Impact Firecrackers

by

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Introduction

Impact Firecrackers results from several years of experimentation with different methods of making old-fashioned toy torpedo fireworks. *Impact Firecrackers* is not intended as a comprehensive text for the novice pyrotechnist. *Impact Firecrackers* describes construction of some of the old fireworks torpedoes, most of which have not been accurately detailed in previous literature. Scant attention is paid here to basic lab procedure or basic pyrotechnic safety procedures -- a knowledge of these is presumed for anyone who might seriously contemplate reproducing the experimental procedures in this report. Never the less, I refer anyone who needs basic safety training to Weingart's *Pyrotechnics* and to Lancaster's *Fireworks: Principles and Practice* as good sources for safety information. The author of "Impact Firecrackers" merely describes procedures, and does not advocate duplicating the work recorded in this paper.

Impact Firecrackers is divided into three sections: a brief introduction, a section on chemicals used in this process, eight sections that describe small-scale, experimental manufacture of torpedoes, annotated bibliography, and end notes.

Many years ago toy torpedoes, impact actuated exploding fireworks, were very popular fireworks items in the U.S. -- particularly popular with young ladies. Fireworks manufacturers produced many sizes and kinds, using a variety of explosive compositions before they were finally banned in the late 1950's. The tiny "Snap'n'Pops" of today are mere shadows of the toy torpedoes once available. Some of the more famous varieties of that bygone era were the silver torpedo, Globe Torpedo, the tube type torpedo, the "safety torpedo", the cracker ball, the ball-type cap, and the so-called "Japanese cap torpedo". Patent documents reveal many kinds of torpedoes of which the inventors thought well enough to expend the considerable time and money inherent in the patent process ([1]).

From the standpoints of relative ease and safety of construction, safety of storage, transportation, and use, the Globe Torpedo is arguably the best option for the novice torpedo maker. The other varieties described call for use of more sensitive compounds such as chlorate / phosphorous, or chlorate / sulfide / magnalium compositions. All of these compositions are dangerous. You be the judge: how skillful and more importantly, how foolhardy are you?

Technical information about torpedoes is scarce, but for further information one can examine *The Chemistry of Powder and Explosives* by Tenney L. Davis, *Pyrotechnics* by George Weingart, *Fireworks: The Art, Science and Technique*, by Takeo Shimizu, and various patent listings since the late 19th century. Weingart's text, *Pyrotechnics*, describes the manufacture of silver fulminate torpedoes ([2]) and should be consulted as the best extant publication describing the silver fulminate torpedo. An interesting inside look at the manufacture of torpedoes from a nostalgic viewpoint is provided in the essay, "Cherry Bombs and Silver Torpedoes" by John Drewes. Other interesting items relating to torpedoes can be found in some children's literature of the late nineteenth and early twentieth centuries; some of this material has been reprinted in *Pyro-Fax*, a periodical published by the Fourth of July Americana Museum. Overall, though, reliable information about the early history of torpedoes is scarce. Torpedoes prepared with fulminating salts may conceivably have been around since the middle ages or even earlier -- prepared in the laboratories of the alchemists in their ceaseless search for the transmutation of metals. This, however, is conjecture. I am not aware of any record that would support that hypothesis. The chlorate based torpedoes can be dated with relative certainty to the era after 1789, the year when Berthollet is credited with inventing chlorates.

Many people have been seriously injured while using, and especially while attempting to manufacture fireworks. There is always risk in the manufacture and use of dangerous articles such as these. Those who learn as much as they can about what they are doing stand a much better chance of survival intact than those who do not. Do yourself a favor, and always work to minimize hazards and risks. A little knowledge is a dangerous thing.

Chemicals

The following briefly describes chemicals used in these processes, and some of their properties and hazards. For further information, consult other sources, such as the publications listed in the bibliography.

Aluminum powder (Al) Aluminum powder used in fireworks is available in many grades, usually described by particle size (mesh number) and particle shape. The finer the size, and the flatter the particle shape, the more reactive the aluminum will be. For the manufacture of torpedoes the preferred grade is called German Black, which is finer than 400 mesh size, and of the "flake" shape.

Antimony Sulfide (Sb_2S_3) Antimony sulfide is a very reactive fuel often used in fireworks making. Antimony salts are toxic, and often have some arsenic content, which is also toxic. For use in torpedoes, the chemical should be a very fine powder, at least 350 mesh, preferably finer. The relatively soft crystals can be ground with steel balls in a ball mill to the desired consistency.

Dextrin Dextrin is a chemically modified starch that is used as a binder in many pyrotechnic compositions. It is very sticky when wet, dries very hard, and is non-toxic.

Gravel Quartz gravel of the grade used in aquariums, about 10 or 15 mesh and not polished is ideal for use in torpedoes. The white marble variety does not work nearly as well because of its low specific gravity and hardness.

Magnalium (Mg/Al alloy) This is an alloy of magnesium and aluminum that is frequently used in pyrotechnics. It is more brittle and active than aluminum of similar particle size and shape. Magnalium is well known in the pyrotechnic community for the distinctive hissing and crackling sound it imparts to many compositions. However, since it does not form a protective coating of oxide upon its particles at the microscopic level as does aluminum, it needs to be treated with special caution, especially in mixtures containing water (like the one described later in this article). Magnalium, like magnesium, can make these mixtures more liable to spontaneous ignition, especially during the drying process.

Manganese dioxide (MnO_2) Ma.gan%se $iox)de (200 mesh powder) is a catalyst, that is, a chemical which lowers the activation energy of the chemical reaction but remains substantially unchanged after the reaction is complete. Without MnO_2, globe torpedoes require a much harder toss to fire.

Phosphorus, amorphous (P_4) The older varieties of torpedoes often used some form of so-called "Armstrong's Mixture" as the explosive component. Making these requires the use of the red, or amorphous, variety of phosphorus. This is not to be confused with the "White" or "Yellow" variety which is even more dangerously flammable and explosive than the red, and quite poisonous as well.

Potassium chlorate ($KCl0_3$) Potassium chlorate is one of the most widely used and dangerous oxidizers in fireworks manufacture. When used carefully and prudently, it is perhaps the most useful oxidizer at our disposal. However, as with all chlorates, become familiar with its properties **before** using. Mixtures containing chlorates are notoriously sensitive to shock, friction, and temperature change. Mixtures of chlorates with sulfur or sulfides, and especially mixtures with phosphorous are prone to spontaneous combustion or detonation. Other chlorates, such as sodium chlorate, are not suitable for use in torpedoes.

Titanium (Ti) Titanium metal powder is useful in some compositions because it can cause a change in flame color to white, or add a shower of white sparks to a flame or report. Titanium does, however, increase the sensitivity of most compositions to shock or friction and so should be used only with great care. For use in torpedoes, material of about 40-60 mesh is adequate.

Water (H_2O) Water used as an ingredient in preparing torpedoes should always be *distilled* water. Tap water contains impurities that often can affect the sensitivity of pyrotechnic compositions. Since torpedo formulations are neccsarily among the most sensitive of fireworks mixtures, it is essential that all ingredients, including water used, be as pure as possible.

Often, these chemicals above can be bought from dealers who supply them for purposes other than pyrotechnics. Ceramics materials suppliers are often excellent sources for good clay, as well as hard to find chemicals which are often used in glazes. Sometimes drugstores can supply certain chemicals, but this is less true today than formerly. I have heard of excellent quality German black aluminum being used as a pigment by British printers; Aluminum powder has been available for making silver paint in the past, so check your local paint store. Many chemical supply houses are now leery of selling chemicals, even to responsible adults because of the fear that they may end up supplying illicit drug labs; some firms may simply wish to avoid liability problems.

Another approach to obtaining hard to find items is to produce or process them yourself on a small scale. Two possibilities are aluminum powder and potassium chlorate. A description of small scale processing follows.

