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Fireworks and Color in the Sixteenth and Seventeenth Centuries

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Abstract

It has commonly been assumed that there were no colors in fireworks prior to the early nineteenth century. This essay argues that there were a variety of color recipes in early modern manuals on fireworks, though the nature and value of color in displays differed quite significantly from later periods. Color was used in pyrotechny in production practices, and carried alchemical, medical and other associations. Colored fire was not the principal or exclusive location of color in early modern displays which gave much weight to colorfully painted scenery, decorations and costumes. That modern authors place so much emphasis on colored fire is due to the promotion of color in pyrotechny by writers working in the age of the Chemical Revolution.

Keywords

Fireworks -- color -- early modern Europe -- artisans -- spectacle -- chemistry

Introduction

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Through the sixteenth and seventeenth centuries, courts and cities across Europe celebrated peace treaties, triumphs, royal occasions and the new year with elaborate displays of fireworks over city squares, rivers, castles and gardens. They were set off by “artificers,” artisans or gunners who made pyrotechnics and ordnance for the state’s artillery, and watched by the courts and great crowds of onlookers.[1] “Artificial fire-works” were similar to those of today, with rockets, candles, wheels and fountains, but many were prized for their exotic motions, zigzagging through the air or in and out of water, or as imitations of celestial and fiery meteors mimicking suns, stars, thunder and lightning.

It has commonly been assumed that besides one or two isolated recipes, there was no color in fireworks prior to the early nineteenth century, when the introduction of potassium chlorate into mixtures made it possible to produce brightly-colored gunpowder explosions, ushering in a ‘modern age’ of pyrotechny. This essay explores the ‘color world’ of early modern pyrotechnics and argues that certain color recipes were quite common prior to 1820 while color itself was understood quite differently in the sixteenth and seventeenth centuries compared to later periods. What later observers took to be a single color of ordinary fire, or ’white fire’, as it is sometimes called, early moderns might see as capable of being multicolored and various. While later observers stressed that color should be sought in pyrotechnic flames, early moderns gave equal weight to colored decorations, scenery and costumes in displays. Probably the emphasis placed on color in the history of pyrotechnics today was a

[1] On the history of early modern fireworks, see Simon Werrett, *Fireworks: Pyrotechnic Arts and Sciences in European History* (Chicago, 2010); Eberhard Fähler, *Feuerwerke des Barock: Studien zum öffentlichen Fest und seiner literarischen Deutung vom 16. bis 18. Jahrhundert* (Stuttgart, 1974); Owen W. Schaub, “Pleasure Fires: Fireworks in the Court Festivals in Italy, Germany and Austria During the Baroque” (PhD diss., Kent, 1978); Gereon Sievernich and Hendrik Budde, *Das Buch der Feuerwerkskunst: Farbenfeuer am Himmel Asiens und Europas* (Nördlingen, 1987); Arthur Lotz, *Das Feuerwerk, seine Geschichte und Bibliographie* (Leipzig, 1941).

product of works by the very people who developed colored fireworks in the early nineteenth century.

Brock's Account of Color in Fireworks

One account of the introduction of color into fireworks comes from Alan St. Hill Brock, who directed the Brock family's pyrotechnic company at Crystal Palace in London in the first half of the twentieth century and wrote several historical works. According to Brock's *History of Fireworks*, published in 1949, color was first introduced to fireworks in the early nineteenth century.[2] Brock identified this innovation with the French revolutionary artificer Claude-Fortuné Ruggieri, who was,

> the first writer to make use of metal salts in the production of coloured flame—apart, that is, from the isolated use by Hanzelet of verdigris. He also introduced sal-ammoniac (NH_4Cl, ammonium chloride), which, by volatizing the metal, greatly assisted colour production […]. Its purpose is now achieved […] by potassium chlorate or perchlorate.[3]

Potassium Chlorate ($KClO_3$) is a high-energy oxidizer which provides more oxygen for combustion than the traditional potassium nitrate (KNO_3). Discovered by Berthollet in 1786, it began to be used in pyrotechnics within a decade or two, the exact date is unclear, and by allowing metal salts to burn more intensely in pyrotechnic mixtures could generate a brightly-colored flame.

Brock proposed that Ruggieri's recipe for green fire, his first color, was not a "true firework effect," because it consisted of draping wicks soaked in verdigris, sal

[2] Alan St. Hill Brock, *A History of Fireworks* (London, 1949).
[3] Brock, *History of Fireworks*, 155.

ammoniac and alcohol over the branches of a wooden palm tree to create a green flame, rather than exploding gunpowder in a firework. Ruggieri claimed to be imitating a Russian technique with his green fire, but Brock dismissed this as "yet another of those traveller's tales of the wonders of Eastern pyrotechny."[4] In fact, as I have shown elsewhere, the Russians were pursuing the development of colored fireworks for many decades before Ruggieri.[5] But Brock took Ruggieri as the man who inaugurated the use of color. He went on to propose that "the modern era of pyrotechny began with the introduction of potassium chlorate," first recorded in a fireworks recipe in 1822 by Philadelphia chemist James Cutbush in the *American Journal of Science*. Cutbush claimed to be recording the French practice of producing a brilliant red flame in the theaters using nitrate of strontian, chlorate of potash, sulphur and antimony. Brock felt "this composition must have been a very striking advance on any previous color mixture."[6] To Brock the transformation to colored fires was then dramatic and abrupt as new chemicals were used to make brightly-colored fireworks. By the 1850s, strontium nitrate had begun to be used to produce a red flame. Copper nitrate created a blue flame, as did antimony sulphide or zinc filings, which made blue sparks. Barium nitrate was used to make a strong green. In a lecture at the Royal Society of Arts delivered in 1950, Brock characterized the introduction of color with this comparison: "[the] change was about as great as that produced in cinema when Technicolor first appeared on the screen."[7]

[4] Brock, *History of Fireworks*, 155.
[5] Simon Werrett, "Green is the Colour: St. Petersburg's Chemical Laboratories and Competing Visions of Chemistry in the Eighteenth Century," *Ambix*, 60 (2013), 122–38.
[6] Brock, *History of Fireworks*, 157; James Cutbush, "Remarks on the Composition and Properties of the Chinese fire, and on the so-called Brilliant Fires," *American Journal of Science*, 7 (1824), 118–40, esp. 132. Cutbush's article is dated 1822 and was published in 1824.
[7] Alan St. Hill Brock, "Fireworks" *Journal of the Royal Society of Arts*, 99 (4852) (1951), 682.

