military forces, whether on land or sea, and so they remain to this day.

Rockets were also made to carry a load for illuminating purposes, attached to a minature parachute. These were the direct precursors of the vastly more powerful parachute flares produced to-day, which are to be described later on.

The use of rockets to signal distress at sea is too familiar to require description. There has been invented also a form of rocket capable of carrying in its flight a light line by which to establish communication between a vessel and the shore.

This cursory historical survey would be incomplete without reference to one other most modern development in the art of aërial fire. That development is the use of electricity for purposes of display. Within a single generation the great cities of the world have become emblazoned with electric fires. Everywhere is the glare of signs to guide the beholder, to charm him, to bewilder him, often to bedevil him. They flaunt coursing flames; they put to shame the rainbow. They render the vista either glorious or grotesque, but always inescapably, overwhelmingly spectacular. The evils we now tolerate will pass as commercialism learns to interpret itself within esthetic limits, and this latest phase of pyrotechny will eventually yield us, from its inexhaustible resources, new and ever increasing beauties to delight astonished eyes.

And now a hint as to the future history of pyrotechny:

It is undeniable that, in the contemporary advance of science generally, and of chemistry specifically, pyrotechny has lagged behind. But the exigencies of the World War have demonstrated much as to the potentialities of this art, and from appreciation of the truth has been evolved a new energy toward accomplishment. There will come a great and varied achievement not only in directions already known, but also in many others as yet unguessed. To-day, vast quantities of colored flares are used on the railways where they safeguard transportation under conditions that render the usual lights dangerously dim or wholly invisible. Equal usefulness for pyrotechnical devices will be manifested presently in diverse and important operations.

The art of aërial fire in the future shall effectively minister to our love of beauty; it shall give its resources freely to the harsh needs of war; but, too, it shall also serve us in manifold other ways of industrial importance—shall serve us cunningly and well.

CHAPTER VI.

GREEK FIRE.

Back in those very ancient days when Amen Ra, the sun-god, was worshiped in Egypt, when the great African empire contained all of the world's learning, and, under a benevolent autocracy, gave to its people a general welfare never surpassed—in that dawn of history the Greeks were savages to whom culture was a thing unknown.

Then, in the course of ages, the glory of Egypt passed, while, little by little, Greece developed until it reached supremacy in war, in the arts and in letters. Avid for knowledge, the wise men of Greece took to themselves the old secret learning of the Egyptians, assimilated it and made it their own, expanded it and fashioned it in new forms, according to their own lively intelligence. Thus, we may trace in the metaphysics of Socrates and Plato the influences of Egyptian philosophy. And, too, alchemical lore was likewise studied, and adapted and improved by Grecian investigators.

One such student of alchemy was Gallinicus, of Heliopolis, a town in Syria. But Gallinicus was not merely a student, he was also a warrior in command of a body of native troops stationed in the city. It occurred to him to avail himself of that secret knowledge which he had obtained concerning combustible materials, to employ it for the purpose of constructing a powerful offensive weapon against the enemy. Th result of his effort in this direction was the invention of Greek fire. He himself demonstrated the value of his device, for, according to reports that have come down to us, he succeeded in destroying 30,000 men of a hostile fleet by this agency alone.

It is certain that there were a number of different preparations, each of which was known historically as Greek fire. From the time of the discovery by Gallinicus in the seventh century, other workers produced many varieties that were effective. These were prepared and used extensively in both solid and liquid forms. The fire was frequently employed in warfare on land, especially in repelling the assaults of besiegers, when it could be poured down upon them from the walls. But it was esteemed also as a weapon in maritime engagements. In such use, it was thrown from large engines, stationed on the deck, against the vessel of the enemy. Sometimes, the fire was contained in jars, or other vessels, which were hurled against the foe by various forms of projective machinery. The principle of the force pump was known in the East ages ago, and the records show that soldiers often carried hand pumps, from which the fire might be squirted against their adversaries. By means of a bellows device the liquid was also blown through pipes. The importance of the fire was made evident by the elaboration of instruments constructed for its discharge. On shipboard, the machines, which were stationed usually in the forepart of the vessel, were constructed of copper or iron, or a combination of the two. The extremity of the engine was shaped in imitation of a lion's head with wide-open jaws. In addition, the contrivance was richly painted and gilded.

For a full 400 years, the Greeks jealously guarded their methods of preparing this combustible, and no other nation was able to penetrate the secret of its manufacture. Its exclusive possession by the Greeks was of almost inestimable value to them in the successive wars waged against their neighbors. The Emperor Leo, in his treatise on the art of war, is enthusiastic in recommending the installation of the fire against an enemy.

Greek fire was so highly combustible that it could not be extinguished by water. Some, indeed, claimed that it had the property of decomposing water itself. At least, it contained such a supply of oxygen as to continue its violent burning unchecked by contact with water. The composition was of sulphur, resin, camphor, and other combustible substances, which were melted along with niter. Woolen cords were soaked in the resulting mass. These were afterward rolled into balls, ready for use. Once lighted, they would burn furiously for a long time. Thrown into the ships of the enemy, or against their tents, they were practically inextinguishable.

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In modern times, an old Latin manuscript has been found in the library of the Elector of Bavaria, wherein are contained precise directions for making Greek fire. Moreover, information is given as to the possible extinguishers, for which purpose wine, vinegar, urine, sand, and various other substances are recommended. One form of the fire, which was composed of naptha, sulphur, bitumen, gum, and pitch, was best combatted by a mixture of wine and vinegar with sand.

By the beginning of the tenth century, the fire was no longer the peculiar possession of the Greeks. Thus, there is an account of a siege by Saracens in the year 901, during the course of which they attacked the wooden defenses of the city with liquid fire, blown from pipes mounted on the decks of their fleet. Fire was also used with disastrous effect against the French in 1249, at the siege of Damietta. The history of conquest by the Moore is filled with evidences as to the efficacy of this weapon. The Crusaders encountered it in their battles with the Saracens, and suffered disastrously from such flaming assaults. The most striking example of the fire's potency is, however, that afforded by the attack on Constantinople, when Leo, the Emperor, by its use consumed nearly 2,000 ships of the enemy's fleet.

Greek fire continued to play an important part in warfare until well into the fourteenth century. Then it was met and overcome by the use of gunpowder. The shorter range of Greek fire rendered it powerless against the new far-flung projectiles. Very quickly the ancient fiery weapon vanished from the conflict—to return only after a lapse of centuries, in new guise, as a final horror of the World War.

CHAPTER VII.

FIRE MIRRORS.

Every small boy knows that by focusing the sun's rays through a lens he is able to kindle a fire. The action is caused by concentration of the rays, due to refraction. But a similar concentration, even to a point of greatest intensity, may be secured by employing a multiple system of mirrors. In this case, the arrangement of the numerous surfaces must be such that the reflected beams will converge at a focal point.

The principle, of both the ordinary burning glass and of what we may term the fire mirror, was known to the ancients, and through the ages such glasses have served as playthings for men of science. Yet, the practical result of innumerable experiments has been almost nothing. In recent years a solar motor has been placed in operation in California, and the device has proved itself to be efficient. It depends for power entirely on the rays of the sun, which are reflected to a focus from grouped mirrors. But this exception serves only to emphasize the fact that the solar energy has never been really exploited. The measureless force thus available remains unutilized, as does that of the tidal movement. Neither sun nor moon has yet been fully harnessed for the driving of man's engines.

One difficulty that stands in the way of success for the solar motor is its dependence on a cloudless sky. As a matter of fact, the brilliant sunlight required is not to be found in regions where are located the great industries of the world. Just those regions where the best effects might be secured are those too remote from the centers of civilization for our practical use of them.

That both burning glasses and fire mirrors were familiar to the learned long ago is shown by the testimony of Empedocles. Euclid, too, gave the subject consideration in his works on optics and catoptrics. Evidently, knowledge was sufficiently widespread to render literary references intelligible to the general public; for Aristophanes did not hesitate to make use of the principle in one of his comedies, where a debtor contrives the cancellation of a bond against him by melting the seal with the sun's rays, concentrated through a globe of water. Plutarch describes disks of polished metal, which were used for the purpose of setting on fire combustible substances properly placed at the focal points. It appears that, in this instance, the mirrors used were concave. Indeed, long after the principle involved in such a concentration of the rays by a concave mirror was familiar to learned men, no extension was made to secure a more intense effect by concentrating the various rays from a number of plane surfaces.

The originator of the multiple-mirror contrivance was Father Kircher. It was obvious to him that the effect of the concave mirror might be obtained, and greatly heightened, by employing a group system of looking glasses, so disposed that the reflected rays of the sun from each should converge at a common focal point. He therefore arranged five mirrors in such a manner that the focal point of reflection from them should be at a distance of about 100 feet. He found the heat thus obtained so great that he became enthusiastic over the possibilities suggested by the device.

"If five mirrors," he wrote, "produced so considerable an effect, what would one hundred or one thousand do, arranged in the same manner? They would excite so violent a heat that it would set fire to everything and reduce all to ashes."

Nevertheless, there is little historical record of a reliable sort as to the practical use of either the burning glass or the fire mirror. It has been claimed that burning glasses were used by the Romans, on occasion, for the lighting of sacred fires at the altar. But the evidence in this regard is inconclusive. There is better justification for the belief that Archimedes made practical use of fire mirrors. We may at least credit the claim in his behalf because of what we know concerning his various ability. When Syracuse was besieged by the Romans, in the third century before our era, Archimedes resorted to the invention of numerous devices, to be employed against the enemy's fleet, in defense of the city. These included engines from which were hurled showers of rock; and also curious machines that could seize the hostile ships, raise them and capsize them. But it is declared, in addition, that his greatest triumph was obtained by the use of an elaborate grouping of mirrors, with which he was able to focus on vessels at a distance heat so intense as to set them afire, and to consume them. There is no doubt as to the success of the great man's efforts, for we know that the Roman leader speedily ordered the withdrawal of the fleet.

Accounts tell of a similar destruction by means of fire mirrors when Proclus defended Byzantium against the navy of Vitellian.

In later times, a notable effect was secured by Magius of Septala, who constructed a system of mirrors 3½ feet in diameter. The concentration of heat from this machine was sufficient to kindle fire at a distance of 3 rods. Similar experiments were conducted by Vilette and Deschirinhausen. La Brocquière, who visited Damascus in the fifteenth century, tells of having seen mirrors of polished steel with curved surfaces, which in the sunlight reflected the rays so strongly as to set on fire wood a rod distant.

Buffon made the most serious experiments in the use of the fire mirror. At the outset, he employed a group of 24 looking glasses. He found that the concentration of rays from these very easily kindled a combustible mass of mixed pitch and coal powder, at a distance of 66 feet. He next constructed a polyhedral arrangement, in which he assembled 168 separate pieces of flat looking glass, each 6 inches square. He tried the effect of this on sections of beechwood board, placed at a distance of 150 feet, where they were readily kindled to flame. In another experiment, a plate of silver was fused at a distance of 4 rods.

Gratified by the result of his efforts thus far, Buffon now devised a machine containing 360 mirrors. These were each 8 inches in length and 6 in breadth. They were mounted on a frame, having a height of 8 feet and a breadth of 7. He made a trial of the instrument by using in succession different numbers of the mirrors for the concentration of their rays. When 120 of the glasses were focused on a combustible substance, at a distance of 20 feet, the material instantly burst into flames. At the same distance, a tin vessel was quickly melted when only 45 of the mirrors were set to reflect the sunlight at a common point. A flake of silver was fused by the combined heat of 117. Various other metals were melted at distances ranging from 25 to 40 feet. The extreme distance at which wood could be kindled, under the conditions of unobstructed sunlight and the full power of the machine, was 210 feet.

Buffon afterward built a machine that included 400 mirrors, but these were each only 6 inches square. This device was capable of melting lead and tin set at a distance of 140 feet.

A little more than a century ago, a series of interesting experiments was conducted by Parker, in London. The man had been a glass manufacturer, and, when he retired from active business, his interest in mirrors led him to undertake ambitious tests as to their power in concentrating the heat of the sun's rays. He was so enthusiastic over the matter that he erected an outbuilding, at the bottom of the garden which lay back of his town residence, and there installed special apparatus for testing his ideas.

He succeeded in constructing a very efficient burning lens, which had a diameter of 3 feet. Platinum, iron, steel, flint, and other hard substances were melted within a few seconds, when placed under the heat of the focal point. The records assert that Parker carried on some trials to determine the influence of this concentrated solar heat on diamonds, and that, in one instance, a stone weighing 30 grains was reduced to a weight of 6 grains, during a period of 30 minutes' exposure at the focus. It is alleged also that during this process the diamond opened and "foliated like the leaves of a flower"; at the same time, it gave forth white flames, perhaps from the combustion of carbonic-acid gas. Then, the gem again closed, and, at the conclusion of the experiment, the surface of the stone displayed its original polish, and, too, its former shape was exactly preserved, in spite of the fact that the bulk had been reduced to one-fifth its weight prior to the operation. In continued tests of this burning glass, Parker readily melted garnets, and other semi-precious stones. His work was so successful as to attract general attention, and the public appreciation was shown by a subscription of 700 guineas, to reimburse him for the expenses of his investigation. The lens used by him finally became the property of Lord Macaulay, who presented it to the Chinese Government.

In considering the above account, it must be borne in mind that, in Parker's day, experiments were not always watched and recorded with that scrupulous accuracy characteristic of investigators in our generation. We may, therefore, with all due respect to the zeal and honesty of those from whom we have received this narrative, regard some of the details with a degree of caution. We are permitted to suspect that there may have been unconscious exaggeration, or other errors, in the description of the effects shown by the diamond. Nevertheless, the account as it stands was given without comment by an American chemical authority, who was an instructor at West Point a century ago, and who was himself a devoted student of pyrotechny.

About the time of Parker's experiment, a French investigator contrived a fire mirror, which was formed out of numerous plane mirrors, so arranged as to concentrate the solar heat in a focus with the greatest precision. This machine was differentiated from its predecessors in the method of adjusting the mirrors so that their position could be controlled with the utmost nicety, and the effect was correspondingly intense.

About the middle of the eighteenth century, following the experiments of Buffon, a polygonal mirror was erected in the Botanical Garden at Paris, by which an intense heat was generated at the focal point. This mirror was composed of 168 plates of silvered glass, each of which was capable of being moved in every direction and of being fixed at different degrees of inclination. The result was that the system of looking glasses could be so disposed as to form essentially one large concave mirror, of which the focus might be located wherever desired. This contrivance was so powerful as to set on fire wood placed at a distance of 200 feet. It fused metals under a focus 45 feet from the compound mirror.

Thus we find, after the passage of many centuries, something to justify a belief that the great brain of Archimedes did indeed evolve a method by which he could gather the sunlight and cast it forth to the destruction of his enemies. But, while we may credit him with such achievement, we are unable to discover any cause for pride over subsequent accomplishment in the matter of fire mirrors. There is nothing in our own day to rival the exploits of tradition.

CHAPTER VIII.

ROCKETS.

We meet even to-day occasional survivals of rites from the ancient sun worship that are consciously practiced. Such is the sun dance of the Arapahoe Indians, with its mystic wheel—that aged symbol common to the religions of all primitive peoples; as shown, for example, by the winged wheel of Ezekiel, concerning which the Hebrew Scriptures tell.

But it is of more curious interest to note certain instances in which such survivals of sun worship are unconsciously practiced. An illustration is afforded by some present-day usages in the Christian church.

Both Greeks and Romans adopted the Persian Mithra for their own, and also worshiped Ahura-Mazdao, whose chief symbol was the sun. Along with such worship went various ritual observances that long afterward powerfully influenced the Christian church in its ceremonial forms. It is due to such influence that we still build our churches with a due regard to their orientation, and that the congregation faces toward the east during recital of the creed.

Now, concerning the origin of rockets, we have only an impenetrable obscurity, so far as historical records go. There is, nevertheless, a tradition which holds some degree of interest, although it is quite incapable of proof. According to this, the rocket was originally devised by priests, ages ago, who represented it to be the living spirit of flame, which, by its own power, at the priestly command mounted from earth to heaven as messenger to the fire god. None who has witnessed a rocket's flight aloft may doubt its effect in exciting the superstitious awe of the devout. So, there is at least a slight excuse for the extravagant fancy that, as we behold the rush of a rocket heavenward, we are indeed watching a spectacle that is still another survival from the sun worship of yore.

A rocket, briefly described, is a projectile containing a composition which, as it burns, generates sufficient gas to drive the rocket forward by reaction against the inertia of the air. As the gas escapes at the base of the rocket, it encounters the resistance of the air, and in the recoil from this the rocket itself is forced upward. The principle involved is exhibited in the recoil of a gun, or even, more simply, in the oar pressure against water by which a boat is propelled. The rocket has been distinguished as the sole projectile having no need of gun or cannon for its discharge. In all other forms of ordnance, the power of the recoil has been wasted—until within a few years, when at last inventive genius set it to work in the operation of quick-fire devices.

A medium between the far past and the present in the construction of rockets is afforded by an account written about 100 years ago by Prof. Cutbush, who was an instructor at West Point. His description is essentially as follows, and it will be interesting, later on, to compare it with contemporary productions:

A rocket is a flying fusee, formed out of paper, having a cylindrical shape, which is filled with a composition of certain inflammable substances, and is also pierced in the diameter of its length. The rocket is furnished with a stick, which serves as a balance to guide it vertically in its ascension. It carries, in addition, different garnitures, or furniture, such as stars, serpents, fire rings, marrons, meteors, and the like, which, as they are thrown off at the termination of the flight, produce an appearance of great beauty.

Rockets have been applied to a variety of uses. Thus, besides serving as a means for entertainment and for signaling purposes, they are used in war as an incendiary weapon. This variety was greatly improved by Sir William Congreve.

The rocket cases are always cylindrical. They are formed generally of pasteboard, which is filled with a peculiar composition, consisting of meal powder, saltpeter, sulphur, and charcoal. Sometimes, however, the powder is omitted, and on occasion pulverized cast iron is added. In the construction of war rockets, iron cases were often substituted for those of paper. This was the case with the Congreve rocket.

The outer diameter of the cylinder is usually from 1½ to 2 inches, while the length of the charge is always 5 diameters. The interior diameter is two-thirds as much as the exterior.

The tools used in the construction are a rod, or former, on which the case is molded, and an artisan's tool employed for rolling the paper. There is also a conical spit, or piercer, by means of which the rocket, when loaded, has a hollow through the middle. This piercer should be four and two-thirds times as long as the outer diameter of the rocket, and one-third of that diameter at its small end. There are required also three rods for the loading. These have each a conical aperture, in order to receive the piercer. There are, finally, a massif, and a ladle, or measure, of which the diameter is equal to the interior diameter of the rocket, and of which the length is three times that diameter.

The construction of the paper cylinder, or cartouche, is of pasteboard, of which three or even more thicknesses are employed, rolling the paper on the former until a sufficient thickness is attained. An important part of the manufacture is the choking of the cylinder. This is accomplished by means of a cord having a diameter of three lines. In the operation, one end of the cord is firmly fastened to the wall, while the other is attached to a stick. The worker then bestrides the cord and regulates its tension by leaning against the stick.

The rocket is loaded by introducing ladlefuls of the appropriate composition, one at a time, after the case has been set in position over the piercer. A rammer and mallet are necessary tools for compressing the charge.

When rockets are designed for signal purposes, they are usually furnished with a load to be set off as the flight comes to an end. The garniture may be of serpents, stars, or petards. The serpents are commonly produced by rolling playing cards, in the direction of their length, upon a former three lines in diameter, which are afterward covered with three coats of paper, the last coat being pasted. Such cases are choked at one end, and in the opening of each choke is placed a strand of tow, primed with meal powder moistened in brandy. The loading is done, by the use of a rod as rammer, until they are three-quarters full of the composition. They are again choked at one-half their height. The remainder is filled with powder to make a report. If a serpent with stars is desired, only half the case is filled with the serpent composition, while the remainder is equipped with the necessary material for production of the stars. It should be noted that serpents are to be set upright in the pot, having a priming at the lower end.

An excellent composition for serpents to be used in signal rockets is as follows:

	Parts.
Meal powder	16
Saltpeter	3
Sulphur	2
Charcoal	½

For stars, the proper composition is fashioned into balls, or perhaps cubes, within a casing of paper, filled with gunpowder. They are wrapped about with two layers of strong thread, drawn tight in every direction. The stars are then dipped in tar, in order to give them a firmer consistency, and they are pierced and coated with quick match.

At the time when the foregoing description concerning rocket construction was written, experiments were made to determine the extent of flight. Especially powerful rockets were manufactured and fired. The average height attained was about 400 yards. One reached an altitude of almost 2,000 feet.

A hundred years ago, the enthusiasm over the rocket as a war weapon was marked by many curiosities of construction, for which their inventors hoped great efficacy in battle. Thus, there was a sanguinary, or murdering rocket. This imposing name was given to a special form of firework that had neither head nor pot. In place of these, such rockets were equipped simply with a cone of iron. The destructive effect was to be wrought by the pointed metal. It was expected that a rain of such projectiles on an enemy's troops would wreak havoc; particularly since ordinary earthworks would be powerless to shield from the attack. Further great advantage claimed for this species of weapon was based on the fact that the rocket itself could be set in flight from cover. Finally, it was asserted that the superiority included a length of flight double that of the ordinary rocket and far beyond the range of musketry.

Another variety of the war rocket was the fougette. It was this form that was used by the native soldiery of India. The fougette was employed against the British very effectively at the siege of Seringapatam. Iron was used in the construction of these rockets, the metal cap being lashed to a cylinder of bamboo. They had a weight of nearly 2 pounds. The action of the fougette was to drive forward with great violence. It was sharply pointed, so as to penetrate any object with which it might come in contact. Moreover, it was capable of inflicting serious wounds by reason also of the formation given to its sides. These were lined with small pipes, so charged as to be readily combustible, and to gush fire at all points. The weapon was thus distinctly effective as an incendiary agent. Its capacity in this direction was increased by the fact that it would hold firmly to whatever it encountered.

French military writers of the time expressed keen appreciation of the value of this war weapon. They pointed out that it could be made applicable to a great variety of uses. One suggestion was that it would serve as a means of defense against the ships of an enemy at the mouth of a harbor. It was maintained that the fougette would render a better defense against a hostile fleet than could the projection of red-hot iron balls. A further advantage, it was argued, lay in the fact that the rockets would require so few hands for their operation, since they needed nothing beyond the mere lighting and throwing forth.

This rocket, devised in India, was also called by the French the baguette à feu.

Almost contemporaneous with the baguette, rockets were employed to a considerable extent in warfare by the British. The most successful form was the invention of Sir William Congreve. This was 30 inches long and 3½ inches in diameter. It was designed primarily as an incendiary weapon, and as such it was used successfully by the British troops in their attack on Copenhagen. This rocket was again used by the British for incendiary purposes in their conflict with the Americans at various places, notably the Chesapeake. As a spectacular display, the rain of rockets at first aroused trepidation among our troops, but dismay from the novelty of such an attack soon passed, as it was found that the effects were inconsiderable. Indeed, our own first-hand experience with the rocket as a war weapon showed the effects of it to be so trifling that we may well receive with suspicion the accounts given of its efficiency in various European campaigns. There existed a strong prejudice in favor of the weapon at the time of its introduction, as will be shown a little later on in this chapter, and it is probable that enthusiasm led to involuntary exaggeration.

Another form of war rocket was named the carcasse. This was first used during an attack on Boulogne, in 1805. About 200 of the projectiles were discharged, with the result that the town was set in flames, and the conflagration continued with the utmost violence for two days.

The various operations with war rockets aroused great enthusiasm at this period on the part of military observers. It is not to be doubted that the weapon proved its efficiency in many cases. But it may be suspected that the enthusiasm in behalf of this device was exaggerated by reason of the novelty attached to it. A French officer, who witnessed the use of the carcasse at both Boulogne and Copenhagen, declared with emphasis that the contrivance offered a powerful auxiliary to the military system.

Success marked the use of such rockets at the siege of Flushing. Indeed, the havoc wrought by them in the town was such that a remonstrance was addressed to Lord Chatham against the employment of such devices in bombardment. The Crown Prince of Sweden resorted to the carcasse during his assaults on various cities, and issued a formal report in praise of this means of warfare. Similar rockets were used, with a considerable measure of success, at the memorable battle of Leipsic. When Wellington's army crossed the Adour, a rocket corps contributed valuable aid against the enemy. This occurred just after such a corps had been formed as a regular branch of the British military establishment.

From a French source has come down to us an interesting account concerning a Congreve war rocket, which was found on the coast by Gen. de Grave, who transmitted it to the Society of Encouragement, at Paris. A description made

Formulas for Chinese flowers.

COMPOSITIONS CHINOISES

Du Pere D'INCARVILLE, *pour repréſenter des Fleurs de diverſes eſpeces.*

Diametre intérieur des cartouches.	Noms des Compositions.	Salpêtre.	Soufre.	Charbon.	Sables.	
					Ordres.	Poids.
		liv. onc. gr.	liv. onc. gr.	liv. onc. gr.		liv. onc. gr.
De 6 à 8 lig.	Pour le ſable le plus fin, ou du 1er ordre	1 . 4 . 0	0 . 4 . 0	0 . 4 . 0	. . .	0 . 9 . 0
De 8 à 10	Pour le ſable du 2e ordre . .	1 . 4 . 0	0 . 4 . 4	0 . 4 . 4	. . .	0 . 10 . 0
De 10 à 12	Du 3e ordre	1 . 4 . 0	0 . 5 . 0	0 . 5 . 0	. . .	0 . 12 . 0
De 12 à 15	Du 4e ordre	1 . 4 . 0	0 . 5 . 4	0 . 5 . 4	. . .	0 . 13 . 0
De 15 à 18	Du 5e ordre	1 . 4 . 0	0 . 6 . 0	0 . 6 . 0	. . .	0 . 14 . 0
De 18 à 24	Du 6e ordre	1 . 4 . 0	0 . 6 . 4	0 . 6 . 4	. . .	1 . 1 . 0
De 15 à 18	Li hoa	1 . 4 . 0	0 . 7 . 0	0 . 5 . 0	des 6 mêlés	0 . 12 . 0
De 10 à 15	Tſing lo ſan	1 . 4 . 0	0 . 5 . 0	0 . 6 . 0	des 2 & 4 mêlés	0 . 10 . 0
De 12 à 15	Mou tan	1 . 4 . 0	0 . 4 . 0	0 . 4 . 0	du 4e . .	0 . 2 . 0
De 12 à 15	Lo ti licou	1 . 4 . 0	0 . 3 . 2	0 . 2 . 5	du 4e . .	0 . 6 . 0
De 15 à 18	Ta ſive hoa	1 . 4 . 0	0 . 5 . 0	0 . 6 . 0	des 6 mêlés	0 . 10 . 0
De 15 à 18	Ta Kiuhoa	1 . 4 . 0	0 . 4 . 0	0 . 4 . 4	du 5e . .	0 . 13 . 0
De 10 à 12	Siao li hoa	1 . 4 . 0	0 . 4 . 0	0 . 4 . 0	du 3e . .	0 . 10 . 4
De 12 à 15	Ta li hoa	1 . 4 . 0	0 . 4 . 5	0 . 4 . 5	du 4e . .	0 . 15 . 0
De 15 à 18	Man chou li hoa . . .	1 . 4 . 0	0 . 5 . 0	0 . 5 . 0	du 5e . .	0 . 10 . 7
De 15 à 18	Pan chou li hoa	1 . 4 . 0	0 . 4 . 0	0 . 8 . 0	du 5e . .	0 . 12 . 0

by an official examiner states that the case was fashioned from a gray paper, painted. The inflammable material was of a yellowish gray, in which the sulphur constituent could be distinguished by the naked eye. It burned "with a fierce flame while exhaling sulphurous-acid gas."

English writers on military subjects at this time were especially optimistic over the future of the rocket as an important weapon. They extolled as one of the peculiar advantages its slight weight and bulk, which gave facility both for its conveyance and operation. It was also strongly recommended for purposes of naval bombardment. Its advocates pointed out a particular worth in this direction because of the fact that there is no reaction from its discharge. While the firing of even the smallest piece of ordnance from the deck of a ship sets up movement in the fabric itself, the largest rocket may be sent aloft without imparting any least trace of motion to the ship. In consequence of this, the carcasse, it was maintained by its admirers, might be thrown from the smallest boat with entire safety, even though it were a projectile equal to that cast from the heaviest mortar.

It was claimed in favor of these rockets for land service that they possessed a peculiar fitness due to easy portability. They were regarded as capable of doing a large part of the work of artillery, while, at the same time, they were so simple in their construction and so compact as to offer almost no difficulty in transportation, as compared with the usual forms of artillery. It was declared that the rockets afforded a practical system of artillery that was, in effect, ammunition without ordnance.

Nevertheless, we find some French critics of this period who stoutly deny English assertions as to the excellence of rockets in warfare—despite the fact that the invention of the war rocket was claimed for a French naval officer, stationed at Bordeaux. Authoritative students of military science maintained that the rocket should not be regarded as a really useful weapon, since its possibilities were extremely limited.

As a matter of fact, there was undoubtedly sufficient justification for high anticipation over the utility of rockets in warfare. It is true that they afford remarkable advantages by eliminating ordnance. Under conditions as they were at the time when the war rocket was developed by the British, it is likely that the device must have flourished to a greatly increased extent. Its range of flight was sufficient to make it a formidable war instrument, as compared with the other ordnance of the period. But the hopes of those who waxed so enthusiastic over the achievements of the rocket were destined never to be fulfilled. The reason for this disappointment was not due to any lack of correct judgment on their part in considering conditions as they were. The advocates of the rocket did not, and could not, foresee the development that was to come in the use of guns. The rifling of barrels, and the various important improvements in explosives, produced results that left the rocket, with its limited range, wholly outclassed, discredited, and inefficient as a missile.

Fortunately, however, the failure of the rocket as a projectile took nothing from its value for other purposes; and, for such other purposes, its merits to-day are more highly appreciated than ever before.

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CHAPTER IX.

CURIOUS WAR DEVICES.

Most of the inventions in pyrotechny, at this period, were of a futile sort, more especially by reason of the fact, to which attention has already been called, that subsequent improvements in ordnance and explosives rendered them essentially useless.

But such a criticism does not apply to the rocket light ball, which was the most important invention of Sir William Congreve. This was not only valuable in the age of its inventor, but the principle of its construction has been applied with advantage in our own day.

The contrivance was a rocket, which, on reaching the extreme altitude of its ascent, discharged a species of light ball that thereafter remained suspended in the air by means of a small parachute, to which it was attached by a chain. "Thus," as a contemporary author writes, "in lieu of the transient momentary gleam obtained by the flaring out of the ordinary light ball, a permanent and brilliant light is obtained, and suspended in the air for five minutes at least, so as to afford time and light sufficient to observe the motions of the enemy, either on shore or at sea. It should be noted that nothing in any way equaling the effect of this light ball can be obtained by any projectile force, from either guns or mortars, for the reason that the explosive charge of the piece must certainly destroy any construction of a sort to produce such a suspension in the air."

From the limitations of knowledge possessed by this writer, he was amply justified in such high praise for the rocket light ball and in the contention that it could not be equaled by any projectile from ordnance. He could not guess at those developments which have resulted in the rifle light of to-day. As a matter of fact, the cartridge containing such a light is discharged from a rifle without injuring in the slightest degree the mechanism of the parachute attachment.

But, too, we must give credit to this invention for the practical use of the parachute in sustaining a flare. Indeed, in the century that has elapsed, we have been unable to increase appreciably the time limit for the burning of such a light, although we have greatly increased the brilliancy of the illumination.

A primitive strategy was the unexpected lighting of a fire by the besieged, with the result that a foe advancing to assault under cover of darkness would be plainly revealed, and thus thrown into confusion. Originally, simply a pile of brush, quickly kindled, sufficed for the purpose. As the nature of various combustibles became known, improvements were made by using suitable compositions that would burn fiercely and cast a brilliant light. A final development came when such materials were compressed into projectile form and thrown to a distance, either by hand or by ordnance, or, as in the case of Congreve's rocket light ball, by their own power. Such flaming missiles were employed also for incendiary purposes, and out of them grew the almost innumerable varieties of incendiary bombs, which were widely utilized in military operations, under many different names. They were of service especially in besieging towns and in naval actions. The prime essential was always that the construction should be of such a sort that the composition would continue to burn even while in contact with water. One of the simplest devices was of rope, which, after being duly soaked in a combustible liquid mixture, was rolled into a ball, and then inclosed in a sack, to be fired from a mortar. This device was invented by a French officer during the siege of Toulon.

