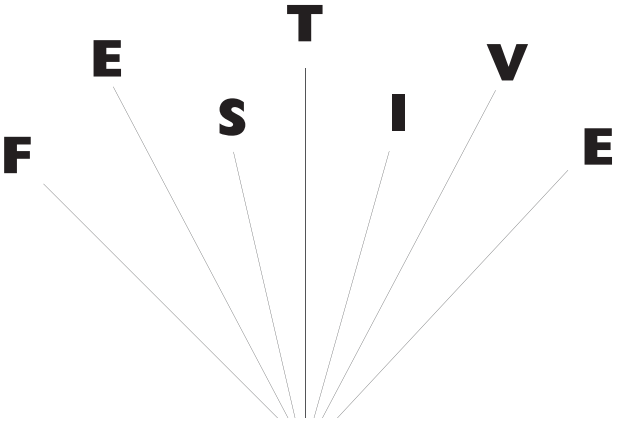


fireworks

BY MARIA BLACKBURN

THE COLORFUL PYROTECHNICS THAT INSPIRE 'OOHS' AND 'AAHS' THE WORLD OVER REQUIRE CRAFTSMANSHIP, PRECISION—AND CREATIVITY

JOHN CONKLING HAS seen millions of fireworks in his day.

He's shot off Roman candles and twirled glowing sparklers at backyard picnics. He's watched in delight as yellow double rings and red hearts illuminated the sky the night before his daughter's wedding. And he's marveled at thousands of aerial shells exploding and spraying peonies, crackling crossettes and glittering golden comets across the night sky.

For Conkling, the former technical director of the American Pyrotechnics Association, it doesn't matter whether he's watching a small display by a group of hobbyists or a million-dollar extravaganza by one of the world's top fireworks companies. When he watches a fireworks display, he always sees the same thing: "Chemistry," he says.

Indeed, aerial fireworks are more than just a collection of colored lights and sounds. They get their entertainment value from a series of reactions that occurs when one combines basic chemical elements in a cardboard tube or sphere, ignites them, and shoots them up into the air where they explode.

"No one enjoys fireworks more than a chemist," admits Conkling, an adjunct professor of chemistry at Washington College in Chestertown, Md., who has been working with fireworks for more than 40 years. "The average person watches a beautiful red shell burst in the air and 'oohs and aahs.' I see it and say strontium, the element used in fireworks that gives off a red light when aflame."

Since their invention in China some 2,000 years ago, fireworks have endured as a popular way to celebrate. From Guy Fawkes Day in the United Kingdom and Diwali in India, to Bastille Day in France, July 4th in the United States, Christmas in Colombia, and New Year in Asia, nearly every culture in the world uses fireworks to mark special occasions. Their appeal is universal, even primal. "When you go to a fireworks show and watch the sky exploding in colors it goes right to the very roots of the human soul," Conkling says. "There is just this fascination with fire."

Revelers celebrate the Lunar New Year in New York City, near right. Fireworks by Grucci set a world record in Dubai in November 2009, with the largest fireworks display in history, far right.

That fascination is felt deeply by professional pyrotechnicians like Joseph Domanico, a longtime member of the Crackerjacks. The mid-Atlantic region fireworks club has 300 members who enjoy legally crafting and shooting fireworks together. Domanico typically spends months drawing up plans and weeks making shells by hand for elaborate "chaos machines"—fixed set pieces festooned with fireworks. The resulting display may last just three minutes. But the effort is worth it. "Once you've smelled the smoke, you are never again free," he says.

* * * * * * * * * * * *

China is the world's largest producer and exporter of fireworks. Some 90 percent of fireworks are manufactured in China, everything from consumer firecrackers and sparklers to the powerful aerial shells only the pros can use. In 2006, China exported nearly $212 million worth of fireworks to the United States, according to U.S. trade data.

China's status as a fireworks powerhouse seems especially fitting when one considers that the Chinese invented not only fireworks, but their core ingredient: gunpowder or black powder. Legend has it that more than 1,000 years ago, a Chinese cook working in a field kitchen accidentally mixed saltpeter or potassium nitrate, charcoal and sulfur together and the mixture burned. When it was compressed in a bamboo tube, this black powder exploded with a brief golden glow, and the firecracker was born.