Aluminum powder can be produced in particle grades ranging from flitter to very fine flake powder suitable for flash. One usable method is to use aluminum foil, a source always readily available. I use a blender, a rock tumbler (the sort rock-hounds use), about two dozen large (about 3/4" to 1" diam.) steel ball bearings, aluminum foil of the cheapest, thinnest grade available, and some stearin. The procedure begins with macerating the foil in an ordinary household blender. Exercising care not to overheat the blender's bearings, I thoroughly grate up pieces of foil into a very coarse powder. I place the aluminum, the ball bearings, and about 3 to 5% of the weight of the Aluminum of stearin into the rock tumbler and seal it up. I set the tumbler on wooden blocks so that it sits at about a 20 degree angle from the horizontal. This will increase the tumbling action of the steel balls. I run the improvised ball mill continuously for about three weeks or so. I check the powder inside every few days to see what kind of progress I'm making. When checking the powder I have opportunity to remove coarser powder grades for use, and introduce oxygen into the system which allows the aluminum particles to build up a protective coating of oxide which will prevent pyrophoricity. The finished powder is the consistency of powdered sugar and leaves a characteristic silvery stain on the fingers when handled.

A final operation can be performed if maximum reactivity is desired. I can wash the aluminum powder with **99%** isopropyl alcohol. This removes the stearin surfactant. I simply place the aluminum powder in a glass or plastic container, and cover with half its volume of isopropyl alcohol and stir thoroughly. Then I drain the alcohol off through filter paper and dispose of. I use caution, as the alcohol vapor is extremely flammable, toxic, and explosive. Good ventilation is a must! I allow the damp Aluminum powder to dry for a couple of days and then package it.

Potassium chlorate is a versatile chemical which can also be produced on a small scale with minimal equipment. Required for this production is a large glass container such as a carboy, a quantity of potassium chloride (available as a salt substitute or sidewalk de-icer pellets), a source of DC power such as a model railroad transformer, a platinum or graphite anode, a supply of de-ionized water, and provision for venting toxic fume byproducts to the outside if I'm working indoors: a three holed rubber stopper will do the job of holding both anode and cathode and a glass tube to hook up to a rubber hose leading outside.

The basic concept here is that a saturated solution of potassium chloride in water is slowly electrolyzed with a low output DC current which passes through a non-reactive anode and an ordinary copper plate cathode. Potassium chlorate is formed as a result of this reaction and rapidly saturates the solution, since it is less soluble than the chloride. Over a period of days I produce a fine mass of crystals of top-notch $KCl0_3$. In the home lab the main constraints on the system are 1) the reaction produces heat, and the more current passed through the system the hotter the reaction vessel will become and 2) **toxic gas** (chlorine) is produced necessitating adequate ventilation: ***failure to insure adequate dispersal of these gases may cause DEATH!***

I don't bother with this process any longer, since I can obtain my chlorate from a chemical supplier. At present potassium chlorate retails in small quantities for about $2.00 US per pound. It is much easier, safer, and less hassle to buy it.

Making Globe Torpedoes

Begin by reading this material through to the end before proceeding further. Globe Torpedoes were one of the perennially popular torpedoes of the mid twentieth century. They were as a rule, loud and powerful, but less sensitive to detonation than the older phosphorus torpedoes. However, they are probably more dangerous to make, since the composition is mixed dry and is therefore quite dangerous during the actual loading process, in contrast to the phosphorus torpedoes which are actually safer to load, but much more prone to detonation when dry and ready to use.

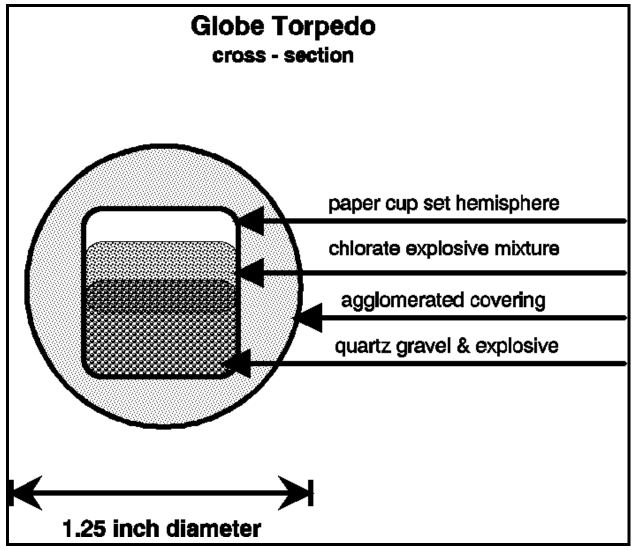
Torpedoes are necessarily **very** sensitive to make and to handle. Manufacture of torpedo fireworks should be attempted only by persons who are thoroughly familiar with the nature of the hazards of this type of device, and with the characteristics of the mixture described below. If *Globe Torpedo Composition* were not sensitive to friction and impact, it would not be useful for making torpedoes. This explosive mixture is both sensitive and powerful. The pyrotechnist should make only very small quantities as needed (i.e. 5 or 6 grams at a time, maximum). This formula is widely known, but note that it has been modified with a catalyst (MnO_2).

Materials needed: 3/4" cherry cup sets, wheat paste, kraft paper strips 1 1/4"x5", *quartz* aquarium gravel, natural hair artist's paint brushes, small powder scoop, small Dixie cups, board with several 3/4"diam. x 3/8" deep holes drilled in it, white glue, Sodium silicate solution, potassium chlorate(fine powder), Antimony sulfide (very fine powder 350 mesh or finer), German Black aluminum, manganese dioxide powder (200 mesh), safety goggles, dust respirator, leather gloves, anti-static spray.

Procedure: I begin by preparing all needed materials beforehand. I prepare my tools and materials before proceeding. I wash the artist's paintbrush with ivory soap and let it dry thoroughly. I wrap a strip of masking tape around the ferrule of the brush to prevent it from creating spark or excessive friction. I spray my clothing and work area with anti-static spray. Static is to be avoided at all costs. Low humidity is undesirable, and will increase the hazards of this procedure by increasing likelihood of static charge accumulation. I prepare a loading board for the cup sets by drilling holes with a dill press into a heavy pine board, such as a 2x4. The holes should be 3/4" diam. x 3/8" deep. A dozen will fit nicely on an 18" length of board. I have a powder scoop which will hold just the appropriate amount of composition for a single torpedo. A serviceable scoop can be made by wrapping kraft paper around a 1/2" diam. wooden dowel about 6" long, and then trimming the paper with a razor blade.

I prepare my wheat paste, using commercial wheat paste from the hardware store. I mix paste according to label directions and then add about 5% sodium silicate solution to the paste which will impart extra hardness to the paper wrap and the cup sets at the end of the process. If the paste is too thick to work with, I use additional water to thin it.

Next, I prepare my chemicals and gravel. The antimony sulfide should be very fine, but is usually available in only 350 mesh or larger. Antimony sulfide can be ground finer by ball milling with *steel* balls for several days. The potassium chlorate I grind very fine in a mortar and pestle or in a ball mill BY ITSELF. Under no circumstances should potassium chlorate ever be ground together with fuels!!! The German black aluminum requires no special preparation, only careful handling. The gravel to be used is tumbled with some of the fine antimony sulfide until well coated. I am always careful when working with Aluminum powder and especially with **antimony sulfide** as both are **toxic**: A good quality **dust respirator** is a must, and so are gloves.