The incendiary bomb was modified so as to include in its effects not only the causing of fire, but also the wounding and slaying of enemy troops. For this purpose the containers of the combustible were fashioned of metal in varying forms, so that their contact would work injury. Often shells were made by uniting two hollow hemispheres, which were duly provided with bores and a fuse. These projectiles were exploited under the name of "murdering marrons."

To us, to-day, some of the methods that were popular a few generations ago seem almost unbelievably clumsy. Yet, simple as they were, they sometimes proved that their efficiency was adequate to the conditions under which they were utilized. Our familiarity with the horrible ingenuity and intensity of explosives crashing from hidden mines is likely to create in us a mood of rather pitying contempt for the primitive attempts of our ancestors in this direction. But it would be unjust to condemn methods that were, in fact, well adapted to the needs of the time.

As an illustration of such former methods, we may consider one of the most pretentious, which was announced by a French publication, in 1815, under the name of the "the pyrophore of defense."

According to the author's description, this device might be constructed and set in readiness for use within a period of 24 hours, and was available for the defense of towns, roads, passages, and defiles. The pyrophore was made up of a square box with a lid, and was commonly large enough to contain 50 pounds of gunpowder. The lid was furnished with crosspieces, by which it might be opened when necessary. Rings were fastened to the sides of the box. These were of iron, very strongly fixed in position by means of bolts, which penetrated the sides and were clenched. Either ropes or chains were fastened to the rings, with crotchets at the ends. These were designed to run on two fixed pulleys, which could be stationed wherever desired. A common position for the pulleys was at the two extremes of a battery, where they might be managed by artillerists. It was usual to have a bar or grate set at the point where it was intended to place the pyrophore. It was then lowered from under cover into the required position, by means of the pulleys. The interior of the contrivance was so disposed that, on raising the lid, the powder would fall into a funnel-shaped gutter, at the end of which the match could be applied.

It is hardly necessary to point out that this machine was of a cumbersome sort, and could rarely be used to advantage, by reason both of the time required for its construction and the difficulties in the way of its operation.

Nevertheless, it appears from contemporaneous accounts that successful results were sometimes obtained by use of the device. It was especially available in defense against an attacking enemy on occasions when it could be exploded by the defenders from cover.

Fire pots were very frequently employed in the early military operations of the nineteenth century. They were an important part of the equipment for ramparts in time of siege. The pots employed for this purpose were of any ordinary ware and of diverse shapes. They were furnished with grain powder, and charged sometimes also with firestone. After being filled with the proper ingredients, the pots were covered over with parchment. The match passed through an opening in the top, to be kindled when desired by a port fire.

In some instances, the fire pot was provided with an iron hoop and hook by which it might be lifted. This form was often used for service at sea, as a means of defense against attack by small boats. For that purpose, the pots were hung over the side of the vessel in such position as to come readily into contact with the approaching boats. They were thus capable of offering effective defense. One account tells of a vessel in the Indian seas that owed to the use of fire pots its rescue from an onslaught by pirates. It was found that flight would not avail for the ship's escape from the enemy. The captain thereupon set the crew to making fire pots for defense, since the foe had them hopelessly outnumbered. The pirates approached the vessel in ignorance of the danger that menaced them. As they crowded against the sides, about to swarm on deck, the fire pots were exploded—with such effect that the enemy was thrown into confusion from which it could not recover, and the ship pursued its way in safety.

A form of firework commonly employed for exhibition purposes gave to military inventors the suggestion for a particular kind of incendiary fire pot. The vessel, in this case, was made of copper, so that it possessed great strength. Pieces of firestone were rolled in a paste of meal powder and brandy. After a charge of powder had been placed in the pot, with a quick match inserted, the fragments of firestone were thrown on top. The match itself was made sufficiently long to extend out over the brim and hang down the side.

Another curious weapon was called the inflammable dart. In the construction of this an ordinary rocket case, having an exterior diameter of one inch, was charged solidly with the usual explosive composition. Sometimes, however, a variation was made by adding one spoonful of earth to three spoonfuls of the composition. The case was duly pierced, and a quick match fixed at the end for setting it off. The dart itself was made of iron, with a very sharp point and edges. It was firmly fastened to the head of the case. With the addition of the usual stick lashed to the case, the inflammable dart was complete. Its advocates praised it especially for the readiness with which it might be sent in any desired direction from under cover. From the current accounts, however, it appears that the only practical efficiency of the weapon was in defense of buildings during assault by an enemy.

The name firebrand was given to a contrivance first developed by the French, and called by them the loupe-feu. This was an incendiary weapon of such simplicity as to possess some merit on that account, if on no other. It was merely a long stick, into one end of which were set two iron prongs. These were wound about with a thick rope, which had been soaked in a liquid explosive. In effect, the loupé-feu was a convenient instrument for quick setting of fires.

Fire flasks were widely employed, chiefly owing to the ease with which they might be prepared. They were formed from any bottle, into which a charge of grain powder, mixed with firestone, was introduced and compressed with a stick. A cloth was then drawn about the bottle as a cover, over which was laid a coating of pitch. The cloth, in turn, was secured by parchment. The explosion was effected by means of a match passing down within the neck of the bottle.

It is interesting to compare this primitive device, which was thrown by hand, with the modern ingenious and highly destructive hand grenades so commonly used in the World War.

CHAPTER X.

NAVAL DEVICES.

The experiments with rockets early extended adaptations of them for use at sea. Their value was, of course, speedily recognized for signal purposes in naval warfare, and also especially for indicating distress to those on shore, in the hope of rescue. This most important use of signal rockets has continued, and has grown steadily during more than 100 years, until to-day every ship is fully equipped with the necessary supplies of rockets for signal purposes.

One variety of the rocket, to be used in case of distress at sea, was first developed fully a century ago. It was called the succoring or marine rocket. This was made sufficiently large to carry aloft a small cord, designed to serve as a first means of establishing communications between ship and shore. The original form of the rocket was described as having an interior diameter of at least 2 inches. An essential difference was displayed in the size of the attached rod for directing the flight. This was reduced by one-half in both length and thickness, to the dimensions usual for a rocket of one-half the caliber. One end of the fine cord was fastened to the rod. Care was taken in coiling the cord to arrange it so loosely that it would offer the least possible resistance on being drawn upward by the rocket's flight.

Advocates of the succoring rocket pointed out that, in addition to its availability for establishing communication with the shore, it could also be employed to advantage in the case of a seaman falling overboard at sea, since by means of it a line could be cast to him immediately, even from a considerable distance.

The device of a shell with cord attached was invented by a Mr. Bell. This shell was to be fired from a mortar on the deck of the ship, thus carrying the line to those on shore, for the purpose of rescue. His contrivance underwent the tests of a practical demonstration, with such satisfactory results that a reward of 100 guineas was bestowed upon him by the British Government for his invention.

A Mr. Holton was responsible for a somewhat similar device, with the same end in view. But, in his contrivance, instead of a shell, a harpoon served as the projectile with rope attached. The harpoon was thrown from a long gun. It was equipped with lateral points, so that it would hold fast to any object with which it came in contact. This construction made it a possible agent, not only for life-saving, but for warfare, to be cast against an enemy ship. Mention of this use is made by the inventor in his description, but he failed to explain in detail any specific value to accrue from such a form of attack.

The ingenious Congreve exercised his facility in invention by adapting his rocket with parachute attachment to use at sea as an incendiary weapon. The advantage of his device lay in the fact that it was capable of taking effect at a distance greatly beyond the range of any other projectile known at that time. It had, too, the added merits of being cheap, simple, and easily portable.

The floating carcasse, as Congreve named this firework, was constructed generally on the pattern of the light ball. The rocket in its flight carried up with it the fire ball, to be set burning and cast forth at the end of the flight. By means of a parachute, the ball remained supported in the air. Thus far, the floating carcasse followed exactly Congreve's earlier invention. Its distinctive feature lay in the fact that it was now to be carried in still further flight by a natural agency—wind. Its effectiveness was dependent, in the first instance, on the duration of burning time for the ball, and, in the second instance, on the degree of nicety with which the flight was adjusted to the prevailing breeze. The floating carcasse was intended to be thrown in large quantities from a blockading squadron, when, with a favoring wind, it might be borne against the enemy's fleet, or an arsenal on shore, with great possibilities of destruction as an incendiary weapon.

One contention in behalf of the effectiveness of this floating carcasse was based on the fact that it was not necessarily visible in its flight by night, since it might be constructed in such fashion as to burst into flame only after it had settled. Thus, it might work havoc by lodging, unperceived, in the rigging of floatillas, or on the roofs of buildings ashore, when all ordinary means of approach were barred.

The French conceived the idea of a firework to which, from its purpose, they gave the name trompe-route. This was an invention intended to deceive the enemy as to the course of a vessel at sea. It was constructed after the manner of an ordinary fire lance, having a length of 12 inches and a diameter of 1 inch. This was fixed in the center of a round piece of plank. When the device was to be used, it was only necessary to set the lance alight, and then to lower it on its plank to the water. It was cast free to float according to the direction of wind and tide. In connection with the use of the trompe-route, the vessel from which it was sent was darkened, so that it sailed with no light showing. It was expected that the watching enemy would take the burning trompe-route for the light of a ship, and so follow it, while the ship itself escaped in the darkness.

It is interesting to contrast this simple device with the elaboration of a somewhat similar purpose to-day in the use of smoke screens, by which the movements of vessels are concealed from enemy observers.

Consideration of naval variations in pyrotechny requires a brief attention to fire ships, which have been persistently employed through the centuries in warfare at sea.

Ships designed to serve as incendiary agents are generally selected, with a view to economy, from the old vessels available. These are filled with combustibles, and are also fitted, when possible, with grappling irons in order to hook fast to the craft of the enemy. In the use of fire ships on rivers, careful calculation of the direction of the currents is necessary, in order to insure successful movement of the incendiary boats against those of the enemy. In like manner, at sea, wind and tide must be regarded, in order to win a favorable issue of the exploit.

Old records tell how seamen of Tyre employed fire ships against Alexander. The Crusaders, also, made use of them in their operations at Acre. At the siege of Antwerp, in 1585, the Spaniards suffered severely from the ravages of fire ships. While the Duke of Parma was endeavoring to throw a bridge over the Scheldt, Gianibelli sent against the structure a fleet of vessels loaded with combustibles, so prepared that they exploded on reaching their objective.

Three years later, Lord Howard of Effingham made use of fire ships, with extraordinary success, against the Spanish Armada. The credit for this operation also should go to Gianibelli, since it was by his advice that Lord Howard undertook the exploit.

The Greeks have maintained their original supremacy in the use of fire as a war instrument by frequent victories against their constant enemies, the Turks, through the use of fire ships.

But a survey of the historical facts does not justify an impression that fire ships are uniformly employed to advantage. It would seem, indeed, that they, like every other form of combat, are dependent on the courage and resourcefulness of their users for the measure of their achievement. Often, their failure is of such a singularly complete character as to be explicable only by the crass stupidity of those sending them forth. Thus, in 1857, during the war between British and Chinese, the Orientals set adrift whole fleets of fire vessels against the warships of the British, but no slightest damage was effected.

CHAPTER XI.

VARIOUS DETAILS.

Apart from the activity of inventors in connection with military devices during this period, there was little progress in pyrotechny. Some improvements, however, were made in the compositions used for fixed fires. Hitherto, the combustible for these had been commonly piled upon a piece of tiling, or a flagstone, without being inclosed, and they were set off by a flame applied at the apex. But now the combustible was frequently inclosed in a light case, open at the top. Various experiments were conducted with success in producing colored effects of great brilliancy, in green and red and blue, as well as white. A variety of such fixed fires was the Bengal lights, which, as the name imports, had their origin in India. These were usually formed by piling the combustible on saucers, after which the whole was covered with gum-paper. The lighting was by means of a quick match extending outside the case.

The French chemists were enabled to improve greatly on such illuminating substances as had been known in India. One of the best compositions in the way of a fixed fire was utilized by French astronomers for signaling purposes. This was known as the feu blanc indien. A description of the form in which this was used states that it was contained in a case having a diameter of 10 inches, with a height of 4 inches. But the size might vary, as required by the quality of the composition and the degree of light required. Illumination from the feu blanc was visible at sea for a distance of 40 miles. In the course of a series of experiments, a case of this fire, lighted on the English coast, was seen distinctly by French observers across the Channel.

Efforts were made to duplicate certain fireworks that had gained high repute in Japan. Among these was the "spur" fire, which is so constructed that during the burning scintillations of remarkable beauty are thrown off into the air.

To the astonishment of the investigators, who had analyzed the contents of the spur fire, the result of their efforts was failure. Repeated attempts to duplicate the brilliancy of the spectacle, as shown by the Japanese firework, fell far short of attainment. It was supposed, naturally enough, that the failure was due to some mistake in the preparation of the combustible. It was finally discovered, however, that the secret of the difference lay, not in the inflammable contents, but in the paper wrapper inclosing them. Thus was suggested to workers in the pyrotechnic field the first appreciation of the importance of such paper as may be consumed in connection with the burning of a firework. The chemical constitution of the paper used in making of cases may play an important part in either increasing or lowering the intensity of illumination, especially in instances where pure-color effects are sought.

One very curious device developed during this period was called, by reason of the noise emitted by it while burning, the whistling firework. The composition was three parts of potassium picrate to two parts of niter, or five parts of picrate to one part of niter.

In the construction of the whistling firework, the case is not packed, nor is the mouth shaped. The result is that, on ignition, the rush of flames and gases causes the emission of a shrill, varying note, having an uncanny intensity. The sound rises gradually to a maximum of loudness, which is followed by a rapid diminuendo. These fireworks are now often used in sets of five loaded into a pot, for the garnishing of a rocket.

It is possible that the principle involved in this firework might be adapted to the construction of a projectile for signal purposes, during weather conditions that would render lights invisible. The sound given out might be controlled by adjustment of the case to determine both the pitch and the duration of the note, while the number of repetitions might be systematized as desired, according to the number of whistles loaded with each rocket.

One of the devices produced by the military inventors was fire rain, which was utilized, like others of its class, as an incendiary firework. It derived its name from the fancied resemblance to a shower of rain. It was capable of readily setting fire to besieged buildings when they were covered with inflammable materials, such as shingles, laths, reeds, and the like. The beauty of this particular firework led to its popularity for purposes of entertainment, long after it had been dismissed from attention as an instrument of warfare.

The historical consideration of pyrotechny would be incomplete did it not include a word in passing as to the origin of gas warfare. Humble forms of such warfare may be directly traced to a crude and ancient pyrotechny.

Indian tribes, such as the Tupinamba and Guaranis, of the Brazil littoral and the borders of the Rio Parana, used poisonous gas against their enemies centuries ago. Savage strategy availed itself of such gases in attacks on fortified villages. Here the method was of the simplest. Included among the besieging forces was a body of men equipped with pans containing glowing coals. Supplies of red pepper also were carried. The manner of operation has been described by chroniclers of the Spanish invasion. Often, the whites were sufferers from this species of warfare. Really, the method depended wholly on a favoring wind. Young warriors, ambitious for fame, then sprinkled the pepper liberally on the live embers. When the fumes penetrated to the village of the enemy, their effect, though not usually fatal, was sufficiently noxious to destroy all resistance.

Agi, is the native name of the pepper. Sometimes, it was used by the medicine men of various tribes for the exorcising of evil spirits. We may believe that the effect of the pepper on those present at such rites pointed the way to its employment in warfare.

PART II.

DETAILS OF MANUFACTURE BY THE EARLY ARTIFICERS IN PYROTECHNY.

CHAPTER I.

INTRODUCTORY.

It would transcend the limits of our space to give in chronological sequence a complete description of the successive steps by which pyrotechny has attained its modern development. It will answer our purpose of investigation if we make a summary by which may be shown the status of the art at that period when it was most flourishing, prior to its present-day achievement. The best opportunity in that direction is afforded by France in the middle of the eighteenth century. And this for the following reasons:

At the time, the French were the best artificers in pyrotechny. A high degree of skill in the art was developed under the monarchy, and this was carefully fostered by the Government, which, through the ordnance department of the army, conducted a long series of experiments and tests for the determining and perfecting of all the processes involved. Careful records were kept by the investigators, and some of these remain available for our use to-day, so that, in the statements to follow, we have dependable information throughout.

In addition to the fact that the French had already attained a high degree of proficiency in pyrotechny at this period, their interest was still further stimulated by those contributions to the art derived from Father d' Incarville. He was a Jesuit priest, who, while serving as a missionary in China, interested himself in the study of fireworks, and finally brought back to Europe a detailed knowledge which he placed at the service of his fellow countrymen in France.

The descriptions here given concerning the manufacture of fireworks may be taken as of general application throughout Europe, during the latter years of the eighteenth century, although they are specifically directed to French methods. If we note especially the scientific limitations of the artificers of that age, we must recognize as well the efficiency displayed by them, which in its fundamentals is identical with modern processes.

It must be borne in mind that the following chapters, constituting Part II of the History of Pyrotechny, deal with descriptions of operations, formulas and recommendations based on the understanding and conception of chemical reactions at a time when chemistry was in its infancy. The worker in chemicals of this period knew nothing of certain laws that are the very foundation of our present understanding. The groping toward reasons for chemical reactions led often only to misconception, even to mysticism. Furthermore, the translation of some of the old records of the French ordnance department has of necessity compelled the use of terms hardly understood by the chemist of to-day. It is enlightening and pertinent to the text, however, to set forth the surprising statements made by artificers, who recorded their activities in this line, despite the fact that some assertions are not in accord with the scientific knowledge of the present day.

CHAPTER II.

MATERIALS.

Both the accurate information of the pyrotechnist, and the handicap under which he worked, due to ignorance of certain chemical facts, are well illustrated in the summing up of one writer concerning colors in fireworks.

This expert declares that saltpeter, sulphur, charcoal, and iron are almost the only materials of which use is made in firework manufacture. Different combinations of these vary both the general effects and the particular color of the fires produced. These colors show a series of finely graded nuances from red to white. Sulphur, when it predominates, gives a blue flame, while iron produces sparks of special brilliancy. Many experiments have been made in an effort to discover other colors, but none has been successful. The materials best suited to such purposes, by which, when melted, the effects are naturally produced, such as zinc, copper, and other metals, fail to produce the desired effects when they are mingled with sulphur and saltpeter, since the more powerful fire of these substances destroys the phlogistic metallic content, which is the color source.

The French writer continues with the statement that there is, nevertheless, a composition producing a beautiful green flame. This consists of a half ounce of salammoniac and a half ounce of verdigris, which has been dissolved in a glass of vinegar. Bits of paper or of linen, or wood shavings, are soaked in this liquid, and show a green light in burning. Unfortunately, this composition is unable to resist the fire of sulphur and saltpeter, so that it is unavailable for use in the making of fireworks.

Another French authority gives a careful study of the various chemical substances employed in pyrotechny. His conclusions, also, are interesting by their revelations of both his knowledge and his lack of it.

SALTPETER.

Saltpeter is a salt from which may be drawn by analysis a fixed alkali similar to the salt itself, and also a volatile acid, which forms the principal constituent. From this acid are derived those properties which distinguish saltpeter from any other salt. These properties are to crystallize in needles, to excite a sensation of freshness when touched by the tongue, and to decompose from contact with a burning phlogistic, to which its acid unites with a report.

This salt forms on the surface of the ground, in caves, cellars, stables, and other covered places, impregnated with vegetable and animal substances, to which the air has access. Old walls formed of materials that have resisted the action of fire, such as plaster and lime, also contain large quantities of saltpeter.

The air is the principal agent in the formation of the salt. This is not because it contains the salt in itself, but because it develops saltpeter by a sort of fermentation which it excites in certain materials, thus deriving it from the latent principle of niter therein contained. There is an analogy in connection with the fermentation of the juice of grapes. The resulting spirits are in no way derived from the air itself, but the action of the air is absolutely necessary for the development of the spirits from the juice, and no artificial means can secure the result, apart from this operation by the air.

It is possible to increase the quantity of saltpeter produced naturally in the soil, by soaking it with liquids derived from the putrefaction of animal and vegetable substances. It is necessary, however, that the soil should be covered against rain, which would dissolve and carry off the saltpeter as fast as formed; and also that the place should be supplied with free air, in order that the salt may condense and take shape. It is required in addition that the earth should be spaded often, for the sake of a free circulation of the air, which, as it penetrates, develops the nitrous principles. The more the soil is stirred, the more it will produce saltepeter. Where it is left undisturbed, the salt forms only on the surface. A good soil, properly treated, becomes freshly charged with a full quantity of the salt in a period of three years. After the removal of the deposit, it will begin to show traces of the new supply at the end of two months.

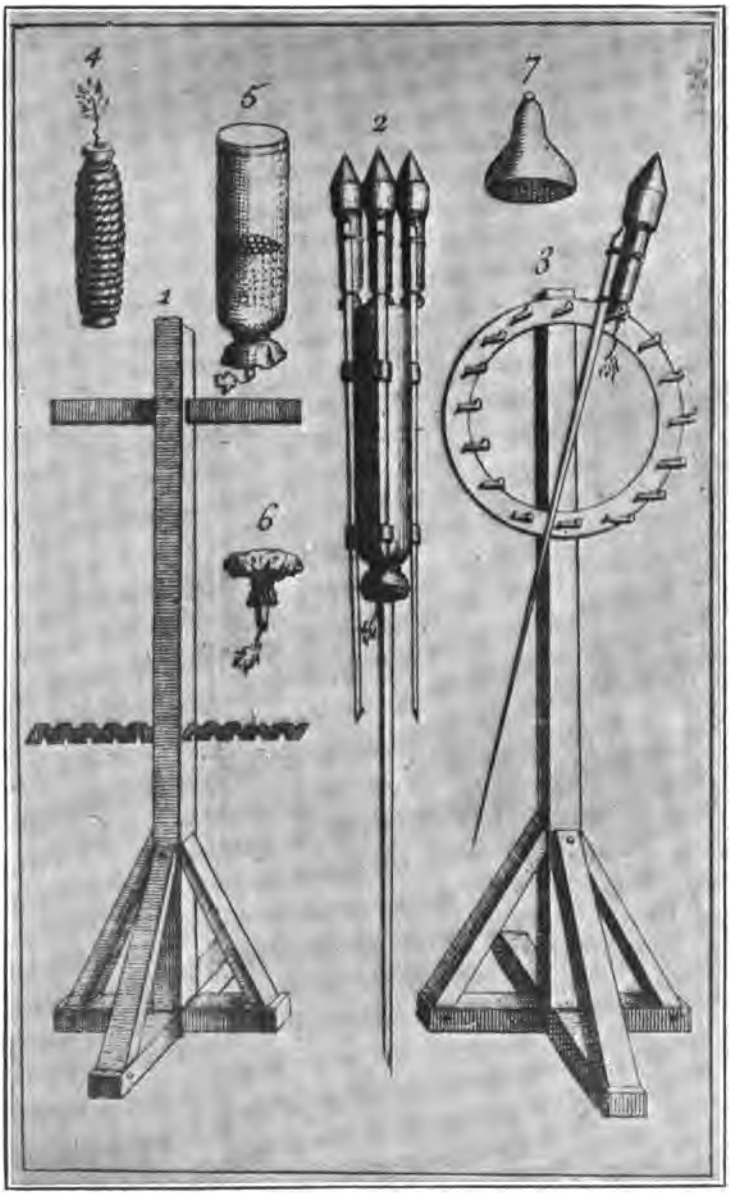
Common salt, whatever its source, has the property of producing saltpeter when it is spread over the ground in a covered place that is exposed to the air. The product will be more abundant if the soil contains vegetable and animal matter. There is, indeed, much evidence to prove that saltpeter and common salt are the same in essence, and that the only difference is in the quantity of the volatile acid contained by each, which is larger in saltpeter, due to the more active fermentation.

Two observations tend to establish the truth of this conjecture. The first is that saltpeter resembles common salt, more or less closely, according to the measure of its acid content. When the acid is entirely removed, the saltpeter is almost identical with common salt. On the other hand, common salt nitrifies in proportion to the fermentation set up by this acid gas. The second observation has to do with the fact that saltpeter is never formed without the presence of common salt, even in earth from which all trace of both salts has been previously removed. It is, therefore, reasonable to believe that common salt is merely an imperfect niter.

Saltpeter is removed from the soil by means of a cold washing in lye. To facilitate the flow of water, and to prevent the earth from clogging the vent of the vat, a piece of barrel bottom is placed within, just in front of the vent, crosswise, and the interval is filled with small stones or fragments of old plaster. Ashes are placed in the vat to almost one-sixth of its height. At the same time as these serve to remove the fats from the saltpeter, they also supply to the acid portion that fixed alkali of which it may be in need. Care must be taken that the quantity of ashes be not too large, since an excess supply would act as an absorbent. When duly arranged, the vat is filled with saltpetrous soil, or plaster, which has been crushed and passed through a screen. When the material is earth, it is essential that it should have been well enriched. It is also necessary that it should be placed in the vat very carefully, since, if compressed to any extent, it will prevent the water from flowing, or cause it to flow with extreme slowness. The earth is covered with straw in order to avoid compression when water is poured in. For the same reason, the water is introduced very gently, until the quantity is sufficient for dissolving the saltpeter. In order to charge the water fully with niter, it is let flow from the first vat into the second, from the second into the third, from the third into the fourth. This series is sufficient to charge the water to the utmost with saltpeter, if the soil be of good quality. The water is drawn out from the fourth vat into a boiler over the fire. While being boiled, the water is carefully skimmed, until it takes on sufficient consistence to congeal when a drop is let fall on a plate. It is then transferred to another vessel, where it is left for a half hour in order to deposit its impurities. Then, before growing cold, it is poured into basins, where the saltpeter forms in crystals as the liquid cools. The water is drained from the basins on the fifth day. It is still impregnated with saltpeter, and to it is given the name mother water. This mother water, together with the skimmings, is poured over other soil that is to be washed in the lye, thus adding to its richness. The saltpeter that results from this series of washings is called the first batch. This batch produces always a certain quantity of common salt, which settles to the bottom of the boiler, and is removed by the skimmer before the water is drawn out.

It should be noted that this common salt, when it is found in a considerable quantity, as in the first batch, is deposited always before the saltpeter. But, when it is found in a small quantity, as in the second and third batches, it is the saltpeter that forms first, while the common salt remains dissolved in the mother water. If it is found that the common salt is constantly formed first, the fact shows that a larger quantity of water is required in order to hold it in solution than is required in order to hold the saltpeter in solution, for the reason that the common salt does not dissolve more readily in boiling water than in cold water, while saltpeter is dissolved twice as quickly by heating the water. Since this is the case where the quantity of common salt is considerable, why should it not be the case when the quantity is small? Can it be that the smaller quantity of common salt, being distributed through a large quantity of salt-

PLATE III.



peter, the particles find themselves too widely separated among those of the saltpeter to unite themselves and thus to crystallize?

The saltpeter is purified by melting it in water and boiling it until a film is formed. A little alum is thrown in while it is thickening, both in the first vat and in the others, and from this comes a thick scum, which is skimmed off. This is the best procedure for removing the fatty materials and for purifying the liquid. Glue is sometimes used instead of alum, but with less satisfactory effect. The water is drained off on the third day and thrown over other earth.

The third batch, or second purification, is made in the same manner. Care should be taken, before using the vats for a new supply of earth, to pass pure water through them in order to complete the removal of any saltpeter. This water, called the washing (lavage), is used for the next washing with lye.

Saltpetrous earth gives commonly a gros[1] of saltpeter to the pound. Earth of the very best sort gives sometimes a gros and one-half.

The vessels used for the purifying of the saltpeter should be deep rather than wide. Much of the water is dissipated in boiling, and this wastage is proportioned to the surface of the water.

Saltpeter should be of the third batch, when it is to be employed in the making of powder, or any of the mixtures used in fireworks. When it is desired for fireworks, it must be ground in a mortar, or crushed on a wooden table with a wooden pestle, and afterward passed through a silk screen. The finer and drier it is, the better its effect.

Saltpeter by itself is not combustible. When it is kindled and burns, this is by reason of the material with which it is brought in contact, as, for example, when it is placed on a plank or on charcoal. Then, the inner air which it contains is developed by the action of the fire, and thus excites the particles of sulphur contained in the material, penetrating the pores so that they burst into flame, carrying with them the particles of saltpeter separated by their action. If, on the contrary, saltpeter is placed on something incombustible, and denuded of its sulphur, as upon a shovel or a tile heated

[1] One-eighth of an ounce.

in the fire, it simply melts without becoming kindled, and is reduced to a liquid form. It takes body again on cooling and forms a salt that is hard and more solid even than the original. The name given to it in such form is rock saltpeter. This is prepared sometimes to be used as a powder for hunting, by melting it over the fire without the addition of water. A little sulphur is thrown over it during the melting in order to remove any fatty material. The sulphur burns along with whatever remains of a fatty sort while the saltpeter itself is not kindled. But it must be noted that this operation can not be repeated without weakening the salt. This is because, when no more fatty material remains, the acid gases have too great facility in escaping.

SULPHUR.

The ordinary sulphur of commerce will serve, and the yellower it is the better. If impurities are contained in it, it should be melted and strained through a cloth. It must not be applied until after it has been reduced to a powder, such as is given by a silk screen of the smallest mesh.

The sulphur adds force to the mixture of saltpeter and charcoal up to a certain point. Beyond this point, however, it weakens the compositions into which it enters, serving only to make them burn more slowly and to give to the fire a color especially clear and luminous. It is to be observed that this augmentation of force from the introduction of sulphur takes place only when a small quantity is used. Examples are afforded by ordinary powder and by the composition with which rockets are loaded. In rockets having a diameter of 12 lines or less the composition will have inferior effectiveness if the sulphur be omitted. On the contrary, the composition will be stronger without sulphur when the rockets exceed 12 lines in diameter. And this force will always continue to increase as the diameter of the rocket increases, being steadfastly superior to that of the composition containing sulphur.

CHARCOAL.

Almost any kind of wood charcoal may be used in pyrotechny, and there is ordinarily little difference in the effects produced by the different sorts. There is, however, some variation in color which is due to the nature of the wood used. Thus, for example, oak gives a flame somewhat redder than that caused by other woods. The artificers prefer for charcoal a wood that is both soft and light, such as willow. It is to be noted that soft woods produce a charcoal that is correspondingly light, and that this wood gives a much larger volume than a harder, heavier wood, even when the weight of the two woods is equal. The proportion of soft wood to hard, as regards the production of charcoal, is about 9 to 6. In France, basswood is commonly preferred.

Wood that is to serve this purpose should be very dry and stripped of its bark. It is burned in the fireplace or elsewhere, and, as embers are formed, they are shut within a vessel. When these are extinguished the attached cinders are removed and placed in a sieve until they become wholly black.

The mixture of charcoal and sulphur, which should give additional force to the saltpeter, is not quite the same for fireworks as for other uses. Less of the mixture is required for fireworks. The crushing for gunpowder separates the charcoal and sulphur into particles smaller than those of the composition used in fireworks, in which there is a large surface to the grains.

For the mixture of the composition to be used in rockets and other fireworks, the greatest force is given by charcoal alone, without sulphur. Six ounces of charcoal from hard wood, or a full 5 ounces from soft wood, are added to 1 pound of saltpeter. This proportion is based on an average size for the grains. Should these be either larger or smaller, a corresponding increase or dimunition of the quantity is required.

Sulphur added to this mixture increases the force up to the quantity of 2 ounces. But this increase will be greater if, when adding the 2 ounces of sulphur, the quantity of hard-wood charcoal is reduced from 5 ounces to 6 ounces. By this mixture of 5 ounces of charcoal from hard wood and 2 ounces of sulphur to the pound of saltpeter, the greatest force is obtained for the powder.

POWDER.