Subsequent accounts of the history of color in fireworks have agreed with Brock.[8] Joseph Needham, discussing fireworks in *Science and Civilization in China*, wrote that "The earliest use of a salt like copper acetate [verdigris] in Europe seems not to antedate Ruggieri in 1801."[9] The MIT organic chemist and explosives expert Tenney L. Davis wrote in 1948 that the "history of fireworks divides itself naturally into two principal periods, the period before the introduction of potassium chlorate and the period after."[10] The latter era led to "brilliant colored and dazzling lights, as can be produced by the use of the new ingredients."[11] If historical accounts do identify color-producing additives in earlier recipes it is assumed that these would fail to produce a noticeable color because they would be eclipsed by the force of the gunpowder exploding. Before the use of potassium chlorate, any "colors pyrotechnicians produced remained pale or otherwise unimpressive."[12]

Color before Ruggieri

Were there really no colored fires before 1800? And were pyrotechnic flames the only element in fireworks displays where color mattered? Early modern artificers do seem to have referred to colored fireworks on many occasions, while their views on the value of color were quite different to those of later times. That colored fire came to be seen as definitive of 'modern' pyrotechny by authors such as Brock is probably owing to a new relationship between chemistry and fireworks that emerged after the French Revolution.

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[8] See Markus Mäder, "Zur Technik der Pyrotechnik," in *Die schöne Kunst der Verschwendung*, ed. Georg Kohler (Munich and Zurich, 1988), 187–218, esp. 210.

[9] Joseph Needham, *Science and Civilization in China: Military Technology, the Gunpowder Epic* (Cambridge, 1974), 145.

[10] Tenney L. Davis, "The Early Use of Potassium Chlorate in Pyrotechny: Dr. Moritz Meyer's Colored Flame Compositions," *Chymia*, 1 (1948), 75-92, on 75.

[11] Davis, "The Early Use of Potassium Chlorate in Pyrotechny," 75.

[12] Laura Anne Kalba, "Fireworks and Other Profane Illuminations: Color and the Experience of Wonder in Modern Visual Culture," *Modernism/Modernity* 19 (2012), 657-676, on 663; See also Michael S. Russell, *The Chemistry of Fireworks* (Cambridge, 2009), 14.

Color, as indicated above, was certainly present in eighteenth-century fireworks in Russia, where artillerists used a mixture of verdigris and sal ammoniac to make a green flame.[13] While Brock and others might deny that this was 'true' color, to do so is to assume that there is a single, definitive standard against which to judge different historical epochs. It is also to assume that present-day authors can act as judges of all past fireworks. If, however, the question becomes one of how artificers and audiences from the past talked about color, being more sensitive to historical actors' views, then it is evident that people of the sixteenth to eighteenth centuries did believe that they were making and viewing color in fireworks displays. What follows is an exploration of such views, and the recipes and materials used to achieve different colors prior to 1700. Just to be clear, this essay does not deny that there was a transformation in the ability to produce colors in fireworks in the nineteenth century. But people of earlier generations did not view their fireworks as weak or colorless affairs even if later chemists, pyrotechnists and historians have represented them that way.

Visual Evidence for Color

It might be supposed that visual evidence could quickly decide the question of color in early modern fireworks. But the reality is not at all that simple. Most images of fireworks from the period are black and white prints, and if they were colored they were hand-colored without any interest in reproducing the authentic colors of the display.[14] Pictures were made when the combustion of a firework might not yet have happened, or it may never even have happened at all. These were not representations

[13] Werrett, "Green is the Colour."

[14] The Musée Carnavalet in Paris has many copies of the same fireworks prints from the eighteenth century hand-colored in different ways. See "Vue perspective d'un feu d'artifice tiré devant l'Hotel de Ville pour la publication de la Paix à Paris" (1763), Inv. No.: G24445; G24454; 429446; a.24453.

of enacted displays but images of how artists wanted an event to be made sense of, or remembered. As with all early modern texts, coloring was no straightforward matter.[15]

There are few paintings of fireworks from the early modern period, and these all seem to indicate that fireworks only showed the natural color of fire. This is true, for instance, of Antoine Caron's *Elephant Carousel* from the second half of the sixteenth century, which depicts an elephant on a turning wheel in a square in Antwerp surrounded by rockets.[16] A detail from Joseph Furttenbach's *Feuerwerkh, welches Herr Johann Kouhn, den 26. Augusti Anno 1644 in seinem garten uff dem word, hat abgehen lassen*, also shows natural-colored fires, as does Stefano della Bella's illustrated manual on fireworks *Traicté des feux artificielz* prepared in Paris in 1649.[17] This might be said to settle the matter, but it might first be objected that even fire of a 'natural' hue might have been considered multicolored by early moderns, as will be explored further below. In addition, the color in these paintings was most likely conventional. Even after bright colors became common in fireworks in the nineteenth century it was still normal to *represent* fireworks with the use of one natural fire color. This was perhaps because using one color provided a clearer contrast, a simpler image, and a more even surface to a painting than showing several different colors. Certainly architects and engineers were advised in the late seventeenth century on precisely which colors to use to represent rockets and

[15] Sachiko Kusukawa, *Picturing the Book of Nature: Image, Text, and Argument in Sixteenth-Century Human Anatomy and Medical Botany* (Chicago, 2012), 62–81; on the history of fireworks prints, see Kevin Salatino, *Incendiary Art: the Representation of Fireworks in Early Modern Europe* (Santa Monica,1997).

