DICTIONARY and MANUAL

of

PYROTECHNY.

Covering the authors work and experiments

from 1890 to 1935.

A drop of ink, t'is said
made millions think:

A spark of fireworks has oft'
made thousands blink.

Though handicapped in the struggle of life, I have achieved some small success through the constant untiring assistance of my wife. As a slight token of appreciation I dedicate to her this work.

The Author.

Preface.

In following work the object has been to place on file a complete record of the developements of the art of pyrotechny up to the present time. Previous epochs, in what may be considered the modern manufacture of fireworks, have been punctuated by Ruggiere, 1812 in Italian; Chertier, 1854 in French; Kentish, 1878 in English and Antoni 1893 in Italian.

There have been writings on the subject as early as the year 1225 and the first authentic manual seems to be in German, written in 1432 but these are mainly museum curiosities. Since 1893 some historical and specialized articles have appeared in connection with pyrotechny but nothing of a general or comprehensive character in the way of a working manual.

In the interim great strides have been made, both in the materials used as well as in the methods employed in the mass production of articles in general use for public celebrations.

Powdered aluminum has added many beautiful effects; picric acid is extensively used and potassium perchlorate has greatly reduced the danger from spontaneous combustion. Phosphorus, both yellow and amorphous is largely used and machines to replace manual operations have been devised in many instances.

The formulars herein given are all taken from those in actual use and will positively produce the effects for which they are indicated. The machines and tools shown are those in use in the largest and most recently equipped factories.

The article on Chinese Firecrackers is the first detailed description of this interesting article ever written in the English language.

A caution added here might not be amiss. Never hold any kind of fireworks in the hand while it is burning. Make this rule without exception because sometimes the most unexpected explosions occur and cause painful injury. If firing shell be sure never to look into the mortar after the shell has been inserted. A spark might have in some manner gotten inside. Also never allow the arm or hand to come over the muzzle of the mortar. Long sections of bare match should be used on shells so that the one lighting them has ample time to reach a safe distance in case of the bursting of the gun. There is always enough danger to avoid all unnecessary risk.

The beginner is advised to read carefully and memorize the instructions given under "manipulations" before attempting the production of any kind of fireworks. Actions which seem trivials are sometimes fraught with gravest danger. The object of fireworks is to give pleasure so do not compound it with tragedy.

In conclusion I might add that in this work pyrotechny is treated rather as a craft than as an art. For the artistic feature, imagination only is requisite but to work out the results of imagination is just plain tedious, patient and often hard work. Consequently, if we have the methods at hand it will be easier to bring to life the artistic ideas.

January 30th. 1937.

INTRODUCTION.

To those contemplating the making of fireworks, either professionally or as an amusement it is desirable to understand the principles which govern the operations of the various devices as well as the compositions of the chemicals entering into their production.

The principle of colored lights is based on:

1st. Producing a mixture that will burn at a reasonable speed while generating an intense heat,

2nd. Adding thereto the salts of such elements, in the spectrum of which, predominate lines of the desired colors.

Heat generating compounds consist chiefly of:

(a). Substances which yield oxygen freely when ignited in the presence of carbon, viz:

Potassium chlorate,
Potassium per-chlorate,
Potassium nitrate,
Sodium chlorate,
Barium nitrate,
Strontium nitrate.

(b). Carbon and carbonaceous sources, viz:

Charcoal,
Shellac,
Fossil gums,
Resins,
Asphaltum,
Dextrine,
Stearine,
Sugar of milk,
Corn flour etc.

In addition to the above there are some substances which when added to colored fire compositions increase the affinity of the several constituents for one another thereby improving the colors, viz:

Sulphur
Picric acid

and in the instance of blue and green fires it is almost essential to add an easily volatilized chloride in order to get sufficient depth of color.
viz: Calomel
Sal Ammoniac.

The exact function of these last named substances is not entirely clear but it appears that the best spectrums are yielded by the chlorides of the elements. However most chlorides are deliquescent and therefore unsuited to fireworks making. By adding a substance that yields chlorine freely at the moment of decomposition the necessary conditions are produced for obtaining the best results.