Globe Torpedo Composition

Oxidizer

potassium chlorate $KClO_3$ (with 1% MnO_2 added as catalyst)	60%

Fuel

antimony sulfide Sb_2S_3	30%
aluminum, German black Al	10%

With gloved hands, I mix the fuel components ($Sb2S_3$ and Al) together first, and sift through a 50 mesh sieve. The dust which floats in the air from this mixing is potentially explosive; therefore I mix slowly and carefully, keeping airborne dust to a minimum. **I *never, never, mix this composition in an area where a pilot light or other flame or spark source might provide a source of ignition!*** **I** place this fuel mixture in a covered container and label appropriately. Next, I mix the potassium chlorate with the manganese dioxide catalyst and sift through a different, clean, dry 50 mesh sieve. I label this mixture appropriately. For a better, more homogenous mixture, I can further mix the chlorate and manganese dioxide. Using a large diameter brass or aluminum rod upon a smooth, flat, clean surface I blend the chemicals much as one might roll out pie dough with a rolling pin. It is easiest, if I am planning to make more than a few torpedoes, to make up a larger batch of oxidizer mixture and a larger batch of fuel mixture than will be used in one session. I can then measure out only as much of each respective component mixture as each batch requires. This makes mixing each batch a simplified, two-component process, with a weight ratio a constant 3/2, respectively. This is also safer than making up a large quantity of the finished torpedo comp at once.

Next, I prepare my cup sets, by placing the inner cups inside the holes in the board described above, and then preparing the outer cups by stretching the walls very slightly to be sure that they will slide *easily* over the inner cups. I fill the inner cups half way to the top rim with the prepared quartz aquarium gravel. Then I pour some white glue into a small paper cup and thin 10% with water. Now, with these preparations already made, I mix up a ***small*** amount of the report composition (5 grams will make a dozen excellent torpedoes) on a square of light weight kraft paper by first placing the fuel mixture on the paper, and then pouring the Potassium chlorate mixture gently onto the paper. I lift each corner of the paper successively, rolling the pile of comp over onto itself in the process. I repeat this lifting of each of the paper corners several times until the mixture appears homogenous. Then, I *gently* stir the mixture with a fine, natural hair artist's paint brush that has been washed in soap (not detergent), which leaves an anti-static residue. The finished mixture goes into a clean paper cup. I scoop out a small amount (200-400 milligrams) of comp into each waiting inner cup, carefully avoiding friction. I don't overdo the amount of composition: it is very potent. I place any remaining composition aside, away from the work area. I take another artist's paint brush, and use it to apply a thin line of white glue around the middle of each inner cup. Immediately and gently I cover the loaded inner cup with an outer cup and gently set aside to dry. I repeat this process for each loaded cup set, being careful not to squeeze the torpedoes nor to drop them. I repeat the entire process until the remaining comp is completely used up. Titanium is sometimes added to the torpedoes in small quantities ($< 3\%$) to produce an interesting silver shower effect. However, this optional addition to the composition increases sensitivity and decreases stability.

When the glue has had time to dry, I finish the torpedoes by carefully covering in strips of pasted paper. Light weight Kraft paper or Japanese tissue paper both work well for the purpose. It is convenient to use a tray such as one used in photographic developing for pasting my paper strips, or I can simply apply the paste with a paint brush. Bear in mind that paste containing sodium silicate solution is impossible to clean from glass or aluminum once dried; I therefore remove my watch when working with this material, and also clean up my messes promptly. I allow the torpedoes to dry thoroughly in the shade. I store torpedoes packed in sawdust, away from other fireworks and flammable materials.

Read This !!

The original globe torpedoes were sometimes made with a sodium silicate and sawdust covering similar to a cherry bomb. I avoid the temptation to imitate this covering, because of the danger of glass-like **shrapnel** which is produced by these devices. Furthermore, **gravel** is invariably propelled at a high velocity when these torpedoes are discharged. Safety glasses or other ***eye protection*** IS indicated!! Be Careful!!!

Cap Type Torpedoes

The name says it -- cap torpedoes are devices which explode a small cap similar to the ones used in toy cap pistols. Cap Torpedoes are quite formidable fireworks, and lots of fun.

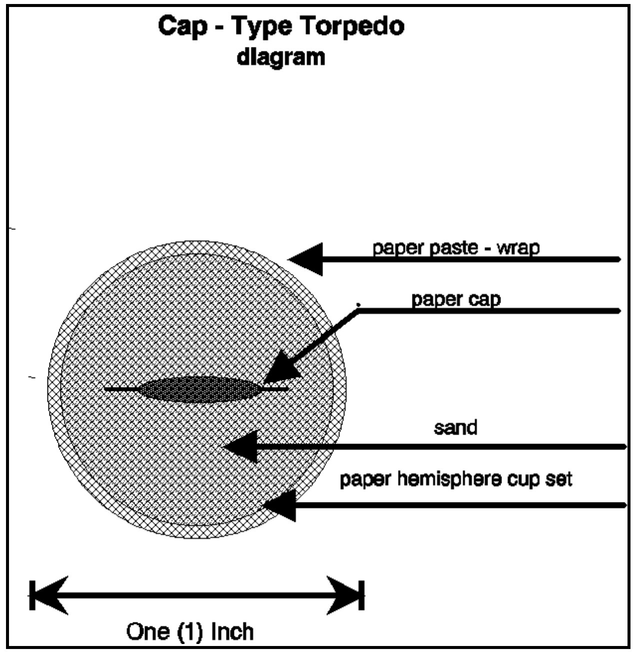
Materials needed: 3/4 inch paper cup sets (such as the ones used to make cherry bombs), unsized white paper (Permalife paper is probably best), Japanese tissue paper, squares of heavy cotton cloth, same size squares of plywood board (2), bricks or heavy books for weights, paper cup sets, glue, eyedropper, beaker, wooden stir sticks (e.g. popsickle sticks), potassium chlorate, sulfur or antimony sulfide, red phosphorus, glutinous rice starch or dextrin, calcium carbonate, distilled water, fine sand, plastic bucket of water for clean-up, safety equipment (face protection, fire extinguisher, etc.).

Procedure: I have found the formula for toy caps from Shimizu works well, although I add a little calcium carbonate to the mix as a buffer for any phosphoric acid that might be present in the phosphorus.

Toy Pistol Caps (white)([3]):

potassium chlorate $KClO_3$	68%
sulfur S [or antimony sulfide]	25
phosphorus, red P_4	6
dextrine	1
calcium carbonate $CaCO_3$	2

I have used the antimony sulfide variant with success. The most important thing about mixing this composition is to be certain that the entire mixture is mixed wet.I wet both the fuel component, i.e. the sulfur/sulfide/phosphorus/starch mixture, as well as the oxidizer (that is, the potassium chlorate) to the consistency of thick oatmeal *before* mixing the fuel and oxidizer. However, back to the process. First, I get all the material together so that the actual mixing of composition and assembly work can be carried out quickly and efficiently with no delays. I will need sheets of paper -- I recommend the archival grade paper because it has an alkaline filler and no residual acid content, sheets of Japanese tissue paper (from my local fine arts supply store or a hobby shop that sells airplane models), along with *damp* sheets of heavy cotton cloth cut the same size as the paper, and pressing boards of the same dimensions as well. I arrange the pressing boards and cloths first, lacing a single cloth atop the bottom pressing board ready for the first sheet of caps. The rest of the cloth sheets and the top pressing board are stacked next to the first board and cloth.



I weigh out all chemicals separately, then mix together everything ***except the potassium chlorate***, and dampen the fuel mixture with distilled water -- stirring with a wooden stir stick, until it has the consistency of tomato soup. I allow this to stand several minutes, and then mix the potassium chlorate with distilled water *using a fresh stirring stick* to the same soup-like consistency. Now carefully and gradually I stir the chlorate into the rest of the mixture. When the mixture is homogenous, I use an eyedropper to drop the liquid composition into drops between 1/4" and 3/8" wide on the sheets of paper. I try for caps about 195 mg (3 grains) each, maximum. However, even half that amount makes a respectable torpedo. Proceeding quickly, I dampen the Japanese tissue with glue solution -- a buffered Gum Arabic glue works well for this -- and then carefully place the tissue directly atop the paper sheet. I place the sheet of caps directly atop the first cloth sheet and board mentioned earlier, and immediately place another cloth sheet atop the sheet of caps. This procedure of making sheets of caps and stacking them atop each other with damp cloth interleaved is repeated until I run out of composition. Then I place the other board atop the final cloth sheet and place heavy weights upon it.