[16] Donald F. Lach, *Asia in the Making of Europe, Volume II: A Century of Wonder* (Chicago, 1970), 150–1.

[17] Furttenbach's painting is in the Germanisches Nationalmuseum, Nuremberg (inv. no. Gm 595); Della Bella's illustrations may be found in Anon., "Traicté des feux artificielz de joye et de recreation," Paris, Bibliotheque nationale de France, MS Français 1247, fol. 17 (Paris, 1649); for commentary, see Phyllis Dearborn Massar, "Stefano della Bella's Illustrations for a Fireworks Treatise," *Master Drawings*, 7 (1969), 294–302.

fireworks. Henri Gautier explained in a 1697 handbook on color conventions for painted maps and architectural plans that fireworks set off during daytime were to be represented using massicot, that is monoxide of lead, or litharge, which gave a warm yellow-orange color, and gamboge, a mustard yellow pigment made from resin. All other fireworks were to be represented using "vermillion, shading with Chinese ink or indigo, which one also uses for the smoke."[18] In the case of rockets, "their trace in the air is marked with points of vermillion and gamboge mixed together."[19] The color in images of fireworks, in this instance at least, was entirely conventional.

Evidence from Texts

While paintings are of little help, texts reveal numerous references to colored fireworks in the early modern period, though it is difficult to assess their relationship to practice. As early as the late thirteenth century, an Arabic treatise on pyrotechny by Al-Hasan al-Rammah included color recipes. Gunpowder containing verdigris and sal ammoniac should tint flames green, while camphor, indigo and incense would add white, blue and yellow respectively.[20] No Chinese recipes from this period are known, but a later manuscript, the *Huo-hsi lüeh* (Outline of Pyrotechnics), written by Chao Hsüeh-Min and dated to the mid-eighteenth century, described the creation of colored light with verdigris (green), realgar (yellow), sulphur, bluestone or blue vitriol (blue), as well as cinnabar or vermilion (red). The treatise made little distinction between colored flames, smokes and powders to be thrown into the air during displays, but did claim that at least in the case of yellow made with realgar the color would "not be

[18] Henri Gautier, *L'art de dessiner proprement les plans, profils, élévations géométrales, et perspectives, soit d'architecture militaire ou civile, avec tous les secrets les plus rares pour faire les couleurs avec lesquels les ingénieurs représentent les divers matériaux d'une place* (Paris, 1697), 97.
[19] Gautier, *L'art de dessiner*, 98.
[20] J. R. Partington, *A History of Greek Fire and Gunpowder* (Baltimore, 1999 [1960]), 202–3; on color in Chinese fireworks see 253–4.

overshadowed by the light of the burning powder."[21] The lack of distinction is normally seen as a problem for determining the 'true' nature of color in Chinese fireworks, but it is precisely to this lack of concern that we should be sensitive when distinguishing colored flames from other colored effects.

Color Recipes

It is not known if or how these recipes may have made their way to Europe, where fireworks began to be used in warfare and festivals around the end of the 1370s.[22] Pyrotechnic recipes were first recorded in Europe in the early fifteenth century, when German artificers wrote a manuscript *Feuerwerksbuch* detailing their techniques. This was copied and amended in many versions before printed treatises on fireworks began to be published after 1560, again first in Germany and then across Europe.[23] Manuscripts and books typically explained how to make gunpowder, then proceeded to describe a variety of military and festive fireworks.[24] Many recipes were copied or adapted from earlier texts, so they were not necessarily a reflection of practice.

A partial survey of these manuscripts and books reveals many references to color in recipes for fireworks. For example, in fol. 130v of MS Ashmole 343, the *Secret of Gunmen*, a seventeenth-century copy of a late sixteenth-century English manuscript held in the Bodleian Library in Oxford, included the instruction,

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[21] Tenney L. Davis & Chao Yün-Tshung, "Chao Hsüeh-min's Outline of Pyrotechnics: A Contribution to the History of Fireworks," *Proceedings of the American Academy of Arts and Sciences*, 75 (1943), 101.
[22] Lotz, *Das Feuerwerk*, 3; Schaub, "Pleasure Fires," 39.
[23] *Feuerwerksbuch*, Freiburg im Breisgau, Universitätsbibliothek, HS 362, fol. 86v (ca. 1430–1445), accessed August 23, 2014, http://dl.ub.uni-freiburg.de/diglit/hs362/0001?sid=128eb19c1a1fb22fa2cc44f21bc97a0a. For commentary, see Gerhard W. Kramer, "The Firework Book: Gunpowder in Medieval Germany," *The Journal of the Arms and Armour Society*, 17 (London, 2001), 1-89; Wilhelm Hassenstein, *Das Feuerwerkbuch von 1420. 600 Jahre deutsche Pulverwaffen und Büchsenmeisterei* (Munich, 1941).
[24] Chris Philip, *A Bibliography of Firework Books: Works on Recreative Fireworks from the 16th to the 20th Century* (Winchester, 1985).

> To make fire of diuerse colours [use] Spanish greene Camphire, Sulphire, Turpintine, oyle of Linseede, oyle benedict, oleum benedictum, oil of bricks, these giue in the night many colours, & fearefull to see.[25]

Several manuals contained recipes for colored stars, consisting of round pellets formed from gunpowder which were packed inside a wooden ball and fired into the air from a mortar, to explode in a pattern in the sky. John Babington, in his printed *Pyrotechnia* of 1635, added oil of spike (lavender oil) and aqua vitae (concentrated ethanol or brandy) to make stars of a "blue colour, with red," a recipe repeated in many later publications.[26] Babington also proposed using camphor to make a white flame in stars, another recipe often reprinted.[27] Robert Anderson, an English gunner writing later in 1696, provided more recipes for colored stars.