The following substances are most generally used for producing pyrotechnical colors.

PURPLE

Strontium and Copper compounds.

ORANGE

Strontium and Sodium salts.

Bright or "Plain" Mixings

Consist almost entirely of:

Saltpeter,
rarely Lead nitrate,
Sulphur,
Charcoal or lampblack.

with the addition of

Steel filings,
Iron borings,
Zinc powder,
Antimony,
Orpiment,
Realgar.

PINK

Calcium carbonate,
Calcium sulphate,
Calcium oxalate.

GREEN

Barium nitrate,
Barium chlorate,
Boric acid,
and rarely Thalium nitrate.

RED

Strontium nitrate,
Strontium carbonate,
and rarely Lithium salts.

BLUE

Copper carbonate,
Copper arsenate,
Copper sulphate,
Copper black oxid,
Copper & Ammonium sulphate,
Copper oxalate,
Copper & Ammonium chloride.

YELLOW

Sodium oxalate,
Sodium bicarbonate,
Sodium metantimoniate.

The intensly bright white sparks are produced by aluminum powder. At one time Magnesium was used for this purpose but it has been entirely discontinued.

PART I.

INGREDIENTS

SALTPETER
(Nitre—Potassium nitrate)

This most important ingredient is produced in New York state of so high a quality that it is needless to look for better. The most suitable for pyrotechnical purposes generally is the "double refined, powdered" which can be obtained at from 5c to 15c lb. in barrels of 350 lbs. the price varying according to market conditions. For some large work granulated saltpeter is used, burning slower and being cheaper at the same time. The most suitable is "Dupont #2".

Specifications for saltpeter to be used in fireworks making call for a salt that is clean, white and should be ground fine enough to pass through a sieve of 80 to 100 mesh. It should contain less than 1% of sodium, calcium and magnesium salts combined.

POTASSIUM CHLORATE
$K\ Cl\ O_3$

This very necessary chemical is now also being prepared in this country, near Niagara Falls, of an excellent quality. The price varies considerably though it usually declines somewhat after July 4th. The powdered ranges from 9c to 16c lb. in kegs of 112 lbs. For pyrotechnical purposes it should be white, odorless and contain not over ½ of 1% of sodium, calcium and bromine combined. It should be of the same fineness as saltpeter.

POTASSIUM PERCHLORATE.

$K\ Cl\ O_4$

This recently produced substance forms another valuable addition to the pyrotechnists art. Containing even more oxygen than the chlorate it is less liable to decomposition due to the fact that it is a salt of perchloric acid which is a much more stable acid than chloric from which the chlorate is derived. It can be substituted for the chlorate in most mixings and can be safely used in connection with sulphur. The price is slightly higher than the chlorate and its specifications are practically the same

SULPHUR.

The "flour of sulphur" which is used almost exclusively is made of good quality in New York state from the product of the Louisiana mines and is sold at 2c to 3c lb. in barrels of 250 lbs. Italian washed sulphur is recomended by some of the older English pyrotechnists for use with chlorate of potash but the writer never uses formulas containing the two substances, if possible. It is almost white and comes in bags of 50 lbs. "Flowers" of sulphur is also sometimes used as well as coarsely ground sulphur which burns somewhat slower than the first two varieties. Specifications call for less than 1/10 of 1% of impurities and the finely ground should pass through a sieve of 120 mesh.

CHARCOAL.

Willow coal is the best for fireworks purposes through coal made from any soft wood is suitable. Pine coal is not very desirable. Excellent charcoal is made near Rochester, N. Y. and can be had finely powdered, granulated or mixed @ 1½¢ lb. in barrels or sacks. Charcoal that has a brown tint indicates incomplete carbonization and should be avoided. Also it should contain a minimum of grit. Shaking a sample in a bottle of water and de-

canting several times will disclose an excessive amount of sand etc.

LAMPBLACK.

Germantown lampblack is very popular with pyrotechnists though there are a number of good brands on the market. To make a good bright star it should be free from oil or other impurities and it is sometimes necessary to bake it as will be explained later, in order to get rid of volatile impurities which impair its briliancy in burning. It can be bought in barrels of 1 lb. packages @ 3¢ lb.