Next, I place the beaker, eyedropper, and any other utensils that are contaminated with the composition into the wash bucket and wash them off promptly, disposing of the washings carefully. It is most important that the clean up be prompt and thorough. This composition is very sensitive and prone to accidental detonation.

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After the caps have set several hours, I remove them carefully and allow them to slowly dry in the shade, until they are just a little damp to the touch. In an area outside, away from any other flammable materials, I clip the caps from the sheet with a pair of scissors using hand and eye protection. I refrain from cutting through any spots of composition, no matter how tiny. I place the caps, still slightly damp, in an appropriate container.

To finish the torpedoes, I fill the inside cup sets with fine sand 2/3 of the way to the top. Then I place a cap on top of the sand, and fill the remainder of the inside cup with sand. Next, I paint the outside rim of the inner cup with Elmer's Glue. Then I take the outside cup, fill it about 1/3 with sand slide it over the inner cup and down snug. I cover the cup set with decorative wrap if desired, and allow to dry thoroughly. I package torpedoes in sawdust, and store carefully, away from other fireworks.

Cane Torpedoes

Many years ago, around the turn of the Twentieth Century, torpedo canes were popular toys. The more common of the torpedo canes can sometimes be found in antique shops even today. Generally they consist of a wooden dowel about 2 1/2 to 3 feet long, with a steel cap exploder attached at the bottom end. The device I have has a steel tear drop-shaped ball about an inch in diameter. This is hollowed out with an internal cavity a half inch in diameter. A slot in the outside of the ball about 7/16" wide and 1/8" thick gives access to the cavity. Through this slot, one loads a cane torpedo -- a pellet of explosive mixture about the size of an aspirin tablet. There is a piston in the bottom of the mechanism that is essentially a heavy rivet free to move up into the cavity. When one strikes the loaded cane on the pavement, the piston moves up into the cavity and strikes the torpedo, grinding it against the upper surface of the cavity. The pellet detonates after one or two strikes, with a report much like a 2 inch salute. These canes are relatively common today, but the ammo is very scarce. Here's how I make my own.

Materials needed: Pellet press, hand spray bottle filled with water, antimony sulfide, potassium chlorate, dextrine, distilled water, magnalium (100 mesh granular)(optional), wooden stir stick, beaker, cutting board, pail of water and wet rags for clean up.

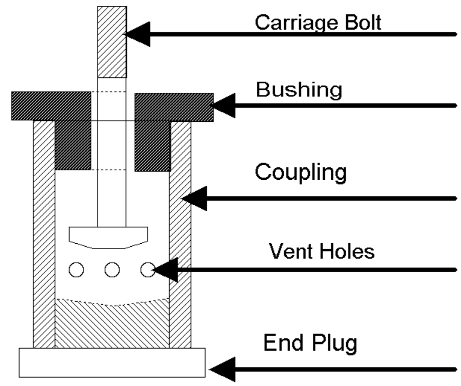
Procedure: First, I use a pellet press. Mine is essentially a modified star pump that produces pellets 7/16" diameter, and of variable thickness. Next time around I'll probably use a standard 3/8" star pump, since the 7/16" pellets tend to be a little big for my tastes. In any case the composition I use is this:

Cane Torpedo Comp

potassium chlorate $KClO_3$	48.5%
antimony sulfide 350 mesh Sb_2S_3	48.5
dextrin	3
Mg/Al alloy 100 mesh (optional)	+2%

Like the cap torpedo mix, this is sensitive stuff that ***needs to be mixed wet***. However, it doesn't need to be a liquid, like the cap mix. The concept here is to mix the *fuel* components together (the antimony sulfide, dextrine, and magnalium) then wet them down to the consistency of oatmeal. After allowing this mixture to set for a few minutes, I stir it again to make certain the composition is thoroughly dampened.

Impact Firecrackers



Torpedo Cane Firing Mechanism
cross - sectional diagram

Note: The Magnalium was sometimes used in the olden days to add an interesting residual crackling effect to the cane torpedoes, but frankly I don't really trust it; I think magnalium is just too reactive to use in a water-dampened composition. If I choose to use magnalium, special care is indicated in the final hours of the drying process; and I'm extra careful to store the stuff away from other pyrotechnic materials.

Next, I add the dry potassium chlorate, gradually and carefully to the fuel components of the composition. I stir slowly and gently until the mixture is homogenous, about the consistency of bread dough or slightly drier. I keep a pail of water handy to clean of excess comp as my pump gets dirty. I keep my equipment clean at all times! Any dried residue of the mixture is very dangerous. I try for pellets of four to five grains, i.e the size of an aspirin tablet, or slightly smaller. Bigger ones may ruin a torpedo cane, and maybe an ankle, too. I roll the comp out into pea size balls and press these in my pellet press under gentle hand pressure. If the comp sticks too much to the press plunger, it is too wet. If the comp won't hold together it's too dry and I watch the Hell out!!! Seriously, I add water if the comp dries too much during the process. The comp should form nice, smooth pellets that easily drop off the end of the pump.

As the bulk composition (from which I am making my torpedoes) dries, I mist it slightly with a hand sprayer filled with distilled water. With small batches, drying is rarely a major problem. The bigger the batch, the more problems I encounter; so I keep my batches down to 10 or 15 grams, which happens to be about as many torpedoes as my neighbors are wont to put up with over the course of a summer.

I allow the pellets to dry slowly in the shade. When dry, I pack the pellets in sawdust and store as I would any impact-sensitive materials -- away from other flammable materials in a secure place.

I clean up my work area thoroughly, and of course clean up all my tools immediately after each batch. I inspect the area for stray bits of this comp. Because this composition is so very sensitive to friction, impact, and heat, it will cause serious problems if allowed.

More Cap Torpedoes

Here's another approach to the old fashioned cap torpedo. One old patent for the manufacture of torpedoes calls for the use of a hollow clay ball loaded with Armstrong's Mixture (a chlorate/red phosphorus explosive[*]). While I don't recommend this approach, it can be modified to produce torpedoes using papier mache' in place of the clay of the original design. The resulting torpedo is somewhat similar to the old-fashioned "cracker ball" or "ball-type cap" of the 1960's.

Materials needed: Balance scale, mixing sieve, either 20 or 30 mesh, paper mache' (the best variety I know of is called Celluclay (TM), a powdered, instant product of exceptional quality), distilled water, small meatball tongs, eyedroppers, wooden stirring sticks, small containers for measuring and mixing composition, larger container for mixing papier mache', Potassium chlorate, red amorphous phosphorus, sulfur, calcium carbonate, 5% dextrin solution in distilled water, pH indicator paper (such as red & blue litmus paper), acrylic paint or lacquer, quartz aquarium gravel (optional). Also I use the usual safety equipment: safety glasses, gloves, fire extinguisher.

Procedure: The basic process is simple. I begin by making some small balls of papier mache'. These could be anywhere in size from 1/4" up to 1 inch or so. The larger the device, the more dangerous it is to store and transport, and to use. My preference is for a ball about 5/8" in diameter. Rather that fool around with making papier mache' from scratch, I use a commercially prepared product sold in arts & crafts supply stores called Celluclay (TM) that consists of finely ground paper with an adhesive binder (probably dextrine or something similar), packaged dry and compressed. The Celluclay I have used was even conveniently alkaline in pH, but I test each batch, ready to add calcium carbonate to increase the alkalinity if it should prove acidic. The package calls for twice the weight of water to be added to the "celluclay", but since I use a press to compress my balls (ouch!) I use considerably less water. When I have dampened my papier mache' mixture, I compress it into balls using a set of tongs that are made for making Swedish meat balls. I can make lots of balls quite quickly with this tool. I leave about a quarter of the papier mache' mixture aside for later use in plugging the torpedoes. The balls I allow to dry thoroughly. This may take up to several days. Next I drill holes into the center of the balls with a drill press. For a 5/8" ball, a 1/4" drill bit is about right.