> Of Rain and Hail. Take any of those Receipts for Stars, viz. 1 [part] Sulphur, 2 [parts] Antimony, and 4 [parts] Saltpetre; if you moisten that Composition with Oil of Petre only made well into Paste, formed into little Globes, rowled into mealed Powder; such Stars will have Red Colour: the same Composition moistned with Linseed Oil will have a Red mixed with White: the same Composition mixed with Oil of Petre and Linseed Oil mixed together, will

[25] "Secret of Gunmen," Oxford, Bodleian Library, MS Ashmole 343, fol. 130v, transcribed in Steven Walton, "The Art of Gunnery in Renaissance England," (Ph.D diss., Toronto, 1999), 382.
[26] John Babington, *Pyrotechnia or, A discourse of artificiall fire-works in which the true grounds of that art are plainly and perspicuously laid downe* (London, 1635), 11; Thomas Venn, "The Compleat Gunner. The Third Part. Of Artificial Fire-Works," in his *Military and maritine [sic] discipline in three books* (London, 1672),17; Tomaso Moretti, *A general treatise of artillery, or, Great ordnance writ in Italian by Tomaso Morretii…with an appendix of artificial fire-works for war and delight, by Sir Abraham Dager* (London, 1683), 123; Samuel Sturmy, *The mariners magazine stor'd with these mathematical arts…Gunnery and artificial fire-works* (London, 1679), book 5, 73.
[27] John Babington, *Pyrotechnia*, 11; see also Sturmy, *The mariners magazine*, 73.

> make an Amethist Fire […]. The same Composition mixed with Gum Araback Water, and Colophone, gives a Red Yellowish Fire.[28]

The most influential treatise after the *Feuerwerksbuch* was the *Artis magnae artilleriae*, or *Great Art of Artillery*, published in Amsterdam in 1650 by the Polish gunner Casimir Siemienowicz.[29] This was translated into French, German and English, and copied in many pyrotechnic treatises of the seventeenth century. Siemienowicz's book dealt with color in a section on the construction of rockets.

> You may also contrive so as to have the Fires issuing from your Rockets of divers Colours. As for Example; if you mix a certain Quantity of Camphire in your Composition, it will yield a White, Pale, or Milky-Colour Fire. If you mix a little Greek Pitch in it, it will produce a Reddish Copper-Colour Flame. If Sulphur, you will have a Blue Fire. If Sal Armoniac, it will be Greenish. If Crude Antimony, the Flame will be of a sad Yellow, or of an Honey or Box-Colour. If the Scrapings of Ivory, it will be of a bright Silver-Colour, inclining a little to the Livid or Lead-Colour. If the Raspings of Yellow Amber, it will appear the same, but inclining to the Citronish. In short, if you mix your Composition with common Pitch, your Rocket will cast forth an obscure gloomy Fire, or rather a black thick Smoke which will darken all the Air. The Sieur de la Porte (sometimes called Baptista Porta) tells us in his *Natural Magic*, Book VII, and Chap. VII, that the Loadstone being buried under

[28] Robert Anderson, *The Making of Rockets* (London, 1696), 11.
[29] Casimirus Siemienowicz, *Artis magnae artilleriae pars prima* (Amsterdam, 1650).

> Burning Coals, commonly emits a Flame that is of a Blueish, Sulphurine, or Iron Colour.[30]

Siemienowicz went on to say that "Fires of various Colours are held in great Esteem with regard to these Works [i.e. fireworks]; as if, for Example, you would represent a Rainbow, an Infernal or Gloomy Fire, Water, Stars, and such like."[31] Siemienowicz evidently took inspiration from other books, such as those from Neapolitan natural magician Giambattista della Porta, and again this casts doubt on the degree to which his recipes were taken from practice.[32] But it seems indisputable that authors at least assumed colored fireworks were a part of pyrotechnics in the sixteenth and seventeenth centuries, and numerous recipes existed for making colors.

The term 'color' should not, however, be assumed to have meant the same to early moderns as it does today. As Doris Oltrogge notes in this volume, there were varying interpretations of color theory in the sixteenth and seventeenth centuries, developing and challenging the ideas of Aristotle on color. Aristotle, among others, believed black and white constituted the basic colors, and colors were ordered in terms of their relative mixture of black and white. Yellow was mostly white and blue was mostly black. Alternatively one could look to an alchemical theory which identified three basic colors—black, which turned into red, which turned into white. By the end of the seventeenth century, Descartes' mechanical philosophy and Newton's optical experiments provided further alternative theories of color.[33]

[30] Casimir Siemienowicz, *The Great Art of Artillery*, trans. George Shelvocke (London, 1729), 168; translating Casimirus Siemienowicz, *Artis magnae artilleriae: pars prima* (Amsterdam, 1650), 119.
[31] Siemienowicz, *Artillery*, 378; translating Casimirus Siemienowicz, *Artis magnae artilleriae: pars prima* (Amsterdam, 1650), 266.
[32] Siemienowicz refers to book 7, chapter 2 of Giambattista Della Porta, *Natural Magick* (London, 1658), 192, where Della Porta writes: "I oft saw with great delight a Loadstone wrapt up in burning coles, that sent forth a blue flame, that smelt of brimstone and iron." For the Latin original, see Giambattista Della Porta, *Magiae naturalis libri XX* (Naples, 1589), 129.
[33] On color theory in this period, see James S. Ackerman, "On Early Renaissance Color Theory and

Writers of fireworks manuals did not theorize explicitly about color in their texts, but certain practices suggest they had some basic version of the Aristotelian theory in mind when creating colors. Bate described the production of different colors in fireworks in what I shall call a ‘composition shift’,

> if you would have [fire trunks] to change color, then alter the composition that is, put in two or three spoonfulls of the composition of Rockets for the water, and ramme that in, then put in two or three spoonfulls of the composition of Rockets for the ayre, and ramme that in, then put in two or three spoonfulls of gunpowder dust.[34]

No substance was here being added to generate color, just two different ratios of the same common ingredients, saltpeter, charcoal and sulphur. But the recipe makes sense if one thinks in terms of color being generated by different degrees of black and white, since it utilized different proportions of charcoal, a black substance and saltpeter, a white powder.[35] Bate’s recipe suggests that what counted as a ‘different’ color for him might only be considered a slight variation today. Just as the early modern physician discerned a myriad of subtly different hues in urine, so the artificer, and perhaps also the audiences for fireworks, might discern many different colors among the varieties of ‘natural’ fire made with gunpowder.