Explorer Marco Polo is said to have transported gunpowder with him in the 13th century to Europe, where it was used by the military. The Italians were the first Europeans to use gunpowder for fireworks and by the 1400s, Florence, Italy, was the center of fireworks manufacturing in the world. Elaborate fireworks displays quickly became a favorite method for marking religious festivals and royal celebrations around the world. Anne Boleyn's coronation in 1533 featured a fire-spewing papier-mache dragon. Shakespeare mentioned fireworks in his works and they served as inspiration to George Frideric Handel, who composed his "Music for the Royal Fireworks" in 1749.

Around 1830, Italian craftsmen realized that by adding metals that burned at high temperatures to their fireworks they could create such new effects as color and sound. They enclosed their mixes in paper shells and wrapped them in paper, glue and string. It's a design still used today. "The Chinese may have invented fireworks but the Italians perfected them," Domanico says. "They gave us color."

Fireworks were a part of the United States from the country's very beginning. In 1775, future President John Adams set the tradition of pairing fireworks and July 4 when he wrote of his vision for the country's first Independence Day celebration in 1776. "The day [Independence Day] will be the most memorable in the history of America ... it ought to be solemnized with pomp and parade ... bonfires and illuminations [fireworks] from one end of this continent to the other, from this day forward forevermore."

The illuminations on display across the continents today still have black powder at their core, but displays have gotten bigger, brighter and more elaborate. "Traditional fireworks shows were shoot them up one at a time slowly, and bore people for an hour or 45 minutes," says M. Philip Butler, a producer with Fireworks by Grucci, a Brookhaven, N.Y., company that's been in the business since 1850. "We don't do that anymore."

Thirty years ago a fireworks display might have lasted an hour. Today it is 20 minutes of nonstop pyrotechnics. Sometimes even shorter. In November 2009 in Dubai, Fireworks by Grucci set a world record with the largest fireworks display in history. The show had a $2.7 million budget and lasted just eight minutes.

* * * * * * * * * * * *

China may dominate world manufacturing and distribution of fireworks, but many countries—including Italy, Spain, Mexico and the United States—are home to companies that still make some of their own.

"It's as much about tradition and quality as it is anything else," explains Doug Taylor, CEO of Zambelli Fireworks in New Castle, Pa. The company manufactures 2 to 3 percent of the 30,000 cases of fireworks used in the several thousand shows it produces annually. Taylor buys the large majority of his company's fireworks from Chinese vendors because they are a good value, he says. But the company's

signature shell, the "star mine," is made by hand every morning by octogenarian Lou Zambelli. He uses a recipe that's been in the family for generations. "We really feel strongly that our star mines are better than what we can buy," explains Taylor.

There are two basic shapes of aerial shells: round or "Oriental"-style shells and cylindrical or Italian-style shells. An Italian shell can hold more than one effect, such as distinct bursts of red, white and blue stars that break individually as the shell rises to its peak of several hundred feet. These shells break "soft," creating asymmetrical trails of color in the form of palms and weeping willows. By contrast, round shells typically hold just one effect. These shells break "hard," forming symmetrical shapes like chrysanthemums.

No matter the shape of the shell, or the size, they are all made roughly the same way: by hand with the same techniques—and in some cases with formulas that have been used for generations.

Join the Club

FIREWORKS LAWS VARY WIDELY. In the United States, there are more than two dozen federal, state and local agencies that govern the use of fireworks. And in order to use display fireworks in the U.S., one must be a licensed professional.

How do you get licensed? Easy, says Joseph Domanico. Join a club.

"Regional and local fireworks clubs teach members about safe construction, transportation, storage and handling of fireworks," says Domanico, who is a member of the Crackerjacks, a mid-Atlantic fireworks club with some 300 members ranging from hobbyists to professionals.

In addition to providing safety instruction, clubs organize meetings and private shoots where they hold elaborate displays of fireworks that members have crafted. Clubs secure permission to fire items that may be banned by state and local laws. "They also teach you how to make fireworks safely," he says.

