CASOC

Colorful Applications of Solid Chemistry

[An enthusiastic amateur's guide to scratch built rocketry and pyrotechnics]

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Dear Reader,

By reading this book or any part of it you accept the disclaimer you will see below.

This is the summary of all my experiments in the field of solid propellants (black powder, sugar rockets), pyrotechnics (stars, shells, bursts), ignition aids (fuses, primers) and tools I have built for the purposes above.

I do not intend to show you the best way (which is usually too costly and out of amateur's reach) nor all the ways (too many) to do things, just my way of doing things. I will try to explain and summarize my experiments as you will see.
Not all of them are included in this book but just the successful ones and the ones I think are worth printing.

I hope you will enjoy it, and maybe also be inspired by it.
I wish you the best of luck with your own experiments.
Please remember that if one plays with fire – then he should expect to be burned.
Please be very careful and remember that safety is above all.

Nonetheless, once you have smelt the smoke you will be hooked forever – I started at the age of 16 and this was over 20 years ago… I still did not test not even 10% of all the ideas and questions I have.
This is a fascinating scientific field that awaits the best of us and the most curios of us… and it is most rewarding, and dangerous.

Yours,
Flint
June 2009

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<u>Disclaimer</u>

By reading this or any of my files you hereby acknowledge that...

- The procedures described on the following pages are for informational purposes only.
- You acknowledge the fact that the information in these files is, under no circumstances, a recommendation to follow to full extent or by part, any of these experiments and formulas given.
- If you **choose** to follow the instructions on the following pages, you do so ***at your own risk***. Pyrotechnics and rocketry propellants, chemicals and other items are dangerous and must be handled with the utmost caution. I takes **<u>no responsibility</u>** for personal injuries, property damage, or legal issues caused by your (or who ever you distributed the information to) application of any of the materials presented on these pages. No warranties are expressed or implied regarding any of this information. There is no guarantee that any device will function exactly as described here.
- Also I **do not** advocate the use of this information for illegal, unsafe, disruptive, or destructive purposes. This includes building salutes, bombs, or other explosives designed to cause noise, harm, or damage.
- The possession and use of fireworks/black powder is regulated by federal, state, and local laws. The reader is solely responsible for observing his/her local laws before using fireworks or applying the information presented at this site.

Note:
When doing the things I love in this fairly rare hobby I make sure I record my results, I make sure my experiments repeat themselves before writing anything about this on my website and I assure myself that the system I work with is reasonably safe to handle. I consult with experts on pyro/rocketry lists if I'm not sure about any aspect of my experiment. Working with propellants is never safe and one should be aware of that. Hence, to the best of my capabilities, I publish safe and workable methods and formulas. However, if you wish to start with this lovely hobby I have two recommendations for you that I consider a must and a few good recommendations:

1. **Read the literature first!**
2. **Find a well knowledgeable person in this field to help you make your first steps in the field.**
3. Join a club and/or join a mail forum such as PML, SugPro, Arocket, R-BP, and so on.
4. Find a safe place to handle your experiments and use safety gear.
5. Be prepared for the worse.

My moto is: “Sof Maase bemachava Tehila” – whatever happens depends on how well you planned in advance.

BLACK POWDER MOTORS

Making Black powder

This chapter summarizes my current methods and tools in making BP.
Many thanks goes to my friends John Collins, Bill Bullock, Yuv and many others that helped me with this old love of mine.

Personal history and intorduction

My most favorite topic of research is black powder, or BP.
Like all propellants BP is a composition of oxidizer and reducers – in this case the "standard" ratio of BP is:
75% KNO3
10% Sulfur
15% Charcoal

I first started my passion for pyrotechnics while reading books in my school library, well over 20 years ago. It took me 3 months to read all the library books from start to finish. In one of the encyclopedias there was a mention of the term BP and a short explanation.
Sadly – there were no chemistry books and I did not realize the numbers given in the text were in weight (as all good pyro numbers should be) and not in volume.
I got some KNO3 and Sulfur and began my experiments.
It took me 3 years to get to a good working formula – by volume.
It is (converted to weight):

KNO3-	59%
Sulfur-	21%
Charcoal-	20%

Years later I found out what my basic mistake was and measured my formula – it was almost identical to the French rock blasting formula (by weight) which is:
KNO3 – 60%
Charcoal – 20%
Sulfur – 20%

These days I have a ball mill (self built, with kind help and tips over the web from friends and forums). My ball mill runs a 200gr batch size – which is enough for my needs (for roughly 3 months). I originally invested 200$ in an Ohuse mechanical triple beam scale (crucial for any rocketry/pyro lover) and recently I moved to the digital scales. Most of my tools are handmade due to financial limitations and the lack of a lath.