Powder employed for fireworks may be in grain, which is designed to explode the case containing it with a report; or it may be pulverized, in which form it burns while contained within the case. A paste is made by soaking the powder in water, and this is employed for various purposes, particularly for priming and fuses.

The powder is pulverized by crushing it on a table with a wooden pestle, after which it is passed through a silk screen of the finest mesh. That portion which does not pass through the screen is put aside to be used in loading fire pots. This powder, which is only partially pulverized, is best suited for fire pots. The finer sort is so quick in its action that the garniture may be consumed by it.

Certain facts concerning powder have been demonstrated:

First. Charcoal alone, without sulphur, when joined with saltpeter, augments the force of the latter, up to 4 ounces of soft-wood charcoal to a pound of saltpeter. Powder made in this proportion kindles so quickly in the breech of a gun that sulphur would contribute nothing, or at least very little, to the burning strength.

Second. The addition of sulphur to the mixture of saltpeter and charcoal shows an increase of force, up to 1 ounce.

Third. The amount of charcoal having been reduced by a weight equal to that of the sulphur, that is by 1 ounce, the powder has the following composition:

	Pound.	Ounce.
Saltpeter	1	0
Charcoal		3
Sulphur		1

Fourth. Comparison of this powder with various others used in Europe and China shows it to be superior. A common European mixture has 2 ounces, 5 gros of charcoal, and an equal quantity of sulphur, to 1 pound of saltpeter. The Chinese mixture contains 3 ounces of charcoal and 2 ounces of sulphur to a pound of saltpeter.

In making the official tests of the composition, the charcoal was made from hazel wood. This is a favorite wood in Europe, but the Chinese give the preference to willow. It is probable, however, that the quality of the charcoal is less important than the quantity in the mixture.

This powder is manufactured in mills operated by water power, in which crushers sheathed in copper are alternately raised and let fall perpendicularly on the material. The mortars containing the material are hollowed from a beam of hardwood, which has a length equal to that of the set of crushers. The mortars are provided with a base of cast iron, or of hard wood, in order to resist the impact of the battery. Each mortar has a capacity of 20 pounds of material. The saltpeter and sulphur are ground separately under a millstone before being placed in the mortars. It is necessary to screen the sulphur, in order to remove the small stones commonly found in it. The charcoal requires no particular attention.

The period during which the powder should be pounded is dependent on many things, to which careful attention must be given. Among these are the flow of water, which should be more or less rapid according to the circumstances; the weight of the crushers and the distance through which they descend; the actual crushing of the materials, whether more or less complete, and the like. Usually from 12 to 13 hours suffice in large mills for this process of crushing. The powder master must bear in mind the fact that the powder gains in strength from being pounded only up to a certain point, beyond which a continuance of the crushing serves to weaken it.

The composition when first placed in the mortar is moistened with water. The water should be changed at the end of each hour for a three-hour perior of crushing. After this time has elapsed, the repetition of the moistening should be regulated, diminishing each successive quantity of water. An excess of water weakens the powder, but enough is needed to cause adherence of the materials, and even a little more, in order to minimize the risk of explosion.

When the powder has been sufficiently pounded, it is taken into the graining room, where workmen shape it into grains by passing it through a sieve made from tightly stretched skin, pierced with holes of a size to permit passage of the coarsest powder. The worker employs a piece of wood having a diameter of 10 inches and a thickness of 1 inch, which, when placed on top of the material, is moved circularly, so that the weight of the stick forces the material into grains.

The powder is next passed through a screen of horsehair, while the grain is still moist and soft. The properly shaped powder remains on the screen, while the finer particles pass through, and are afterward taken again to the mortars for further pounding. It should be observed, however, that this second crushing must not be continued for a longer period than two hours, and that the powder must be moistened less than is necessary for new material.

After screening, the powder is dried in the air on stretched canvas, or it may be simply spread out on tables. It should be protected from sunlight, which causes alterations in its character. The powder dried in a darkened place is always stronger.

After drying, the powder is passed successively through various screens, in order to separate the different sizes of grains. It is finally inclosed in canvas bags, which are packed in barrels. For fowling pieces, the powder should be of finest grain.

Usually it is the practice to smooth the grains, although this adds nothing to the effectiveness of the powder. To this end, the powder is inclosed in a cask, which is traversed by the extended axle of a wheel turned by water power. The movement of the cask in rotating causes a sufficient smoothing of the grains. They are then again screened, in order to remove the finest particles.

This manner of powder making, which is the only one used in France, gives a grain that is angular and of irregular shape. In Switzerland, where the best powder in Europe is made, the grain is perfectly round. This spherical form has the advantage of creating between the grains interstices of a regular sort, which are larger than those in other powders. The effect is to render the burning much swifter, and the resultant energy is greater. Nevertheless, it is believed that the excellence of the Swiss powder is due chiefly, not to the method of manufacture, but to the superior quality of the saltpeter used, which is obtained from stables on the mountains. Two methods of forming the grains are employed in Switzerland, which are equally successful. In the large factories, the work is done by a machine, while in the smaller places it is done by hand.

Plate XII represents the machine, of which the explanation is as follows:

The first figure is a bobbin of wood, which traverses the axis, A, on which it turns. The second figure is the same bobbin covered with a cloth of fustian. This cloth is sewn in the form of a sack, with the ends closed by the bobbin to which they are nailed. B is the opening of the sack, by which it is filled with powder. The diameter of the sack should be a full third more than that of the bobbin.

The third figure represents the bobbin filled with powder, of which the part B, closing it, is folded over and inward. The powder in its irregular form should be placed within the sack immediately after the graining has been completed, while it is still moist.

The fourth figure represents the same bobbin mounted on its axis and ready to turn on the round table, which carries it, when the shaft, C, of the machine is placed in motion.

The table is furnished with rays at regular intervals. These are formed from bars of wood, having a rounded upper surface, which are nailed firmly in place. The rays, by their resistance to the movement of the bobbin, compress the powder inclosed within the sack, and transmit to the grains a shaking and rotary movement, which rounds them.

The shaft of the machine is capable of acting on three bobbins, each containing in its sack 100 pounds of powder. The rate of movement should be such that a man may follow the bobbins at an ordinary walk. A half-hour is sufficient time in which to effect a perfect rounding of the grains. Afterward the powder is once more screened to get rid of the fine particles, and also to separate the grains of different sizes.

The procedure when the operation is by hand is almost the same. It differs only in the fact that it is not necessary to have any preliminary graining of the powder. The lump of material as taken from the mortar is screened to get rid of the dust. A small bag of canvas is then filled with the powder. The bag is tied close to the top of the contents, but care must be taken to avoid compression. The bag is now rolled by the workman with considerable force on the surface of a solid table. In this operation, he is careful to keep the bag always in front of him, though never rolling it steadily in any one direction. If the bag grows flaccid, by the compression of its contents under the rolling process, it becomes necessary from time to time to lower the position of the ligature, so as to hold the powder in a solid mass. This is essential in order to secure due effect from the rolling. The bag should hold a weight of not more than 15 pounds of the material, nor less than 3 pounds. One hour of rolling serves fully for the formation of perfect roundness of grains.

IRON.

Iron filings, or, still better, those of steel since they contain more sulphur, give a fire that is very brilliant for the purposes of pyrotechny. As a rule, these are used as required for all varieties of fireworks. The metal to be employed should be new, since that which is rusted either fails to give sufficient brilliancy, or makes no display of sparks whatever. It should be noted that the filings possess no lasting qualities. Their value usually endures for no more than six days. The saltpeter attacks and destroys the metal, thus causing it to lose its brilliancy day by day.

The use of such filings in pyrotechny is due to the researches of Father d' Incarville, a Jesuit, who conducted a mission in Pekin. While stationed there he contrived to gather full knowledge concerning the methods by which through countless years the Chinese have produced brilliant fires, especially employed in the representation of flowers.

This preparation, carefully kept secret until the present time, is gained by reducing the iron into tiny fragments, so that the fire of the combustible composition into which they enter shall be sufficient to cause fusion. Each particle of the metal when it is fused, even though it may be no larger than a poppy seed, gives a large "flower," 12 or 15 lines in size, from a fire of utmost brilliancy, and this fire assumes various forms such as may be desired, following both the quality of the metal itself and also the shape and bulk of the grains, according as these may be round, flat, oblong, triangular, and the like. Each gives to its particular flower a different formation. This material, which Father d' Incarville names iron sand, is made out of old iron pots, or such other articles of the metal as are capable of being broken and reduced into tiny fragments on an anvil. Use may be made also of pieces too small in size to be easily broken up, for the operation may be facilitated by heating the metal, and then plunging it into a bucket of cold water. This process renders it more readily breakable. Moreover, the effect is improved when the hammer and anvil also are of iron. It is customary to spread cloths on the ground about the anvil, in order that none of the sand shall be lost. Care should be taken that no dirt be permitted to mingle with the particles of metal. When a sufficient quantity of sand has been thus secured, it is first passed through a very fine screen, in order to get rid of the useless dust. Afterward, it is passed through screens of various sizes, in order to separate it into grades as required, from those that are finest up to those as large as a radish seed.

The separate sorts are placed each by itself, to be kept in a very dry place, so that they shall not rust. It should be noted that the plunging of the hot metal into the water not only increases the facility of its reduction into the sand form, but also causes a structural or chemical alteration. There is an appreciable difference between the sand from metal thus tempered and that from other metal. The tempered sort produces flowers both larger and more brilliant. In addition, this sand will remain for a much longer time without suffering deterioration.

Since this material has no effect except when it is fused, it is evident that a greater amount of heat is required in order to make the coarser sand effective. The size of the case in making any sort of fireworks must be proportioned to meet this need of fusing the metal, and the character and amount of the loading charge also must be similarly proportioned. Such proportions must be increased very considerably to insure a due effect with the coarser forms of the iron sand, since the combustion must continue for a much longer time.

It is easily possible to observe the effect of the iron sand without troubling to prepare the firework itself. It is only necessary to throw a pinch of the sand into the flame of a candle. It becomes fused while passing through the flame, and displays its "flower forms." Ordinary filings may be tested in the same manner. Since these contain less sulphur than the sand, they merely give out sparks, similar to those thrown off by steel striking against a flint.

A firework containing this sand retains its effectiveness for about a week when the particles are small, and for about a fortnight when they are of the large size. It is to be hoped that there may yet be discovered some means of protecting the iron sand from the chemical reaction of the saltpeter, which destroys it.

PASTEBOARD.

The pasteboard used for fireworks is made up from several sheets of good grade paper for the inner portion, and white for the outer, fastened together with flour paste. It should be sufficiently thin to be rolled easily in forming the case. Three thicknesses of this suffice for small rockets, up to and comprising those of 18 lines in diameter. Five sheets are necessary for larger rockets, and eight sheets for the pots à aigrettes. Large brushes of hog's bristles are used in pasting. Two hundred sheets are thus prepared, and then placed in a press between two smooth pieces of board. If a press be lacking, the boards may be held down by heavy weights. After the pasteboard sheets have remained in the press for six hours they are taken off to dry. Each sheet is pierced in two of the corners, and they are then hung on a line equipped with brass hooks, which are caught into the holes. After thoroughly drying, the sheets are returned to the press, in order to correct any warping.

The paste used in constructing the sheets, and also in the subsequent molding, is made from wheat flour. The flour is first thoroughly soaked in water, after which it is placed on the fire, and boiled until it loses all trace of the flour smell. It is finally passed through a screen of horsehair, in which it is worked in order to reduce the lumps, and to remove anything that might cause unevenness on the surface of the pasteboard.

Father d'Incarville brought from China precise information as to the method of making paste. The Chinese, for the sake of obviating the danger of accidents by fire, introduced both clay and common salt into the paste used for making cases. The effect of these constituents is to lessen the possibility of the case taking fire. Experiments along this line have been made in France, and the value of the method has been proved. But it has been found that alum is even better suited to the purpose than is common salt, since it does not attract humidity, as salt does, and it is equally incombustible. It is, therefore, recommended that a handful of powdered alum should be added to a pound of flour before boiling. When the paste is taken off the fire there should be mixed with it an almost equal quantity of clay, reduced to the same consistency by the use of water.

THE FUSE.

The fuse is used for setting off rockets and other varieties of fireworks, and also to communicate fire from one piece to another.

The material of the fuse is cotton thread. The size may be increased to any desired extent by repeated doubling of the thread. It should be soaked for a number of hours in vinegar, or, better still, in brandy. After it has absorbed sufficient of the liquid, powder is spread over it, and the cotton is worked, on the plate where it has been soaking, until it is thoroughly penetrated and completely covered by the powder paste. It is then taken from the plate and passed lightly through the fingers, in order to distribute the paste equally and to soften it. It is finally placed to dry in a shaded place.

When dry, the fuse is cut into pieces two and one-half feet long, after which it is wrapped up or boxed, and stored in a dry place.

The fuse used for communicating fire varies from one line in diameter to one and one-half lines, according to the size of the firework.

THE PRIMING.

Grain powder is used for the priming. After it has been moistened with a little water, it is ground on a table with a wooden pestle, until it is reduced to a fine paste. It serves as a mastic to fasten and retain the fuse in the mouth of the rocket and elsewhere as required.

THE ESSENTIAL TOOLS.

The tools necessary are the following:

A table of hard-wood, and a mallet, also of hard-wood, for pounding. But a wooden hammer, such as is used in charging rockets, may be employed in default of a mallet.

Some skimmers of various sizes, for picking up and for mixing the different compositions. These should be made from sheets of brass, very thin, with a length of 4 or 5 inches and a width of about 3 inches.

A hare's foot, to be used in connection with the skimmers for picking up compositions.

A table, for the molding.

Three or four brushes, of various sizes, made of hog's bristles, for pasting.

Some larger brushes of hog's bristles, for use with glue and for moistening with water.

A hand saw, for trimming the large cases.

A large knife, for trimming small cases and for cutting pasteboard.

Scissors, both big and small, for trimming pots and small cases.

A perfumer's drum, equipped with screens as follows:

Three screens of silk gauze:

The first of a very close tissue which is used to separate the finest particles of powder, and also the iron dust, when making sand after the Chinese method.

The second a little more open, for passing sulphur, saltpeter, and iron of the first order.

The third of still larger mesh, for passing sand of the second order.

Three screens of horsehair:

The first of a close tissue, for passing charcoal, and for sand of the third order. A second less close, for passing coarser charcoal, and for sand of the fourth order.

A pair of balances, of a size to hold 2 pounds of composition.

Weights running from a half gros up to 2 pounds.

Some boxes closing with a sliding lid, of the sort used by grocers, for holding the screened materials and the various compositions.

Two spoons of wood, or of tin, for taking materials out of their receptacles.

Three small kegs, in which to keep separately saltpeter, sulphur, and charcoal, after these have been crushed.

A cask for powder, containing 10 to 12 pounds.

Rocket molds of different sizes, together with bases for these, on which are mounted spindles, or piercers.

A rolling stick.

Three wooden tubes.

A loading stick.

A mallet.

A loading spoon, which contains the measure of each charge of the composition.

A mold for forming the pot.

Bases with spindles, for charging serpents and jets; and also bases with spindles for loading table rockets and other fireworks.

A rolling stick.

A loading stick.

Small mallet, for making fire lances.

Two molds of different sizes, for forming stars.

Three awls, for piercing rockets.

A longer awl, for piercing fire pots; and one much shorter, for piercing marrons and saucissons.

Gimlets of different sizes, for piercing table rockets and other pieces.

A compass and square, for measuring diameters and lengths.

A large screw staple, which is placed in a wooden post to assist in the process of choking cases.

A plane, for reducing the size of rocket sticks when they are too heavy.

Flat pincers.

A tin pot, for heating glue in the boiler.

A cast-iron anvil and two sledges of the same material, for making iron sand.

An assortment of strings of different sizes, for choking and tying the various pieces.

An assortment of pasteboard, and other paper of various qualities.

A plane table, for tracing the dimensions of cubical cases.

A sack, for holding rockets.

A metal mortar and two pestles, one of metal, the other of wood.

A locksmith's vise.

A wooden grater, and a number of files.

The tools last mentioned are for no specific use in the making of fireworks, but they are handy oftentimes, and it would be difficult to do without them.

CHAPTER III.

THE MAKING OF ROCKETS.

The French official experiments in the manufacture of rockets were carried on with great care, and the results of the work have been preserved in records of the ordnance department, from which the following specific accounts were gathered concerning all essential details.

MOLDS.

The mold serves to sustain the case in position firmly while it is being loaded. Its exterior is so fashioned usually as to give it the appearance of a miniature cannon. It is hollow throughout its length, and this cavity, into which the case fits, should be perfectly round and very smooth. The mold is commonly made of hard wood. (Pl. II, fig. 1.)

The height of the mold should diminish in proportion as the interior diameter of the mold increases. The reason for this diminution is that, since the force of the burning material in a rocket does not increase in the same ratio as the diameter of the rocket, the gases developed by combustion would be unable to raise a rocket of large size, with its length proportioned to the diameter in the ratio employed for small rockets.

The mold is supported by a cylindrical base of the same material, which is called the culot. (Pl. II, fig. 2.)

The height of the culot, or base, is equal to the interior diameter of the mold, and its width is one diameter and one-quarter.

The mold carries a piercer, or spindle, of iron running upward from the middle. This spindle, although in a single piece, has four distinct parts: The first part is called the tail of the piercer. This is wholly below the surface of the cylindrical base, which it enters sufficiently to permit of being solidly fastened in position. The second part of the piercer has a cylindrical form, with a diameter that of the interior of the mold and a height equal to its diameter. The third part of the spindle is the half-ball. This is immediately below the cylinder. It has a diameter two-thirds the interior diameter of the mold and a height one-half the same diameter. The half-ball fits snugly in the throat of the case during the loading, thus serving to maintain the pasteboard in shape. The fourth part is the piercer proper. The purpose of this is to maintain an empty space within the interior of the rocket. The hole thus contrived is called the soul of the rocket, because it is essential to that display of energy which causes the upward flight. The vacant space offers to the fire a larger surface of inflammable material. The gases thus formed exert their force on the surrounding walls and also against the air in the direction of the orifice. The resistance of air is such that the reaction of the gases within the chamber drives the rocket forward.

The difference between the height of the mold and the length of the piercer, when the mold is in position on the culot, gives the height to which the charge reaches. Experience has taught that it becomes necessary to diminish the height of the mold, while increasing the length of the piercer proportionately, as the rockets are given a larger size.

If this proportion were not modified for the various sizes of rockets, the results would be found wholly unsatisfactory. If, for example, the height of the charge should be measured in each case by one and one-quarter of the diameter of the mold, the result would be that in small rockets the charge would be consumed too quickly, so that the garniture would be thrown out long before the completion of the flight, while in the case of large rockets the charge would be lighter in effect, so that the garniture would ouly be thrown out some time after the fall back to earth was begun.

Little rockets, having an exterior diameter of 5 lines or less, require no piercing in order to ascend. These should be loaded within a mold resting on a base to which no spindle is attached. Such rockets, with a stick duly fastened in place, ascend properly. If pierced, the flight upward is so rapid that it is almost impossiple to perceive the effect.

CASES.

Cases are made by rolling pasteboard over a round piece of wood (baguette), which is called the rolling stick. This should be very smooth and without handles. Its diameter should be two-thirds that of the mold's interior. The one-third less is occupied by the case, of which the thickness is a sixth of the same diameter, or a quarter that of the stick. (Frontispiece, figs. 1 and 2.)

The pasteboard should be pasted throughout, except for the first turn about the stick. It is necessary to use care in order that the paste should not wet the stick. Where it has been wet, soap should be used to prevent adherence. The last turn of the pasteboard should be dipped in water, before pasting, in order to take away its resistance, which would tend to unroll the case after it had been shaped.

Cases for lances and for communicating fire are made of paper. For this purpose, the stick is placed on the sheet at about one-third of its width. This one-third is turned back and carefully adjusted in that position. One turn is then made about the stick without paste. Afterward, the remainder of the paper is rolled, both the double portion folded on that third of the sheet which has been turned back, and the single portion of the sheet. These cases are called fire carriers, or port fires, since they are commonly employed for communicating fire from one firework to another by means of a fuse, or match, inclosed within them.

The cases for serpents and for various small fireworks are made with an exterior diameter of from 4 to 6 lines, and the paper for these is afforded by ordinary playing cards. It is necessary first to dip the cards in water, and then to use them while they are still only half dry, since thus they are more flexible and more easily rolled. In the use of these, one is first rolled on a suitably sized stick, and this is covered by a second, after which the case is completed by two turns of gray paper, the second turn being pasted. (Pl. II, figs. 18 and 19.)

CHOKING.

The choking should be done before the case becomes entirely dry. As a preliminary to the process, a cord of size proportioned to that of the firework is attached by one end to a staple driven into a post, or into the wall, while the other end is fastened to the artificer's belt, or to a stick over which he straddles, placing it behind him across the buttocks in such a manner that by leaning against it the cord is tightened, and he is thus enabled to use the weight of his body in the choking. With the cord tautly stretched, the throat of the case is placed against it, and the worker, with that part of the string between him and the case, makes two loops around the throat, about one-half an exterior diameter from the extremity of the case. While holding the case with his left hand, a small stick of proportionate size is thrust within the throat by the right hand, to preserve the opening. The cord is then tightened as the artificer throws his weight backward. At the same time, he revolves the case, in order to distribute the choking evenly about the throat, until there remains only a small hole, barely sufficient in size to permit the entrance of the piercer.

It is necessary to soap the string to prevent the case, which is still moist, from adhering and tearing.

After a number of cases have been choked, they should be tied, lest the choking loosen. This is effected by passing around the choke three nooses of thread and tightening each loop in a knot, called the knot of the artificer. (Pl. II, fig. 21.)

COMPOSITION FOR ROCKETS.

Rockets of 10 or 11 lines are loaded with a composition containing 4 ounces of charcoal to a pound of powder. Rockets of from 7 to 9 lines are loaded with a composition having only 3 ounces of charcoal to a pound of powder, while rockets of 6 lines, or less, need only 2 ounces of charcoal to a pound of powder.

After the materials have been weighed, they are put through the coarsest horsehair screen three times, in order to mix them thoroughly. This is the only operation required in making the composition.

A composition that is too lively causes the rocket to burst, while if the charge is too light, or if the end is not carefully closed, the composition may be consumed without causing the rocket to ascend. Such a rocket is described as "breaking down." By this term the artificer describes the effect when the doubling over of the end of the case is not done with sufficient firmness. The result is a failure of solid resistance against the rush of gases.

The extreme of dryness is required for the rocket composition, both for the purposes of preservation and for effectiveness in discharging. If it becomes damp, the humidity causes the forming of spaces that admit too much fire, from which the bursting of the rocket is likely to result.

An exception should be noted in reference to Chinese fire. It is necessary to moisten the iron sand somewhat in order to secure the adherence of the sulphur to it. Details concerning the preparation of this composition are given under the heading of "Jets."

LOADING ROCKETS.

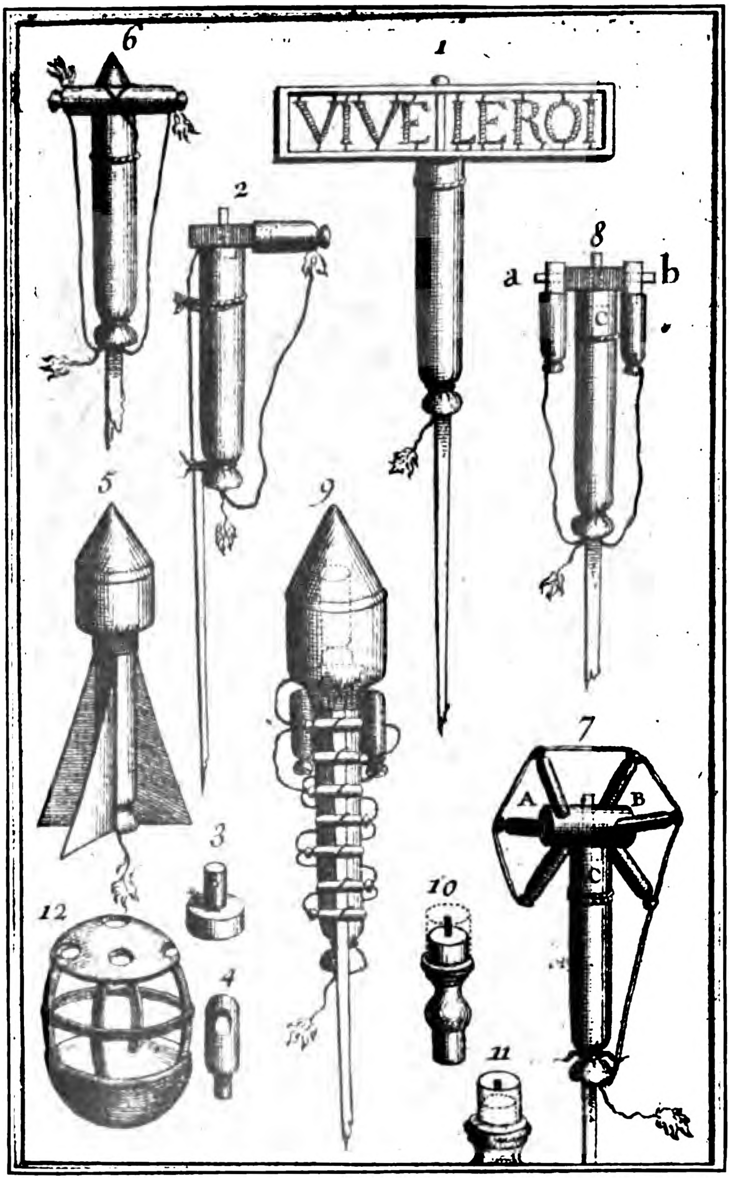
The first requirement is a loading spoon, to which the artificer gives the name corné. The diameter of this is equal to the interior diameter of the case. It should contain so much of the composition as is necessary for filling the case to a height of one-half the exterior diameter of the rocket. (Pl. II, fig. 9.)

Three hollowed sticks are necessary for loading the smaller rockets and four for the larger rockets. The hollowed-out space should be such for the first stick as to receive the whole length of the piercer; for the second, to receive two-thirds the length of the piercer; for the third, one-third the length of the piercer. Care must be taken that the dimensions of the cavity should be such as not to force the case while it is being loaded. In order that these sticks may be easily withdrawn, they are made a little smaller than the loading stick. (Pl. II, figs. 4, 5, and 6.)

A shorter stick of the same diameter as the others used in loading, but with no cavity, is called the massif. This is employed for loading that portion of the composition which extends above the point of the piercer. This part of the charge also is called the massif, by reason of its entire solidity. (Pl. II, fig. 7.)

A special stick is used for folding over the pasteboard of the case above the top of the charge. This stick has a diameter two-thirds and one-sixth that of the mold. (Pl. II, fig. 8.)

PLATE IV.



A mallet of hard wood is advisable, but basswood will serve. The diameter of the head should be two and three-quarter times that of the mold, and its length three and a third times the same diameter; the handle five diameters, excluding the part that enters within the head. (Pl. II, fig. 10.)

When the case has been trimmed and reduced to the length of the mold, the piercer is rubbed with soap in order that it may penetrate more readily through the aperture left after the choking. This opening should be somewhat smaller than the largest part of the piercer, so that when the piercer is thrust through, the orifice will be shaped to roundness.

The exterior space beyond the point of choking is filled with string to render support to the case, which might otherwise be so weakened by the blows of the mallet as to cause the subsequent bursting of the rocket in this place. It is to be noted that, in spite of this precaution, the like disaster may be occasioned if the composition is compressed too forcibly. (Pl. II, fig. 11.)

The case is now placed in position over the piercer, and covered by the mold. The first loading stick is thrust down in the case, and given a dozen blows of the mallet, to fit it firmly in position, and also to smooth the folds over the choke. If these were allowed to remain uneven, they might cause spaces into which the air would enter, and so bring about the bursting of the rocket. (Pl. II, fig. 4.)

When the first loading stick has been withdrawn, a spoonful of the composition is poured in. The loading stick is then introduced gently into the case. It is pressed firmly against the composition, and light taps of the mallet compress the charge sufficiently. When the rocket is of 18 lines, the number of strokes is 40.

The operations with the second loading stick and with the third are made in a similar manner. The only variation is that, at each change of stick, the number of mallet blows is reduced by 5. The strokes on the massif, or solid part of the charge, should number 20. The reason for this diminution is to be found in the increase in amount of the material, in proportion to the height as the measure of the piercer lessens. A smaller surface is thus presented for burning, and there is, therefore, less need of compression.

When the rocket exceeds 18 lines in diameter, the number of mallet blows is increased in proportion to the size, up to 50 for the first loading stick. Afterward, from this number, the blows are diminished regularly by 5 for each stage, down to 25 for the shortest stick.

A rocket should be loaded with from 12 to 15 separate charges. Of these, 9 or 10, or more, serve for covering the piercer, and the other 2 or 3 for the massif.

When the massif has reached the level of the mold, a wadding of torn paper is placed upon it, to which are given a dozen blows. The part of the case left empty above the massif is folded over upon the wadding to half the thickness of the stick, and 20 blows are given to make it hold its position. Two or three holes are driven through the folds by a stop-awl under the blows of the mallet. The stop prevents too great penetration. It suffices if the hole reach to the composition. Extension too far would weaken the massif, and cause it to communicate its fire too quickly to the load. These holes are, of course, designed for the purpose of communicating fire from the massif to the load.

The rocket is next taken from the piercer. The string that retains the choke is removed, and that part of the case which exceeds the doubled-over pasteboard is trimmed off.

Unless the rocket is to be used immediately, it is further necessary to paste a thickness of paper over each end, in order to protect it from the influence of the air or possible fire. This precaution taken, the rocket will remain in good condition for a long time, if the materials used in the composition were thoroughly dry, and if the storage place also is wholly free from humidity.

POTS, CAPS, AND GARNITURES.

The pot should be made of the same pasteboard as is the rocket. This is shaped on a wooden cylinder, used as a mold. The pot has a thickness of two or three turns of pasteboard according to the size of the rocket, whether large or small. (Pl. II, fig. 13.)

The mold of wood for shaping the board is all of one piece, but is made from two cylindrical parts of different diameters: One, on which the pot itself is rolled, has a diameter one and three-quarters times that of the rocket's exterior diameter and a length of three of these diameters. The diameter of the other cylindrical part of the mold, on which the pot is choked, is three-quarters and one-eighth of the rocket's exterior, and its length two of the same diameters.

It should be noted that with rockets of 12 lines the height of the pot should be the same as for ordinary serpents made from playing cards, so that the rocket can carry these as its garniture. As the packets of stars used for garniture have less height, the pot is accordingly reduced when they are to be used.

After the pot has been choked, that end is trimmed, leaving only sufficient length beyond the choke to permit easy tying to the rocket. This part is soaked in water to render it flexible, and after the ligature has been made, a band of blotting paper[1] is pasted over it, which serves both to conceal the cord, and to prevent its loosening. (Pl. II, fig. 12.)

In garnishing the rocket, a pinch of powder is first dropped into the pot. By tapping against the case, the powder is made to enter into the holes through which fire is to be communicated to the load. A ladleful of the rocket composition is commonly called the charge. On top of it are deposited the serpents or stars that are to be cast forth. Care must be taken that these be no heavier than the body of the rocket. A rocket of 4-ounces weight must not weigh more than 8 ounces after it has been garnished, and the proportion is the same as to other rockets, whether heavier or lighter. A rocket can not mount beyond a very moderate height if overloaded, but quickly returns to the earth in a curve.

The artificers describe such a firework as arched (arqué), by reason of the line followed in its descent.

Waddings of torn paper are placed in the interstices about the serpent or the packet of stars, in order to prevent their shaking about, and the pot is finally closed with a round of

[1] The paper thus named was of a firmer and tougher tissue than the blotting paper of to-day.

paper pasted over it. This paper should be snipped around the edges to prevent unevenness where it is bent over the case. Pains should be taken also to dip the packets of stars into powder before placing them in the pot, in order that they may catch fire more quickly.

The cap is the name given to the end piece of the rocket, which has the form of a cone. It is made from a single thickness of pasteboard.