Club members get together at regional and national meets and spend days making fireworks and hours setting them off. "When we fire firecrackers, it's hundreds of thousands of them," says Domanico.

And they come up with some pretty creative fireworks, too. "In this country in particular, many of the innovations in the field come from not only the pros but from amateurs," says John Conkling, former technical director of the American Pyrotechnics Association. "Some people come up with some incredible devices that are spectacular."

To find a fireworks club in your area, go to the Pyrotechnics Guild International website at www.pgi.org —M.B.

To make an Italian-style single break shell, one starts with a tube of brown craft paper. At the bottom of the cylinder is a pouch of black powder. This is the lift charge. When ignited, it will propel the shell into the air. The rule of thumb is for every pound of shell, use 1 ounce of lift charge. It's a delicate balance. Too little lift charge and the shell won't rise high enough; too much and it might explode too early.

Layered into the cylinder are "stars"—small pellets of chemical mixtures that are pressed, cut or formed by coating tiny pieces of rice with a slurry of chemicals. Stars range from the size of a pea to a golf ball. The smaller the star, the faster it burns. "These stars are what make each shell burn with specific colors and effects," Conkling says. For green, pyrotechnicians add barium nitrate or barium chlorate. For purple, it's a strontium and copper compound. Other ingredients in stars may include charcoal for a twinkling effect and titanium for sparks. Copper chloride makes blue, but achieving a bright blue remains difficult because it doesn't survive well in a hot flame.

Don't ask for too many details about measurements or ingredients of signature shells like Grucci's gold split comet or Zambelli's star mine. Those are company secrets. "If you have a great shell, something you're proud of that's in your history, that recipe is well-guarded and strictly for our inventory," Butler explains.

Coarse black powder is inserted into the center of the stars to serve as the break charge, which will cause the shell to burst and the stars to be distributed once the shell reaches its maximum height. A time-delay fuse also is inserted. To ensure the shell casing is strong enough to withstand the pressure that will spread stars evenly in the sky, fireworks manufacturers wind string

Popular fireworks types

Don't know the difference between a peony and a palm? Read on to learn more about the effects made by a variety of popular aerial fireworks:

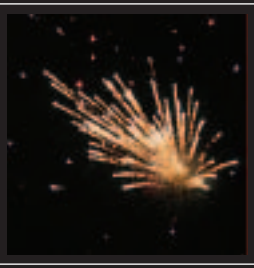
1. Chrysanthemum: A sphere of colored stars that leave a visible trail of sparks.

5. Palm: A shell that leaves a trail as it goes up, forming a tree trunk. When it reaches its apex the shell bursts open and creates the leaves of the palm.

2. Crossette: A shell containing several large stars that travel a short distance before breaking apart into smaller stars, creating a crisscrossing pattern.

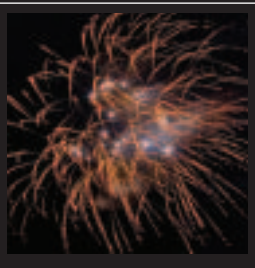
6. Peony: A loose pattern of color stars that break up and drop.

3. Diadem: A type of peony or chrysanthemum with a center cluster of non-moving stars, normally of a contrasting color or effect.



7. Salute: A flash of bright light and a loud boom.

4. Kamuro: A dense burst of silver or gold stars that leave a shiny, glittery trail. The name comes from Japanese for "boy's haircut," which is what the shell looks like when it explodes.



8. Spider: A shell containing a fast burning tailed or charcoal star that bursts hard so that the stars travel in a straight, flat trajectory before slightly falling and burning out.

More than music fills the air over Australia's famed Sydney Opera House.

around the shells or coat them in wallpaper paste and allow them to dry. The last step is to add a quick match fuse to the main fuse, which when lit will simultaneously light the lift charge and the time-delay fuse inside the firework.

Aerial shells can range in size from 2 to 16 inches in diameter. The shells you'll typically see in a professional show range from 3 inches in diameter (about half a pound or .2Kg), to 6-inch shells (about 4 pounds or 1.8 Kg).