Practice,” *Memoirs of the American Academy in Rome*, 35 (1980), 11–44; Martin Kemp, “The Aristotelian Legacy,” in *The Science of Art, Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven, 1990), 264–84; Alan E. Shapiro, “Artists’ Colors and Newton’s Colors,” *Isis*, 85 (1994), 600–30.

[34] John Bate, *The mysteries of nature and art in foure severall parts* (London, 1635), 123; a similar recipe may be found in Francis Malthus, *A treatise of artificial fire-works both for warres and recreation* (London, 1629), 108.

[35] Bate provides many recipes for air and water rockets, but here are two. He does not say what the proportions of ingredients are in his gunpowder. Water rockets: 1lb saltpeter; 0.5lb sulphur; 0.5lb gunpowder; 2oz charcoal (p. 103); Air rockets: 1lb saltpeter; 4lbs gunpowder; 4oz charcoal (p. 99) Bate, *The mysteries of nature and art*, 99–100; 103.

Materials of Color

The ingredients proposed for making color in fireworks were quite varied, and tracing their origins, uses and circulation in the early modern period reveals networks and exchanges between different ‘color worlds’ that shaped pyrotechnic practice. Examining materials also helps to illuminate the differences between early modern perceptions of color and common understandings of color today. Table 1 summarizes some of the substances used to produce colors in the texts surveyed in the previous section.

Red	Oil of petre; Greek pitch
Yellow	Colophone; Antimony; Amber
Green	Verdigris [aka Spanish Green]; Sal ammoniac
Blue/Red	Oil of spike; Aqua vitae;
Blue	Sulphur; Loadstone under burning coals
Amethyst	Oil of Petre and Linseed Oil
Black smoke	Common pitch
White	Camphor
Silver	Ivory

Table 1: color-generating substances in early modern fireworks

Camphor was an aromatic spice used in perfumes and to make white flames. The waxy, inflammable substance was extracted from the wood of the camphor laurel tree.[36] Colophone, another name for rosin, was a yellow resin similar in appearance to amber. Along with gum arabic, the hardened sap of the acacia tree, this was used to produce a yellow flame. The blue-red color of aqua vitae, or brandy, is still familiar

[36] R. A. Donkin, *Dragon's Brain Perfume: An Historical Geography of Camphor* (Leiden, 1999), 160–1.

today. However, it is not clear that either oil of spike (lavender oil) or linseed oil, made from pressed flax seeds, could produce any color in a pyrotechnic fire. Verdigris, on the other hand, easily burns to give a green flame. Verdigris, copper acetate or copper carbonate, is a pale green rust used for paints and pigments from ancient times, leading to its name, Green of Greece (or *vert de Grèce*). Verdigris was made commercially in the seventeenth century, especially in Montpellier in France, by exposing copper sheets to the acid fumes of soured red wine then scraping off the green residue and selling it in lumps. A purer verdigris could be made by dissolving it in vinegar and letting it re-crystallize.[37]

These materials might be said to have some common properties. Many evidently travelled in a global economy to reach artificers in Europe. The sulphur and saltpeter used to make gunpowder came from Venice, Naples, Sicily and North Africa and were shipped by Italian, German and Flemish traders.[38] Camphor trees were found in Japan, Borneo and Sumatra. Materials did not yield color through a chemical reaction, but their intrinsic hues were thought to add further color to flames. Yellow flames should be made with yellow materials, and so on. Many materials were used in painting, pottery, medicine and alchemy, and suggest a link between these practices and pyrotechny. Aqua vitae, or spirit of wine, for example, was concentrated alcohol or ethanol, made by repeatedly distilling red wine. It was used in a wide range of medicines from the eleventh century, being described in the thirteenth as the "mother and mistress of all medicine" for its power to absorb qualities and flavors from herbs and flowers.[39] In the sixteenth century aqua vitae was used to treat aches and pains, corns, sciatica, and to encourage urination (fry with hot horse dung and butter and

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[37] On verdigris, see R. D. Harley, *Artists' Pigments c. 1600-1835: A Study in English Documentary Sources* (London, 2001), 80–3.
[38] David Cressy, *Saltpeter: The Mother of Gunpowder* (Oxford, 2013), 40–1, 51–2.
[39] Taddeo Alderotti, quoted in Angela Montford, *Health, Sickness, Medicine and the Friars in the Thirteenth and Fourteenth Centuries* (Aldershot, 2004), 208.

apply the paste to the patient's "fundament" as long as they can bear it).[40] Antimony, used to make yellow flames, was deployed by Bernard Palissy in yellow glazes for pottery, and was another ingredient widely used in alchemy and medicines, notably to make the "star regulus of antimony," a key product of Isaac Newton's alchemy, by heating stibnite with iron and saltpeter.[41]

Aqua vitae also had strong alchemical associations, equated by many with a certain quintessence or elixir that was able to give life or animation to non-living things, though the term could be used in alchemy to mean many different kinds of distillates, not just alcohol. Alchemy was itself referred to by some early moderns as *pyrotechnia*, because it worked with fire. Indeed, the use of certain fireworks to imitate the motion of cosmic phenomena or to behave like animated beings such as serpents echoed the generative goals of some alchemists.[42]

Two other materials used to color fireworks featured frequently in the material culture of painters—linseed oil and verdigris. Linseed oil, proposed as a way to make red fire, became the most popular solvent for oil paints in the fifteenth century, and was also used for varnishes (containing dissolved resins) and for making ink (mixed with soot). Verdigris was widely used by painters for green glazes and paints.[43] Substances and recipes were able to transfer between the color worlds of the artist and pyrotechnician, not least because these might very well be the same people. As Brock noted, the French writer Jean Appier, known as Hanzelet, in his book *La pyrotechnie*

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[40] A. T., *A rich store-house or treasury for the diseased Wherein, are many approued medicines for diuers and sundry diseases, which haue been long hidden, and not come to light before this time* (London, 1596), 22.