To secure the proper size, the workman traces on the pasteboard with the compass a circle of which the diameter should be one and one-third that of the pot. This round of pasteboard, when cut into halves, gives the material for forming two caps. One of these is first moistened, to take out the stiffness, and then, by turning, it is made to assume the shape of a cone with the overlapping edges pasted. (Pl. II, fig. 15.)

When the cap is dry, the edge of the circumference is cut at intervals with the scissors, in order that this part may be more readily joined over the pot to which it is to be pasted. This edge is also moistened to reduce its stiffness before pasting. The cap should be placed upright over the pot. A band of paper is pasted over the place of junction, partly to conceal it, and partly to prevent any loosening during the drying process. This band of paper should be moistened with paste on both sides. Indeed, a similar precaution should be observed in connection with any paper employed for covering the points of junction in rockets or port fires. By this means, the paper is made easier for manipulation, and the folds are less conspicuous.

The match is next attached to the rocket. A piece of fuse, folded double and of suitable length, is made to enter the hole left by the piercer, to a height, within the air chamber, of one exterior diameter. The fuse is made fast in the throat of the rocket by an application of priming paste. Care must be taken to use no more of the priming than is necessary for holding the fuse firmly. Too large a quantity would give an excess of fire, which might cause the bursting of the rocket.

A round of paper is now pasted over the throat of the rocket. This final process is called by the artificers the bonneting. The paper protection is designed to prevent the communication of fire from one rocket to another at the time of discharge. It also tends to protect the composition with which the rocket is loaded from the attacks of humidity.

Very frequently, pots are not placed on the smallest rockets. Instead, a square of gray paper is rolled and pasted on the top of the rocket, so that it projects to the height necessary for containing the garniture. The charge and garniture having been placed within this paper, the upper end is folded down over the contents, and pasted. The load of such rockets is so light that the flight is correspondingly high, but the display from the garniture is correspondingly less impressive.

STICKS.

The stick attached to a rocket serves to maintain it upright during flight. It acts as a counterbalance against the weight of the rocket. Thus, the action of the gases, from combustion within the air chamber of the rocket, is downward, and the resultant flight of the rocket is upward. (Pl. II, fig. 10.)

The lightest wood is best for these sticks. Those for rockets of 18 lines, or over, should be made of sawn pine. For smaller rockets, walnut, willow, and elm give excellent sticks.

The length of the stick should be at least eight times that of the rocket mold. The thickness in a square at one of the ends should be half the exterior diameter of the rocket. From that end which is attached to the rocket, the stick should diminish gradually in size to the other extremity, with its end one-eighth of the rocket's exterior diameter. (Pl. II, fig. 3.)

The greater the length of the stick, the more nearly vertical the ascent of the rocket. The stick can never be too long for this purpose, since, having its head only the size given above, it balances at a certain distance from the body of the rocket when this is attached. The distance is regulated by the exterior diameter of the rocket. Two and one-half times the interior diameter of the rocket is the distance of the stick's balancing point from the body of the rocket for small rockets, up to and including those of twelve lines.

For the rockets of larger size, up to and including those of 2 inches, the distance of the stick's balancing point from the body of the rocket is two diameters. For those still larger, the distance is one and one-half diameters. Following these proportions, the stick of a 1-inch rocket should balance at 2½-inches distance from the throat of the rocket. The equilibrium is tested by balancing the stick on a knife blade. If the stick is too light, it must be changed. When the error is slight, it may be rectified by fastening the rocket an inch or two higher on the stick. This gives greater length to the stick and consequently greater weight. If the stick is too heavy, it must be taken from the rocket, and its thickness reduced. A groove is made in the stick at the point where the rocket is to be attached, in order to insure stability for the fastening. The large end of the stick should be beveled, both for the sake of a neat appearance and in order that it may offer less resistance to the air.

The rocket is placed in the groove, but with the ligature of the pot somewhat beyond the end of the stick. The rocket is secured in its place by cords, which catch in notches cut on the stick. The first cord passes around the stick and rocket a little below the beveled end of the stick; the second is attached at the point where the rocket is choked. These cords are tied with the knot of the artificer.

In England, some have entertained the idea of escaping accidents caused from the fall of large sticks by the use of substitutes for such sticks made from saucissons, of which the cases are playing cards. These saucissons are arranged in such a manner that one projects from another. The series is glued together in a straight line, and the ends are covered with bands of paper pasted on. Thus, the saucissons form one long, solid piece. Between each two of the saucissons, a small quantity of powder is contained, to set off the charge. A fuse which takes its fire from the rocket pot and communicates with all the saucissons, each of them being supplied with its individual fuse, gives them fire at the instant when the rocket casts out its garniture. The saucissons thus fulfill all the purposes of a stick for the rocket, and then finally are divided up into individual parts, which as they are consumed increase the beauty of the spectacle.

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RACKS.

The rocket rack is merely a post set in the ground, or sustained in position by means of a base having the form of a cross. It is traversed at the top by a bar of iron, on which the rockets are placed one after another for firing. (Pl. III, figs. 1 and 3.)

Such racks have several forms, but the simplest is also the most convenient, since it may be transported easily. This is simply a pole, equipped at its lower end with an iron point, and at the other with a long screw on which to hang the rocket for firing.

It is necessary to unbonnet the rocket, by breaking the paper cover over the throat with a stroke of the thumb-nail after the rocket has been placed in position on the rack. For kindling, a wick is used, which is held by an iron device on the end of a light stick about 5 feet in length. A ring attachment serves to lengthen or shorten the projection of the wick.

CHAPTER IV.

SERPENTS AND OTHER GARNITURES.

Serpents for garnishing rockets and firepots have cases made from playing cards. Those formed from one card have 3 lines of interior diameter; from two cards, 3½ lines; from three cards, 4 lines. Those of large diameter should be made of pasteboard. (Pl. II, figs. 18 and 19.)

The serpents having 3 lines of diameter are loaded to a height a little short of the rim of the case, as follows:

The cases are first choked and tied, and are then arranged upright in any convenient vessel that will contain the required number.

A small wadding of paper is packed down into each, in order to close the vent in the choke, and a measure of powder is then poured in, which should fill the case half full. The composition is next added above the powder, and the surface of this is brushed even with the rim of the case. When all the cases have been thus filled, a loading stick of the proper size is used, and the contents are tamped down by eight blows of the mallet to each case. The operation is repeated until all are solidly filled to a height of almost 4 lines. The remaining space is reserved for choking. The cases are next taken from the containing vessel and choked. The throat is then opened by introducing the point of that base which fits them. A piece of fuse is introduced into the hole and fastened with priming paste.

Serpents of two cards, and of three, are charged on a base carrying a point, of which the length is one and one-quarter times the interior diameter of the case, and of which the thickness is one-third of the same diameter. In loading these, ten strokes are given to each successive charge. The artificer begins by loading them half full with the composition. Then grain powder is introduced, with a wadding on top of it. They are then choked and primed in the fashion already described for the smaller size. When it is desired that the serpents be exceptionally lively in the air, they are charged on a piercer having a height three and one-half times the interior diameter of the case, and having a thickness one-third of the same diameter. These are used especially for the pots à aigrettes. (Pl. II, figs. 18, 19, and 20.)

For a rain of fire, small pieces of paper are molded on an iron rod 2½ lines in diameter. These have a length of 2½ inches, and they are not choked. It suffices, after the load has been placed, to twist the end of the case, and then to tap it lightly with a mallet in order to fix the folds in position. The cases are then filled by being dipped into the composition. They receive as much of it as is necessary for each charge in succession, and after they have been fully charged they are primed without choking. The effect of this garniture is to fill the air with undulating fires.

Marrons are made of grain powder inclosed in a pasteboard case of cubical form, which is covered with one or two windings of string held firmly by glue. A hole is pierced in one of the corners, wherein a fuse enters, held fast by priming paste. (Pl. II, fig. 22.)

In order to cut the pasteboard exactly, which should form a perfect cube from a single piece, the worker draws his design by using a plane-table. This design is divided into 15 squares, 5 on one side and 3 on the other. This parallelogram is separated by scissors into 5 squares, each of which is folded to form a cube. (Pl. VII, fig. 1.)

The size of the marrons is proportioned to that of the pasteboard from which the cases are formed and that of the string used to cover them. Sparkling marrons differ from the others only in being covered with star paste and then rolled in powder, which serves for priming. Two bands of paper fastened over them in the form of a cross retain this paste in position, and prevent it from peeling off when dry.

Saucissons do not differ from marrons, except in shape. Their effect is precisely the same. They have round cases, with a height four times that of their exterior diameter. After choking, a rather large wadding of paper is rammed within. They are then charged with grain powder, over which a similar wadding is placed. This wadding, however, is compressed under the pressure of the hand, care being taken to avoid crushing the powder. The upper end is then choked, and any excess length of the case beyond the two chokings is trimmed off. The cases are now covered with two windings of string, made fast with glue, as for the marrons. They are pierced at one end, and primed at that point.

These are used often to terminate with a report certain fireworks, such as lances and others, which, owing to their small volume and the thinness of their cases, can not carry sufficient powder or make sufficient resistance to explode noisily. (Pl. III, fig. 4.)

Stars are made from a paste composed of:

Saltpeter	1 pound.
Sulphur	8 ounces.
Powder	4 ounces.

These materials, after they have been passed three times through a screen, in order to mix them thoroughly, are moistened with water. When they have reached the consistence of a rather thick paste, they are covered with a tin mold, which shapes a round, flat pastille, pierced in the center. This hole is formed by a small iron point running from the center of the mold's handle. The mold has a depth of four lines, which measures also the thickness of the star formed by it, and a width of seven lines. (Pl. IV, figs. 10 and 11.)

After each star is shaped, it is pushed to one side by the handle of the mold, and slid carefully on a sheet of paper. When the stars are dry, a piece of fuse is laid over them, as they lie slightly separated in sets of six. The fuse is then cut at these points of separation, and the ends are fastened with priming on the first and sixth star of each set.

The stars have commonly a diameter of 7 lines and a thickness of 4 lines, in the proportions above given for the mold. Larger stars have less effect, because they fall too low.

Crackling stars (etoiles à pet) are small saucissons having an exceptionally long throat, which is filled with star paste.

FIRE POTS.

The case forming the fire pot is closed at the bottom by a wooden disk fastened with glue. This disk ends in a screw.

Its diameter is that of the pot into which it enters, and its thickness is at least 6 lines. It has a shoulder of which the breadth is equal to the thickness of the wall of the case that is to be placed on it. The disk and screw are pierced in the direction of their length with a hole 2½ lines in diameter. (Pl. X, figs. 15, 16, 17, and 18.)

The diameter of the case should be proportioned to the size of the seven serpents with which it is to be garnished. Seven are usually employed, since that number may be easily arranged in a circle. The height of the case is from six to seven times its interior diameter.

In arranging the garniture, a beginning is made by passing a match end through the hole that traverses the disk and screw. The match extends onward within the case about an inch, to a distance 5 or 6 lines beyond the end of the screw, where it is held in position by priming paste. (Pl. X, fig. 15.)

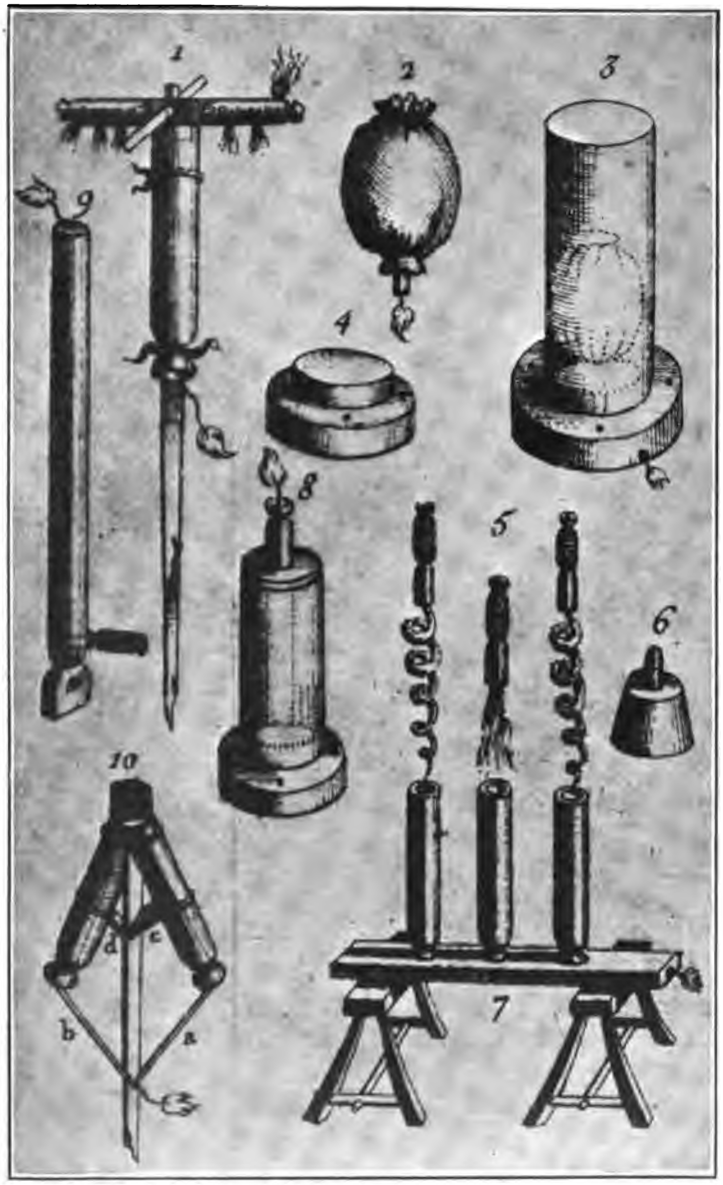
The worker next takes as many squares of paper as there are pots to garnish, from which to fashion what is called the powder bags. These are placed on the end of the stick that has been employed for molding the pots, and, by rolling, the squares of paper are made to take a cylindrical form. (Pl. X, fig. 18.)

A measure of the composition is placed in each of these papers. The portion for each should be one-seventh of the garniture's total weight. Two match ends are also placed in each, of sufficient length to reach an inch beyond the point at which the neck of the powder bag is to be tied. The bag is now closed at the top, and a string is tied about it. Care must be taken to preserve the round shape throughout the length of the paper sack, and the excess of paper beyond the ligature is cut off with scissors.

The mixture employed contains about 4 ounces of charcoal to a pound of powder.

The charge having been made ready and the pot primed, a little powder is scattered within, and the powder sack is then placed inside with the ligature downward. The bag is pushed to the bottom of the pot by means of the molding stick. The charge is next pierced with seven or eight awl holes. Another pinch of powder is scattered over the bag.

PLATE V.



The garniture is now set in place, and, lest it should be shaken about, it is fixed in position by wadding made from torn bits of paper. The pot is then closed with a disk of heavy paper, snipped around the edges, which is firmly pasted in place. Finally, a band of paper is pasted about the cylinder, covering the bent-down portion of the disk. The pot thus prepared is ready to be screwed on the brin. This is the name given by the artificers to a wooden bar prepared for holding a series of pots.

The brin has commonly a length of 8 feet, a width of 2¼ inches and a thickness of 1½ inches. It is pierced with screw holes, in order to receive the screws of the fire pots, and these holes are sufficiently near one another so that only 3 or 4 lines of distance intervene between each two pots. (Pl. X, fig. 15.)

As the screw holes do not extend through the brin, the artificer, reversing the bar, shapes on the underside a groove 3 lines in width and 3 lines in depth, in which are made small holes of from 2 to 3 lines in diameter, reaching to the screw holes. A fuse is laid in this groove. It is fastened on each of the small holes with priming paste, and the whole is then covered over with a strip of pasted paper along the length of the groove.

The worker now returns the brin to its original position with the screw holes up. A pinch of powder is placed in each hole, and, by tapping, this is caused to fall into the small communicating hole underneath. The pots are now screwed in position, and the brin is ready to be fired. At the time of discharge, it is necessary to break one end of the paper covering on the underside of the brin, to expose an end of the match.

The effect of this firework is to discharge all of the pots at the same time, and thus "to embellish the air with a great quantity of very brilliant fires."

FLYING SAUCISSONS.

The flying saucissons have commonly 7 lines of interior diameter and 5 inches of height. A long match is fastened within the case, and extends out through the choke. That part of the case beyond the choke, a length of 2 inches, is set over a rounded base block, which holds it in position, while the other 3 inches of length are loaded. The composition used is the same as that for serpents of three cards. Each part of the charge should be small, and, after it has been put in place, the match which has been threaded through the case is given a turn over the surface of the composition. The repetition of this procedure after each charging insures that the match inclosed within the composition shall be arranged as a spiral. The match extends a half-inch beyond the end of the saucisson, and the choke is primed. The case is then reversed, and the empty section is filled with grain powder. A wadding is placed in position above the powder, and this end is duly choked. (Pl. V, figs. 5, 6, and 7.)

Saucissons thus prepared are placed over the charge in pots proportioned to their size—usually 16 inches long. The effect of the saucissons on being discharged from the pots is to twist while mounting, and to terminate their flight with a loud report. This spiral movement is given to them from the winding direction taken by the fuse, which burns more quickly than does the composition, and thus marks out a path in the burning material that follows the revolutions of the spiral and impresses this torsion on the charge as it is consumed.

CHAPTER V.

POTS À AIGRETTES.

Pots à aigrettes do not differ from fire pots, except that they are made larger and that they have a jet in the center, which at the finish gives its fire to the garniture. The case has commonly 6 inches of interior diameter and about 16 inches height, and 6 or 7 lines of thickness. The case is mounted upon a base of rounded wood, which extends 1 inch within the case. The case is firmly fastened to this by the use of tacks and glue. This base has a shoulder 15 lines wide. Its thickness for that part entering the case should be somewhat in excess of 2 inches, and the shoulder should have a thickness of 2 inches. (Pl. V, figs. 3, 4, and 8.)

The garniture is made up of a powder bag containing 9 ounces of composition similar to that used in loading fire pots, above the center of which is fixed a jet, charged with Chinese fire. The bag is pierced with several awl holes. A little powder is scattered over it, and the serpents, or other forms of fireworks, are then placed upon it. Several torn sheets of paper are stuffed into the pot, in order to hold the whole in position and to prevent the garniture from shifting. The pot is closed with a disk of pasteboard, having a hole in the middle, through which the jet passes, to extend out beyond the pot. A circle is drawn about this hole in the disk, and then with the scissors the pasteboard is cut in eight straight lines from the center of the circle to its circumference. The eight pointed sections thus secured are pressed upward, and, after the jet is in position, are held firmly against it by pasting over them a paper band. The rim of the disk is snipped and bent down over the sides of the case, where it is held firmly by a pasted paper band.

These pots à aigrettes have a pleasing effect due to the quantity of fire thrown out by them after the jet has ended its display of Chinese fire.

TROMPES.

The name trompe is given to an assemblage of several fire pots placed one above another, which are discharged successively in such a manner that the first in throwing out its garniture kindles the slow-burning composition of the second's port fire; then this latter, in discharging, sets fire to the third, while at the same time it drives away the first pot which has ended its functions; similarly as to the various other fire pots. This variety of firework is seldom employed on the ground, but it is often used on water—to vomit forth a marine monster; or to produce other bizarre effects. (Pl. VII, fig. 2.)

A case having 2½ inches of interior diameter, 20 inches long and 3 lines thick, is first molded. This case is called the sheath of the trompe. It is mounted, like a fire pot, on a base of wood carrying a screw

Five fire pots, each 3½ inches high and 1 line thick, with a diameter such that it may enter easily into the sheath, are next fashioned.

The fifth of these pots, which is to occupy the bottom of the sheath, should be entirely closed by a choke. But the four others have each a hole of 6 lines at the choke to receive the port fire.

The four cases not choked, having an exterior diameter of 6 lines and a length of 4 inches, are charged with ordinary powder, for the purpose of communicating fire from one pot to another. For this reason they are named port fires. When these have been primed at one end, each in turn is attached by this end to one of the four pots, in the same manner as the pots are fastened to the fuse. At the other end, a powder bag is fastened, and around each port fire the artificer fastens, along with the match, as many serpents as the pot is capable of containing.

When the four garnitures have been thus prepared, that attached to the fourth pot is placed within the fifth pot, on which the fourth pot is set. The garniture carried by the third pot is then placed within the fourth pot, upon which the third sits, and similarly as to the remaining pots. A trompe ends in a jet charged with sparkling fire, or with Chinese fire, which kindles the first pot and the serpent garniture.

The opening of each pot is closed with paper pasted over it, to prevent the fire of one from being communicated to another, and the interval between the pots, which is about a half inch, is covered with a paper band, pasted from one pot to another in such a manner that the five pots appear to make only a single case.

When the trompe is dry, it is set within the sheath, and the top of the sheath is closed with a round of pasteboard, pierced in the middle in order to allow passage to the jet. A surrounding circle is cut in eight sections, and the ends are pressed up and pasted to the jet, in the manner described for the pots à aigrettes. The garniture of the trompe may be diversified by employing stars or other devices in place of serpents.

BALLOONS AND GRENADES.

The balloon is an imitation of a bomb, and it is thrown in the same fashion from a mortar, either of metal or wood or pasteboard, but commonly pasteboard. (Pl. V, figs. 2, 3, and 4.)

The balloon itself is made of wood or pasteboard. Those of wood are composed of two hemispheres, which close by fitting into each other. A greater thickness is given to the lower side of the globe, which has to receive the impulsion of the powder. This is called the base.

The eye of the balloon is pierced either in the base or in the upper portion, according to the position which is required when it is placed in the mortar—that is to say, so that, if it is fired by hand, the eye will be in the upper part of the balloon, but, if fire is to be communicated from the driving charge, the eye will be in the base.

Balloons of pasteboard are made in three different methods.

For the first, use is made of a wooden ball having a diameter equal that to be given to the interior of the balloon. This ball is well rubbed with soap, and is then covered with a pulp of paper to a thickness proportionate to its diameter. It is pressed with a sponge to draw off the humidity, and also to give it form. When it is dry, the globe thus made from pulp is severed around the middle, so that, on being detached from the ball, it forms two hollow hemispheres, which, on being filled with the necessary materials and reunited, form the balloon.

The pulp is made from clippings of paper or pasteboard. These are placed in water, and manipulated from time to time until thoroughly softened. A little flour paste is added to the pulp, to give it the proper degree of consistency.

In the second method, a ball of string is made by winding it on the end of a small stick, to which one end of the string has been fastened. This stick has a diameter equal to that intended for the eye of the balloon, which is to be formed by it. The ball, after being brought almost to its full size, is completed by winding over it a covering of thread, in order to make it smoother. It is next rubbed with soap, and bits of paper are pasted over it to a thickness forming one-twentieth of the ball's diameter for the lower half, and one-twenty-fourth of its diameter for the upper portion. After the ball has taken on some degree of consistence, in drying, the stick is withdrawn, and by it the string also is pulled out through the hole until the case is left entirely empty. (Pl. VII, figs. 5 and 6.)

In the third method, the case is molded from pasteboard as are rocket pots. They have a size sufficient to permit their being choked, and the height is equal to the diameter. The portion that is to receive the impulsion of the driving charge is fortified by means of paper pasted over it. (Pl. V, fig. 2.)

Balloons, whether of wood or of pasteboard, are garnished with a mixture of different pieces, such as serpents, saucissons, stars, and the like. Among these, after the balloon has been filled, is scattered some of the composition used for charging fire pots. The quantity should be sufficient to cause the bursting of the case.

The fuse is placed in the eye of the balloon, to set fire to the garniture. When the balloon is of wood, care must be taken to have the fuse thicker at one end than at the other, in order to prevent any risk of its being driven through into the balloon by the pressure of the burning powder of the driving charge; and, also, glue should be used to hold it fast in position.

It is necessary for experimental purposes to set off balloons loaded with dirt, for guidance in regulating the duration of the fuse, which should give fire to the garniture only when the balloon has mounted to its greatest height. Such experiments, moreover, serve to show the exact quantity of powder required to hurl the balloon to the greatest possible distance without risking destruction of the case by the force of the discharge.

The duration of the fuse is regulated by cutting it longer or shorter, or by making the paste in which it is soaked livelier or slower. It is usually impregnated with the composition given for serpents of one card.

After the match has been placed in the balloon the whole is covered over with canvas, which is glued on, or the balloon is wound about with a string of suitable weight. It is then finally coated with a paste made from iron scalings and glue. These scalings are to be found in blacksmiths' shops, where they may be picked up around the anvil. They are the bits of metal detached from iron when it is being forged. This paste mixture of glue and scalings fills up the interstices of the string, and gives the balloon a solidity in its outer surface almost equal to that of iron. The balloon is now rolled on dry scalings, which adhere to it, and give it the color of the metal, so that the final appearance is exactly that of a bomb.

Mortars of pasteboard, used for throwing balloons, have the form of pots à aigrettes. There is no difference except in the base of wood upon which they are mounted. This base for the mortars should have such a thickness that the worker may hollow out in its center a cavity of sufficient size to place within it a chamber of cast copper in the form of a funnel. The powder is placed within this chamber. The end of the funnel reaches to the exterior center of the mortar bottom, and thus forms a channel through which a fuse runs. (Pl. V, fig. 3.)

The chamber contains a quantity of powder equal to one-thirty-second part of the balloon's weight. This charge is inclosed in paper cases, which also are funnel-shaped. The fuse passes from the charge through the neck of this paper funnel, and then extends on into the neck of the copper funnel, through a hole in the bottom of the mortar.

After the charge has been placed within the chamber, the paper containing it is pierced with a number of pin-holes. A little powder is then spread over the top. The balloon is next placed in the mortar, with its fuse resting on the driving charge by which it is to be kindled. Bits of torn paper are wadded between the balloon and the walls of the mortar, which serve to offer resistance to the action of the powder, and thus to increase its effect. They also aid in preventing any shifting of the balloon's position within the mortar.

Balloons under 6 inches may be discharged from an ordinary pot à aigrette. A rounded piece of board on which the pot is mounted should be pierced in the middle by a hole of 2 or 3 lines in diameter, communicating with a groove on the underside, extending from the circumference of the board to its center. The pot is loaded with a bag of powder to which a match is fastened. The match is passed through the hole in the baseboard, and its length is laid along the groove on the underside of the board, so that it reaches to the rim. Paper is then pasted over the groove and hole.

The charge should weigh one-twenty-fourth the weight of the balloon itself, when the balloon's diameter is 5 inches. For a diameter of 4 inches, the weight of the charge should be one-sixteenth that of the balloon. Thus, the weight of the charge increases its proportionate relation to the weight of the balloon as the size of the balloon decreases.

Mortars and pots made of pasteboard, when they are to be used for projecting balloons, should always be covered throughout the length of their cylinders by winding them with strong cord, fastened with glue. Without this precaution, the cases would not be strong enough to withstand the action of the powder.

BARRILS.

Barrils, or small barrels, designed to hold grenades, are made of pine wood. The usual dimensions are 21 inches of height, 12 inches of interior diameter at the base, and 12½ of interior diameter at the mouth. The thickness of the staves should be 1 inch.

Three pounds of powder are inclosed within a canvas sack, along with four ends of an 18-inch fuse, of which 12 inches of the length should extend outside the bag. This sack is placed at the bottom of the barrel. Above it is placed a round wooden cover, with the same diameter as the barrel, in the middle of which is a hole allowing passage to the four fuses that are to give fire to the charge. On this cover are set 40 or 50 grenades, which are carefully primed and supplied with matches. A pound of ordinary composition is poured upon these. In the middle is placed a jet, which is designed, as it ceases burning, to communicate fire to the grenades and also to the bag of powder. The grenades are held in position by stuffing bits of torn paper about them. The remaining space within the barrel is filled with hay. The barrel is then closed with a cover of wood an inch thick. This sets within a hoop, and is held securely in place by pegs. In the center of the cover is a hole to allow the projection of the jet. A paper collar is pasted to the cover around the jet to maintain it in position.

The grenades are essentially marrons, which are given a round form and are covered with a winding of string. They are coated also with a paste of glue and iron scales.

When such barrels are to be discharged, holes are made in the ground, in which the barrels are set so that the tops are on a level with the surface of the soil, which is solidly packed about them.

The effect of this firework is very handsome and brilliant. It offers an agreeable contrast when used in conjunction with the cases of rockets next described. The two should be fired alternately.

As many as 20 or 30 barrels may be discharged at one time.

CASES.

The cases are merely wooden boxes to contain any desired number of rockets. The rockets are set inside the box on a board, which is pierced at equal distances with holes proportioned to the thickness of the rocket sticks. The box itself should be proportioned to the length of the stick, so that the rocket may be entirely inclosed. The strip of pierced board is called the grill. A covering of paper is pasted on the grill, through which the sticks force holes when they are placed in position. The paper holds powder or a lively composition, which is poured over it to serve for communicating fire to all the rockets at the same time. The box, after having been equipped, is closed by means of a wooden cover, which is opened when the rockets are to be fired.

The principal box of this sort is called the girande. This firework is commonly employed for the termination of a display. It is provided with rockets of different sizes. The largest are placed in the middle, the medium-size next, and the smallest at the ends. This arrangement gives to the spectacle the form of a bouquet.

TABLE ROCKETS.

Table rockets are so-called because for firing them a table, or some other plane surface, is used. (Pl. VI., fig. 8.)

A case of 15 lines is commonly employed. This is placed upon a base without a spindle, and a plug is driven to the bottom. The case is then loaded with the composition hereinafter described. Twenty blows of the mallet are struck for each charge. The case is closed at the top with another plug. To give greater facility for choking, about half the length of the empty case above this plug is pushed inward over it, and crushed down upon it by blows of the mallet. The case is then choked and tied just above the plug. The excess length above the choke is cut off with scissors. The circumference of the rocket is divided into four equal parts by drawing four parallel lines from one end of the case to the other. One of these lines is called the superior, and that opposite it is called the inferior. The other two lines are called the laterals. A hole is pierced in each of these laterals near the plug that closes the throat of the rocket. Four other holes are pierced on the inferior line at equal distances, by which means the length of the case is divided into five equal parts. The six holes should be made with a gimlet having a diameter one-quarter that of the interior of the rocket. The holes should reach to the composition, without penetrating it. They are filled loosely with powder. A match is then placed along the line of the four inferior holes, and another match extends between the two lateral holes. Both these matches are held in position at each of the holes by a bit of wet priming, and they are covered with strips of pasted paper.

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When the paper has dried, a groove is made in the middle of a small stick, having the length of the rocket, and this stick is attached crosswise over the middle of the inferior line. The notch serves to contain the match, which otherwise would prevent the stick from proper contact with the case. The stick is held firmly in position by winding with wire. String can not be used, since it would be burned during the discharge. The purpose of this stick is to maintain the rocket in its proper position.

The rocket is fired by a small piece of match, which is pasted to the fuse that communicates with the two lateral holes.

The effect of this rocket is first a rotation, so that it forms a revolving sun on the table where it is placed for firing. This continues until the fire, which has begun with the lateral holes, is communicated to the four holes underneath. The rocket is then raised in the air, but the gases, forcing their passage through the lateral holes, continue to give a rotary movement. Thus, there is shown a sun which both revolves in the air and also raises itself to a horizontal position. The result is especially pleasing when the rocket is charged with Chinese fire.

A similar method is employed with four rockets. These are fastened on a wooden cross, each pierced with one lateral hole and two inferior holes, or even three, following the length. The cross fulfills the function of the stick placed at right angles as above described.

Such rockets may be made either large or small as desired. Care must be taken, however, to diminish somewhat the force of the composition used, as the size of the rocket increases, or to increase its force correspondingly as the diameter of the case diminishes.

CHAPTER VI.

FIXED FIRES.

FIRE LANCES.

Fire lances have for a long period been commonly used as torches for purposes of general illumination during a display of fireworks at night in the open air. But, though they produce a handsome effect, objection to their employment in this way arises from the fact that their powerful light diminishes the brilliance of the spectacle offered by the various pieces set off. Moreover, the amount of smoke given off is likely to prove troublesome. For these reasons, it is better that the lances, if thus used, should be reduced to a very small size, from which may be formed figures of any desired outline without causing inconvenience, while, by reason of their limited light and short duration, they afford an agreeable contrast to the other exhibitions, and this contrast is emphasized by the whiteness of their fire. (Pl. V, fig. 9.)