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[*]Remember, this type of mixture is extremely hazardous and special precautions must be taken when using Armstrong's Mix.

Armstrong's Mixture

Next comes making the explosive mixture. For these torpedoes I use an alkaline-buffered Armstrong's Mixture *prepared as a liquid slurry*. The mixture is described in Davis's Chemistry of Powder and Explosives ([4]) and is repeated below:

*Armstrong's Mix**

potassium chlorate $KClO_3$	67%
sulfur S	3
phosphorus, red P	27
calcium carbonate $CaCO_3$	3

It should be noted that additional alkaline buffer (that is, either calcium carbonate or magnesium carbonate) may be called for if the phosphorus includes significant oxide content. If the phosphorus has oxidized during storage, it will generate acid when water is added, and *this must be neutralized* for safety.

Preparation of Armstrong's Mixture

This mixture must always be prepared wet, and in the smallest quantities possible. I begin by measuring out all chemicals to be used on a balance scale. The best way to proceed is to prepare a relatively large quantity of the fuel/buffer component of the mixture, and then to measure out small quantities of this mixture for use in preparing the final, finished Armstrong's Mix. Therefore, I measure out a quantity of chemicals: 27 parts red phosphorus, 3 parts sulfur, and 3 parts calcium carbonate, and mix this thoroughly on a sheet of paper. **Never, never, do I add the potassium chlorate at this stage !!** This fuel mixture is sifted twice through a 20 or 30 mesh screen. I take a small sample of this mixture and add enough distilled water to form a thin suspension. If any foaming is noticed, I test the liquid for acidity using indicator paper. If acid is present, I mix more calcium carbonate or magnesium carbonate into the entire fuel mixture batch until further tests with indicator paper show slight alkalinity.

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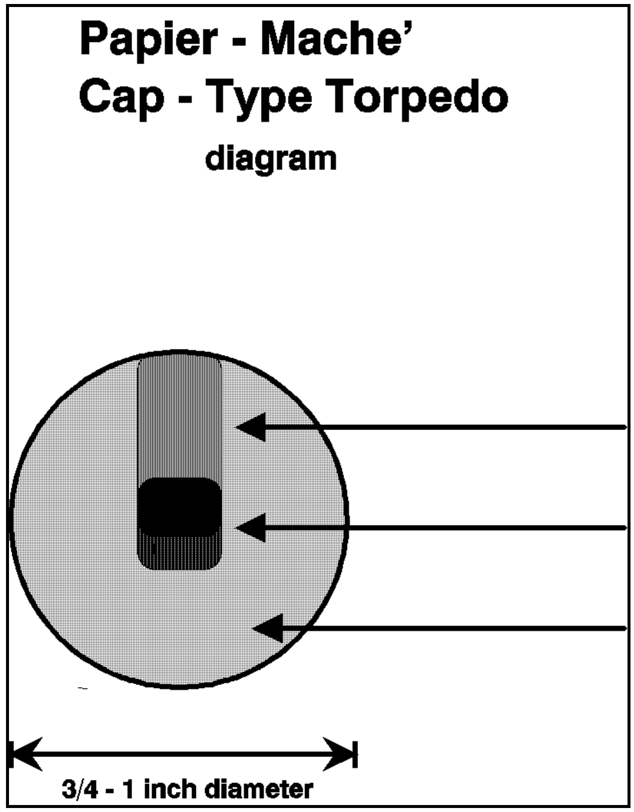
*At the risks of sounding like a broken record on the subject, I interject here that many people have lost their lives and more have been seriously injured while working with Armstrong's Mixture. This process demands attention to detail and to safety.

I prepare a solution of 5% dextrin by weight in distilled water, and add to this 2% of either calcium carbonate or magnesium carbonate. The carbonate buffer will sink to the bottom of the container, but will still neutralize any acid present.

Now the Armstrong's Mixture can be prepared. I measure out 1/2 gram of the fuel mixture, and dampen this with dextrin solution from an eyedropper until the mixture is about as thick as Elmer's Glue. I next measure out 1 gram of potassium chlorate, and in a separate container add more dextrine solution to the chlorate until it also attains the thickness of Elmer's Glue. Now in a third container I mix the two slurries together, stirring them together with a wooden stirring stick. I add sufficient distilled water to yield a slurry about the consistency of tomato soup.



Now I use an eye dropper to drop a small quantity of this mixture into the cavity previously drilled into each ball. To ensure detonation of torpedoes, I may add a few grains of quartz aquarium gravel into each cavity before dropping in the liquid Armstrong's mixture. In a 5/8" ball three to five drops of the explosive should be very adequate. Next, I plug the holes in the balls with the left over papier mache', pressing a sufficient quantity into each cavity to completely fill the ball. I then allow the balls to dry thoroughly. When the torpedoes are dry, I paint the outside of the balls with colored lacquer, and the job is done. These torpedoes store and transport well, and can be fired from a slingshot with great effect.

Charles Nelson's
1867 Clay Torpedo

For the sake of history, Charles Nelson's 1867 clay torpedoes merit discussion. Viewed alongside other, later designs, this clay torpedo is a study in simplicity. The design works reliably, and is easy to make. Mr. Nelson, of New York City, received this patent on June 11, 1867. His is definitely not the oldest torpedo design -- that distinction probably belongs to the French *pois fulminans*, or mad peas. Nelson's torpedo is, however, an old and noteworthy design. It uses a molded clay ball for the structural mass of the torpedo combined with an explosive of the Armstrong's Mixture type. The patent (#65,764) claims that the design "involves the consumption of no paper or other valuable fibrous materials" which were in short supply following the Civil War. Nelson states that he prefers a mixture of fire-clay and pipe-clay about 50/50, although he states that "other material than clay may be used."[5]

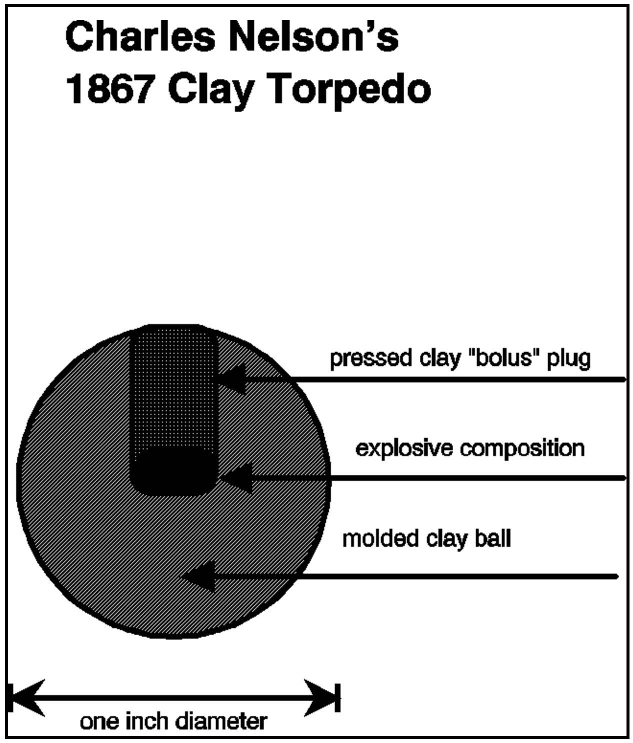
I became intrigued with Nelson's design late in my experimentation with torpedoes. Having worked with clay at other times as an artist and pyrotechnist, I am somewhat familiar with the properties of clay. Also, I happened to have on hand some samples of high grade ceramics clays. I therefore performed some experiments that were based on Nelson's patent documents. The torpedoes I produced were different than any others I had ever made, in form, performance, and sensitivity. In form they resemble larger clay marbles, similar to some I have seen in antique shops. They are quite dense, relatively heavy for their size compared to other torpedo designs, which lends them easily to throwing from the hand or firing from a slingshot. They are more sensitive than globe torpedoes and the papier mache' torpedoes but somewhat less sensitive than silver fulminate torpedoes.