[41] Hanna Rose Shell, "Ceramic Nature," in *Materials and Expertise in Early Modern Science*, eds. Ursula Klein and Emma Spary (Chicago, 2010), **50-70, on** 56; Ian R. McCallum, *Antimony in Medical History: An Account of the Medical Uses of Antimony and Its Compounds Since Early Times to the Present* (Edinburgh, 1999); William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry* (Chicago, 2002), 107–9.

[42] This idea is explored in chapter one of Werrett, *Fireworks*.

[43] Mary Philadelphia Merryfield, ed., *Medieval and Renaissance Treatises on the Arts of Painting* (New York, 1999), ccxvi–ccxxi.

of 1630, proposed using verdigris to make green fire. "*Si vous desirez avoir du feu vert, il ne faut qui adiouster un peu de vert de gris en poudre parmy la composition*" (If you wish to have green fire, it is necessary to add a little powdered verdigris into the composition).[44] Hanzelet also worked as an engraver and so presumably employed paints and inks. Bate's *Mysteries of Nature and Art* included both fireworks and paint recipes, and he used verdigris to make an "Emerauld Colour" paint though not to color fire.[45] Fireworks often involved painting decorations so paints and pyrotechnics may have often been prepared simultaneously.

The use and exchange of materials between pyrotechny, alchemy, painting and medicine demonstrates the strong connections between these arts in the sixteenth and seventeenth centuries. Paul Hills has argued that Renaissance painters took the imitation of fiery effects as a challenge, prompting Titian to use varnish and oils to evoke ideas of fire in works such as his *Annunciation* (ca.1560) and *Martyrdom of Saint Lawrence* (ca. 1548-1557).[46] Pamela Smith has shown how painting was considered a kind of alchemy in the Renaissance, and medicine and alchemy indeed share a long history.[47] As early as 1390 Cenino Cennini insisted that verdigris and vermilion were made by alchemy, and in the sixteenth century the writer on metallurgy and fireworks Vannochio Biringuccio wrote in his *Pyrotechnia* (1540) that art, alchemy and medicine were all practices that sought to restore Man and Nature after the Fall.[48] Painting and medicine were also important adjuncts to military arts, and besides Hanzelet at least one other fireworks artist, working in the eighteenth century, also trained as a painter of heraldry. Mikhail Vasil'evich Danilov of the

[44] Hanzelet, *La pyrotechnie* (Pont-à-Mousson, 1630), 257.
[45] Bate, *The mysteries of nature and art*, 122.
[46] Paul Hills, "Titian's Fire: Pyrotechnics and Representations in Sixteenth-Century Venice," *Oxford Art Journal*, 30 (2007), 185–204.
[47] Pamela H. Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago, 2004).
[48] Ibid., 140; 145.

Russian artillery went on to create a green firework using verdigris, which began the Russian tradition of making colored fires subsequently imitated by Ruggieri.

The Uses of Color

The substances added to gunpowder to produce colors might not have yielded the bright chromatic displays of modern fireworks, but early moderns still took them as colored fires. It might be assumed that color was intended to create a pleasing effect for an audience, but this was not always the case. Early modern authors often claimed that fireworks terrified "vulgar" audiences, who were unable to distinguish between artificial thunder and lightning and the real thing.[49] Color may have been thought to enhance this fearful effect. The *Secret of Gunmen* manuscript discussed above explained how to make fires that "giue in the night many colours, & fearefull to see."[50] As Sven Dupré has noted, painters of the period explored the fearful color of fire. The Dutch painter and poet Karel van Mander wrote how,

> The dangerous fire of disastrous conflagrations seizes with fright the human heart when raising with its sparkles a fierce sputtering. The blacker and thicker the dark veil of the night is, the brighter its powerful flames light; and they give the houses, temples and other buildings a re-reflection of the same colour; and they also give the water a horrible look.[51]

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[49] Simon Werrett, "Watching the Fireworks: Early Modern Observation of Natural and Artificial Spectacles," *Science in Context* (Special Issue: *Lay Participation in the History of Scientific Observation*, ed. Jeremy Vetter), 24.2 (2011), 167–82.
[50] "Secret of Gunmen," Oxford, Bodleian Library, MS Ashmole 343, ff. 128r–139r, on fol.130v; transcribed in Walton, "The Art of Gunnery," 389–412.
[51] Quoted in Sven Dupré, "The Historiography of Perspective and *reflexy-const* in Netherlandish Art," *Nederlands Kunsthistorisch Jaarboek*, 61 (2011), **34-61, on** 54.