Customarily, the lances have an interior diameter of from 4 to 5 lines, with about 15 inches of length, when they are designed to serve for purposes of illumination. The small lances used in forming designs have a diameter of 3 lines, with a length of from 3 to 4 inches.

The cases are made of paper, which is very thin so that it may burn at the same time as the composition. Four turns of paper suffice for the large size, and either two or three turns for the small size. The manner of molding these has already been described.

Four sticks of various lengths are used for loading the large lances. The first has the same length as the case, and each of the others is shorter by one-fourth than that which preceded it. The case is loaded entirely by hand without the assistance of either mold or base. Ten blows from a light mallet are used for each charge. The lance is not choked after it has been loaded. The opening of the case is merely closed by wet prime set about the match end.

In order to form a figure by means of small lances, holes are pierced following the contour of the desired design in a board on which this has been traced. These holes are disposed at distances of 1½ or 2 inches from one another. The lances are placed in the holes, and fastened there with glue.

Another method is to drive small nails into the wood, following the design as with the holes, and then to set the lances over them.

Port fires are placed above the lances after they are arranged for the design. The port fires are opened with scissors at the point of contact with each lance in such a manner that the match inclosed within them touches on the priming of the lances. The hole is then covered over with paper for the twin purposes of holding the port fire in its position on the lance and of protecting the communication.

ROCKETS RUNNING ON A CORD.

The rocket running on a cord is loaded over a base having a spindle. The composition used is somewhat milder than that ordinarily employed for rockets. This sort of rocket carries no garniture.

An empty case, which has not been choked, is fastened on one of these rockets and is then threaded on a taut cord. When the rocket is set on fire, it moves rapidly from one end of the cord to the other.

If a jet, charged with the composition for turning suns, is fastened on this rocket so as to form a cross, then, when both pieces are set off at the same time by a communicating match, the rocket, in addition to its flight forward and backward, will also revolve in the manner of a sun. (Pl. VI, fig. 5.)

Rockets having a double movement are made by attaching two rockets one to the other in such wise that the massif of one rests against the throat of the other. Or they may be placed end to end, massif against massif, with a single match to communicate the fire. The match is inclosed in a lance case, which is firmly fastened to both rockets by pasting paper over it. An empty case is then attached to the pair of rockets, and is threaded on the cord. (Pl. VI, figs. 7 and 9.)

FIRE JETS.

The name fire jets is given to all rockets loaded solidly, so that there is no air chamber, which operate without leaving the place where they are fastened. Of this sort are the fixed suns, turning suns, and those designed to imitate with fire the play of spouting water. (Pl. VII, figs. 3 and 4.)

The thickness commonly given to the case for a fire jet is one-fourth of its interior diameter when a brilliant fire effect is intended, but only one-sixth of this diameter for Chinese fire.

Four sticks are required for loading the large jets, of which the first should be pierced to receive the short spindle.

The space left for choking should be filled with string, to support the case while it is being loaded.

Each charge when compressed should occupy a height equal to one-half the interior diameter of the case. From 15 to 20 moderate blows of the mallet are struck in the tamping of each charge. The variation is proportioned according to the size of the particular jet. The mallet used should be somewhat smaller than that employed in the loading of rockets having the same diameter.

The case is closed with a plug, unless it is to be used for a turning sun, or a pot à aigrette.

Before priming, the throat is filled with the composition used in loading. The powder is merely pressed into the empty space with the point of a knife; it is not rammed down. It is necessary thus to fill the space, since otherwise there would be a risk of explosion from dilation of the air inclosed within it.

Since it may happen in connection with large jets that the throat will burn too soon, it is expedient that it be reinforced by ramming into it potter's clay. A jet thus equipped casts its fire much higher.

Such jets may be pierced with two holes near the throat, in order to make them spout fire from three orifices at the same time. The jets produce a beautiful effect when Chinese fire is employed, and are excellent for purposes of decoration.

The composition for sparkling fire is particularly adapted to the representation of playing fountains and of waterfalls, since the fire is thrown high and scintillates.

Jets intended to represent by their fire falling sheets of water should not be choked. For this use the jets are placed horizontally very close one to another.

When the artificer has weighed out the various materials required for the making of Chinese fire, he passes the charcoal and saltpeter three times through the horsehair screen, in order to mix them thoroughly. The iron sand is slightly moistened with brandy, so that the sulphur flour will adhere to it, and the sand and sulphur are then mixed. This mixture is afterward spread out over the combined charcoal and saltpeter, and the whole mass is thoroughly blended. In the making of the composition for jets, when sand above the second order is used, the mixture is moistened with brandy to a point at which it begins to swell. It is then kneaded until the humidity penetrates throughout the whole substance. It should be noted, however, that if the mixture be too moist, it will not give out flowers at the time of its discharge. The object of such moistening is merely to retain the distribution of the sand throughout the composition while it is emptied into the case. This is effected by increasing the tenacity of the parts. Without such precaution, the sand by reason of its weight would tend to mass at the bottom of the case when the composition is poured in, and this tendency would be especially marked for the larger jets.

Such moistening of the composition is not required for rockets, and in fact should be avoided, inasmuch as the humidity would so weaken the driving force as to prevent ascension; while, if they were kept until the composition became thoroughly dry, they would explode on being fired.

It must be observed that the need for moistening the entire composition to be used in jets does not exist when the sand used is of the first three orders.

FIXED SUNS.

A fixed sun is an assembly of jets, charged with sparkling fire, or with Chinese fire, which are arranged about the support so as to form rays, and equipped with a fuse communicating from one to another so that all are kindled at the same time. (Pl. VIII, figs. 1 and 2.)

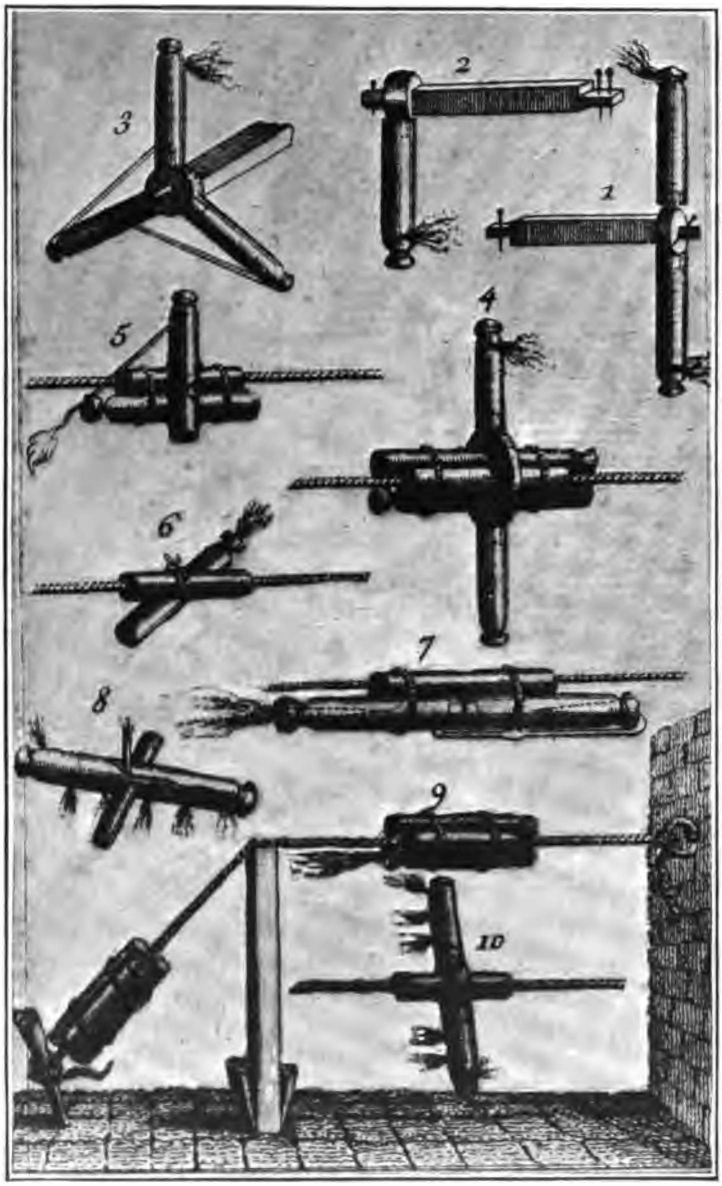
A fixed sun of one row is ordinarily composed of 12 jets. The artificer rounds a piece of wood having a suitable thickness, and 12 holes are pierced in the rim, after the fashion of those to receive the spokes in the hub of a wheel. The holes are provided with a thread to hold the screw end of sticks to which the jets are to be fastened. These sticks have a length two-thirds that of the jets. A groove is made along each, in which the jet lies, being tied to the stick at two points. A touch of glue to the knot on each string prevents its loosening. (Pl. VIII, fig. 2.)

After the sticks with the jets attached have been screwed in position on the hub, a port fire is laid circularly over the end of the jets, so that it is in contact with the throat of each, which has already been primed. The port fire is then opened with scissors at the point of contact, in such a manner that the inclosed match touches directly on the throat, where it is fastened by means of two threads, which are knotted into the choke and tied crosswise over the port fire. A strip of paper is then pasted over each one of these points of communication.

The center of the rounded wood support, or hub, is also pierced with a screw hole, in order to fasten it to a wooden rod, which is to hold it in a vertical position. Sometimes the hole is made square, and the piece of wood has a corresponding form, when a key-pin is used for fastening. A small sun is commonly used to garnish with fire the space from the center of the hub to the throat of the jets. This is oftenest charged with white fire. The sun should carry three jets of good size, such that they will increase the effect of the display, yet will go out quickly, so that their flames shall by no means continue longer than the burning of the fixed sun.

Suns are also constructed with spiral parallel rows of jets. For placing a second row, it is necessary to tie a light wooden hoop on the jets of the first row in the middle of their length, to which the new jets are fastened. Likewise, a third row of jets is mounted by attaching them to a circular hoop placed midway in the length of the second row of jets; and so on to any desired extent. All the additional jets are sup-

PLATE VI.



plied with port fires as were those of the first row, and the communication reaches from one row to another, so that all take fire at the same time. (Pl. IX, fig. 11.)

It is a common practice to charge the jets with two sorts of fire; the first half of Chinese fire and the second half of sparkling fire. Such variation increases the beauty of the sun's effect.

TURNING SUNS AND GIRANDOLES.

The sole difference between a turning sun and a girandole is in the position at the time of discharge. The sun is placed vertically, while the girandole has its plane parallel to the horizon. A turning sun is a wheel, which is caused to revolve by the discharge of one or more rockets attached to it. These operate with the same expenditure of force as when they make a free ascension, with the same action of gases from combustion against the resistance offered by the inertia of the air. (Pl. VIII, fig. 3.)

A wheel may be equipped with 20 rockets or even with a larger number. But, to secure the revolution of the wheel, four of the rockets must be discharged simultaneously. For example, the first, sixth, eleventh, and sixteenth may be fired together, and these, on finishing, will give their fire to the second, third, twelfth, and seventeenth; and the like method should be followed in the discharge of the remaining rockets. The effect is that the wheel, although equipped with 20 rockets, has only five separate periods of discharge. The fire is communicated from the end of one to the throat of another by means of a fuse, over which a strip of paper is pasted from one rocket to another.

Ordinary paper is not fitted to withstand the action of Chinese fire. It is penetrated too quickly by the iron sand in fusion. A double strength of paper is required. This is secured by pasting together two sheets, using a paste made from potter's clay.

Two methods are followed in placing the jets on the wheel in such a manner that it shall be made to revolve. One is to attach one or more jets on the rim of the wheel, in such a position that they spurt their fire from the throat. The other method is by fastening them on the spokes of the wheel in the direction of their length. In this instance, they spurt their fire, not by way of the throat, but from a lateral orifice, which is pierced with a gimlet in the body of the rocket, a little below the plug that closes the opening of the throat. A description of such lateral holes has been given in connection with table rockets.

Each hole should have a diameter one-quarter that of the interior diameter of the jet. When only one or two jets are used, it is preferable to attach them to a tourniquet having either one or two arms. But when three, four, or five jets are employed, they are mounted on a wheel having an equal number of spokes. A larger number of jets may be carried, by the use of hoops in the manner described above for fixed suns. (Pl. VI, figs. 1, 2, and 3.)

A third method of making girandoles allows the small jets to turn the piece. The advantage of this is that, after the motion has been begun, various garnitures may be discharged. The body of this machine consists of a wooden tube of a length proportioned to the base that is to be used, ordinarily 9 inches. It is closed at the top by an iron disc, in the middle of which there is a small opening to receive the point of the pivot on which the piece is to turn. Three screw holes are made in the central part of the tube at equal distances from one another, into each of which is screwed a jet carrier, made from two pieces of wood having the form of a T. This carrier supports a jet which is laid along the crosspiece of the T, where it is securely tied. A port fire runs from one to another of these jets, arranged in such a manner that the first one in finishing gives fire to the second, and this in turn to the third. (Pl. X, figs. 13 and 14.)

The firework, when the garniture has been completed, is set on a pointed rod of iron, which serves as the pivot about which it revolves.

The tube may be equipped with two or three rows of jets, each row numbering three, four, or five jets. When the rows are of more than three jets, since the circumference of the tube is not sufficient to allow the placing of more than three holes in a horizontal plane, the holes are pierced underneath, one a little higher, the next a little lower; and this process is repeated for the necessary number of times. It is also possible, by placing the jets of the second row opposite those of the first, to cause the piece, after having turned to the right, to return to the left.

Ordinarily, there are added to the garniture of this firework a number of jets placed upright, which cast their fire vertically upward, or at any angle desired. These offer a contrast to the fire thrown from the jets at a right angle to the upright of the T.

Turning suns and girandoles serve in the making of a great variety of pieces, among which the commonest are the following:

Figure 1: This is formed from two wheels, each garnished with 12 jets arranged in three groups, which turn in opposite directions on the same axis. Within each wheel is contained another wheel, having iron cogs that engage in a pinion wheel common to the two larger wheels. The engagement serves to regulate the movement, so that neither shall turn more quickly than the other. Four jets on each wheel are discharged at the same time, and the fires from these, crossing, form the special effect.

Figure 2: This firework is formed by placing turning suns within an open-fronted box behind cardboard frames. The box contains the fires so that they are seen only within the frame. This device is extremely effective for decorative purposes.

Figure 3: A turning sun is placed within a wooden receptacle having a star-shaped opening in the front. Thus, when discharged, the fire shows the form of a star. Or any other desired shape may be used at will. Usually, such a star is equipped with six girandoles, made from tourniquets of two jets set in each point of the star. These are discharged at the same time, and their combined effect is to form a hexagonal figure bordering the star. A good contrast is afforded by having a star of Chinese fire, with the inclosed girandole of the ordinary mixture.

The jets with which turning suns are garnished should be charged solidly on a base carrying a spindle, and choked.

A sun of five rays is ordinarily garnished with jets that are loaded with Chinese fire for the first discharge, with common fire for the second, with white fire for the third, with new fire for the fourth, and with red Chinese fire for the fifth. To increase the effect, each jet may be loaded half with one fire and half with another.

The force of the composition should be proportionate always to the size of the jets, just as their size should be proportioned to the size of the wheel which they cause to turn. The force of the composition should be either diminished or increased, according as the jets are larger or smaller.

COMMUNICATING FIRE.

The secret of the communication of fire between different pieces was brought from Bologna into France in the year 1743 by the Sieurs Ruggiere, official artificers for the Italian crown. The pyrotechnic display given by the brothers excited great admiration, especially by reason of the skill shown in the communication of fire to various pieces in succession. The Italians were obliging enough to explain their method, as follows:

Let us imagine a fixed sun set between two turning suns on an iron axis. The first is fastened from above by a peg, which traverses a hub and axle. The other two are held by screw holes in the axis, by means of which they have as much or as little play as may be required. (Pl. X, fig. 12.)

The space between the first turning sun and the fixed sun is 6 inches and 4 lines. They are supplied with two cylinders, each 3 inches long and 2 inches in diameter, mounted on the axle. These are fastened with glue, one on the hub of the fixed sun, the other on the hub of the turning sun.

Between the two cylinders, there should be mounted on the axle a button 4 lines thick, having 1 inch of diameter. This serves to hold them apart, a distance of 4 lines one from the other. In order not to multiply parts, the button is usually added to one of the cylinders, of which it forms an integral portion, or it may be added by gluing it on.

Upon the plain surface of each cylinder, a little above the button, a circular groove should be cut, with a length of 2½ lines, and an equal depth, in which a match is fastened by the use of priming. It is by these matches that the communication of fire is to be accomplished, that of one cylinder not being able to burn without giving its fire to that of the other opposite, since there are only 4 lines of distance between them. The fire is carried to one by means of a match, which, passing from the end of the last of the jets of the turning sun, kindles the match lying in the circular groove above described. This match is carried in a groove cut along the spoke. It is continued over the hub and cylinder. From this point, it communicates by its extension with the match in the circular groove opposite. It is carried thence to the throat of one of the jets in the fixed sun by a match lying in a groove made along the cylinder and over the hub to the foot of the jet. From this point the match extends out to set fire to the throat. These matches should be well covered with paper pasted over them, except in the case of those placed in the circular grooves. They are protected from sparks of fire by a tube of pasteboard, or of very thin brass, which almost entirely covers the two cylinders. In order that this shield should not hinder their movement, it is given an additional two lines of diameter. (Pl. X, figs. 9, 13, and 20.)

The length given to the cylinders has two objects. The first is to separate the circular matches from the rims of the tubes covering them, by which sparks might be introduced. The second is to hold the fixed and turning suns sufficiently far apart so that fire can not be communicated from one to the other, which would occur if they were closer, even though the communication might be well covered.

The space between the fixed sun and the second turning sun is supplied with a like communication between the two cylinders, and fire is carried to this second sun by a match, which draws its fire from the foot of one of the jets in the fixed sun. A hole is pierced in this, in order to establish communication with the match to which it gives fire when finishing.

From this second turning sun, the fire may be conducted to a second fixed sun; and so on successively to any desired extent.

MACHINE PYRIQUE.

A form of firework device is called the pyrotechnic machine (machine pyrique). This ends ordinarily with a star. It is formed from six bars having a length of from three to four feet. These are screwed on a hub equal to that of a fixed sun. Two jets are attached on a traverse. Their throats cross, and the opening of the angle given them is the measure for the formation of a star. A match laid in a groove on each one of the bars communicates from one end with the throat of the jets and from the other with a circular match, which surrounds the hub in the foot of the bars, and thus communicates the fire to all at the same time. In place of the jets forming the star, the bars may be garnished with six turning suns. (Pl. X, figs. 1, 2, 7, 8, 9, 19, and 20.)

It is with such suns that decorations are formed for those displays set within frames and the trellis effect in flaming arbors. They are usually constructed with three jets which take fire successively.

ANIMAL FORMS.

We again owe to Father d' Incarville the method of forming animal figures. This depends on a paste made of sulphur, reduced to powder, and wheat paste mixed together, with which are covered frames of willow, or pasteboard, or wood. After having been smeared with fuller's earth, in order to prevent it from burning, the frame is coated with sulphur paste, and it is next covered with powder, while still damp. When it has been well dried, matches are fastened on the principal parts so that fire will be carried throughout at the same time. Finally, the whole is covered with paper pasted on. The Chinese, from whom this paste is derived, paint the figures according to the color of the animals that they represent. The duration of the burning is proportioned to the thickness of the coat of paste covering them.

When the figures are small, they may be molded or modeled solidly. Since this paste does not run while burning, the figures conserve their form until entirely consumed.

They may be used to form any desired sort of design. They are also employed by the Chinese to represent grapes. These are given a purple color by substituting for the wheat paste the meat of jujubes. The jujubes are first cooked, and the skin is then separated from the pits, which are thrown aside.

CHAPTER VII.

FIRES FOR WATER DISPLAY.

There is no particular composition for this variety of firework. The pieces are made of the same materials as those discharged on the ground or aloft. They burn equally well on the water as in the air, and to vary their effects it is only necessary to make such an arrangement as shall sustain them, whether diving or floating as may be desired, but always they must be of a sort such that water is prevented from penetrating the case and wetting the composition before it has taken fire.

GENOUILLÈRES.

The genouillères are for display on water—the equivalents of serpents for display in the air. They are used to garnish fire pots, water balloons, and barrils de trompes. They are also called dolphins and ducks. Their effect is to rise from the surface of the water, to throw themselves repeatedly into the air, and to finish with an explosion. The cases have a length of nine interior diameters, without including the throat. They are loaded upon a base holding a spindle, which has a thickness of one-quarter of the interior diameter. After three charges of the composition, a half-charge of powder is added; and this method is continued with each three charges, until the height of the seventh diameter is reached, when a wadding is driven down on the composition. This is pierced with an awl, which just reaches to the composition. A pinch of powder is placed in the hole, and grain powder is then used to fill the remaining space, reserving only room for a final wadding, with which the powder is covered, and for the choking.

The sheath is next attached to the same end of the loaded case. This sheath is an empty case, very thin, of the same size as the other, and closed at one end, either by choking or by a pasteboard disk pasted over it. It is cut at the other end into several little tongues. The loaded case is pushed within this cut portion, which serves for bending the sheath. This bend should form an angle of about 50 degrees. Heavy thread is tied over it, and a band of paper is pasted over the string. The sheath, apart from the tied portion, should have a length half that of the case. The piece is then choked and primed as are jets. (Pl. VIII, fig. 4.)

All aquatic pieces for use should be rubbed with tallow to prevent water from penetrating. The tallow is melted, and with a large brush of hog's bristles is spread over the entire surface of the genouillères. They are then ready to be employed as garnitures, or to be fired directly by hand.

The sheath should sustain on the surface of the water that part to which it is attached. As to the throat, this is sustained by the empty space created by the burning of the material. The elbow joint of the sheath gives the genouillères an uneven and tortuous movement, while the powder, of which one-half a charge is added after three charges of the composition, causes them to leap into the air when the fire reaches it.

DIVERS.

The effect of the diver is to give forth a light extremely brilliant and very white, and to plunge from time to time into the water, only to reappear with the same splendor. It is charged also with fires that gush forth to represent jets of water, or trees in blossom, which dive at intervals in the same manner. (Pl. VIII, fig. 6.)

The case has a length of 12 interior diameters. If the composition is a slow-burning one for illumination, the case is loaded upon a base from which issues a spindle having a diameter half that of the case. If a lively composition for forming jets is used, the spindle should have one-fourth of the same diameter.

For cases 10 lines in interior diameter, in which the throat has a quarter of the diameter of the opening, three charges of composition are first poured in, and this is followed by three-quarters of a gros of grain powder. If the throat has a semidiameter, the quantity, is 1¼ gros. An equal quantity of powder is added to each series of three charges of the composition. When the case has been loaded, it is closed with a pasteboard plug, and choked. The effect of this quantity of powder is to make the piece dive, by reason of the resistance which the sudden burning causes it to encounter in the air and the reaction within the case.

The case is lengthened by rolling on the lower end three or four turns of paper, which have a length sufficient to contain 4½ ounces of sand, or of earth, which serve as a counterbalance. This is tied on the choke, after the sand has been placed within. It is closed tightly by a ligature.

Since this counterweight, of which the effect is to hold the firework on the water in a perpendicular position, would draw it to the bottom by its weight if it were not sustained on the water, the case is equipped to be thus sustained by gluing on, in place of the choke, a disk of pine pierced in the middle, into which it is forced. The diameter of this disk should be three of the exterior diameters of the case, and its thickness two-thirds of one diameter.

The case is primed and greased in the manner already described for the genouillères.

RUNNING FUSÉES.

These are fusées, or jets, which have an upright position on the water. They are charged and garnished like the genouillères, except that no powder is placed in them, and that the sheath is attached to the fusée without a bend. (Pl. VIII, fig. 7.)

TURNING SUNS ON WATER.

A turning sun for use on water is formed from two jets joined together by their ligatures. The pair is fastened on a pine board, cut round, of a diameter equal to the length of a jet, and sufficiently thick to sustain the two jets on the water. A lateral hole is made with a gimlet at the end of one of the jets to the right, and another hole at the opposite end of the other jet to the left. A match inclosed in a lance case, which extends from one hole to the other, communicates its fire to both at the same time. The movement of rotation is produced by the holes so pierced as to oppose each other. The fire, issuing thus, impresses on them two opposed movements by which the piece is forced to turn, and the middle of the length becomes the center of this movement. (Pl. X, fig. 10.)

BARRILS DE TROMPES.

A barril of this sort is an assembly of seven trompes, in which each sheath is mounted on a disk with a screw, as has been described for the fire pots, by which it is attached to a base of wood having a diameter equal to that for an assembly of seven trompes. (Pl. VIII, figs. 8 and 9.)

The barrils are formed like those described for use on land, and they are garnished in their several sections alternately with fires to be discharged on the water and with fires to be discharged in the air. A port fire, which carries a match to the throats of the jets terminating the trompes, gives fire to all at the same time. If it is desired that only one trompe should be discharged at a time, it becomes necessary to pierce the first trompe at the bottom opposite the pot of the last set, which it must also penetrate, and to introduce into this hole the end of a match inclosed in a port fire, which conducts the fire to the throat of the jet in the second trompe; and so on as to the others.

The communications of the fire having been arranged, the assembly of seven trompes is inclosed within sheets of paper pasted over it, which give the form of a barrel. When the whole is dry, it is greased with melted tallow.

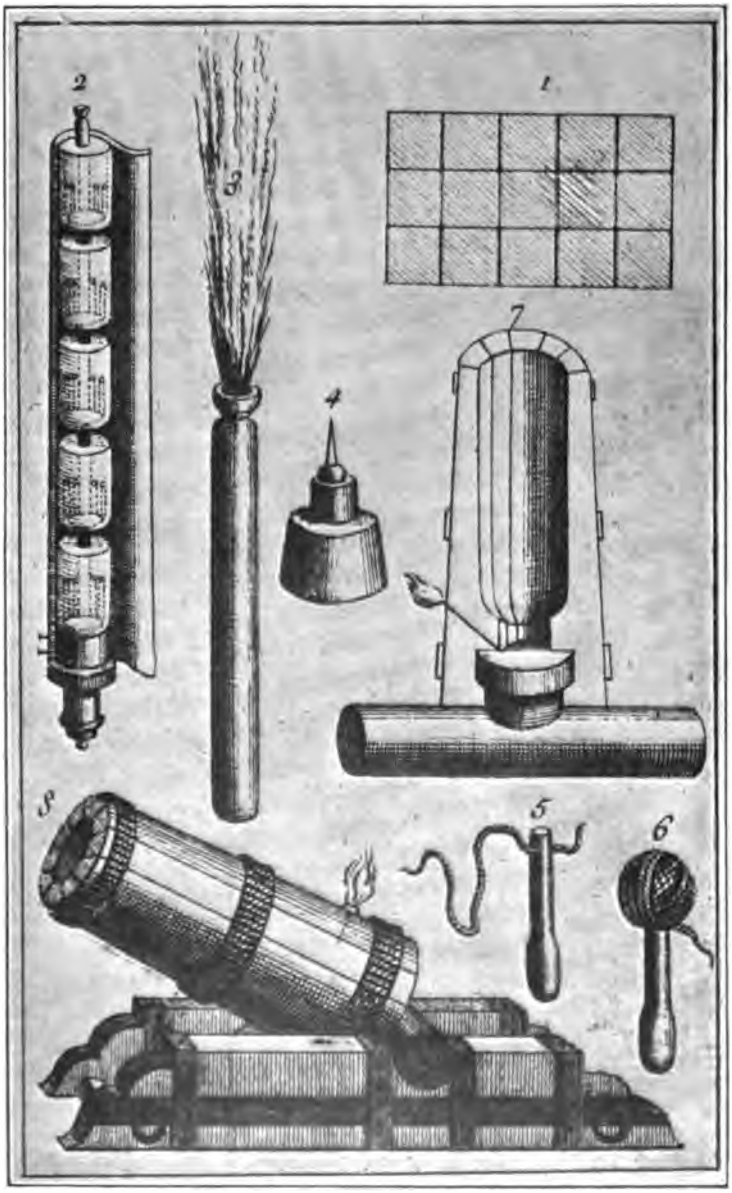
If the barril should not be sufficiently heavy to sink in water to the proper depth, a counterpoise is fastened to its bottom. This is usually a sack filled with sand, in order to add to, or take from, the amount of weight as may be necessary for the counterpoise. The adjustment should be such that almost the entire length of the barril is submerged.

AQUATIC FIRE POTS AND BALLOONS.

These fire pots have the same form, and are made in the same manner, as the pots à aigrettes; with this difference, that a counterbalance is attached underneath as for the barrils de trompes, and that they are smeared with tallow.

The fire pots are garnished with genouillères, with divers and with other pieces designed for water display. A bag of powder, placed at the bottom of the pot to which a jet communicates fire at the finish, throws them into the air, whence they fall back to writhe along the surface of the water.

PLATE VII.



The genouillères are arranged upright in the pot, reaching to the rim in a circle, with the throats on the bag of powder and the sheaths outside of the pot. The space left in the middle is garnished with stars. The pot is next covered with a pasteboard disk, through which a jet passes. But, since this cover does not rest on the rim of the pot, by reason of the interposition of the sheaths of the genouillères, among which there is a space to be closed, these openings are sealed with paper bands, fastened at one end on the pot and at the other on the cover, and the joints also are covered in such a manner that water can not penetrate.

When it is desired to throw forth balloons, the jet is fastened on the exterior of the pot, and on finishing it gives fire to the charge by a communicating match, which passes through a hole pierced in the bottom of the pot.

The balloons are made of wood, or of pasteboard, similar to those for use on land. They are filled with pieces suitable for display on the water, and are smeared over with tallow. Since they should not explode, for their best effect, except on the water after they fall, care must be taken that they are not thrown above a medium height, and they are made lighter in weight than an equal volume of water, in order that they shall not sink. Several may be fired at the same time in a cask made of stout staves, banded with iron hoops, by arranging them in the manner that has been described in connection with grenades to be fired from a barrel.

JATTES.

Jattes are a sort of fire pot, formed from a bowl of wood, around which are fastened five jets, arranged for discharging in alternate sections after the manner of turning suns. The effect of the jets is to cause the bowl to rotate on the surface, and other jets are arranged within the bowl as for the pots à aigrettes. The jet in the middle receives fire from the last section of the turning sun and gives this fire in finishing to the charge, which casts forth the garniture. (Pl. VIII, fig. 10.)

Some varieties of this firework are much larger and more complex, with a diameter sometimes as much as 4 feet. These are made by the use of numerous vessels, which do not turn, but only serve to carry the fire pots and a light frame, which is garnished with jets placed in various positions. Fire is kindled only at one point, whence it is communicated to all the parts of the piece.

SPIRAL MACHINES.

A similar arrangement is employed also to carry on water a kind of firework called the spiral machine. This is a cone formed by six light strips of pine, 5 feet long, nailed at one end on a wooden disk 3 inches in diameter and at the other on a disk of wood 2 feet in diameter. The middle of their length is sustained by another disk of intermediate size, to which they are nailed. The cone is finally twisted to make spirals, in which form it is held by another strip of wood, very thin and very flexible, extending from the top to the bottom, which is nailed on the spirals. When the machine is finished it is garnished from top to bottom, following the turnings of the spirals, with small lances fastened on it. It is finished by attaching to the bottom disk a dozen turning suns, arranged in four sections of three jets each, which are discharged together. (Pl. VIII, fig. 3.)

This piece is placed in the middle of the bowl on an iron rod. The rod is the pivot on which it turns, receiving its movement from jets attached to the bottom disk. The first of these jets gives fire to all the others by a communicating match.

PART III.

MODERN METHODS.

CHAPTER I.

MATERIALS.

The foregoing account concerning the art of pyrotechny, as it flourished in France during the eighteenth century, is of particular interest in connection with a study of present-day conditions by reason of the two contrasting phases shown. One of these has to do with the limitations of the art due especially to ignorance in the matter of many chemical facts now deemed vital to pyrotechnic purposes. The other fact has to do with the actual completeness of the art as thus practised. The narrative demonstrates that the French artificers wrought with a zeal and effectiveness so great that their achievement determined methods which have endured, essentially unchanged, throughout all the tests of experience until to-day.