SHELLAC

and other gums etc.

Shellac, a gum like substance, is the secretion of an insect living on a large variety of trees in northern India. After going through various processes it finally reaches this country in some dozen different grades. The T N is a good grade for fireworks making and costs 25¢ to 35¢ lb. As it is practically impossible to powder this article oneself, a ball mill being necessary, great care must be excercised in purchasing powdered shellac as it is frequently adulterated with sand etc. For the best work shellac is almost indispensable but for stock goods, tableau fires and torches a number of substitute gums have been introduced such as Kauri, a fossil resin of a light yellow to a dark brown color, obtained from New Zeland. Red Gum comes from the Kangaroo Islands, 5 miles from Australia. K. D. dust is used for green fire. Asphaltum produces excellent colors when finely ground but owing to its containing sulphur, or perhaps on account of being so easily decomposed it is liable to cause spontaneous combustion when mixed with potassium chlorate. A mixture of these will explode violently when struck with a hammer on an anvil. With potassium perchlorate, however, it is entirely safe. The Syrian Asphaltum is the

best. So called Green Gum is merely powdered coconut shells and has no more value in pyrotechny than sawdust. Flour, dextrine, sugar of milk etc. are also frequently used as sources of carbon. Another article of this character is

STEARINE.

In making blue fire it has been found that stearine produces a better effect, especially with paris green and other copper salts, than most any of the other hydrocarbons. It is mostly obtained in cakes and is reduced to a servicable condition by setting a carpenter's plane upsidedown over a box and shoving the cakes against the blade so as to shave the stearine as fine as possible. When it is then mixed with the other ingredients it will pass through an ordinary sieve.

STRONTIUM NITRATE.

This article is made principally in England. Its chief source is celestite which is also shipped to Germany and this country for conversion into the nitrate. It is put up in kegs of 110 lbs. and casks of 600 lbs. in a sufficiently pure condition for use as received, costing here from 6c to 8c lb. It is probably the most useful color producing chemical used in fireworks making, as the deep red light which it gives is the most marked effect which the pyrotechnist has achieved. Owing to its deliquescent properties, however, a number of methods have been devised to overcome this tendency one of which is to melt in an iron pot over a fire some shellac and stir in the nitrate of strontia, cooling and pulverizing. Another plan is to use carbonate of strontia but at the cost of considerable depth of color. Strontium nitrate is used in a somewhat coarser powder than the potassium salts but should be a clean white and contain not over 1/5 of 1% moisture and ¼ of 1% sodium salts.

STRONTIUM CARBONATE.

In damp climates there is no alternative but to use this strontium compound for most exhibition work as a piece of lancework made with nitrate of strontium, if exposed for one hour to a damp atmosphere, will hardly burn. Precipitated carbonate of strontium is the only kind which should be used and may be purchased for about 16c lb. or can be easily made by adding carbonate of ammonia to a solution of strontium nitrate, thoroughly washing and drying the precipitate. If sodium carbonate is used as a precipitant it is almost impossible to remove every trace of it from the carbonate of strontium and causing an orange tint to the red light.

BARIUM NITRATE.

Like strontium this chemical also comes to us mainly from England and Germany in similar packings and costs usually from 5c to 7c lb. on this side. As a color producer it is far inferior to strontium though it does not attract moisture. If used without calomel its color is so pale as to be almost indistinguishable from white. Specifications for fireworks making are practically the same as for strontium nitrate. A better salt for making green fire is

BARIUM CHLORATE.

This salt give a very beautiful emerald color but its high cost, viz: about 30c lb. makes it little used except in exhibition work. Some recipies have been given for green fire using boracic acid, thalium salts etc. but if used at all it is to a very limited extent. All barium salts are very poisonous.

SODIUM OXALATE.