Another use of color in pyrotechny came at the production stage of making gunpowder and fireworks. Artisans had an acute knowledge of materials through their senses and bodies, feeling, smelling and observing ingredients carefully to learn their properties. Colors could reveal much. Hanzelet explained that in making gunpowder, "*Le Saltpetre doit estre tres-blanc* […] *si l'on desire auoir de la bonne poudre*" (the saltpeter has to be very white […] if you desire the best powder).[52] Siemienowicz wrote, "You may know the Goodness of Sulphur by pressing it between two Iron Plates; for if in running it appears yellow like Wax, and emits no suffocating Scent, and if what stays behind is of a reddish Colour, you may conclude it to be natural and excellent."[53] Beginning with the early *Feuerwerksbuch*, many texts on pyrotechny included recipes for colored gunpowder, made by adding color-bearing substances to sulphur and saltpeter:[54]

> If you want to make a white gunpowder, then take a pound of salpetre, a pound of sulphur, a pound of wood and dry them properly in an oven and grind it and mix it into a powder. If you want it to be almost white and strong then mix add Sal Ammoniac and Camphor by weight.[55]

Red powder could be made with *Sandelholz* (sandalwood), blue with *Kornblumen* (cornflowers) and *Faulbaumholz* (black alder wood), and yellow with the flowers of the Alpine *Speik* plant. In the seventeenth-century *Ars magnae artilleris*,

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[52] François Thybourel and Jean Appier dit Hanzelet, *Recueil de plusiers machines militaires, et feux artificiels pour la guerre, & recreation* (Pont-à-Mousson, 1620), book 4, chapter 2, 11.
[53] Siemienowicz, *Great Art of Artillery*, 99.
[54] Partington, *History of Greek Fire*, 154.
[55] *Feuerwerksbuch*, Freiburg im Breisgau, Universitätsbibliothek, HS 362, fol. 86v (ca. 1430–1445): "Wilt du ein weyß büchsen puluer machen so nymm ein pfund salbeter ein pfund schwebel vnd ein pfund holtz vnd dörr es wol in einem ofen stoß dz vnder einander zepuluer wiltu dann das es vast weyß vndf starck werde so th Salarmoniac vnd kampffer nach gewicht."

Siemienowicz proposed using camphor or elder pith to make white powder, verdigris for green, saffron for yellow and red sanders and amber for red. Such colored powders may have been used to generate colored fires but this would not work in the case of adding, e.g., azurite or blue bice to make blue powder as the English gunner and mathematician Nathaniel Nye proposed to do in 1647.[56] The addition of color ingredients was rather discussed in terms of changing the quality of gunpowder's strength. The quotation from the *Feuerwerksbuch* above perhaps indicates that changing the color of gunpowder could add to its strength, and this may have set the terms for Siemienowicz' discussion of color and the strength of powder.

> The Blackness of Gun-powder is entirely owing to the Charcoal; but that Tincture is no necessary Adjunct to its Nature, nor does it so far contribute to the strengthening of it, but that you may make it of several Colours with equal Success. For Example if instead of Charcoal you take rotten Wood, or white Paper that has been first moistened, then put into an hot Oven, and after that pulverized, or any thing else that is of a very combustible Nature […] you will have a Powder to the full as effective as the Black Sort.[57]

Discussions of whether a change of color could strengthen gunpowder seem not to have waned. As late as the second half of the eighteenth century, the English author Robert Jones still had to deny its truth,

> Notwithstanding the repeated trials and experiments, made by the greatest artists, to add to the strength of gun-powder, all have proved ineffectual […] therefore it is evident, that any thing being mixed with the present composition

[56] Nathaniel Nye, *The Art of Gunnery* (London, 1670 [1647]), 22.
[57] Siemienowicz, *Great Art of Artillery*, 106.

> would rather reduce its strength than add to it; consequently coloured powder must be weaker than black: so that the making of powder of different colours, is only a fancy that serves to please the curious, without any other effect.[58]

Using different colors to generate different properties was not unknown in other early modern arts. As Pamela Smith has shown in her study of the dye vermilion, blood, redness, and aqua vitae all had associations of renewal, redemption and the recovery of strength in this period (which is why manuscript corrections were made with red ink).[59] Many fireworks recipes employed aqua vitae. The *Feuerwerksbuch* claimed that sulphur could be made stronger, that is "*trückner vnd hitzig vnd besser*" (dryer, hotter, and better) by grinding it with *kecksilbers* (mercury) and soaking it in *gebrennten win* (aqua vitae).[60] In the seventeenth century, Nye included vinegar made as "red as blood" with brazil wood in a recipe for red powder, which he followed with a recipe for renewing the strength of old gunpowder.[61]

Scenery and Decorations

The appreciation of color difference and function evidently changed over time and this was also true of the appreciation of where color mattered in fireworks displays. The idea that the color of fire is of principal importance in pyrotechny seems to have originated in the early nineteenth century just when brightly colored fires became possible. Throughout its history pyrotechny has been allied with a great variety of sciences and different forms of expert knowledge, ranging from architecture and

[58] Robert Jones, *Artificial Fireworks, Improved to the Modern Practice,* 2nd ed. (London, 1776), 11; Amédée François Frézier, *Traité des feux d'artifice* (The Hague, 1741), 36, makes a similar point.
[59] Pamela H. Smith, "Vermillion, Mercury, Blood, and Lizards: Matter and Meaning in Metalworking," in *Materials and Expertise in Early Modern Science*, eds. Ursula Klein and Emma Spary (Chicago, 2010), 29–49; see also Smith, *The Body of the Artisan*.
[60] *Feuerwerksbuch*, Freiburg im Breisgau, Universitätsbibliothek, HS 362, fol. 86v (ca. 1430–1445).
[61] Nye, *The Art of Gunnery*, 22.

mathematics to chemistry and painting.[62] The alliance with chemistry might seem obvious today, and certainly pyrotechnic operations were articulated as a form of alchemical art in the fifteenth and sixteenth centuries. But alchemy, with its links to medicine and the generation of elixirs, was not the same as chemistry, which really only came to be associated with fireworks in the wake of the Chemical Revolution in the early nineteenth century, in particular in the writings of Claude-Fortuné Ruggieri, the creator of green fire. Ruggieri represented pyrotechny as a chemical science, employing a new vocabulary taken from Lavoisier's *Eléments de chimie* to distinguish it from eighteenth-century treatises which instead emphasized the importance of architecture in displays.