The progress in the art shown during our own age is due wholly to the advance in chemical knowledge. It is true that the slowness of hand processes has to a considerable extent given way to the rapidity of mechanical operation. But the sole gain from this substitution has been in the matter of the quantity produced, rather than in the quality. The use of machinery for various purposes in connection with the making of fireworks was begun in the last quarter of the nineteenth century. Various mechanical devices are now employed for the commercial making of certain pyrotechnic pieces, but, too, even in the largest establishments, an astonishingly large proportion of the work is still done by hand.

It would be confusing, rather than enlightening, to enumerate separately each step in the advancement of the art during recent years. For the purposes of an historical survey, such as this, it seems advantageous to present, in contrast to the foregoing examination of the past, a summary of the more distinctive features in the situation to-day.

Thus, we may consider at the outset the list of chemical materials now commonly employed in the making of fireworks. It is not necessary here to attempt a precise description in each instance as to the nature of the substance or the facts concerning its discovery and application. Such information belongs to the chemistry of pyrotechny, rather than to its history. Moreover, simply the naming of the various modern constituents is impressive, when these are considered in connection with the materials at the disposal of the French investigators. The reader will remember the lament of the French authority on pyrotechny, who deplored the lack of adequate means for producing a green fire. His hope that some substance might be found to serve the purpose has been fulfilled. And as of this, so of other effects. The contemporary resources of chemistry free the artificer from any serious lack. He has but to avail himself of materials ready to his hand, in order, by the exercise of patience and ingenuity, to accomplish any ambition in the way of spectacular display.

The first use of fireworks in Europe, as has been pointed out, was by the Romans, who brought home with them from their foreign conquests a rudimentary knowledge of pyrotechny. It is, therefore, appropriate that in this concluding portion of our historical study we should revert to the Italians, who have, indeed, greatly developed the art within recent years—even to such an extent that their mastery of it may be regarded as sufficiently indicative of contemporary attainment.

In 1916, the handbook of Di Maio, an Italian authority, included the following materials in its list of requisites for the manufacture of fireworks:

Antimony.—Used for white fires. Crude antimony (sulphide of antimony) is employed in the production of a bluish-white flame.

Clay.—This is made plastic with water, and molded in any desired shape, to serve for plugging cases, etc.

Bicarbonate of soda.—Used to secure a yellow color in fire.

Chloride of mercury (*calomel*).—The effect is to increase the vividness of colors.

Camphor.—Used to moisten various compositions and increase the brilliancy of the fire.

Carbonate of copper.—Used with nitrate of strontium in producing violet-colored flames.

Carbonate of strontium.—This gives to the flames tints varying from red to violet.

Charcoal.—There are two sorts—the light, made from soft wood, and the heavy, from hard woods. The first is easily inflammable, and is used in the making of ordinary fires and jets. The second is of slow combustion, and is used in the composition of various pastes for jets, colored flames, stars, etc.

Paper.—This should be both smooth and pliable, yet strong, not easily breaking or cracking. The paper used for wrappers is of various colors, to indicate the particular contents of fireworks. For port-fires, ordinary writing paper, or press paper, of a lighter and weaker texture may be used.

Pasteboard.—This is prepared by pasting together two or three thicknesses of cardboard with wheat paste. For incombustible cases, the pasteboard is made up of sheets fastened together with a fireproof paste. For cases of large caliber to spurt fire, strawboard is used.

Chlorate of barium.—Employed in the production of green flames.

Chlorate of potassium.—Used for the sake of its explosive violence, in connection with other substances.

Paste.—This may be either of rye or of wheat flour. The flour is moistened with eight and one-half times its own weight of water, and boiled slowly about one-quarter of an hour, while being stirred, until it begins to thread. To prevent souring of the paste, a little alum should be added to the water before boiling the paste.

It will be noted here that no reference is made to the virtue of the alum as tending to prevent the inflammability of the paste. The statement of Di Maio concerning the reason for the use of the alum is corroborated by all modern makers of fireworks, who regard the alum simply as a preventive of acid action in the paste. Yet, it will be remembered that the first use of this substance was by French investigators, who employed it as a substitute for common salt, which the Chineses added in order to render the paste

PART III.

MODERN METHODS.

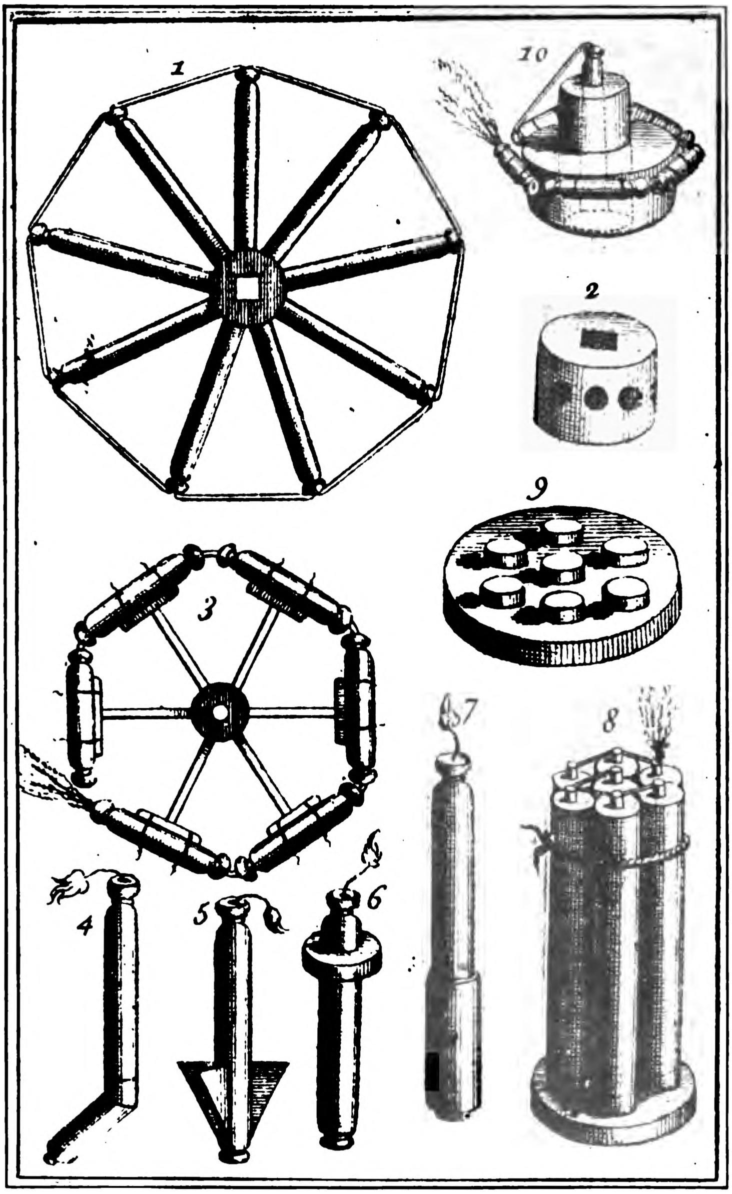
CHAPTER II.

COLOR FORMULAS

At the present time, there are numerous advantages enjoyed by the maker of fireworks, which were wholly unknown to his predecessors. Thus, for example, the paper used for the making of cases is prepared at the paper mill in the exact manner necessary, so that no preliminary treatment of the sheets is required before the actual rolling of the case. The amount of time and labor directly saved by this process is considerable. But of far more importance is the fact that, for the ordinary purposes of firework-manufacture, the materials of the various compositions are procurable in a condition that approximates chemical purity. The result is a vast saving of labor on the part of the artificer. He is spared tedious, and oftentimes difficult, tasks. Such various aids, together with the mechanical assistance he now enjoys, enable the manufacturer to give full attention to those details that increase the variety and brilliancy of the spectacular displays produced.

Yet, curiously enough, there has been hardly any essential change in theory and practise since the days when the French artificers flourished. The methods now employed are in their integrity strictly a continuance of those practised long ago. They are modified in many respects, sometimes developed highly, but they remain essentially identical. The various stages of the manufacture show no particular variation from the processes already described in detail, and this is true even in those instances where machinery takes the place of hand labor. The rolling of the cases, the loading of them, and the attaching of the fuses, all alike are merely repetitions of a former manner. The variation is so slight as to be negligible. For example, the artificer of a former age deemed it necessary to test the balancing point for each individual rocket, and so balanced it on a knife blade. The

PLATE VIII.



present method foregoes such particularity. The manufacturer to-day finds that the best efficiency in rocket construction is gained when the balancing point is close to the bottom of the case, instead of 1 inch down on the stick, which was the point of equilibrium for the French artificer. Moreover, the manufacturer now is able to dispense with such critical examination of each rocket separately. The exactitude of the various processes is so nearly complete that, once the proper equilibrium of the firework is determined, it is automatically assured in the general production.

The modern improvement of chief importance is that gained by the use of new materials for various color effects. This is at once apparent when we consider the different fires used for garnitures of rockets. In a general way, the composition is manipulated just as it was two centuries ago. The variations are of the slightest. The proper composition is mixed with white of egg to make a thick paste, or gum arabic may be used for the same purpose, in a proportion of from 16 to 18 grams to a liter of water. The paste is rolled on a stone slab until it is reduced to about the thickness of one's little finger, and is then cut into small cubes. These cubes are rolled on a table sprinkled with fine powder, and when thoroughly dry, are ready for use.

It is in the composition itself that we discover the great advance of to-day over a former period. Thus, for white stars, a number of formulas may be given as follows:

	1st.	*2d.*	*3d.*	*4th.*	*5th.*
Niter	16	16	16½	16	12
Sulphur	8	8	5	--	4
Powder	3	5	6	10	--
Antimony	--	2	6	--	2
Zinc filings	--	--	--	6	2
Red arsenic (realgar)	--	--	--	--	2

For yellow stars, a formula is as follows:

Nitrate of sodium	12
Charcoal	3
Sulphur	4½
Bicarbonate of soda	1
Sulphate of strontium	1

In the formula above, nitrate of strontium may be used in place of the sulphate. In this case, the proportion, instead of being one, is either one-half or three-quarters.

The formula for golden yellow is as follows:

Chlorate of potash	5
Bicarbonate of soda	1
Shellac	1

The formulas for green are as follows:

	1st.	2d.
Chlorate of potash	7	7
Shellac	3	3½
Nitrate of barium	10	12
Black smoke	--	1.3

Other formulas for green fire are the following:

	1st	2d.
Chlorate of barium	5	3
Nitrate of barium	2	–
Chloride of mercury (calomel)	1	1
Shellac	1	½

The formula for blue is as follows:

Chlorate of potash	5
Ammonium sulphate of copper	1
Shellac	1

The formula for a rosy flame is as follows:

Chlorate of potash	12
Chlorate of strontium	3
Carbonate of copper	2
Shellac	1½
Sulphur	2

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CHAPTER III.

GARNITURES.

The serpents are fashioned after the manner already fully described. Three most familiar forms of these small jets are distinguished one from another chiefly by the arrangement of the fuses, by which may be secured as desired either a whirling movement of the piece in discharging, or a spiraling motion. Whether of the simplest sort, which is not designed for revolving, or whirling, or spiraling, this firework is always small in size. Usually, the diameter is one centimeter, or a little more, and the length is three inches, or more. The composition for this simplest form of serpents is made up merely of 16 parts of powder, with three parts of hard-wood charcoal. But sometimes the charcoal is omitted.

For the whirling serpents, the composition contains 16 parts of powder and 3 parts of steel filings.

For spiraling serpents, the composition is exactly the same as the foregoing, since the only difference between this and the whirling variety is in the arrangement of the fuse within the case. Jets called pigeons, which have a length of 3 or 4 inches and a diameter of 2 or 2½ centimeters, sometimes carry, within an added pasteboard case at the bottom, a small load of star composition, or other special mixture, which is set off by a fuse after the burning out of the jet's charge. The composition with which such jets are loaded is as follows:

Powder	16
Grain powder	3
Bits of iron wire	3

The same composition is used in loading a form of whirling serpents, which are so made as to carry attached to each end a small case of pasteboard containing a Bengal light. These lights, in addition to being glued in place, are also held by a length of wire that passes over them and along the whole length of the jet, drawn taut.

The lights are so equipped with fuses that both burn at the same time as the jet itself.

A distinctive effect is sometimes secured by the use of a serpent for which iron filings are included in the charge, while the head of the jet carries also a pasteboard container holding a portion of star mixture, of a lively sort. The arrangement of the fuse is such that the star composition burns first, and the appearance of the serpent follows.

Often cartons 2 or 3 inches long are loaded in successive charges with compositions to give variously colored lights. Such cases carry usually at the bottom, within an added case, a portion of star mixture or other composition, which terminates the display.

When the garniture is designed to give the effect of a rain of fire, the case, which has ordinarily a length of 3 inches and a diameter of from 1 to 2 centimeters, is closed by a plug of clay at the base. It is then loaded loosely to within an inch of the top. The end of the case is merely folded over, and is not held firmly in place. In burning, therefore, the jet of fire issues from the orifice freely and copiously, thus giving the desired effect. Three different mixtures give satisfactory results, as follows:

Powder	16
Charcoal (hard wood)	3

Powder	16
Niter	1
Charcoal (hard wood)	8

Powder	16
Steel filings (finest)	8

CHAPTER IV.

FIXED FIRES.

JETS.

Fixed fires are those retained in their original position on the ground during the period of their discharge, but within the limits of their own place they may be given a considerable variety of movements. Jets used for such fixed fires are made in a variety of ways, according to the preference of the manufacturer. One method employs sections of cane, which is wound very closely with tarred string to within an inch of the top. Such a jet is loaded solidly with a rammer and mallet, which vary in size according to the caliber of the cane. Each sucessive charge is struck 14 or 15 blows with the mallet for the larger jets. A jet 3 inches in length contains three or four charges, one 4 inches in length has four or five charges, and so on. The cane is pierced to permit the introduction of the fuse, and loose powder is added in the space left for it above the charge. When such a jet is fired, a long tongue of flame darts from the mouth with vehemence. The force with which the fire issues is such that when the jet is mounted on a movable axis, it causes this axis to turn, with a speed proportioned to the liveliness of the composition. On this account, for revolving jets a quick-burning mixture is employed, while a slow composition is used in loading those jets that are to remain immovable. For the same reason in connection with the movement, the revolving jets are fashioned with a smaller orifice at the top than are the fixed pieces.

The different effects for such jets are controlled easily by the method of mounting and the arrangement of the fuses so as to control the combustion and to direct the energy of the burning gases in any required direction. The number of diverse forms in which such jets are attached is, in fact, only limited by the ingenuity of the artificer, and the special sorts are listed by manufacturers under many different names. Among the compositions used for loading fire fountains of small size are the following:

COMMON FIRE.

	1st.	2d.
Powder	100	16
Charcoal (hard wood)	--	3

SPARKLING FIRE.

	1st.	2d.
Powder	16	16
Iron filings	2	--
Steel filings	--	3

	1st.	2d.	3d.	4th.	5th.
Powder	16	16	16	18	16
Iron wire	4	3	--	--	--
Niter	--	1	1	2	4
Steel filings	--	--	3	5	3½
Sulphur	--	--	1	1	2

CHINESE FIRE.

	1st.	2d.	3d.
Powder	16	16	16
Cast iron	3	3	2
Niter	--	1	2
Charcoal (soft wood)	--	--	1
Sulphur	--	--	1

Compositions for fountains of large caliber are as follows:

SPARKLING FIRE.

	1st.	2d.	3d.	4th.
Powder	16	16	20	32
Niter	1	8	6	6
Sulphur	1	2	6	6
Steel filings	5	3½	6½	11

	1st.	2d.	3d.
Fine powder	16	15	14
Grain powder	2	2½	2
Niter	1½	6	10
Sulphur	--	6	8
Iron wire	5	6½	9
Charcoal (soft wood)	--	--	4

CHINESE FIRE.

	1st.	2d.	3d.	4th.
Powder	16	16	16	16
Niter	12	2	16	8
Sulphur	8	2	8	4
Charcoal (soft wood)	4	2	—	—
Cast iron	10	16	12	6

CAISSES OR MARRONS.

The variety of fireworks originally named marrons by the French is still popular, and is frequently shown under different names. The term caisse is employed to describe a similar piece for which the case is cubical. The charge used in these fireworks is the same, whether the pasteboard container has a cubical or a cylindrical form. The load is either of powder merely, or of a fulminating composition, which has a much greater violence. When the marron or caisse is loaded with powder, it is tightly wrapped with strong tarred string, in order to increase the force of the explosion. But when the fulminating composition is used, the wrapping is done with a lighter cord, and the turns about the container are not in the closest possible contact with one another.

The fulminating composition may be made as follows:

Chlorate of potash	4
Sulphur	1
Charcoal (light wood)	1

Another formula is:

Chlorate of potash	12
Antimony	12

It is to be noted that, while the first formula affords a composition of great strength, the second is still more violent. It is also of such susceptibility that extraordinary care is required in the handling of it, or a premature explosion may result.

FIRE LANCES AND BENGAL LIGHTS.

The lances have a long cylindrical case, loaded individually with a number of charges, which produce fires of various colors. Such pieces are adapted for purposes of illumination in the representation of temples, palaces, and the like, for elaborate pyrotechnic displays. The cases for these are made from paper of light weight, and since its strength is not sufficient to withstand the pressure of a rammer in loading, it is customary to use a sort of funnel, which extends its tube within the length of the case, closely fitting it. The charges are poured into the funnel and duly tamped, and, after the loading has been completed, the tubing is withdrawn. These lances may be of any desired size. There is nothing in the construction of them that requires explanation, beyond the one distinctive feature concerning the use of the funnel in charging.

Bengal lights are usually of the same character as the lances in the matter of the charge, but they lack the length of the latter. They are made with a diameter of two centimeters or more.

The difference in height between the lances and the Bengal lights requires a corresponding difference in the mixtures employed for loading them. It is necessary that the composition for the lances should be somewhat lively, that for the Bengal lights somewhat slow. It is required also that the composition for the lances should be of a sort leaving the smallest possible residuum from combustion, since an accumulation would choke the orifice of the tube, and the resulting flame would be rendered uneven and lacking in brilliancy.

Care must be taken in loading both the fire lances and the Bengal lights to observe a definite order in placing the successive charges within the case. The preference is to give first place to the composition producing a white flame. This should be followed in order by red and then green. After the green may come violet or blue or yellow. The green should not be next to the white, and it should never follow the red, because in such case the effect of the green would be changed to a light-blue tint. The order of charging may take any one of the three following forms, or it may be varied as desired within the limitations already suggested concerning the green light:

White, violet, green, red, white.
White, blue, green, red, white.
White, yellow, green, red, white.

The compositions for the colored lights displayed by fire lances are illustrated by the formulas that follow:

WHITE.

Niter	33
Sulphur	11
Powder	2
Antimony	5

YELLOW.

Chlorate of potash	4
Sulphur	2
Bicarbonate of soda	1
Nitrate of barium	½

An alternate formula is:

Nitrate of sodium	12
Sulphur	5
Charcoal	2

GREEN.

Chlorate of barium	3
Shellac	3⅛
Nitrate of barium	4
Black smoke	⅛

BLUE.

Chlorate of potash	8
Sulphur	3
Ammonium sulphate of copper	2

An alternate formula is:

Chlorate of potash	5
Oxychloride of copper	2
Shellac	1

RED.

Chlorate of potash	6
Sulphur	2½
Nitrate of strontium	9
Black smoke	⅛
Shellac	2

VIOLET.

Chlorate of potash	10
Shellac	3½
Gilder's chalk	2
Verde purgato	½
Chloride of mercury	½

The compositions for the various colors in Bengal lights are illustrated by the formulas that follow:

WHITE.

Niter	33
Sulphur	11
Powder	2
Antimony	4

An alternate formula is:

Niter	12
Sulphur	4
Realgar	1

YELLOW.

The formula for yellow is identical for both the lances and the Bengal lights.

BLUE.

Chlorate of copper	4
Shellac	1

But the formula of the blue composition for lances may be followed for Bengal lights.

RED.

Chlorate of potash	6
Nitrate of strontium	12
Shellac	4½
Black smoke	½

An alternate formula for the red is:

Chlorate of potash	3
Carbonate of strontium	8
Shellac	1

GREEN.

Chlorate of barium	18
Milk sugar (zucchero di latte)	3
Shellac	1

But the formula given for the green composition in lances may be used also for Bengal lights.

The violet fire for Bengal lights may be obtained from the formula already given for lances.

A variety of the Bengal lights is made of a larger size, reaching sometimes a length of two decimeters. The compositions for these are different, in some instances, from those for the smaller size of lights. The special mixtures for the white and red are here given:

WHITE.

Niter	33
Sulphur	8
Powder	$1\frac{1}{2}$
Antimony	5

RED.

Chlorate of potash	8
Sulphur	6
Nitrate of strontium	18
Black smoke	$\frac{1}{4}$

One of the most popular forms of fireworks is the Roman candle, the effect of which is universally pleasing to all observers. It consists simply of a long cylindrical case of especial strength, which is loaded with a lively composition. At regular intervals between the charges of this composition, stars are placed, each resting on a small charge of powder. In loading such a candle, a charge of grain powder is introduced into the case, and duly rammed. On this a star is laid lightly. The star should be of cylindrical shape and of such a diameter that it passes easily within the case. Above the star a charge of composition is poured in, and this is tamped very carefully in order not to explode the star underneath. Then a second charge of powder is poured on the composition, with another star following upon it, then more of the composition, and so on. The loading is completed with a charge of the composition, which reaches to about 2 inches below the orifice of the tube. A small quantity of powder paste is spread over the top of the charge. Some measure of practical experience is necessary for the proper loading of these cases. The quantity of grain powder that should be placed beneath each star varies. The amount is largest near the orifice, and it is smallest at the bottom of the tube. This is due to the fact that the case does not burn along with the composition, but much more slowly. Therefore, the first stars have a limited length of tube through which to issue, and require a larger charge to launch them, while the lower stars have a greater length of unburned tube, and so require a lighter charge, of which the force is augmented by the cylinder's length.

It is necessary that care be taken to regulate the charge with utmost nicety, in order to give the requisite degree of energy. Too much violence in the expulsion will cause the star to be extinguished by the swiftness of its flight through the air, while a lack of velocity will result in the star's dropping earthward immediately. Attention should be given also to the amount of the composition between the stars, since carelessness in this particular might result in setting off two stars at the same time. Any lack in due compression of the composition may have a like result. The minimum height for each charge between stars, after adequate ramming, should never be less than three times the interior diameter of the case.

Roman candles are sometimes equipped with globes of fire in place of the stars. These, in their passage through the air after their emergence from the case, leave behind them a long trail of sparks.

The composition employed for making such globes of fire is as follows:

Powder	32
Niter	8
Sulphur	1
Charcoal (hard wood)	6

The composition used for loading Roman candles is the same whether they carry the usual stars or the globes of fire. For the candles of small caliber, either of the two formulas following may be employed:

Powder	16
Charcoal	4

Powder	16
Niter	1
Charcoal	4

For large candles, the following formulas:

Powder	16
Niter	4
Sulphur	1
Charcoal	7

Powder	4
Niter	18
Sulphur	6
Charcoal	7

Niter	13
Sulphur	5
Charcoal	2

Sometimes the container is given a funnel shape, either larger or smaller, and is thus made to serve as a miniature mortar for the discharge of stars or globes or small grenades. The composition used in such pieces is the same as that given above.

CHAPTER V.

AËRIAL FIREWORKS.

ROCKETS.

In all the great diversity of fireworks that has been developed, the rocket still maintains its supremacy. It is today manufactured in various forms and equipped with distinctive garnitures adapted individually to serve a vast number of purposes. Its importance is by no means limited to its spectacular effect, designed for pleasant entertainment to the beholder, but it is of an impressive practical value in certain phases of its employment as the instrument of signaling or of direct illumination. As its utility in such directions has advanced, so its construction has been perfected, and the intensity of its effect has been magnified to an extraordinary extent. The largest sizes are now provided with lights of utmost brilliancy, which are supported by parachutes proportioned in size.

The general principles governing the construction of rockets have remained unchanged. The only present variation is in the matter of details. The most interesting variation in the present methods from those of the past has to do with the air chamber, or the "soul of the rocket," as it is still called in French and Italian. There have been alterations as to this cavity, both as to its dimensions and as to the means employed in making it. Where formerly the case was loaded on a spindle, by which a conical empty space was secured inside the charge, the present fashion prefers a solid loading of the case without use of a piercer, and the subsequent boring of the charge from the bottom, in order to secure the required air chamber. In this case, the opening is made by means of a gage which has a sharp, curving cutting end, with a shaft somewhat smaller in diameter and of a length appropriate to the size of the rocket. By the use of this tool, a cylindrical opening is made within the charge, which extends to the required distance. Of course, during this boring process, care must be exercised to avoid any overheating of the tool, which might kindle the charge. The usual measurements for the air chamber made in this manner give it a diameter one-third that of the interior diameter of the case and a length two-thirds that of the charge. This method is followed generally in the manufacture of small rockets and those of medium size. It is not, however, employed in the making of large rockets. The rockets of smaller size are loaded merely with powder, and a subsequent making of the cavity offers little danger. Frequently, too, where a more striking effect is desired, ease in the making is secured by loading the case for two-thirds its height with powder, and then completing the charge with a livelier mixture. This compromise method permits a reasonably safe boring.

While various facts, long ago determined, as to the proper relative weights of garniture and rocket remain essentially undisturbed, the rule now is that the garniture shall not exceed one-third the weight of the rocket.

So, also, the balancing point of the rocket remains about the same, and the usual proportion of the stick's length is about twelve times that of the rocket.

While powder of an ordinary sort has sufficient force for giving flight to a small rocket, a special mixture is demanded for the rocket of larger caliber.

Three formulas for such compositions are as follows:

Powder	16
Niter	4
Sulphur	1¼
Charcoal (hard wood)	4

Powder	33
Charcoal (hard wood)	2

Or the charcoal may be reduced to one and one-half.

Powder	16
Niter	10
Sulphur	2¼
Charcoal (hard wood)	6

Of the above formulas, the first and second may be properly used for rockets of medium size, but the third is designed exclusively for large rockets.

Formulas for the brilliant fire to be used in loading large rockets are as follows:

Powder	16
Niter	1
Sulphur	1
Steel filings	5

Powder	24
Niter	5
Sulphur	13
Steel filings	5¼
Charcoal (soft wood)	19

The following formula is used to secure the effect of Chinese fire:

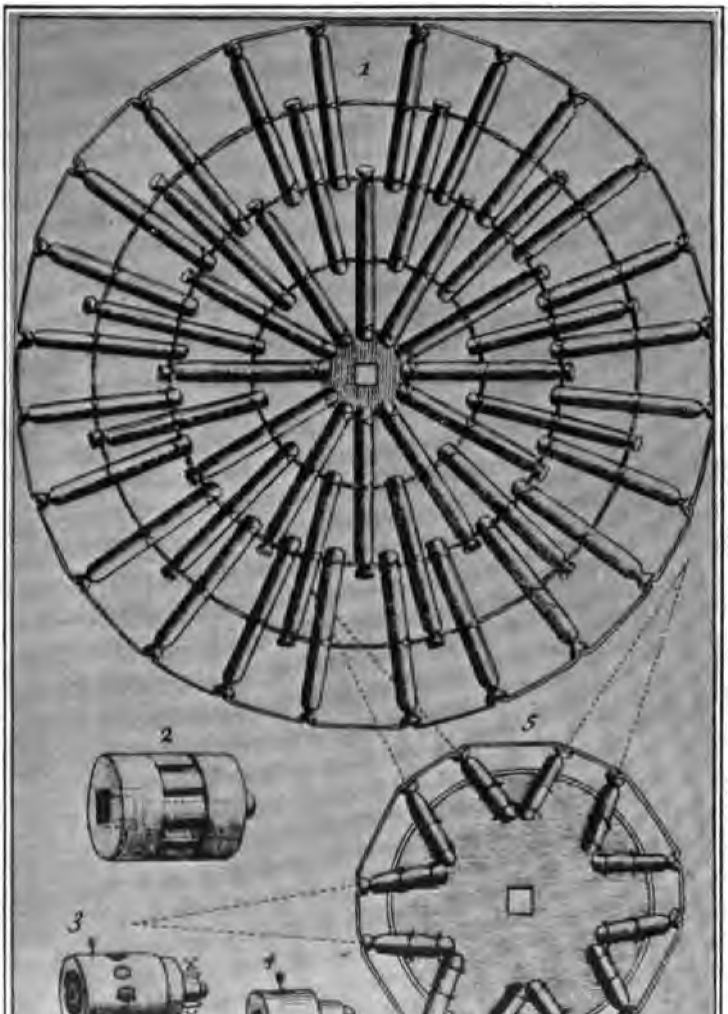
Powder	15¾
Niter	10
Sulphur	5
Cast-iron filings	5

The mixtures indicated above are commonly used for the upper third of the charge, while the lower two-thirds is of powder and charcoal, loaded solidly and afterward bored. This method is followed especially in the manufacture of medium-size rockets, and the change in the spectacle, offered as the fire passes from the first part of the charge to the second, produces an agreeable effect. Such contrast is often emphasized by added variations between the two mixtures.

The garnitures with which rockets are equipped are almost endless in the diversity of their forms, but the innumerable variants are all derived from sources with which we are already thoroughly familiar from our historical examination of the subject. In addition to the different garnitures, the rockets themselves are often combined so that a number are united in their flight to form a distinctive display, regulated by their arrangement and the manner of their discharge, which may be either simultaneous or in sequence, according to the distribution of the fuses.

There has been no notable change in the principles governing the construction of table rockets, which are still unfailingly popular for their pleasing effects of light and movement directed by the disposition of the fuses. Powder alone

PLATE IX.



suffices for the loading of small table rockets. For those of larger size, charcoal is added.

Powder	16
Charcoal	3

For a sparkling-fire effect:

Powder	16
Steel filings	8

Either of two formulas may be employed to produce Chinese fire:

Powder	16
Niter	2
Sulphur	1
Charcoal	1
Cast-iron filings	2

Powder	8
Niter	2
Sulphur	1
Cast-iron filings	3

BOMBS AND GRENADES.

Bombs or grenades share with rockets the popular favor as spectacles. They are now manufactured in an almost endless variety, but in their essentials they are unchanged. They are so constructed as to withstand the shock of being projected from a mortar, and are filled with any desired collection of small fireworks, which, when a certain altitude is reached, are kindled and cast out. Great ingenuity is often displayed in the loading of bombs or grenades. Thus, stars of various colors are arranged in orderly ranks, and in combination with them are used the different styles of serpents, girandoles, and the like. The rain of fire also is thus carried aloft, and the grenades are sometimes finished with caisses or marrons. One of the most charming effects is obtained by the use of grenades carrying fiery globes. These spheres are essentially a larger form of stars. A particular formula is employed in making the paste:

Powder	33
Sulphur	8
Charcoal	6
Niter	4
Black smoke	1
Dextrin	1

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Practical experience in connection with this mixture has demonstrated that the charcoal is most satisfactory when made from oak or beech, very finely ground. The composition in which oak charcoal is used has a more ruddy tinge to the flame in burning, while the beech charcoal gives a golden color; but the reddish hue endures during a longer interval than does the gold.

The dextrin, which serves to give adhesiveness to the mass, is first dissolved in an equal weight of water, and this quantity of water is sufficient for moistening the whole composition.

Grenades are also sometimes finished with balls of white fire, for which the following composition is used:

Niter	36
Powder	12
Antimony	12
Sulphur	10

The mixture is made into a paste, using the necessary amount of gum-arabic water.

By suitable changes in the composition, the spheres may be given any desired color.

An effect of peculiar beauty is secured by adding to the stars, or other pieces in a grenade, a number of parachutes supporting colored lights. The making of such grenades requires extreme nicety on the part of the worker, and much practical experience as well. But the result, when successful, fully justifies the labor involved.