Materials needed: cleaned, good quality ceramics clay such as ball clay or red Georgia earthenware clay, potassium chlorate, red phosphorus, calcium carbonate, sulfur, dextrine, small eyedropper, wooden stirring sticks, small mixing cups, balance scales, distilled water, 1/4" diameter pin punch or wooden dowel, 1/2 tablespoon measuring spoon. All the usual safety equipment is required as well: fire extinguishers, water bucket, safety glasses, gloves, lab apron.

Procedure: I begin as usual, by assembling beforehand all of the materials I will require.

The first step in the assembly process is to prepare the clay I will use. This process is practically identical to the process used for preparing clay used for modeling; sufficient water is added to form a plastic mass that is still not too sticky or wet to prevent molding into small, firm, round balls. This process took some experimentation, and I consulted a text on ceramics for reference*.

Ideally one would use a mold to produce identical clay balls with identical cavities impressed by the molding process. However, since I'm not a tool and die man, and am on a budget I elected to simply measure out the clay I used to produce each ball with an ordinary half-tablespoon measuring spoon. One of these spoons leveled off with a scraper yielded sufficient clay to produce balls about 5/8 diameter. I simply took the clay and rolled it between my hands to form a more or less spherical shape and then put each ball aside. Next, I took a steel pin punch from the local hardware store that was 1/4 inch diameter and used this punch to push a hole about 3/8 inch deep into each clay ball. I left a small portion of the prepared clay aside to use for plugging the cavities; the same batch was used because I wanted the shrinkage of the drying clay balls and their plugs to be identical, so as to avoid cracking of the plugs after loading and final assembly.



Next I prepared my explosive mixture. Nelson gives his version in the patent documents, and it is different than the usual mixture I prefer, much heavier on the fuel component:

Nelson's Torpedo Fuel

potassium chlorate $KCl0_3$	34%
phosphorus, red P_4	33
sulfur S	16.5
calcium carbonate $CaCO_3$	16.5

Nelson says the mixture was "compounded with sufficient water to form a paste, and …introduced into the holes by hand or by machinery"; I would add that I prepare the mixture somewhat wetter than Nelson implies, as a slurry instead. The patent documents do not

*Daniel Rhodes, Clay and Glazes for the Potter (New York: Chilton, 1957)18-33.

convey the hazards of the mixture that were known even back then. I carefully mixed the fuel components (everything but the chlorate) in a slurry with a 5% dextrin solution until homogenous. Then I wetted the chlorate with the same 5% dextrin solution, and added it to the fuel mixture, stirring with a wooden stirring stick. The finished mixture was just thin enough to easily load into my eyedropper, resembling condensed tomato soup. I placed two to three drops into the cavity of each clay ball, and then sealed the cavity with a clay plug. The plug completely filled the rest of the cavity. Then I smoothed the area where the plug fit into the ball with my damp finger so that the ball appeared to be a homogenous mass of damp clay without a visible cavity or plug. I put the finished torpedo aside to dry for several days.

Nelson indicated that "after the whole has dried, the surface is varnished…and the torpedo is packed in sawdust for use or transportation." I think this to be a sound way of finishing the process of making Nelson's Torpedo. The varnish will add some durability to the surface of the torpedo, and render the torpedo resistant to humidity.

My experience with the results of Nelson's design suggest that the torpedoes thus produced have certain advantages over some of the other designs. I the first place, their relative density and heaviness allows them to be flung to a greater distance with either the hand or a slingshot than most of the other torpedo designs. Also, the clay body disintegrates into extremely small particles when the device explodes, avoiding the problems of flying gravel associated with designs such as the Globe Torpedo that use gravel to actuate an explosive mixture. This tendency of the clay to disintegrate easily may, however, cause problems should the clay ball fracture prematurely. If the torpedo should crack open prior to intended use due to improper manufacture, inept handling, or other problems, the central core of dried Armstrong's Mixture could be exposed, resulting in an unintended explosion.

Altogether, though, if made and handled with care, Nelson's 1867 Torpedo is an interesting and entertaining member of the torpedo family of fireworks.

Cracker Balls

The cracker balls I recall from my childhood were small ball-shaped torpedoes about the size of a pea, and came in several bright colors that leant them the appearance of Trix, a popular breakfast cereal. As children, my friends and I shot off cracker balls by the scores. Finally, the corner grocery where we used to buy them ceased to sell them. The story we got was that some children had eaten some cracker balls and been poisoned or had their teeth blown out, or some such disaster. The allegations of poisoning seem in retrospect to have the greatest credibility; cracker balls used an explosive mixture composed of potassium chlorate and arsenic disulfide, the latter a compound of some toxicity. None of my friends or acquaintances were foolish enough to munch on these explosive treats, though, and we all enjoyed them thoroughly and without adverse consequence.

Now, years down the road, I have done some experiments with cracker ball composition and cracker ball-like devices. I share the procedure here for posterity.

Materials Needed: 3/4" paper cup sets (as used for making cherry bombs or smoke balls), fine quartz aquarium gravel (about 15-20 mesh), white glue (such as Elmer's), gummed paper tape (2 inches wide), potassium chlorate, arsenic disulfide aka realgar (fine powder), distilled water, jig for holding cup sets while filling, small eyedropper or hypodermic syringe (no needle required), wooden stirring sticks, small medication cups or other small container for mixing composition, lab spatula or small powder scoops, small artist's paint brush, sponge, rubber or plastic gloves, safety glasses, protective clothing and all usual safety equipment.

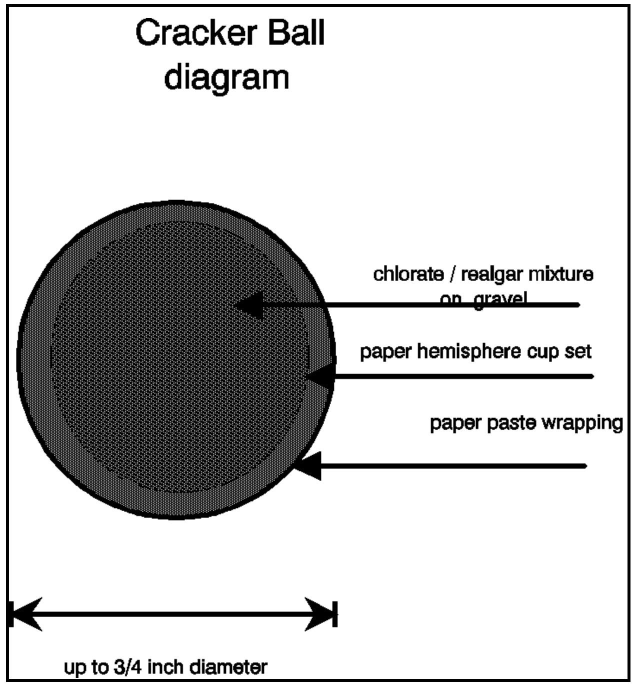
Procedure: I begin by making ready my usual safety equipment and wearing my protective gear -- safety glasses, gloves, and the like. I place all the materials I need for the project within easy reach in my work area. I place my jig for holding cup sets during assembly in the vise on my work bench. Then I fill the holes of my jig with the bottom halves of the cup sets I'll be using. I measure out *separately* the chemicals to be used to make the realgar explosive mixture, for which the following formula is followed:

Realgar Explosive (cracker ball) Composition([6])

Potassium chlorate 67%
$KClO_3$

Arsenic disulfide 33%
As_2S_3

Impact Firecrackers



Cracker Ball diagram

It is possible to vary the amount of composition to be used by a substantial margin, but I prefer to use about three (3) grains (about 195 mg) per torpedo. These chemicals I then set aside for use shortly. I then cut three (3) four (4) inch lengths of the gummed, 2 inch wide paper tape for each torpedo to be assembled. I place my sponge in a shallow dish and wet it with tap water. Next I mix my composition. This is accomplished by mixing each of the components of the mixture with sufficient water to form a thin paste, and then stirring the two slurries together in a small medication cup with a wooden stirring stick to form a single composition. I try for a mixture in which one gram of finished composition is present in 2 cc of finished slurry; mixed this way each 1/10 cc measured out by volume in my syringe will deposit 50 milligrams of active composition into the torpedo. While using this composition it is necessary to stir it frequently in order to maintain an even distribution of the insoluble realgar and the slightly soluble chlorate in the slurry. *Remember, that when dry, this composition is very, very sensitive to shock, friction, and heat! Be careful to wipe up any and all spills immediately with a damp cloth*.

I begin loading the torpedoes by using a powder scoop to load each of the bottom cups in the jig about half full of fine quartz gravel. I fill my syringe with the slurry composition and deposit 4/10 of 1 cc in each bottom cup. Then I slightly over fill the cups with more gravel. I use a fine artist's paint brush to paint a fine line of glue around the top outside edge of each bottom cup, and then slip a top cup snugly over each bottom, forming a more or less spherical torpedo. I should now have several dense, solid, ball-shaped torpedoes that do not rattle at all when shaken in the hand. The torpedoes are now ready for wrapping with the gummed paper tape.

Wrapping is the final step in assembly of the "cracker ball" torpedoes. For each torpedo I use an assembled cup set and three (3) four (4) inch strips of gummed paper tape. I wet one strip of tape on the sponge, and carefully, tightly wrap the cup set around its vertical axis. I wet another strip of tape and wrap this one around the horizontal axis. Finally, I wet the third strip and wrap it also around the vertical axis. I roll the finished ball between my hands to flatten any ridges or bumps in the tape. Then I allow the "cracker balls" to dry slowly in a warm dry area. When completely dried, the cracker balls can be fired from a slingshot against a brick wall or other hard object with great effect. Remember, though, that these "cracker balls" are not just explosive, but poisonous, too. Cracker balls should not be fired where small children might be likely to find "duds" I might leave behind.

Automobile Tire
Blow-Out Simulator

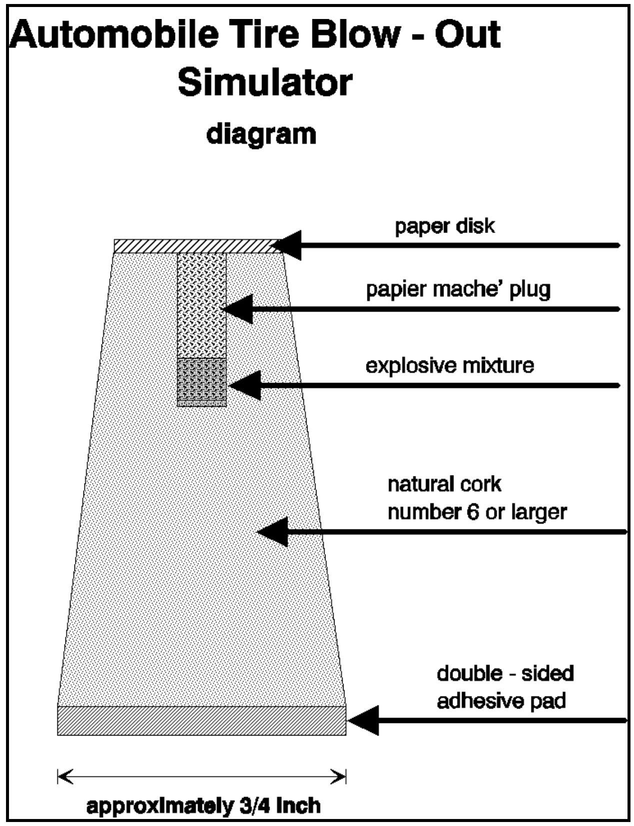
This automobile tire blowout simulator was inspired by some old fireworks catalog listings I have seen that date back to the first half of the twentieth century. The present design is a modern variant of the original design. The "Auto Tire Blow-out Simulator" is just what the name implies -- a device which, when affixed to the tire of a parked automobile, makes a noisy but harmless report that mimics the sound of a blow-out tire failure. The old-fashioned ones, reminiscent of the old railroad torpedoes, came equipped with metal bands, with which one would strap the simulator to the targeted tire. The new versions use instead a peel-and-stick, pressure sensitive adhesive. This is much more convenient and quick that fooling around with lead straps. The result is a blow-out simulator just as much fun as the old ones, with less chance of being observed in the act of application, and less chance of property damage, thanks to the durable, modern tires of today.

Materials needed: Corks (number 6 or larger natural cork), 1/4 inch wood drill bit, drill press (or steady hand on a drill motor), quartz aquarium gravel, kraft or pasteboard disks to fit small end of corks, potassium chlorate, red phosphorus, calcium carbonate, sulfur, distilled water, eyedropper or hypodermic syringe, white glue, double-stick foam rubber pads (as used for mounting posters on walls), x-acto knife or punch cutter to fit larger end of corks.

Procedure: I begin by assembling all the materials needed. Then I prepare my corks by drilling holes 1/4 inch in diameter and 3/8 inch deep into the smaller end of each cork with my drill press and a 1/4 inch wood boring bit. I arrange all of my corks upon my work table and place the hollowed end upright. Then I fill each hole halfway up with aquarium gravel.

Now I am ready to fill the corks with explosive mixture, for which I use the same Armstrong's Mixture, made in exactly the same way as described in the section on "More Cap Torpedoes" (pp. 15-17). Rather than repeat the details of the process for mixing this formula, simply refer to that section and follow those instructions exactly. Remember that *Armstrong's Mixture is the most hazardous mixture commonly used in small fireworks* and all precautions must be observed.

I use my eyedropper place slurry equivalent to two to three grains of dry mixture in each cork, directly upon the grains of aquarium gravel. This should be about three or four drops, depending on how much the mixture is diluted and the size of my dropper. Next I fill any remaining space in the corks with fine sawdust; I don't want any room inside for the gravel and mixture to move freely. Then I use white glue to affix pasteboard or kraft disks to the small end of the corks, sealing them tightly. I finish the devices by adhering a double-stick pad to the opposite (larger) end of the cork. I like the professional-looking touch of cutting the double-stick pad in circular shape to match the diameter of the cork; I have found a punch such as machine shops use for cutting gaskets to do very well for this application. However, one could just trim the edges with an x-acto knife. These devices may take up to several days to dry thoroughly. When dry, however, I can simply wipe clean a spot on the center of a car tire with a handkerchief, and affix the "Auto Tire Blow-out Simulator" with its double-stick pad. When the car tire begins to roll, it will crush the cork, causing a loud report.



Exploding
Blow Gun Darts

Back in the old days kids used to have some great fireworks goodies to chose from. Fireworks could be ordered by mail and sent by rail just about anywhere in the country. Advertisements appeared in publications of all sorts, even in ordinary mail order department store catalogs. One I saw (many years after it was published, I add) offered a cap-exploding dart, which got me to thinking. When I was a kid, one of our favorite toys when I was about 12 years old was an improvised blow gun with home-made darts; for some reason blow guns seem to fascinate our young minds. So now, years down the road, I've come up with this blast from the past -- a home-made blow gun dart that makes a nasty report.