Following Ruggieri, pyrotechnic authors joined chemists such as James Cutbush in celebrating new colored fires made with potassium chlorate and a growing variety of metal salts.[63] This chemical approach entailed a more systematic investigation of color effects based on chemical theory and using combinations of precisely measured quantities of substances. By the 1840s, publications listing colored fireworks using potassium chlorate multiplied. As indicated above, these used a variety of new chemicals to produce color. By the late 1850s, this new alliance of chemistry and pyrotechnics was reflected in book titles such as Paul Tessier's *Chimie pyrotechnique*.[64] Enthusiasts of this new chemical pyrotechny now presented earlier fireworks as pale imitations of their own creations. F. M. Chertier wrote in 1843,

[62] Werrett, *Fireworks*.
[63] See also Moritz Meyer, *Pyrotechnie raisonée ou Application de la chimie aux artifices du guerre*, trans. T. Hippert (Brussels, 1836); F. M. Chertier, *Essai sur les compositions qui donnent les plus belles Couleurs dans les Feux d'Artifice* (Paris, 1836); F. M. Chertier, *Nouvelles Recherches sur les Feux d'Artifice* (Paris, 1843).
[64] Paul Tessier, *Chimie pyrotechnique, ou Traité pratique des feux colorés* (Paris 1859).

> For a long time […] we obtained very little variety in our effects. Later, we discovered white flames; that was already quite a discovery; we also made some attempts to obtain flames of different colors. We even convinced ourselves that we could make yellow, red, pink, and violet; but these colors were dull, vague, and, in the end, just plain bad.[65]

Such criticisms misrepresented earlier views of color, however. Prior to Ruggieri, artificers were certainly interested in color and the chemistry of their compositions, but these were not singled out as being of special importance. Manuals of fireworks might carry color recipes to signal authors' pyrotechnic expertise, but did not prioritize color as a desirable aesthetic component in displays. Nor was color added to fireworks just to create pleasing effects, but could evoke fear and change the strength of gunpowder. Staging fireworks involved sounds, smells, scenery and decorations, costumes, music and story telling, and artificers paid attention to all of these elements to create an impressive spectacle. Color did not necessarily need to be produced solely through pyrotechnic flames.

For example, before the early nineteenth century, much effort was expended to create grand temporary edifices called 'machines' from which fireworks were launched or set off. These took the form of full-scale castles, temples, columns or scenes from ancient mythology, constructed with painted canvas and papier-mâché on wooden frames. Machines were typically adorned with emblems, statues, festoons and garlands, urns and trophies whose symbolism suited the occasion being celebrated. Automaton figures of beasts, monsters, warriors and knights might be made to roam about the machines. Typically, all of these were brightly painted, as contemporary

[65] Quoted in Kalba, "Fireworks and Other Profane Illuminations," trans. Chertier, 663.

manuscripts and prints make clear.[66] Histories of fireworks following Brock have claimed that this colorful scenery was used to make up for a lack of colored fires, but this would only make sense if artificers could compare their colors to later ones or if colored fire was even the principal goal of displays. But it was not. Fire effects might not have figured at all in the aesthetic evaluation of displays. As late as 1798 the British essayist Isaac D'Israeli defined pyrotechny as an art where

> in proportion as the inventors have displayed ability in combining the powers of architecture, sculpture, and painting, have produced a number of beautiful effects, which even give pleasure to those who read the descriptions, without having beheld them.[67]

The enduring elements mattered more to D'Israeli than the fleeting pyrotechnics, because they transcended their specific instance of performance and were available to a broader audience through print. D'Israeli's comments reveal the novelty of Ruggieri and Cutbush's idea that fireworks should be principally about the chemical creation of colored fire. This idea became a common assumption in pyrotechny, and has distorted the view of early modern fireworks, as a practice lacking color, ever since.

Conclusion

In conclusion it is difficult to make many secure statements about the presence of color in early modern fireworks, but the aim of this paper has not been to do so. While it should be evident that color was certainly a part of pyrotechny in this period,

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[66] Dragon figures in fireworks should be given "*diuers couleurs*" according to Thybourel and Hanzelet, *Recueil de plusiers machines*, Book 5, 18.

[67] Isaac D'Israeli, *Curiosities of literature: consisting of anecdotes, characters, sketches, and observations, literary, critical, and historical*, fourth edition, 2 vols. (London, 1798), 2: 416.

appearing in recipes, methods, decorations, representations, it quickly becomes apparent that it is impossible to determine whether colored flames of the kind we see today were or were not present in early modern fireworks. Yet as previously stated, the aim of the essay has not been to make a definitive claim about this. Rather, the goal has been to explore different visual and textual sources of evidence in order to consider how they treat color and to identify some of the historical possibilities and constraints on what may be said about pyrotechnic color in these sources. Paintings do not show colored flames, but were highly conventional in their representations of fire. Technical manuals included many recipes for colored fires and powders, but it is hard to assess how these were reflected in actual practice. It seems clear that early modern pyrotechnic authors did assume colored fireworks were part of pyrotechny, against the views of later historians who have supposed they did not.

Simultaneously, what color actually meant to early moderns should not be taken for granted. Some recipes describe what must have been quite subtle shifts in the hues of gunpowder flames as a change of color, while some substances presented as changing the color of fires would probably have had little discernible effect. Powders may have been colored not to change the color of flames, but in the belief that it strengthened the powder. Color was certainly an important feature of architectural decorations in displays. These uncertainties are important, not only because they raise interesting questions about the nature of color use and perception among early moderns, but also because they suggest that perhaps articulating the precise nature of color was not given much importance in early modern fireworks. That is, while color might have been present and valued in fireworks, being very concrete about where and how color should figure in displays was apparently not a preoccupation of early modern authors. It was only in the nineteenth century that a more precise discourse of color emerged in pyrotechny, matching the concern to use chemistry to produce specific, pyrotechnic colored flames. The diffuseness of early modern color, then, should not just be taken as a product of incomplete historical knowledge, but is perhaps better seen as itself a feature of the 'color world' of early modern pyrotechnics.