BP composition

There are many BP formulas.
I will refer to the "standard" one:
75% KNO3
15% Charcoal
10% Sulfur

KNO3
KNO3 can be bought from fertilizer/gardening supplies as technical grade KNO3. This means typically that it is 99% pure or so.
It can be bought at other levels of purity – but this is what I have and so far I had very constant results with it.

Sulfur
Sulfur should be also tech. grade (99% pure).

Charcoal
Charcoal is the key ingredient in the black powder.
I make my own charcoal and then hand grind it with a big mortar and pestle to get rough "grit" that can go through a mosquito window net. I don't need it any finer than that as the ball mill will grind to a fine powder.

Using a "low grade" charcoal (for example – barbecue charcoal, activated charcoal) will result in a weak BP, burning slowly and producing lower amounts of gas.

Basic charcoal retorting (making charcoal from wood) requires very few simple tools:
I found a large metal container (~40cm or 16" diameter).
I drilled about 12 2.5cm (1") holes in the bottom of the container and the same in the container lid. The container is filled with charcoal briquettes (they are best as they burn hot, even and burn for a long time).
The metal container is placed on two bricks so that the bottom section is vented and air can rise from the bottom to the top.

Two metal coffee cans with metal tubes coming out of them contain the wood. The coffee can lids are secured and the metal tube allows the hot gasses to be vented outwards.
The wood is sliced into small pieces (as tall as the tin can and about 1-2cm wide) and inserted into the coffee cans. The coffee can is then placed on its side on the red hot briquettes. I keep turning it every 10min or so.

Soon after the coffee cans have been placed on top of the hot briquettes (with long forceps) it will start to smoke. This smoke is highly flammable and will ignite soon after. I stop the retorting as soon as I see there is no more smoke emitted.
This rule of thumb was given to me by my friend Yuv and I have found it to be an excellent rule.
I then take out the coffee cans (with long forceps) and allow them to cool on a brick.

The cans will cool down in about 10min and then I open them up, take out the charcoal for another 24hr cooling and oxidation. The cans are re-filled and the process repeats itself.

1. **Notes:**

- Ash from the briquettes also accumulates – just shake the main container to allow the ash to fall down and hence offer better ventilation and hotter flame.
- Wood is best turned to charcoal as fast as possible. Wood decays, charcoal doesn't.
- Charcoal has been known to burst into flames spontaneously which is due to slow oxidation of the charcoal, which builds up heat and in due time can cause spontaneous combustion. To avoid such a problem allow the charcoal to cool in the open air without grinding it first. Let it sit for some a day or two (don't pile it – you want to spread out the heat not contain it).

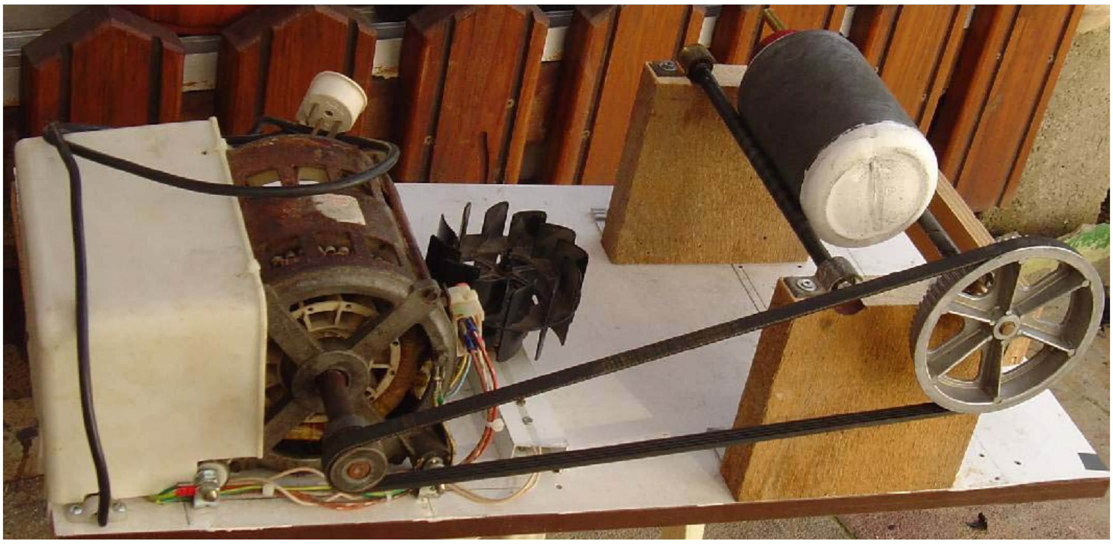
Ball Milling

Ball milling - apparatus

BP is made in two basic methods:
CIA method which uses ethanol to cause precipitation of nitrate crystals around the sulfur and charcoal using ethanol. I will not discuss this method as I have no experience using it.
I use the other method which is ball milling.
A ball mill is a jar containing balls (of some sort). As the jar rotates the balls tumble and fall, hitting each other and grinding any material that was in between the balls.