It is a strange fact that while yellow is the most common color of fires in general its practical production

in pyrotechny is accompanied with some difficulty from the fact that there is practically only one insoluble salt of sodium while all the others are more or less hygroscopic. The nitrate and bicarbonate give deep yellow lights but the least dampness will render them incombustible and even the oxalate, will in damp weather, attract moisture. The exception is Sodium met-antimoniate but as this salt costs $4.00 lb. and at best gives a pale color, it is not much used. Oxalate of soda costs about 20c lb. or can be easily made by adding bicarbonate of soda to a hot concentrated solution of oxalic acid. A copius precipitate falls which however cannot be washed but must be dried on a filter. An excess of oxalic acid should be maintained in this operation.

COPPER ARSENITE

(Paris green)

This article is made in New York state and elsewhere in this country and can be bought for from 10c to 15c lb. from dealers in painters supplies. It can also be easily made by adding a solution of blue-stone to one of arsenius acid, washing and drying the resultant bulky precipitate. It is used in making blue fire. The kind used for green paint is entirely satisfactory for fireworks making.

COPPER CARBONATE.

This substance is also used for making blue fires but better effects are obtained by the use of other copper compounds, with less trouble. The native carbonate is almost useless for fireworks purposes but the precipitated is easily obtained from dealers in pyrotechnical chemicals or can be made by adding carbonate of ammonia to a solution of blue-stone. Chertiers Copper is made by carefully adding aqua ammonia to a solution of blue-stone, evaporating and chrystalising. Black sulphuret of copper, black oxide of copper and various other copper compounds are occasionally used. The author has obtained the best results

with copper ammonium chloride, and calomel is unnecessary with this salt.

COPPER SULPHATE.

For most purposes where a good blue was required for exhibition purposes the older pyrotechnists used this salt but owing to its being a sulphate great care must be used in mixing it with chlorate of potash and a separate sieve should be used for mixtures of these substances, which should not be employed in any other work. It costs usually 10c to 15c lb. Mixtures containing it must not be stored but used promptly after making. Exposure to moist air oxidizes this and releases sulphuric acid. This can be obviated by using potassium perchlorate but the resulting mixtures are much more difficult to ignite in the form of stars etc.

ANTIMONY.

Metalic or Reglus antimony, when finely powdered in an iron mortar is used in making white fire. It may be had from machinery dealers at 6c to 7c lb.

ANTIMONY SULPHURET.
(black)

This may be obtained from drug dealers and costs 6c to 8c lb. but is often so impure as to be entirely useless. If 70% pure it is still servicable for pyrotechnical purposes and is used for making white fire, maroons and smoke effects. Red and orange sulphurets are also sometimes used. The compounds are poisonous.

RED ARSENIC, (REALGAR)
$As\ S_2$
ORPIMENT
$As\ S_3$

These minerals come mostly from Hungary, in iron

kegs of several hundred pounds and range in price from 6c to 9c lb. for the powdered. They are useful in making white stars, especially as these take fire far more easily than those made from antimony. Arsenic compounds are also used for making yellow smoke in day fireworks.

ALUMINUM.

When, about 50 years ago, it was found that a star of unusual briliancy could be produced by the use of magnesium this metal suddenly came into considerable demand in spite of its then cost of $75.00 lb. About the time that its price was reduced to $5.00 lb. it was found that aluminum was in every way better and cost little more than $1.00 lb. in fine powder. It can now be gotten from most paint dealers, in 1 lb. cans or papers at 60c lb. Aluminum powder should be 95% pure. It may contain 2% fatty meterial and 1% silicon. The fine should pass through a 100 mesh sieve and the flake, through a 50 mesh sieve.