In a multi-break shell, stars are contained in separate cardboard compartments inside the shell. These breaks may also contain sound charges, small cylinders of perchlorate mixtures, which create crackles and booms when they explode. As the time-delay fuse burns, it ignites the bursting charge in each compartment and activates the stars and sounds. In round shells, stars can be placed in a heart, smiley face or other pattern around the bursting charge, to form a specific geometric shape in the night sky. "It's all up to the imagination of the designers," says Conkling.

* * * * * * * * * * * * *

People who make fireworks could go on for hours about the artistry and traditions of their business. But safety is never far from their thoughts. Fireworks may be considered a low explosive, but they're still dangerous, even in the hands of trained professionals.

Fireworks by Grucci has suffered two major accidents during its 160 years in business. In 1929, an explosion in the company's Elmont, N.Y., factory killed two family members. And in November 1983, the company's Bellport, N.Y., plant exploded and killed two family members, injured 24 people and damaged more than 100 homes. Though the blast destroyed the factory and devastated the family, the company still managed to stage its annual New Year's fireworks displays in two New York City parks less than two months later.

Fireworks may be considered a low explosive, but they're still dangerous, even in the hands of trained professionals.

Even Chestertown, Md., headquarters to Dixon Valve and Coupling, had its own brush with disaster when the sprawling manufacturing company known as "The Defense Plant" (it produced flares, fuses for detonators and military fireworks) exploded in a flash of blinding light on July 26, 1954. The culprit? Some M-80 firecrackers that workers had been warming beneath a fluorescent light to leach away moisture. The resulting series of blasts shook the town for 50 minutes, killing 12 workers and injuring 50.

"How to do it safely, now that's the proverbial question," says Butler, of Fireworks by Grucci. "What you do is you eliminate as much risk as possible, but you can't ever reduce that to zero because of the nature of what you're dealing with."

At Zambelli's manufacturing plant, where there are 70 buildings for production and storage, fireworks production takes place in a series of small, one-story buildings made of cinderblocks reinforced with concrete. To help prevent accidental ignition, workers touch a copper plate by the front door before entering to eliminate any static electricity on their bodies. "Static electricity is just as volatile as someone lighting a match," Taylor explains. In fact, he says, in some parts of the world where static electricity is especially high on some days, manufacturers might have to forgo production because the risk is too great.

The roofs in these workshops are detached from the walls, so that they will blow upward and minimize injuries to workers in case of an explosion. In addition, some of the buildings are separated by 10-foot-high blast walls designed to help contain explosions to a small area. Production facilities vary all over the world. In Mexico and Vietnam, for example, fireworks are produced in three-sided buildings to minimize injuries to workers in case of explosions.

On production days, workers gather the chemicals they need for that day's work from steel drums stored in separate buildings and bring them to the production building. "You try to have only exactly what you need," explains Taylor. "These processes are very regimented. We aren't adding a little bit of this and a little bit of that. We are doing things the same way they have been done for years."

A worker might produce 20 shells per hour. Once the fireworks have been made, they are kept in storage magazines—secure buildings without electricity that are isolated by earthen berms. Zambelli might keep two years' worth of fireworks on hand at a time.

Painstaking preparations for a Lake Union Fourth of July celebration in Seattle, Washington, above left. Fireworks light up the night sky as the *Queen Mary II* departs on her maiden world voyage from Auckland City, above right.

Fireworks storage is controlled tightly by the U.S. Bureau of Alcohol Tobacco Firearms and Explosives, and manufacturers are required by law to keep a detailed inventory.

The transportation of fireworks is also heavily regulated by the U.S. government, Taylor says. "We are moving a hazardous product, just like those propane tankers you see on the highway, so we are governed by the same rules about what we can carry and what routes we are allowed to take." In some cities, such as New York, Pittsburgh and Detroit, fireworks trucks are met at the city limits by police and escorted to their launch site.