To make a ball mill I took what I had around – an old washing machine motor. I hooked it up to an axel (a brass rod I had).
The two axels on top of which the jar sits are 12cm apart and the jar itself has a diameter of 15cm. I tested to find the best gripping/rolling action and secured the axels at that point.

This is my ball mill:



The motor is an old laundry machine motor, running at low speed.
I'm using a regular laundry machine band, but I have changed the wheel and now it's much smaller and adapted to 60rpm speed (measured according to the jar, of course).
The fan near the motor isn't very efficient and I use another external fan to cool the motor.

Below there are two pictures of my rods and "balls" (short rods, to be exact), which I use as milling media. From current tests both methods (rods vs. balls milling) give fairly good and similar results
My apologies for the quality of the pictures – I'll try to fix this later on.

The balls, as you see are small segments of brass rod, cut with a circular disk (yes… it does take a long time!)

Here are the rods.
Notice that the cap is sliced around the edge and has been re-glued with a little bit of hotmelt. This has been done so that in case of an ignition, it will let go before the box will explode, this will release the pressure and avoid the nasty shrapnel of high speed metal fragments emitted from the blown up milling jar.

Here are a few crucial comments from both John and Bill on the subject who have greatly helped with my ball mill design.
Milling with small "rods" (small segments cut from a metal rod) are optimally 2:1 length to Diameter. A mix of two cylinder sizes promotes faster milling of softer material, and good mill flow preferably with hemispherical ends, and a smooth a finish as possible. Bill suggested three media sizes – which is what I use: 15, 10 and 7mm OD rods (0.6", 0.4" and ~0.3" respectively).

Good options for milling media are brass, bronze, lead (which I don't recommend) stainless steal 304, 316 310-24, or 410s24 ss - as both types contain a low percentage of steal, a fairly high percentage of chrome and hence will not spark. I chose brass since it's the cheapest of them all – it does the job for me.

According to Bill's advice I took 15, 10 and 7mm diameter brass rods, and cut them with a circular disk at about 1:2 diameter/length ratio. Bill suggested that that 20% box volume will be filled with the 7mm media, 20% with the 10mm media and 10% with the 15mm media. This is what I did.

As for a milling jar – I found a plastic jar (no erosion over the last 10 years or so!!) which is 1liter volume with a fairly big opening. A milling jar should be filled with about 50% grinding media and 25% material to be filled. If you can't find a suitable box buy some HDPE pipes and plugs at any local hardware shops. These pipes come in many sizes. My batch size is 200gr each time. Although I can go up to 250gr it's easier to calculate per 100gr and double it as the BP ratios are in percentage...

The mill rotates at 60rpm.
This is fairly optimal if you don't want to get into the math. This is not optimal for all the milling systems but it's a rule of thumb so to speak. I found that 60rpm works just fine for me.

I did check the milling times in my apparatus:
1.5hr – not good, fairly crude BP, although it will burn nicely, but not so vigorously.
2.5hr – much better and will provide fairly good quality BP for good bottle rockets
3.5hr – far better and more "energetic" BP – i.e. higher burn rate.
I should have kept on going for longer times… BUT –
I'm not a factory. Electricity costs a lot and I'm using two motors (electric fan and ball mill) running at the same time.
Also – consistency is much more important than high burn rate. I do get consistent results and 3.5hr of milling provide me with high quality BP – high enough for my needs.
I settled then, on the 3.5hr milling time.

Ball milling procedure

To start the ball milling process I go through the following process:

1. The KNO3, sulfur and charcoal are weighed.
2. I sift the ingredients through a mosquito window net (regular gray net you can find anywhere, I've glued it to the bottom of a box for ease of use). If there are any chunks I grind them up together in a mortar and pestle and then return the powder to the mix.
3. I place the milling media into the milling jar.
4. I add the BP green mill mix into the milling jar.
5. I add 5% of 50% ethanol (1:1 water + ethanol – add 5% or 10cc to 200gr BP) into the milling jar.
6. The milling jar is taken and placed in my ball mill. I activate the mill from a distance.
7. After 3.5hr I disconnect the mill, and use a set of two boxes (top on with 5mm holes drilled in its bottom) to separate the black powder from the milling media.
8. The Black powder is stored safely, and the milling media is washed thoroughly with water and left to dry in the sun.