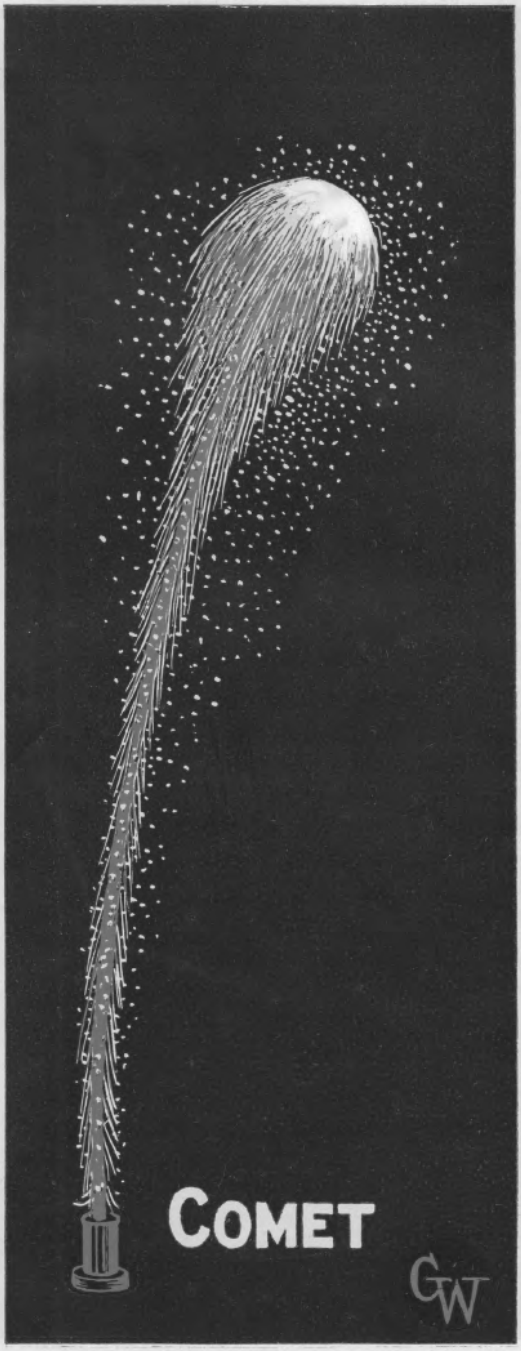
CALOMEL.

This is used to deepen the color of fires when they are not sufficiently deep without its use. It has been found that the chlorides of metals give the best spectrum but chlorides are not usually practical for fireworks making so the addition of an easily decomposed chloride to fireworks compositions is to produce a chloride at the moment of combustion, thereby acquiring the desired result. Finely divided metals also take fire spontanously in chlorine gas and the great heat thereby produced probally causes the increased depth of color. Calomel is made in Philadelphia and elsewhere and costs 65c to 70c lb. but this price has recently been advanced.

AMMONIUM CHLORIDE.

Sal Ammoniac.

This is sometimes used as a substitute for calomel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but its affinity for moisture seriously interferes with its general use. The crystalized salt is almost useless.

DEXTRINE.

In all the old works on pyrotechny, either a solution of shellac in alcohol or gum arabic in water is used to bind compositions for making stars and other similar purposes, but at present, in most cases the necessary amount of dextrine is added at once to the mixture and then nothing but water is needed to form it into the desired objects. Dextrine also improves the color of some fires and it may be advantageously used in place of glue for light work. Potato dextrine usually comes in sacks of about 200# and costs from 2½c to 5c lb. When used for gumming rocket sticks, tabs etc. it is simply mixed with water to the desired consistency. The light brown #152 is most suitable for pyrotechny.

GLUE.

Several forms of glue are used in fireworks making. For attaching lances to frame work a good grade of carriage glue is best. For attaching mine bottoms etc. to the cases cheap carpenters glue will suffice. For placing shell fuses and securing the ends of cannon crackers, good liquid glue is most convienent.

GUM ARABIC.

In powdered form this is used in some star compositions, especially for making Japanese Stars. It is also used in "Son of a Gun" composition.

STEEL FILINGS.

Cast iron borings etc.

A beautiful scintilating effect is produced with steel filings used in various ways. The Japanese make a little

tube of twisted paper, at one end of which is a composition which when lighted produces a glowing bead of molten flux. The balance of the tube contains steel filings, which when reached by the fused bead, burst into feather like flashes. In other countries steel filings are added to gerbs, fountains and driving cases with resulting brilliancy. A beautiful waterfall effect is produced by charging from 50 to 200 cases 2 inches in diameter and 12 inches long with a composition containing cast iron borings. These are fastened to scantlings at intervals of about 15 inches, each scantling holding about 16 gerbs. These are matched and hoisted to a wire cable some 50 feet above the ground. When burned the effect is most realistic as the arc of the suspended wire gives just the right curve to cause the appearance of perspective while the roar of the burning gerbs is also characteristic of Niagara Falls as the fire from the iron borings drops to the ground.