Materials needed: Gummed paper tape (3 inches wide), wooden match sticks, 4d 1 1/2 inch nails, dental probe or small nail for crimping paper tubes, sponge, colored yarn, Japanese tissue paper cut in 1" squares or circles, clear arts and crafts glue, potassium chlorate, red phosphorus, sulfur flour, dextrine, distilled water, eyedropper, large soda-pop straws (such as found at MacDonald's), wooden stir sticks, small measuring cups, balance scales, safety equipment.

Procedure: I begin by cutting paper tape to be used for rolling the tubes used to make my darts. I use ordinary, non-reinforced, gummed, kraft paper package-sealing tape that comes on a three-inch wide roll down at the office supply store. I cut it in lengths 1 1/4 inch long, each of which will form a dart.

I make a jig to hold my darts while I work on them and load them by drilling several holes 3/16 inch diameter by 1/2 inch deep into a piece of scrap wood.

Next I cut my wooden match sticks into 1/2 inch lengths with an x-acto knife, and set these pieces aside for later use. I also cut a similar quantity of 1 inch lengths of colored yarn.

After cutting the paper tape, I roll it on 4d 1 1/2 inch long common nails to form tubes about 3/32 inch inside diameter and a little larger than 5/32 outside diameter. I roll the tape onto the nail dry, and tighten it up as I go along. After rolling the tape completely around the nail, I unroll the last inch or so and wet that inch with my damp sponge, and then re-roll it. I then pull the nail half way out of the nearly finished tube. Next, I take one of my half-inch pieces of match stick, and proceed to insert it into the center cavity of the tube, finally pushing it down inside the tube so that barely 1/8 inch of the central cavity shows at the end of the tube. I now use a dental pick to crimp a layer or two of paper from the central wall of the tube over the end of the match stick, forming a tiny cup-like cavity at the end of the dart tube.

To finish the dart tube, I turn them around, exposing the other end of the hollow central cavity in the tube. I take a piece of yarn, double it over, and put a dab of white glue on the center of the yarn. I then use a toothpick to insert the yarn into the central cavity, allowing the two ends, each about 1/4 inch long, to protrude from the end of the dart tube. When the glue dries, I can trim an excess or uneven strands with a razor blade or x-acto knife. I now have a complete, but unloaded blow gun dart.

I use the same Armstrong's Mixture described in the section, "More Cap Torpedoes" (see pages 15-17) to load the darts. I follow exactly the same methods and precautions detailed in that section to produce a slurry that I use to load my darts. To load the darts, I simply use my eyedropper to place a single drop of the slurry -- less than 1 grain (65 mg) -- into the tiny cup-like recess formed in the end of the dart tube. I keep the load small because of how sensitive the finished product is and also because of how it is fired: from a straw close to my face. While this comp is still wet, I cover it over with two or three layers of Japanese Gampi tissue paper that I wet with clear paper glue. I affix the edges of the tissue to the outside paper wall of the dart tube. This part of the process takes a little practice. I try for eliminating any air space or bubbles between the tissue and the composition. After everything has dried for several days, the dart can be carefully inserted into and fired from a large soda straw. It will explode upon collision with any hard object. These darts are very sensitive and must be stored in fine sawdust, handled and loaded with great care.

Annotated Bibliography

John A. Conkling, *Chemistry of Pyrotechnics* New York: Dekker, 1985). Conkling's book is the most up to date source of elementary information on the chemistry of pyrotechnics. A must read for the novice pyrotechnist, especially if he has little formal training in chemistry.

Tenney Lombard Davis, *The Chemistry of Powder and Explosives* (New York: Wiley, 1941). Davis taught chemistry at Massachusetts Institute of Technology, where he was regarded as a leading authority on explosives. This text was prepared for his graduate class in explosives chemistry, and is geared toward persons who have substantial competence in the field. *Chemistry of Powder and Explosives* has an interesting but dated section on fireworks history, but is otherwise dry reading.

John Drewes, "Cherry Bombs and Silver Torpedoes" (California: West Coast Pyro Board, 1990). This is an interesting essay, actually by one of the old pyrotechnists, as told to John Drewes. For a time it was posted on a public computer bulletin board that had a conference for pyrotechnists.

Donald J. Haarmann, aka "The Wiz", "Fireworks and Selected Patents," *Bulletin of the Pyrotechnics Guild International* number 60 (Indianapolis, IN: David Peat, 1988) 22-30. "Fireworks and Selected Pyrotechnic Patents is just what it sounds like, a listing of pyrotechnic patents. The listing is chronological listing of approximately 500 U.S. fireworks patents that gives for each entry the patent number, date issued, name of inventor, title of patent, and the class of fireworks to which it applies (for example, "torpedo"). This document is an invaluable aid to locating particular patent records, and should be sought out by anyone who needs to do pyro patent research.

Dennis Manochio, editor, *Pyro-Fax* (Saratoga, CA: Fourth of July Americana Museum, 1990-1992). *Pyro-Fax* is an erratically appearing periodical catering to fireworks collectors and fireworks history buffs. It is a very limited circulation publication available only by mail from the editor.

Daniel Rhodes, *Clay and Glazes for the Potter* (New York: Chilton, 1957). Clay and Glazes is an excellent references book providing information about clays that can be useful to the pyrotechnist in many different applications.

Takeo Shimizu, *Fireworks, the Art, Science, and Technique* (Austin, TX: Pyrotechnica Publications, 1988). Shimizu's book, *Fireworks, the Art, Science, and Technique* is one of the finest currently available books dealing with fireworks making. Shimizu limits himself to description of Japanese fireworks, which he accomplishes brilliantly. Translated into English and reprinted by Robert Cardwell and Pyrotechnica Press of Austin, Texas, the book is a must have for all students of pyrotechny.

I.C. Sparks, *Torpedoes* vol.1 (Orem, UT: Sparks Enterprises, 1990).
Torpedoes is a booklet published under an obvious pseudonym, for obvious reasons. Mr. Sparks presents a method of making torpedoes in the form of solid balls of homogenous, impact-sensitive compositions. I have seen the results, and they do work wonderfully. Perhaps too wonderfully, for these torpedoes are very dangerous to handle, store, etc. The approach, however, is novel. Exercise caution, extreme caution with these devices!

George W. Weingart, *Pyrotechnics* (New York: Chemical Publishing Co.: 1947). Weingart's *Pyrotechnics* has often been lauded as a seminal work of modern pyrotechnics. This may be an overstatement, but Weingart does describe many processes relevant to the making of torpedoes, as well as good general background on handling pyro chemicals and compositions. Taken with a grain of salt, the book is a valuable part of any pyro reference shelf.

Robert C. Weast, et al, *Handbook of Chemistry and Physics* 48th edition, (Cleveland, OH: Chemical Rubber Co, 1967). The venerable *Handbook* is an excellent reference for anyone engaged in any work with chemicals. Thousands of references on chemicals -- names, formulae, molecular weights, solubilities, and much, much more are all in this indispensable reference.

Special thanks to the United States government's patent office, without whose records, this report would have been next to impossible.

End Notes

1.Don Haarmann, "Fireworks and Selected Pyrotechnic Patents", Bulletin of the Pyrotechnics Guild International 60, (Indianapolis IN: Pyrotechnics Guild International, 1988) 22-30.

2.George Washington Weingart, Pyrotechnics, 2nd edition, (New York: Chemical Publishing, 1947) 174-176.

3.Takeo Shimizu, Fireworks: The Art, Science, and Technique (Austin, TX: Pyrotechnica Publications, 1988) 275.

4.Tenney L. Davis, The Chemistry of Powder and Explosives (New York: Wiley, 1941) 105.

5.United States Patent Office, *Letters Patent No. 65,764, "Improved Toy Torpedo and Explosive Compound," June 11, 1867.*

6.Shimizu, Fireworks, 277-278.