A distinctive variation in the effect is secured by loading a bomb with grenades that have the appearance of luminous globes floating through the air after their discharge. For this purpose, the grenades are prepared by covering them with a star paste. To strengthen the grenade, it is first wound with cotton thread, which has been soaked in the paste. The whole is then thoroughly coated with the composition. A white light is usually preferred for such globes, and the following formula may be used.

Niter	16
Sulphur	8
Powder	6
Camphor	1

CHAPTER VI.

SPECTACULAR EFFECTS.

In the present development of pyrotechny there is almost no limit to be placed on the ornate forms of spectacular entertainment. The principles that have already been described are capable of infinite modifications and variations. Almost any desired effect may be achieved by a suitable mingling of pyrotechnic materials and devices. All the resources of chemistry are at the disposal of the artificer, so that he has full control over both the appearance and the activity of the chosen fires. He is free either to imitate the most majestic and the most terrible wonders of Nature's own displays, or he may give free reign to his imagination, and so contrive other dreadful or glorious interpretations of his mood by the fire magic. His requirements for the task are of the simplest in essentials, yet endlessly complex in the possible variations and adaptations. Now, as always, he has need of a suitable composition, the combustion of which shall be exact, in harmony with his purposes. He has need also, for his more impressive pageants, of frameworks to hold any given number of pyrotechnic pieces in such disposition as shall render their discharge accurate according to his plan. The colors of the flames are completely subject to his will, through his intelligent choice of chemical substances in the mixtures with which the various pieces are charged. The exact moment of discharge for each piece, as well as the precise manner of its discharge, is carefully regulated by the fashion in which the matches are laid. The total of the spectacular results is definitely subject to the artificer's will, by means of the framework. This contains, in fact, the bones of that skeleton over which he lays a wondrous-hued flesh of living flames.

The commercial exploitation of fireworks adequately demonstrates the vast possibilities for such scenic triumphs. Displays of the most ornate character are offered to the public. The crowd is familiar with the burning of Rome, with the eruption of Mount Pelée, with innumerable other cataclysmic panoramas. And, too, the crowd is familiar not only with the splendors of the terrible, but also with the splendors of pure beauty. For the art of pyrotechny gives all its treasures gladly for the presentation of ideal loveliness, wrought in shimmering textures of fire. The artificer is, indeed, a magician, at the touch of whose wand subtle dreams of glory become incarnate in flame.

Perhaps the only essential novelty developed within recent years is the use of daylight effects. An interesting phase has come from the Japanese. To their ingenuity we owe the idea of garnishing a bomb or grenade with the figures of persons or animals, or what not. These effects are not produced by combustion, but by the constructions of an exceedingly light framework, which is covered with sheer silken fabric, duly colored in accordance with the particular design. As the projectile reaches its extreme altitude, the figure is thrown out, and then floats in the air, suspended by parachutes.

Since we have given credit to the Japanese, it is only fair that we should refer also to the Chinese, who, through so many ages, have remained steadfastly devoted to the simplest forms of the art of pyrotechny. Generation after generation, the Chinese have gone on making firecrackers, of which they were the originators. To the Chinese, firecrackers are appropriate to almost every occasion. They are often a conspicuous part in hospitable rites. They crackle merrily at wedding celebrations and birthdays. They make noisy every day of rejoicing. They are believed to ward off evil, to woo good influences. The coarse bamboo paper used in the manufacture of them is colored red because this hue attracts good fortune, according to the Chinese superstition. China itself annually consumes an enormous number of firecrackers, which are chiefly manufactured in the Canton district. In addition, the exports of this humble, yet highly esteemed, pyrotechnic device amount to about three million dollars' worth yearly.

CHAPTER VII.

PYROTECHNY IN THE WORLD WAR.

If any person be inclined to doubt the practical importance of pyrotechny in military operations, let such a skeptic consider the fact that, in the World War, the British troops used position lights at the rate of ten millions a month. When we consider that this quantity was for merely a single sort of firework, while a great number of various other devices were in constant use, and when we consider, further, that the figures are for the requirements of only one nation among the many battling nations, we are compelled to realize the vast and vital significance of the pryotechnic art in modern warfare.

Throughout history, darkness has always been recognized as a supreme hindrance to military operations. The first efforts toward an effective artificial form of illumination that should serve to dispel the obscurity of nighttime, and thus permit some degree of successful belligerent activity, was undertaken by the French in the reign of Louis XIV. To this end, the military experimenters employed powerful rockets equipped with parachute flares, which attained a considerable measure of success. At this same time, also, the British military experts, following a similar line of experimentation, secured almost parallel results. Reference has been made in a previous chapter to the enthusiasm prevalent in this period over the possibilities of pyrotechnic agents in warfare, and it has also been pointed out that this enthusiasm vanished when the increased range of rifles and cannon reduced the flight of any firework to comparative unimportance. Indeed, the reaction was such that the military authorities ignored even the value of devices for purposes of illumination, apart from any use as missiles. So, exact knowledge in this direction, obtained with much difficulty, was first neglected, and then lost.

There was, in fact, no serious revival of the effort toward night illumination as a war measure until 1870. But, during the siege of Paris, the engineer Bazin contrived an electrical lighting post, which was established at the Moulin de la Galette, on the Heights of Montmartre. This light was operated with a fair degree of success. Its shaft had a range of about 10 kilometers. This was sufficient to cover the peninsula of Gennevilliers. The illumination was effective in preventing the Germans from crossing the Seine at this point.

Nevertheless, 30 years elapsed before this matter of night lighting was again taken up. Experiments were conducted year after year, but it was not until 1910 that a specific result was attained. This was an illuminating automobile, which appeared in the maneuvers at Beauce. Its achievement, however, was not notably successful. A primary defect lay in the fact that its power was insufficient. The shaft of light was so narrow that it necessitated constant movement in every direction. The effect was to render observations both difficult and unsatisfactory. Moreover, the slightest obstacle in its path nullified the effect. It was wholly at the mercy of any irregularity in the terrain, or any interference by walls or buildings. The removal of the apparatus to an elevated site, in order to overcome such obstacles, was a dangerous expedient, since the light thus immediately became the target of hostile projectiles, a prey to quick destruction.

But, already, the evident difficulties in the way of electrical lighting had led the French authorities to consider a revival of the old methods of illumination through the use of rocket devices. The pyrotechnic school at Bourges busied itself with the problem, but found many difficulties in the way. The skill displayed by the artificers centuries before, under the monarchy, had been forgotten, and its restoration was a tedious task. It was not until near the end of 1901 that the long-continued research produced an illuminating apparatus approximately satisfactory. But, once a start had been made, progress was swift and sure, and its end was triumphant.

Naturally, the German staff, in its avid preparations for combat, did not neglect a means of such importance. The Krupp works developed a projectile, which appeared in 1913 under the name of searchlight shell. In its essentials, this is the star shell made familiar to the world in the war. It contains within the shell a number of small cylinders, called stars, loaded with the illuminating composition. The mixture used is similar to that in white Bengal lights; but threads or ribbons of magnesium may be substituted. The usual number of tubes is six. A very small folded parachute of silk is placed in the bottom of each tube, to support it when cast out of the shell. . . . The French have constructed a similar projectile, containing eight cylinders, which is fired from the short 155 gun.

The shell of the Krupp firework contains a very light charge of powder. This serves two purposes: to kindle the composition in the star cylinders and to throw out the base of the shell, which is held in place only by a weak resistant thread, and, along with this, the tubes. As each cylinder thus issues from out the shell, its parachute is released by the extension of a small lock spring. The parachute is fitted also with a spring that causes the silk to spread open instantly. The cylinder, on dropping, immediately assumes its required position under the parachute, with the burning end downward. The combustion of the illuminating material continues for a period that varies from 45 seconds to several minutes, according to the particular model. The star projects a vivid light toward the ground in the form of a huge cone.

The powder charge of the shell in the German firework is ignited when the projectile has reached the proper point in its flight, by means of a mechanical time fuse, or clockwork movement. The French preference, however, is for a time fuse using a powder train.

It has been found that the most advantageous height for the explosion is 300 meters.

A more recent variation of the luminous projectile manufactured at the Krupp works substitutes for the star cylinders a six-sided prism, which carries the combustion material. This shape leaves a smaller amount of space unoccupied within the shell. Moreover, the prism itself is completely filled with the composition, while the stars were only partly filled. In the old construction, the folded parachute occupied the upper half of each tube. In the new construction, a totally different parachute method is employed. Instead of individual support for each separate cylinder, the parachute is a single one for the whole prism. It is formed from six plates, which have the office of supporting planes. One end of each plate is attached by a hinge to the upper part of the prism. This plane exactly corresponds to a face of the prism, and folds down flat over the face. Thus, when the prism is inserted within the shell, the six plates take up almost no room, as they lie flat against the sides of the prism. But, with the expulsion of the prism from the shell, when the powder charge is exploded, a spring instantly sets them at right angles to the faces of the prism. The resistance of the plates has the effect of a parachute, and the descent of the prism is sufficiently retarded. By means of this device, the economy of space is such that a light of greater intensity, or of longer duration, is secured. This form of projectile, as thrown by cannon, has also been adapted for use with rifles and special pistols, and with carbines of large caliber.

The star shells have been constantly used during the war, and their efficacy has been enormous. But there have been endless other means of illumination, with equally endless variations in the styles of construction. Among the simplest and most useful of these are the illuminating hand grenades. These are of the utmost practical value at night in the effort to repulse wave attacks against intrenchments. When they are thrown in front of an advancing enemy, the light from their combustion renders possible a precise aim in firing, so that shots which would otherwise be wasted in the darkness have a deadly effect. Such grenades are also of much utility to aëronauts in dirigibles and in aëroplanes, since they are available as illuminating agents, whether for purposes of observation or of bombardment.

A distinct class of the illuminating projectile is the tracer bomb, which is directed against both dirigibles and aëroplanes. The difficulty of attacking either the dirigible or aëroplane in the air is due, not only to the great mobility of the objective, but also to the fact that the marksman is unable to determine precisely wherein lies any inaccuracy of aim. He cannot detect the exact nature of his fault, whether the error be as to height or direction. The conditions of markmanship aloft are radically different from those on the ground, where observation is possible concerning the point at which the projectile falls, and by careful observance one may rectify any error. The tracer bomb solves the difficulty for aërial combat, since it defines a luminous trajectory, by which its failure to reach the mark is clearly indicated, and opportunity is offered for remedying mistake.

This variety of bomb has the ordinary form, but there is an essential variation in the construction. The point is pierced with holes, and the space adjacent within the point is filled with a powerful illuminating powder. The powder is also incendiary. When the projectile is launched, the powder is immediately ignited. Flames from the combustion issue out of the holes in the nose, and thus a luminous light flashes for the whole trajectory of the bomb.

While such tracer bombs may also be incendiary, they are not to be identified with the ordinary incendiary projectiles. The purely incendiary bomb contains a number of cylinders filled with a mixture suited to incendiary purposes. This is a composition in which nitrate of baryta is used with priming powder. The cylinders are equipped with quick fuses. Each cylinder is separately covered with tarred cloth. The interstices about the cylinders are filled with powder.

It must be conceded that, under particular circumstances, fireworks may prove futile when used in an effort for communication. This is not due to any inherent fault in the devices themselves, but is occasioned by some extraordinary difficulty encountered. An illustration is afforded by the experience of a British sector, when the Germans preceded a local offensive by a discharge of fireworks, in which every conceivable variety was employed. The effect of this spectacular medley was a flaming confusion in the heavens, through which nothing could be distinguished with the exactness essential for the reading of signals. When the British front line sent up its summons for the barrage, the artillery watchers were powerless to read the message amid the baffling flames flung forth by the enemy. Often, too, the air becomes charged with dust and smoke overlying the battlefield until it attains a density in which lesser lights vanish utterly, and even the most brilliant radiance becomes powerless to pierce the dun war cloud with its rays.

Nevertheless, this war has shown, as never before, the vital worth of pyrotechnic devices in military operations. Under anything approaching normal conditions, the use of fireworks offers a method of communication that is equally quick and exact. It suffices admirably for messages from the foremost positions to headquarters, or to the artillery stations. It is available for ready communication between sectors; between the front line and its advanced posts; between aëronauts aloft and persons on the ground. It has been proven that fireworks often remain a possible means for sending messages when all other methods of communication have been cut off. Since such communication is a prime necessity for successful warfare, the importance of pyrotechny is manifest.

On the entry of the United States into the war, it was decided to adopt the French system of pyrotechny, since the American forces were to operate in a sector held by the French Army, which rendered imperative an identical system of signals. There has been much discussion concerning the respective merits of French and British methods, which differ radically. The French employed a far greater variety of signals, and were even increasing the number of types when the armistice was declared. In spite of this divergence, however, both systems worked very satisfactorily. The American adoption of the French method was due to the circumstances of location, rather than to superior merit as compared with the British scheme.

Four general designs in firework devices were in constant use by both the French and the British armies. These included signal pistols, rifle lights, rockets, and position or ground lights. In a general way the fireworks employed by the Germans were similar to those of the French. But there was an important difference in the method of construction for the signal-pistol cartridge. The German cartridge was lighted on the instant of leaving the pistol. The illumination thus began at the moment of discharge, continuing throughout the trajectory. This effect was sometimes of great value, as, for example, when such a cartridge flared suddenly over no man's land and the raiders, unwarned, had no time even to flatten out on the ground. All the French cartridges were fitted with delay fuses, by which the ignition was effected only when the star reached its limit of height.

Some realization of the development in pyrotechnic construction due to the war may be had by considering the latest French products for the 35-millimeter signal cartridge, which are enumerated in the following list:

Trail of black smoke.
Red star.
Green star.
Two white stars.
Three white stars.
Six white stars.
Six red stars.
Red smoke.
Yellow smoke.
White caterpillar.
Red caterpillar.
Green caterpillar.
Changing-color cartridges.
Message cartridges.

Before the outbreak of the war the art of pyrotechny had reached such a point that there was little difficulty to be encountered in securing adequate star mixtures for the various colors required in signaling. The use of various lights had by no means been limited to merely spectacular display. The certainty of the coloring had been tested in many practical ways and found efficient as a working agent. Thus, the railroad companies regularly employed such pyrotechnic devices, with results wholly satisfactory, after the manner to which reference has been made in a previous chapter.

So, too, the pilots of Boston and New York are familiar from actual experience with the blue light.

The military artificer, therefore, had ready to his need formulas for the making of compositions to produce whatever color he might desire. The following will serve by way of illustration:

Aluminum white star:	
Aluminum	2½
Potassium nitrate	14
Sulphur	4
Antimony sulphide	3½
Dextrin	1
Meal powder	1½
Aluminum green star:	
Barium chlorate	8
Aluminum	6
Potassium chlorate	4
Fine charcoal	1½
Dextrin	1
Barium nitrate	8
Red gum	2
Aluminum blue star:	
Potassium chlorate	16
Paris green	8
Shellac	½
Aluminum	4
Dextrin	1
Aluminum gold star:	
Aluminum	2
Potassium chlorate	8
Barium chlorate	2
Shellac	1
Sodium oxalate	1
Magnesium carbonate	½
Brilliant aluminum flash:	
Aluminum	5
Potassium chlorate	5
Aluminum red star:	
Strontium carbonate	2
Potassium chlorate	12
Aluminum	4
Shellac	1
Fine charcoal	½
Dextrin	1
Aluminum hand lights:	
Barium nitrate	17
Aluminum	5½
Sulphur	3
Aluminum granule:	
Potassium nitrate	7
Sulphur	2
Antimony sulphide	1¾
Aluminum	1½
Dextrin	½

Marine flare torch:

Barium nitrate	24
Potassium nitrate	12
Sulphur	3
Red gum	3
Strontium carbonate	1½

Pilot's blue light:

Potassium chlorate	11½
Calomel	¾
Shellac	12
Sulphur	7
Copper oxychloride	8

Railroad fusee signal (red):

Strontium nitrate	180
Sulphur	25
Potassium chlorate	30
Red gum	10
Sawdust and grease mixture	10
Calcium carbonate	2½

Potassium perchlorate may be largely substituted for potassium chlorate.

French white fire:

Potassium nitrate	36
Antimony, regulus	12
Red lead	11
Sulphur	4

White smoke:

Calomel	4
Potassium nitrate	3
Copper oxychloride	2¾
Potassium chlorate	2
Sugar	1
Sulphur	½

The Germans used a signal-pistol light having a star contained in a metal cylinder. The mixture used was of barium nitrate and aluminum dust, together with a small amount of binding material. In other pistol signals, a small cartridge was employed for a flash of illumination, which had its body sometimes of cardboard, sometimes of copper, with the mixture inclosed within a zinc tube. Still a third form was a small cartridge with a long fuse. This was distinguished by a more powerful firing charge. A zinc cylinder within the cartridge contained two free stars, which were surrounded with priming powder. At the base, a compact mass of black powder and aluminum powder assisted in the propulsion.

The Germans used also long cardboard cartridges that carried either two- or four-star signals, contained in zinc cylinders. One style of cartridge, fitted with a parachute, served for bearing aloft either a signal or a message. This had a shell of cardboard. The dimensions were 78 millimeters of length and 26 millimeters of diameter, the diameter of the base having an additional 4 millimeters. A smaller cardboard cylinder, 18 centimeters in length, was introduced into this shell. It contained the parachute and fuse. The parachute was of paper, somewhat similar to the Japanese, with a diameter of about 20 centimeters. A propelling charge was placed in the lower part of the cylinder, which communicated with the charge of the small cartridge by means of a match. This construction is of especial interest since it points the way for a pistol light carrying the desired number of stars, which can be fired from ordinary 10- or 12-gauge cardboard shotgun shells, readily available in any desired quantity.

The Eizfelds signal cartridge, employed by the Germans, was made up of a metallic case loaded with powder, and carrying a cylindrical block of illuminating mixture, of which the composition was:

Barium chlorate	84
Gumlac	16

It should be remarked that in this instance barium chlorate serves in place of the nitrate. Thus, the Germans effected a necessary economy. This substitution was made possible by perfecting the electrolytic manufacture of barium chlorate through development from the chloride.

In general, the German signal cartridges included four distinct types. The first of these had a non-removable charge, giving a white light; the second, a removable charge, burning with a yellow light; the third, a non-removable charge, having a red illumination with stars; the fourth, a removable charge, having a red light.

In every instance there was a cartridge case of either brass or galvanized iron, which merged into a cylinder case of stout cardboard, colored on the outside according to the fire to be given off. The cartridge contained a primer and a charge of black granulated powder. A zinc tube was inserted into the cardboard case and allowed to project, or it was maintained solidly in position by crimping the cardboard on the inside of the case. The former method was used in connection with the removable charge, while the latter was used for the non-removable. This zinc tube contained a charge of black powder that ignited at the moment of discharge. It thus acted as a relay, and kindled the illuminating mixture. These cartridge cases were 31-millimeter caliber at the base, and 26.5 millimeters at the orifice, while the cardboard cases were 26 millimeters.

The length of the cartridge varied according to the type, from 104 millimeters for the red removable, to 75 millimeters for white non-removable. But the cardboard case was always very short, varying from 8.5 millimeters to 11 millimeters.

A special pistol was required for firing such cartridges.

The various mixtures used were as follows:

Non-removable white firing charge (0.800 grams black powder):	
Nitrate of potash	75
Charcoal	15
Sulphur	10
Powder relay (6 grams black compressed powder):	
Nitrate of potash	69
Charcoal	19
Sulphur	12
Illuminating charge:	
Compressed compounded baryta nitrate	61.5
Aluminum powder	20
Sulphur	18.5

This mixture burned excellently with a dazzling white flare.

Yellow removable illuminating charge:	
Firing charge 2 grams black powder, of the same composition as the preceding.	
Powder relay (9.5 grams mixed powder):	
Nitrate of potash	65.9
Sulphur	8.5
Powdered aluminum	5.1
Charcoal	16
Agglomerating material	3.5
Humidity	1

The illuminating charge was composed of four small cylinders formed from slightly agglomerated substances. The total weight of the cylinders was 10.8 grams. They were placed one on top of another. The composition was as follows:

Magnesium	67.9
Chlorate of potash	2.6
Oxalate of soda	17.4
Powdered aluminum	2
Sawdust	9.6
Gum-lac	.5

This mixture burned readily with a yellow flame.

In the other two types the illuminating charges were as follows:

Red with stars (weight 13.4 grams):

Chlorate of potash	66.9
Carbonate of strontium	8.7
Gum	16.4
Bitumen	8

This burned with a beautiful red flame.

Violet red with stars (weight 14.8):

Chlorate of potash	55
Aluminum scales	25
Carbonate of strontium	10
Bitumen	10

The color of this also was brilliant.

The use of small scales of aluminum, instead of the powder, caused the mixture to burn more readily. It is to be noted, also, that carbonate of strontium was substituted for the oxalate generally employed.

A special perforated luminous ball cartridge was devised by the Germans for use with aëroplane machine guns. This cartridge contained two charges, one above the other, for driving and for illuminating, respectively. The composition was as follows:

Igniting charge:

Permanganate of potash	54.9
Iron	45.1

Illuminating charge:

Magnesium	64.68
Strontium nitrate	19.29
Hydrated lime	11.74
Resinous organic matter	4.29

An interesting revival of an ancient form of war rockets was made by the Germans, who fashioned cases of iron for a signal rocket of large size.

This rocket, carrying stars, consisted of a cylindrical iron tube, fitted also with an iron head containing the garniture of stars, over which was set a conical cap. The base of the tube was equipped with a cone-shaped tail, which was hollow, but with no orifice at the point.

The tube was fashioned out of sheet iron, with a brazed longitudinal single-riveted lap-joint. In the lower end of the tube, a brass plate was brazed and riveted, with an internally screwed boss projecting 9.5 millimeters from its center. This brass plate was also pierced with six holes, each 16 millimeters in diameter, which were arranged in a circle around the projecting boss.

Five of these holes were covered with paper and painted linen cloth. The sixth hole contained a wooden plug, pierced centrally to receive the igniting device.[1]

The tubular case of iron was loaded with a rocket composition. A cylindrical cavity of 24 millimeters diameter reached from the bottom of the charge almost to the top. Immediately above the rocket composition was a copper plate, from which a brass tube, filled with the igniting powder, led into the rocket head. Over the upper surface of this plate was a layer of cast sulphur, 60 millimeters deep.

The conical tail was of sheet iron, brazed at the joint end to a solid screw plug by which it was made fast in the base plate of the rocket tube.

The head was a canister of thin tin sheet iron. The connection with the rocket case was by means of a short tube of sheet iron fastened to the base of the canister by four lugs. These were contiguous to the short tube, and were set at right angles to it. Four cup-head screw bolts, with square nuts, attached the tube to the rocket case. The head itself was lined with brown paper, and contained the stars. Loose meal powder was poured in with the lower layers of stars, and a double strand of quick match, 780 to 790 millimeters in length, was placed within the head. A paper tube, containing two strands of quick match, extended upward to

[1] Compare description of Hale's war rocket in Appendix A.

the center of the head from the small tube set in sulphur within the rocket case.

The stars for this rocket were of two sizes, arranged in layers. The large stars were placed in an outer ring of nine, and the small stars in an inner ring of four. This disposition was followed for the lower five layers of large stars, and for seven layers of the small stars. But in the top outer ring, the sixth, two of the large stars were replaced by two small stars. Finally, above these layers, the space within the conical cover was occupied by two small stars and one large. A mass of coarsely felted crude wool was placed over the stars.

The conical cap itself was of thin tin sheet iron. It was held to the head by two bayonet joints, and painted linen tape covered the junction of head and cap.

In a consideration of bombs used for purposes of illumination, the war has emphasized the importance of a construction such that the projectile may be sent up without leaving a trail of light, which would give warning to the enemy and prevent surprise. For this reason, special care has been given to the ignition device for such bombs. It has been found best that they should be ignited from both ends, so as to burn rapidly. Meal powder is used for the ignition, so that the smoke trail may be avoided, while the kindling of the bomb is both quick and certain. Thus, for example, the dark ignition cartridge, fired from a Véry pistol at an elevation of 60°, reaches the height of its flight at a distance of about 100 yards, when the bomb is ignited. Another form of this cartridge for the large Véry gun has a parachute attachment, and it may be employed either for illumination or for signaling.

Ground flares giving lights of various colors have been found extremely useful. The latest form is remarkably compact, the material being contained in a small cylinder about 1½ inches long. This is water tight, but the covering is easily broken off at the end, where it may be ignited by the disclosed tape and cap. Such flares, when placed in a trench or shell hole, are distinctly visible from aëroplanes even in the daytime, while they are hidden from the enemy. Their worth in military operations of various sorts is obvious. It is of such flares that the British forces have been using ten millions monthly.

The British have developed also a 3-inch paper mortar for projecting signal bombs. Bombs of this variety when aloft release three colored stars that remain suspended in the air by means of a parachute. The stars are held together by 12 feet of asbestos thread. The convenience of the device is increased by the fact that the package containing it is easy to carry. A similar contrivance has been adapted to rifle grenades.

The Germans made use of a green position light, which was contained in a cylindrical zinc box, 205 millimeters in diameter and 30 millimeters in height. The illuminating charge was provided with an igniter, which was acted on by a function striker. The edges of the cover were extended over almost the entire lateral cylindrical surface of the box. The joints were protected by a band of gummed paper. A short tube, 40 millimeters in diameter and 30 millimeters in height, penetrated the cover in the center. This was soldered on the outside, and threaded to receive a zinc cap forming the plug. A function striker was set on the exterior face of this cap. A match stick was placed in the center of the tube, head upward. The head was protected by a felt washer in the bottom of the cap. The upper part of the tube contained a layer of black powder around the match, which aided in the ignition of the charge below.

The illuminating charge for one such light was as follows:

Barium nitrate	82.5
Tar	14.5
Rough nitrate (lime salts, magnesium salts, etc.)	3

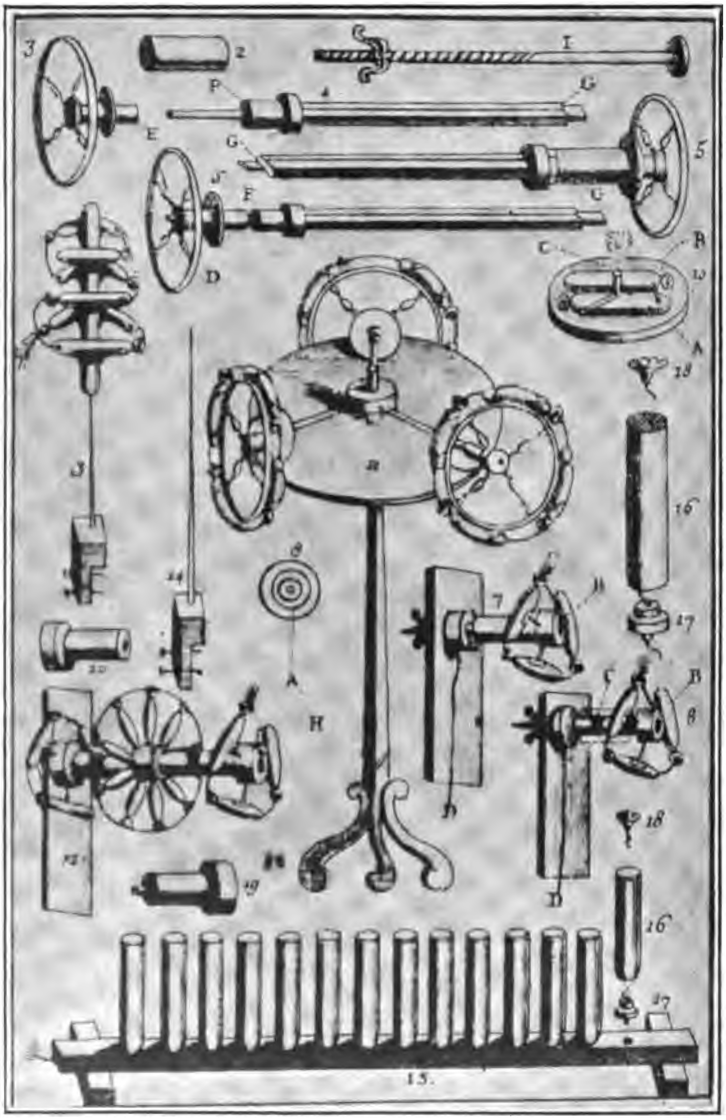
Another composition was as follows:

Barium nitrate	66.4
Potassium nitrate	9.5
Powdered aluminum	7.5
Resin (wood-tar pitch), with some oil and wood fiber	15.8
Volatile matter	.8

The paste covering the head of the wooden match stick was of the following composition:

Potassium chlorate	48
Clay	40
Glue	12

PLATE X.



This coating was topped with a red paste having a phosphorus base.

In the operation of the light, the first effect of combustion within was to melt the zinc cover. The burning then proceeded with great rapidity, and a vivid greenish-white flame was produced, with very little accompanying smoke. The containing box itself was consumed. The whole period of combustion was nearly a minute.

The Germans employed also a lighting device of calcium phosphide contained in a metal basket. When this was released from an airship no special effect resulted if the basket fell to the ground. But if it fell into water it was instantly rendered active. Phosphoreted hydrogen was thus generated, which ignited spontaneously in the air. The combustion was easily visible to the personnel of the airship. The effect was to reveal the fact that the flight was over water.

This bomb consisted of a cylindrical tin box, having a length of 20 centimeters, and a diameter of 7 centimeters, which was divided into three compartments by means of two transverse partitions. The outside compartments were left empty, and thus served as floats. The metal covering the center compartment was cut into a latticework over a portion of its extent. This same part was provided with a hole in the center, which was closed by a lead plate, soldered on. The plate served also as ballast for the device when in the water. One end of the basket was equipped with a ring, by which it was supported before the launching. A tin band was soldered over the latticework. When the bomb was to be released, this band was removed by a pull on a ring fixed in one of its ends. The middle compartment of the basket was filled with grains of calcium phosphide having a chocolate color. The total weight of the contrivance was 470 grams, of which 250 grams were for the charge.

The construction of this device was such that, on falling into water, it immediately rose to the surface, and the effect of immersion on the calcium phosphide was the generation of phosphoreted hydrogen, which instantly burst into flame on contact with the air.

A German torch flare, in a zinc case 20 millimeters in diameter, used a mixture of barium nitrate, potassium chlorate, shellac, and aluminum powder. One of these flares burned quickly with a fairly brilliant green flame for seven and one-quarter minutes. The zinc tube of this torch, 1.5 millimeters thick, was consumed during the process of combustion, partly by melting and partly by oxidation.

Another variety of German flare was formed from a red cardboard cylinder closed at the top end with a brass cover, in which was set the percussion cap. The base of the cylinder contained two thick felt wads, on which the incendiary candle rested. A third felt wad was set in the cylinder above the top of the candle. This was perforated in order to afford communication between the candle and the cavity immediately below the percussion cap. The cavity was filled with coarse black powder, 1.9 grams. Priming paste was smeared over the lower surface of the cap. The incendiary candle itself was a red Véry light, of cylindrical shape. It was marked with two lateral grooves. It was also perforated centrally. Six strands of non-nitrated cotton wick were thrust into the hollowed-out part of the candle. The ends of these strands projected upward outside the candle tip. An additional two strands of non-nitrated twine were tied lengthwise around the candle, running in the lateral grooves. These lateral grooves were thickly smeared with priming paste, as were also both the top and base of the candle. The weight of the candle itself was 21.7 grams. Its composition was as follows:

Potassium chlorate	52.30
Strontium oxalate	14.85
Resin (soluble in ether)	18.85
Pitch and resin (insoluble in ether)	14.00

Still another flare was contained in a white cardboard cylinder, painted black. This contained a candle nearly three times as large as the other, having a weight of 58.35 grams. The composition was as follows:

Barium nitrate	40.9
Magnesium	12.5
Potassium nitrate	37.8
Resin and wax	8.8

The use of smoke-producing devices has been highly developed during the war, with an increasing realization as to the importance of the results thus secured for a large variety of military operations. The improvements throughout the conflict have been continuous and extraordinarily effective. Chief among the employments to which this sort of device is peculiarly suited are the following:

1. To increase the visibility of explosions for shells of either small or average caliber, as an aid in determining the exact range.