The best steel filings for gerbs is known as "needle steel". This resembles broken sewing needles but is really a by-product of some turning or planing operation. The steel filings from saw filing shops are quite good provided they are the result of hand filing and not the particles thrown off by emery wheels, which are useless for pyrotechnical purposes. When steel filings are added to gerb compositions, the saltpeter quickly attacks them, frequently causing the gerb to become quite hot. The steel is rusted and this action practically destroys its usefulness. To prevent this the steel must be coated in some way that the saltpeter cannot attack it which may be accomplished as follows:

In an agateware saucepan place a piece of paraffin and carefully melt it, heating as much as possible without permitting it to smoke. To this add clean steel filings, as much as the paraffin will thoroughly coat. There should be no surplus of paraffin but just enough to completely cover each filing. Shake the pan and stir frequent-

ly while cooling to prevent the filings from caking. Steel filings are also used for stars in rockets and shells.

CLAY.

This is used for closing the ends of most cases as well as choking them when they are not crimped. Most any kind of clay will do. It must be thoroughly dried, pulverized and sifted. Before using, it may be slightly dampened. For convienence where a large quantity is required, powdered fire-clay in barrels may be used as this saves the rather tedious job of drying and powdering.

GUN POWDER.

This is used in all grades from Dupont FFF Rifle to the coarse grains as large as cracked corn, for shells. A slow burning powder is preferable for a driving charge as it reduces the liability of shells bursting in the mortar

MEAL POWDER.

This article is used considerably in display work for gerbs etc. and in shells and rockets as a blowing charge. It is generally supplied in 25 lb. wooden kegs but is sometimes difficult to obtain. In that case some pyrotechnists make a fairly good article themselves, as follows:

Mount a 50 gallon wood barrel on two uprights so that it will revolve freely on centers fastened to the heads. On one center attach a crank and cut a hole (closed by a suitable plug) into side of barrel for putting in and removing the necessary ingredients. Place in the barrel 300 to 500 lead balls about one inch in diameter. When it is desired to make meal powder put into the barrel a thoroughly mixed composition as follows:

Saltpeter, double refined	15 lbs.
Willow charcoal	3 "
Sulphur flour	2 "

The barrel is now revolved for about 500 turns. The longer it is turned, the stronger the powder will become Great care must be exercised to see that no foreign matter such as nails, gravel etc. find their way into the barrel as this might result in an explosion.

New Ingredients.

Some years ago powdered magnesium was added to the ingredients used in pyrotechny and very fine bright effects were produced with it. Just when its high price and its affinity for oxygen, causing it to decompose the chemicals with which it was mixed, made pyrotechnists look at it askance aluminum came on the scene. Added to stars and torches it greatly increases their brilliancy and beauty. Exquisite water fall effects are produced with it as well as comets, tailed stars and intensly bright flares. Large quantities of finely divided aluminum (pyro aluminum) are used in the new "flash crackers" and the same composition is used in maroon shells. Besides increasing the report it gives a startlingly bright flash to the explosion. Being unaffected by water it is likewise much safer than magnesium but care should be used in handling it because as, before mentioned all finely divided metals are liable to explosion when in contact with oxygen producing chemicals. Rubbing into it a small amount of vaseline seems to reduce the danger of accident.

Picric acid is another valuable ingredient in fireworks making. When added in small quantities to colors it deepens them and increase their brilliancy without making them burn much faster. Also beautiful colors can be produced with it, almost free from smoke. But it must always be kept in mind that picric acid (tri-nitrophenol) is a first cousin to T N T the tremendous explosive force of which is only too well known. For this reason it cannot be used in shells as stars made with it will detonate when confined, instead of burning. Another effect for which large quantities of picric acid were used until some years ago when a fatal accident occured

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