* * * * * * * * * * * *

Although the gunpowder at the heart of fireworks hasn't changed, there have been a number of advances in the field during the last 20 years, including the creation of brighter colors and patterns. The advent of firing shells by computer instead of by hand has made a big difference in the sophistication of displays and the ability to set them to music, Taylor says.

"Probably the biggest distinction between what fireworks were 30 or 40 years ago and today is the technology that permits us to choreograph the shells down to one one-hundredth of a second," Taylor says. Instead of having someone walk around a line of tubes buried in the ground and light fuses by hand to fire shells, electrical signals fire the shells, allowing technicians to precisely match the burst in the air to a particular note or notes in the music playing. "Our designers will spend between two and three hours designing for every minute of a show."

Companies are constantly coming up with new designs that leave crowds cheering for more. In 2002, Fireworks by Grucci invented a new shell called a "rumble digit," for a piece called *Transient Rainbow* that was commissioned by New York's Museum of Modern Art. Each rumble digit was embedded with a computer chip to control the exact timing of its firing. When Grucci fired more than 1,000 of these shells into the air and they exploded, they created a dreamy rainbow of light over the East River.

The effect had never been done before and has yet to be repeated. "It was probably 35 to 40 seconds worth of fireworks with a $140,000 budget," Butler says. "So you can imagine we don't do it very often."

Despite recent technological advancements, fireworks manufacturers still haven't figured out how to triumph over a barrier that has kept displays from going off as planned for years: weather. Excessive winds, drought conditions and heavy rain all can get in the way of a holiday fireworks spectacular by creating concerns about spectator safety, accidental fires and lack of visibility.

But even meteorological obstacles can sometimes be surmounted. Conkling tells the tale of a 1998 display in Orlando, Fla., that brought together some of the best companies in the business to celebrate the 50th anniversary of the American Pyrotechnics Association. "Hurricane Jacques was about to come ashore, and the following night's program had already been cancelled," says Conkling, who was the group's executive director at the time. But the rain and wind held off so the 30-minute show could go on as planned.

The display was spectacular. "The finale was unbelievable and contained hundreds of salutes," says Conkling.

The show wasn't just beautiful, it was powerful. "Hurricane Jacques made a U-turn that night and never made it ashore," the chemist says.

Maybe it was a simple change in weather. Or maybe not, says Conkling, with a twinkle in his eye. "To this day, I think the shock wave from the finale overwhelmed the hurricane and caused it to change direction."

FACTS AND FIGURES

Here's the chemistry behind some favorite fireworks effects:

Symbol	Name	Fireworks Usage
Al	Aluminum	A common component of sparklers, it produces silver and white flames and sparks.
Ba	Barium	Creates green colors in fireworks, and it can also help stabilize other volatile elements.
C	Carbon	One of the main components of black powder, which is used as a propellant in fireworks.
Ca	Calcium	Used to deepen fireworks colors, and calcium salts produce orange fireworks.
Cl	Chlorine	An important component of many oxidizers in fireworks. Several of the metal salts that produce colors contain chlorine.
Cu	Copper	Produces blue colors in fireworks.
Fe	Iron	Makes sparks. The heat of the metal determines the color of the sparks.
K	Potassium	Helps oxidize fireworks mixtures.
Li	Lithium	A metal used to impart a red color to fireworks.
Mg	Magnesium	Burns a very bright white and is used to add white sparks or improve overall brilliance of a firework.
Na	Sodium	Imparts a gold or yellow color to fireworks.
O	Oxygen	Fireworks include oxidizers, which are substances that produce oxygen in order for burning to occur. The oxidizers are usually nitrates, chlorates or perchlorates.
P	Phosphorus	Burns spontaneously in air and makes some glow in the dark effects.
S	Sulfur	A component of black powder that is found in a firework's propellant/fuel.
Sb	Antimony	Creates firework glitter effects.
Sr	Strontium	Strontium salts impart a red color to fireworks and strontium compounds stabilize fireworks mixtures.
Ti	Titanium	Can be burned as powder or flakes to produce silver sparks.
Zn	Zinc	A bluish white metal used to create smoke effects.

Source: *Phantom Fireworks*