2. To neutralize an enemy battery, or to conceal observation posts at great distances.

3. To hide enemy shelters and different organizations near at hand.

4. To simulate the effect of either rifle firing or the discharge of shells, in order to deceive the enemy.

5. To screen important organizations or movements of troops from view of the enemy.

As to the first of these employments, it must be borne in mind that explosive shells on bursting give off smoke from only a small quantity of black powder. This is not very distinctly visible, and, too, it is dissipated rapidly. On this account, it is of advantage often to increase the visibility of such explosions by the use of some additional material that shall supply a larger volume of smoke with sufficient density. For this purpose, the smoke-producing material most frequently used is red phosphorus, to which arsenic may be added. The arsenic may be either free or in combination. Paraffin serves as a casing for the phosphorus, and protects it against dampness. This material is ordinarily inclosed in a cardboard cylinder, to which the name *unter Korper* is given. It is buried in the explosive charge.

By this means, at the time of the shell's exploding, an abundant white smoke is thrown off. When arsenic is used, the smoke has the powerful alliaceous odor characteristic of this substance. Shells equipped with such a smoke-producing device are of especial value for establishing the range. It suffices that only a certain proportion of the explosive shells should be provided with the contrivance. The proportion is usually one-third for field guns, but one-half for the light 105 millimeter howitzer. The shells bear distinctive markings.

The Germans, on occasion, made use of a gray smoke, which was produced from a heavy carbonated powder with impure tolite (T. N. T.). The composition used for this purpose in a 105-millimeter explosive shell had a weight of 100 grams, made up as follows:

Sodium nitrate	65.5
Carbon and bitumen	22.5
Sulphur	4.9
Impure tolite (T. N. T.) approximately	5
Not measured	2.1

It seems probable that this gray smoke was employed for the sake of establishing the range, while a smoke screen was being used to hide both the objective and the explosions. The explosions producing the gray smoke were distinctly visible, since the color stood out in sharp contrast to the white of the screen.

As to the second employment of such smoke-production—for the neutralization of an enemy battery or observation post at a distance—the composition of the special charge in the shells includes tolite, carbon, bitumen, and sodium nitrate, or it may be a mixture of sulphureted arsenic and potassium nitrate.

For the third employment of smoke-producing devices—the hiding of enemy shelters or other organizations near by—9-centimeter trench projectiles are commonly employed, or projectiles in containers of cardboard, or special grenades. When a very close approach can be made, tubes charged with a composition that is both incendiary and smoke-producing are effective.

The smoke candle was found to be of especial value for use in trench and field warfare whenever a small compact article was required. In the construction of these, three pounds of smoke mixture are packed within a tin container. The kindling of the composition is by means of the match-head type of ignition. A uniform volume of smoke is given off for a period of four minutes, which lies in a thick, foglike cloud, close to the ground. The smoke has the great advantage of being perfectly harmless, so that it may be breathed without discomfort. Its power of obscuration is extremely high.

Phosphorus has been found the best available substance for smoke barrage. A common type contained a mixture in a tin case, of which the dimensions were 5 by 3 inches. The mixture was of red phosphorus lumps, 70 parts, with red phosphorus powdered, 11 parts. This was fired either by a detonator, or a time fuse. Grenades for use by hand or by rifle contained molten white phosphorus in a quantity of 12½ ounces. These grenades also were fired by either a detonator or a time fuse, set for 6½ seconds. Where a supply of phosphorus was lacking, effective substitutes were found in various other substances.

Perhaps the most interesting single development of pyrotechny in the war was the use of rockets similar in type to those over which military experts waxed so enthusiastic 100 years ago. Thus, the Germans followed Congreve's construction in the use of metal, but modified the type in order to eliminate the necessity for a stick. Over a century ago, various attempts were made to do away with the stick attached to the rocket, but the results were never wholly satisfactory. The usual method was by dependence on holes pierced in the case, for the escape of gas in such a manner as to impart a rotary movement to the rocket, forcing a direct flight forward. In Hale's rocket,[1] the added apertures for such escape of gas were made in the forepart of the firework. In the German war rocket, however, the openings for the escape of gas were in the base. It is sufficient to add that the Germans were not alone in endeavoring to utilize this principle by which the stick might be eliminated in the construction of war rockets. It is reasonable to believe that such a method of construction, long ago accepted with enthusiasm, may ultimately be revised and perfected.

It should be noted that the British, by reason of the efficiency attained with other forms of fireworks, were able in the last months of the war to discontinue the use of rockets. This, however, was a measure of economy, rather than of preference. As a matter of fact, the war has demonstrated once again the unique merits of the rocket—carrier of its own projecting mechanism.

Certain novelties of a pyrotechnic sort showed themselves during the conflict, some of great value, others of doubtful worth. Thus, the Italians developed a hissing flare,[1] which, while suspended from a parachute, burned with a hissing noise

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[1] See appendix.

distinctly audible over an area 3,000 meters in diameter. This was found practically effective as a gas alarm.

Both British and Italians successfully employed the rocket stick as a message carrier. The message (or map) was contained in a metal tube fastened at the lower end of the stick. In combination with this was a smoke bomb, which was set burning when the stick struck the ground. The plume of smoke from the bomb marked the resting place of the message.

The British experimented with an aërial flare to be used for illuminating enemy aircraft while in flight. This was designed to float with a parachute and to cast its cone of radiance upward. Great difficulty was experienced in securing adequate reflection of the light rays, and the contrivance had not been perfected at the conclusion of hostilities.

It would be impossible within the limits of this space to enumerate all the diverse forms of fireworks exploited by the various belligerents during the war. The details already set forth are sufficient to indicate in some degree both the importance and the novelty of the aspects under which pyrotechny has been demonstrated in the exigencies of conflict.[1]

It is a far cry from the flubdubbery of primitive priests and magicians to the amazingly effective displays of art in aërial fires over the blood-drenched fields of Europe. The grim needs of war incited all the combatants to strenuous effort for the enlarging and strengthening of their skill in pyrotechny. The end of the struggle shows a fireworks construction marvelously developed in many phases, yet to a considerable extent incomplete, in some directions confused, in others probably worthless. Under the less-hurried conditions of peace, the nations will now test their achievements with a discrimination that must finally determine the usefulness of every device, its essential practicality. Thus, we may believe that, presently, the art of pyrotechny will attain to scientific precision throughout its vastly broadened scope, a precision to which it has never reached in its more meager past. Moreover, there is the blessed assurance that, with pyrotechny as with all else, lessons learned under the scourge of war shall yet serve beneficently the gentler arts of peace.

[1] Various types are summarized in the appendix.

APPENDICES.

APPENDIX A.

ORDNANCE MANUAL OF 1849.

In 1849 there was published by the Ordnance Board of the United States Army an Ordnance Manual, by A. Mordecai, brevet major, United States Army. The book deals with all branches of ordnance used in the United States Army at that time. The question of fireworks for signals, lights, and incendiary purposes, is discussed, beginning on page 283, substantially as follows:

Under the heading of "Signal Rockets" is taken up the manufacture of the rocket, which to all intents and purposes was quite similar to the rocket manufactured to-day. The manufacture at that time, however, was entirely by hand. The rocket case was made of paper and the driving charge was the same as that in use to-day, with the exception that one ingredient, steel filings, was added to the composition. Great care was used in having the proper dimensions for the rockets both in the case and the stick, and it was necessary that the rocket should balance on a knife blade three diameters from the throat.

Under the heading of "Decorations for Rockets," it is said that the pots of rockets were charged with various decorations, such as stars, serpents, gold rain, rain of fire, marrons, crackers, etc.

Stars are said to be the most beautiful decoration of rockets. They were made from a formula consisting of alcohol, gum arabic, sulphur, niter, and antimony.

Serpents were made of small paper rolls about one-fourth of an inch in diameter, filled with driving composition and then partially closed at one end. They were placed in the pot of the rocket with the open end down, so that when the expelling charge was detonated they were fired and performed their peculiar antics. In fact, the serpents were miniature rockets released at an altitude of 500 to 800 feet.

Gold rain was made in the same manner and from the same composition as the stars, except that the composition was cut into very small pieces and then rolled in meal powder.

Rain of fire was loaded in a small case three-tenths of an inch in diameter and 2 inches long; the end was closed, and it was charged and primed exactly as for serpents, except that the powder for cracker was omitted.

Marrons were cubes filled with grained powder and enveloped with two or three layers of strong twine or marline; to give them more consistency they were dipped in kit, after which they were primed by inserting a small quick match. They were made from strong pasteboard cut in the form of a parallelogram.

WAR ROCKETS.

For war rockets, the cases were made of sheet iron, lined with paper or wood veneer. The head was cast iron, either a solid shot or a shell with a fuse communicating with the rocket composition. The case was usually charged solidly by means of a ram or press, and the core was then bored out. These rockets were of two kinds:

1. The Congreve, which had a directing stick attached to the tailpiece.
2. Hale's rocket, which required no stick, its direction being maintained by a peculiar arrangement of holes in the tailpiece through which the flame issued.

War rockets were usually fired from tubes mounted on portable stands or light carriages. The Hale rocket was made in two sizes, one having an outside diameter of 2¼ inches, and the other an outside diameter of 3¼ inches. The maximum range of the 2¼-inch rocket was seventeen hundred and sixty yards.

FIRESTONE.

The composition of firestone was:

	Parts.
Rosin	3
Sulphur	4
Niter	10
Regulus of antimony	1

These materials were mixed together and then later were added one part of mutton tallow and one part of turpentine. This composition was then cast into cakes, and was fired from mortars to set fire to enemy property.

VALENCIENNES COMPOSITION.

This was composed of:

	Parts.
Niter	50
Sulphur	28
Antimony	18
Rosin	6

The composition was mixed and then cast in cylindrical molds 6 inches long, of a diameter to suit the shell in which it was to be loaded. It was used as an incendiary composition in charging shells, and was inserted along with the bursting charge in pieces as large as the shell would admit without interfering with the fuse.

FIREBALLS.

Fireballs were projectiles of an oval shape, formed of sacks of canvas filled with a combustible composition, which consisted of:

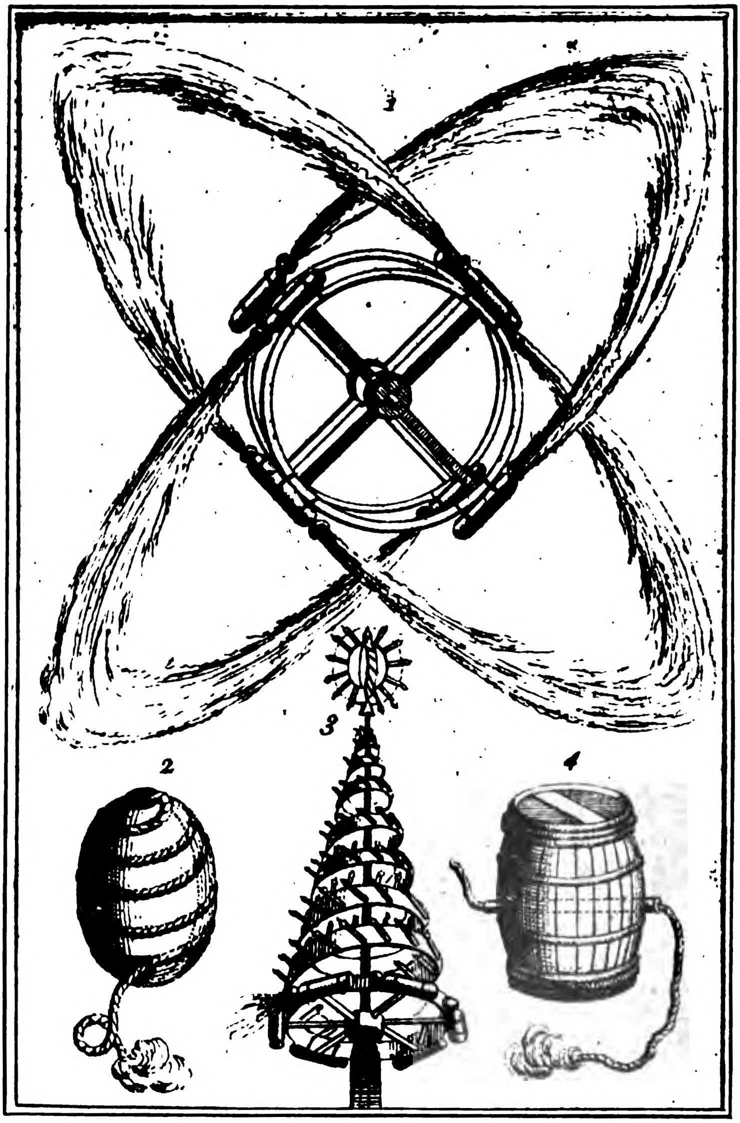
Rosin.
Pitch.
Tallow.
Spirits of turpentine.
Linseed oil.
Gunpowder.
Dry composition (beeswax, niter, flowers of sulphur, sawdust, regulus of antimony, gunpowder).
Chopped tow.

These fireballs were shot from mortars, and were used in setting fire to enemy property.

LIGHT BALLS.

Light balls were made in the same manner as fire balls, except that there was no shell in them, and they were used for lighting up our own works.

PLATE XI.



TARRED LINKS.

These were made by dipping coils of soft rope which had been immersed for 10 minutes or more in composition consisting of 20 parts of pitch and 1 part of tallow. They were used to illuminate our own territory.

PITCHED FASCINES.

These were made by dipping twigs of combustible wood about 20 inches long and 4 inches in diameter in the same composition that was used for the tarred links.

TORCHES.

These were made by boiling old rope or a slow match in a solution of water and niter. After it became perfectly dry, it was wrapped around a piece of pine wood and was then covered with mixture of equal parts of sulphur and mealed powder moistened with brandy. The intervals between the cords were filled with paste consisting of:

	Parts.
Pitch	3
Venice turpentine	3
Turpentine	½

INCENDIARY MATCH.

Composition for 100 lights consisted of:

	Lbs.	Ozs.
Saltpeter	9	10
Sulphur	2	6¼
Red orpiment (As_2S_3)		11

These ingredients were thoroughly mixed and were then pressed into a hemispherical cup 2½ inches in diameter, made of seasoned wood with a handle the size of a 13-inch fuse. This was primed with a strand of quick match and covered with paper which was pasted to the bottom of the cup.

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APPENDIX B.

ORDNANCE MANUAL OF 1861.

In 1861 an Ordnance Manual was published by T. T. S. Laidley, brevet major, Ordnance, United States Army.

Under the heading of "Incendiary Compositions, Lights, and Signals," in the manual, are described the various pyrotechnics in use by the United States Army at that time, substantially as follows:

ROCK FIRE.

Rock fire was a composition which burned slowly, was difficult to extinguish, and was used to set fire to buildings, ships, etc. It was apparently usually contained in shells. It consisted of:

	Parts.
Rosin	3
Sulphur	4
Niter	10
Regulus of antimony	1
Mutton tallow	1
Turpentine	1

The ingredients were thoroughly mixed, then cooked over a slow fire until they became brown. The composition was then run out into such forms as were desirable.

PITCHED FASCINES, TORCHES, TARRED LINKS, FIRE-BALLS, LIGHT BALLS, AND BLUE LIGHTS.

The formulas and methods of manufacture of these are practically the same as given in the Ordnance Manual of 1849.

SIGNAL ROCKETS.

The manufacture of the rocket is the same as in the manual of 1849, except that it is described in more detail. The formulas and materials used are the same.

Under the heading of "Decorations for Rockets," the garnitures are the same as in the 1849 manual, with the addition of streamers, which consisted of small paper cases two-tenths of an inch in diameter and about 4 inches long, one end closed, the case charged and primed like that of a lance. The effect of streamers was similar to that of fire rain.

WAR ROCKETS.

The war rocket described as being used in the military service was made according to Hale's patent. It consisted of: first, a sheet-iron case lined with paper and charged with rocket composition; second, a cast-iron cylindro-conoidal head, with a small cavity communicating with the bore of the rocket and pierced with three holes obliquely to the surface for the escape of gas; third, a wrought-iron plug welded into the rear of the case and having a hole in its axis for the escape of gas.

The rocket was driven forward by the escape of gas through the hole in the rear end and a motion of rotation around its axis was given to it by the escape of gas through the holes in the head, whereby its direction was preserved without the use of a directing stick. It was made in two sizes—2-inch and 3-inch. The rocket was charged with a composition consisting of:

	Parts.
Niter	10
Sulphur	2
Charcoal	3

The case was placed in a press, about 3½ ounces of rocket composition were put in at a time, and it was then subjected to a pressure of 20 tons. This was continued until the case was filled within about an inch of the top, when a layer of potter's clay was added. After this the rocket was bored, and later the head was added. These rockets were fired from open tubes, formed of rods of iron bent spirally and mounted on a portable stand.

PETARD.

The petard was a box of wood filled with about 20 pounds of powder. It was used to blow down doors, gates, barriers, etc.

APPENDIX C.

ITALIAN TYPES.

The operation of Italian pyrotechnics was demonstrated before the Second Corps Gas School of the American Expeditionary Forces on February 28, 1919. The conspicuous features exhibited were the following:

1. PARACHUTE ILLUMINATING FLARE (MODEL POMA).

Description and method of employment.—It is composed of a heavy pasteboard tube that surrounds another tube of sheet iron, which when it arrives at the top of the trajectory expels an illuminating flare that is suspended from a parachute. For the firing of this flare, hold firmly with the left hand the throwing tube, giving it an inclination of 45°, and with the right hand pull out the ignition string that is in the lower part of the flare. This string should be pulled with an energetic stroke. The flare is used to illuminate an extensive zone of ground and has a duration of about 40 seconds.

Composition of illuminating mixture.—Barium nitrate, potassium nitrate, gumlac, and aluminum.

2. ROCKET FOR DAY SIGNALING (MODEL POMA).

(a) BLACK SMOKE.

Description and method of employment.—It is composed of a tube of pasteboard with a charge of black powder that serves to raise the flare. When this flare arrives at the top of its trajectory it expels a smoke bomb, which emits a black smoke, while suspended from a parachute, giving off smoke for about 20 seconds. This is a stick rocket and is fired in the usual way with a string pull.

Composition of mixture.—Coal tar, potassium chlorate, red phosphorus, white napthaline and wood sawdust.

(b) YELLOW SMOKE.

Description and method of employment.—This rocket is similar to the one which produces the black smoke, except that a yellow smoke is produced for a period of 20 seconds. It is fired as in 2 (a).

Composition of mixture.—Potassium nitrate, sulphur, antimony sulphide, and red arsenic.

(c) SMALL BLUE CLOUD.

Description and method of employment.—When the rocket arrives at the top of its trajectory a small bomb in a paper envelope is expelled and after three seconds produces a small blue cloud. It is fired as in 2 (a).

Composition of mixture.—Ultramarine blue and potassium nitrate.

(d) SILVER-COLORED SPRAY.

Description and method of employment.—At the top of the trajectory there are expelled 32 capsules of the aluminum mixture which light and drop rapidly, forming a spray of very bright small white lights. Duration of action ten seconds. It is fired as in 2 (a).

Composition of mixture.—Gumlac, aluminum, barium nitrate, and potassium nitrate.

(e) RED SMOKE.

Description and method of employment.—This rocket is similar and is fired similarly to 2 (a), except that a red smoke is produced.

Composition of mixture.—Mercuric sulphide (cinnibar).

3. FLARES FOR NIGHT SIGNALING (MODEL POMA).

(a) RED SPRAY.

Description and method of employment.—Methods of firing same as for No. 2. At the top of its trajectory it expels 30 small capsules of red fire that drop rapidly. It has a duration of action of about ten seconds.

Composition of mixture.—Potassium chlorate, lamp black, strontium carbonate, gumlac, and magnesium.

(b) GREEN SPRAY.

Description and method of employment.—General description same as for No. 2. Action same as of No. 3 (a), except that the 30 capsules are filled with green-fire composition. Duration of action, 10 seconds.

Composition of mixture.—Barium chlorate, gumlac, magnesium.

(c) CHANGING BETWEEN RED AND GREEN.

Description and method of employment.—General description same as for No. 2. A flare is expelled which is attached to a parachute. The flare changes from red to green, green to red, and to green again. Duration of action, 40 seconds.

Composition of mixture.—For red, same as 3 (a); for green, same as 3 (b).

(d) TRICOLOR.

Description and method of employment.—General description same as for No. 2. At the top of the trajectory there is expelled a wire to which are attached three capsules. This wire is fastened to a parachute. The three capsules are filled with three different mixtures, giving red, white, and green colors, respectively.

Composition of mixture.—White, same as No. 1. Red, same as 3 (a). Green, same as 3 (b).

These flares above enumerated are used to effect liaison between the Artillery and Infantry. Each flare has a different meaning. In the Italian forces each army has its own code. In case one code falls into the hands of the enemy, the code is changed only for the sector covered by that code and not for the whole front.

All these flares, except No. 1, have wooden sticks. In firing, No. 1 is held by the left hand and the interior portion shoots out. The others are fired similarly to American firework rockets. The recoil of No. 1 is very strong, and it must therefore be properly supported before firing.

4. SIGNAL BOMBS FOR AËROPLANES (MODEL POMA).

(a) RED CLOUD.

Description and method of employment.—These flares are dropped from aëroplanes and serve to indicate the enemy target for the artillery. They are composed of a pasteboard outer tube, which contains a number of paper cartridges that explode and produce a varicolored cloud. The red-cloud flare contains three capsules, which are attached together. After the explosion of the inner tube the first cartridge lights immediately and the other two light at intervals of 3 seconds. The method of firing is by means of a cannon match lighted by friction. These explode 20 seconds after release.

Composition of mixture.—Mercuric sulphide (cinnibar).

(b) BLUE CLOUD.

Description and method of employment.—Same as for 4 (a).

Composition of mixture.—Ultramarine blue.

(c) YELLOW SMOKE.

Description and method of employment.—This flare contains two cartridges which produce a yellow cloud. They are attached to a wire at a distance from each other of 10 meters. The wire is attached to a parachute. Duration of action 20 seconds.

Composition of mixture.—Same as 2 (b).

(d) BLACK SMOKE.

Description and method of employment.—General description same as 4 (c).

Composition of mixture.—Same as 2 (a).

(e) SILVER SPRAY.

Description and method of employment.—This flare is composed of a pasteboard outer tube having an inner tube which contains 12 capsules filled with an aluminum mixture. These light upon the explosion of the inner tube and drop rapidly, giving the appearance of a silver spray. Duration of action 12 seconds.

Composition of mixture.—Same as for No. 1.

5. ILLUMINATING FLARE FOR DETECTING AËROPLANES (MODEL POMA).

Description and method of employment.—This flare is composed of a large pasteboard tube containing an illuminating mixture similar to No. 1. Its purpose is for illuminating enemy aëroplanes during a night attack. It is lighted by means of a cannon match, which is ignited by means of another special match containing a very large head of phosphorus in order to prevent the blowing out of the match by strong winds. Duration of action five minutes. Flare is burned on ground. This is also made in two other sizes with duration of action of two minutes and one minute, respectively.

6. MANIFESTOS (MODEL POMA).

Description and method of employment.—This rocket is composed of a pasteboard tube containing an inner tube similar to those above mentioned except that in this tube are placed the messages which it it desired to distribute to enemy trenches to serve as propaganda among enemy troops. The method of firing is by lighting a cannon match as described in No. 5. Range, 300 meters.

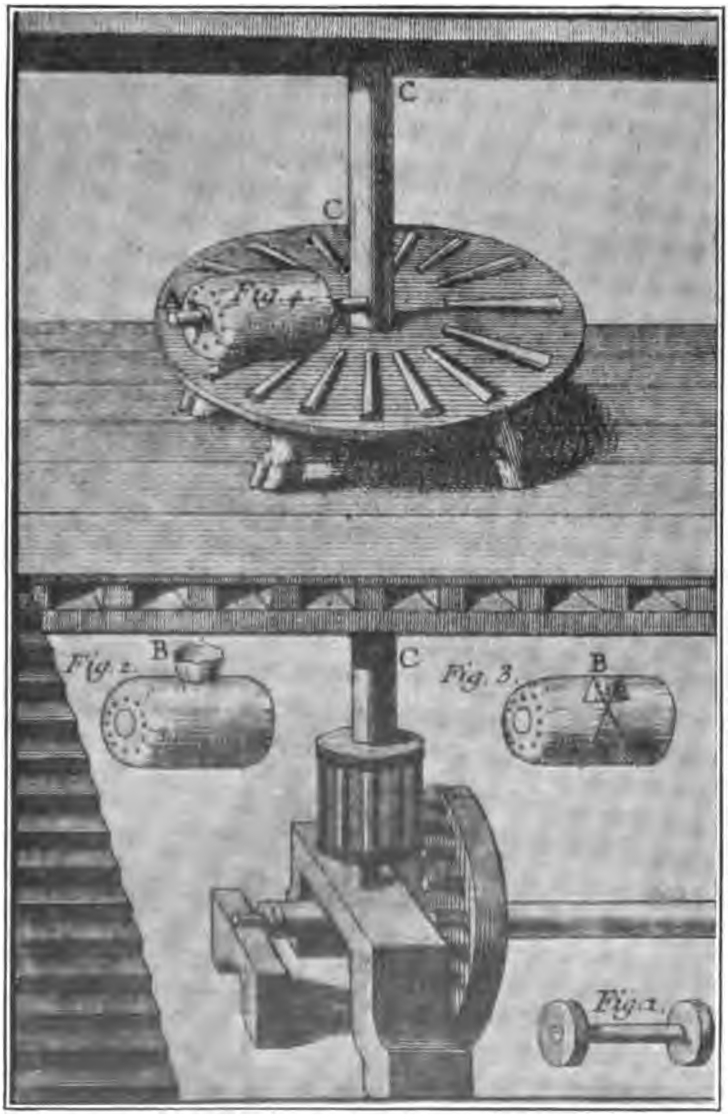
7. MESSAGES (MODEL POMA).

Description and method of employment.—General description is the same as for No. 6. The message is in a tube on the rear end of the rocket stick. When the rocket containing the message strikes the ground a smoke bomb is lighted which produces a yellow smoke. This serves to aid in locating the messages. The purpose is to convey messages from the front line to commanders in the rear when other means of communication are severed. There is considerable recoil to both No. 6 and No. 7 and they must be held firmly against an improvised brace or propped so as to be able to regulate the inclination of fire, as the range depends on the inclination. The maximum range is 800 meters.

8. HISSING FLARES (MODEL POMA).

Description and method of employment.—This flare is composed of a pasteboard outer tube containing a long, nar-

PLATE XII.



row sheet-iron inner tube. This sheet-iron tube contains another pasteboard tube filled with potassium picrate and potassium nitrate. The sheet-iron tube is projected by a charge of black powder and at the top of the trajectory explodes, liberating the inner pasteboard tube which remains attached to the parachute. The mixture of potassium picrate and nitrate takes fire and the reaction produces a hissing sound which is heard for a distance of 3,000 meters. This signal is used for a gas alarm. The method of firing is by means of pulling a wire which is attached to the lower portion of the flare, the friction thus produced igniting a phosphorus exploder on the inside of the tube. Duration of action, 15 seconds. This is also made to use on the ground instead of as a rocket. In the latter type, ignition is by means of a match composition.

SMOKE BOMBS.

Description and method of employment.—These smoke bombs are composed of a heavy pasteboard outer tube filled with a smoke-producing mixture and covered at each end by two wooden caps with a hole in the center through which the smoke issues. The lighting system is the same as described in No. 8—that is, by quickly pulling out a wire attached to the lower part of the tube. The purpose of these smoke bombs is to conceal movements of troops.

Composition of mixture.—Wet wood sawdust, heavy oil, sodium nitrate.

APPENDIX D.

ADDITIONAL FORMULAS.

AMERICAN AËROPLANE SMOKE-SIGNAL GRENADES.

RED.

Potassium chlorate	20
Lactose	20
Paranitraniline red	60

YELLOW.

Potassium chlorate	33
Lactose	24
Auramine	34
Chrysoidin	9

GREEN.

Potassium chlorate	33
Lactose	26
Auramine	15
Indigo (synthetic)	26

BLUE.

Potassium chlorate	35
Lactose	25
Indigo (synthetic)	40

SMOKE-TORCH FORMULA.

	Parts.
Potassium nitrate	23
Sulphur	2
Hard tar	15
Powdered borax	5
Sand	5

This was later changed to increase burning time to:

	Parts.
Potassium nitrate	22¼
Pitch	15
Borax	5½
Sulphur	2
Sand	2¾
Whiting (calcium carbonate)	2½

With an alternate formula of:

	Parts.
Saltpeter	16
Pitch	11 to 12
Borax	3 to 4
Sulphur	3 to 5
Ground glue or sand	1 to 1½

These compositions were satisfactory.
A small smoke torch was advocated, but never made.

CAPT. WILEY'S FORMULAS FOR POSITION LIGHTS, MARK I.

WHITE.

	Parts.
Barium nitrate	7
Sulphur	1¾
200- to 250-mesh powdered aluminum	1¼

RED.

	Parts.
Strontium nitrate	6
Potassium chlorate	3
Orange shellac	1

GREEN.

	Parts.
Barium chlorate	5
Barium nitrate	4
Orange shellac	1

All to be mixed through a 24-mesh sieve.

GERMAN STAR SIGNALS.

RED.

Barium chlorate	81.76
Barium carbonate	1.39
Shellac	9.49
Dextrin	6.32
Undetermined	1.04

GREEN-SMOKE CARTRIDGE.

Arsenic	66.00
Phosphorus	26.00
Fatty matter	8.00

GERMAN SMOKE-PRODUCING MIXTURE USED IN BIG SHELLS.

Parafin	8.40
Arsenic	19
Phosphorus	71.21
Undetermined	1.39

BRITISH SMOKE CANDLE.

	Parts.
Potassium nitrate	22
Sulphur	6
Pitch	15
Borax	4½
Glue	2

The case is of a size to contain just over three pounds of the composition.

APPENDIX E.

MISCELLANY.

FRENCH PERCUSSION FLARE.

Used only in small quantities, fired from one-and-one-half Véry pistol. Ignited upon coming in contact with earth. Burned for a period of from 30 to 40 seconds.

P. BOMB.

Contained 1 pound of amorphous phosphorus in a tin container. Exploded by detonating cap. Produced a very dense smoke. Used in "mopping up."

BROWN PUFF SIGNAL.

Used by British for daylight signaling. Visible to a considerable distance.

ANTI-AIRCRAFT ROCKET.

In British experiments attained height of 8,000 feet. Garnished with flare reflecting light upward against aëroplanes. Difficulty with reflector.

MAGNESIUM METEOR ROCKET.

Range of 1,100 feet. Light to pierce mist or fog.

SIGNAL MARRON.

Held 390 grams of black powder. Used by men on signal post for attracting attention to signals by detonation.

FLASH MARRON.

Made by the French from a mixture of gunpowder and aluminum (powdered). Intended to confuse enemy by imitating effect of their range-finding shell.

GABA CARTRIDGE.

Made by the French to be fired from a special gun. Carried mixtures for either light or smoke to be used in signaling by infantry and aircraft.

CATERPILLAR CARTRIDGE.

Seven flares attached to parachute in cast-iron tube. Fired from gun.

COSTON NIGHT SIGNALING LIGHTS.

Made in nine models by the French. Various colors or combinations of colors.

EHRMANN PERDU SYSTEM, TYPE B, WARNING LIGHTS.

Used for revealing approach of the enemy at night. Successfully employed near wire entanglements. Consisted of tube in which a Bickford fuse was attached to a string so that at an alarm a pull ignited the piece and disclosed the enemy.

GLAKE GUN.

Used by British for firing messages. Range of 800 yards. Flare attached to the projectile ignited after 300 yards. Continued to burn until it struck the ground. Was used as substitute for a chain of runners, as when the gun was once set, messages could be delivered at the same place very handily, since one man could carry gun and 10 projectiles easily.

BRITISH PHOTOGRAPHIC BOMB.

Emitted light to illuminate one mile in diameter for instantaneous photographing. Duration two-fifths of a second. In effect a giant flashlight powder.

MULTIPLE SMOKE TRAIL.

Consisted of seven yellow and seven purple smoke trails.

CIBIE LIGHT.

Lamp with revolver handle and trigger, using acetylene or electricity. Employed by French for aëroplane landing, etc.

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