Corning

Tools

Ideally, corning is done with a press. I don’t have a press and I don’t have a place for one – or I would have built one. It’s easy and low cost to make your own press and I have everything I need but I lack the space for it. I highly recommend this method.
I use the following alternative method since I can’t use the better one.

First you will need a 2 meter long ~ 25mm or 1" OD steel bar. I coated mine with a nice white paint and an epoxy coat on the ramming end.
Yuv uses a rebar – the steel rods used to reinforce cement; they are cheap and widely available.
If you can get a stainless steel (300 series I'm told would be best), brass or bronze rod – that would be much better and safer (less prone to cause a spark).
The second item would be a 1.5 meter long piece of 1" or 25mm ID, schedule 40 (or even better – schedule 80) PVC pipe.
The tube and rod must fit each other, but it doesn't have to be close tolerance - a gap of a few millimeters between the rod and the tube is still OK.

These are the tools that Yuv and I use – alterations are always an option. Use what you have and see how it goes. Do remember to use non-sparking materials and use the safety rules listed below. If you can add another safety factor we may have missed – do so and please let us know about it.

Procedure

WARNING: read safety notes before trying this!
You must also read and accept the disclaimer!
I HIGHLY recommend you use a press (arbor press, bought press or homemade press). I use this method because don't have the space for a press now.

Place a brass coin at the bottom of the tube (a perfect fit is best, but not crucial).
Yuv uses a single coin at the bottom of the tube, to prevent BP from "leaching" out (at the beginning) and to form a stabile surface for the grain to form against.

Place 20gr of freshly milled BP into the tube.
Usually the BP is milled while it is damp: 4% moisture level that consists of 50:50 ethanol/deionized distilled water.
Ram/pound the BP with the metal ramming rod.

Ramming in this case means that you lift the steel bar with your gloved hand, and lower it as hard as you can on the BP sample. No mallet is needed or used; the weight of the bar does the work.
Keep pounding the rod until it feels like pounding on concrete, and then another 2-3 blows.

Add another 20gr of BP and ram/pound it as well.
Turn the system upside-down and press the BP puck out.

It's very important to place the tube on a very hard and stabile base. The blows are strong enough to break a concrete slab – I have a proof for that! I use a compressed concrete brick used in many streets now as interlocking bricks of varying colors. Placing the brick ON sand is bad, as the sand will cushion the blows.

Yuv has reported that this will result in a final density of 1.6gr/cm^3
In case you have forgotten or you don't know, BP's maximal density is 1.7gr/cm^3.
This means that the compression rate is 94%. Allow to dry and corn it carefully.
Remember – safety above all!

Safety considerations

Common sense dictates the need for heavy leather gloves, full face mask, a nearby water source, extinguisher and a safety escape route for you to follow if something bad happens. Make sure there is no one not involved in the process around – and of course, don't work in a residential area.

Yuv's points:
The ramming/pounding/packing procedure is done with MOISTENED BP.
Hence, the chances for ignition are lower than usual, BUT POSSIBLE.
Still – a brass coin or coins ARE used to separate the BP from the pavement and the epoxy head and paint coat separate the steel rod from the BP to avoid some sort of spark. Note that (according to Yuv) the top brass coin will stick to the top of the BP grain, and that's why he uses only a single coin at the bottom of the tube.

Steve's points:

1. A brass or stainless steel rod would be far superior in safety to plain steel. If you can't afford one – try the following: Add a brass nipple at the end of the rod (with some lathe work, this will allow you to screw a brass nipple on the end of the steel rod).
2. A second alternative would be to cast an epoxy cylinder on the "head" of the steel rod, hence lowering the chance of metal to grit or metal to metal sparks. Make sure it's at least 5mm thick at the front end. Check that it is not a static electricity generating hazard! Rubbing the surface of the cast epoxy cylinder with graphite powder may help drain off any static charge build-up.
3. Build a wood container, and fill it with sand bags. Insert the bottom of the PVC tube in a cavity in the sand bags of this "barrier box" before ramming. The reasoning here is that if something goes wrong and the BP ignites it is best to remove sharp fragments of PVC from the sand bags instead of your legs. Probably, only the lower section of the PVC tube will be likely to fragment in this type of accident, so the box doesn't have to be very tall.
4. Make sure you are not doing this in a populated area – a flying heavy steel rod (in case of an accident, it might be launched out of the tube) is no fun, and can cause injury or damage.

Other than the box idea, using a full length polycarbonate blast shield to protect your body would be a good idea.

Update

20/9/06

I just bought my own set (as above) for ramming BP pucks.
It's a 25mm ID x 80cm long PVC tube (schedule 40) with a 1.5cm tall 23mm OD steel rod (6kg total weight). I added a thick layer of epoxy on top of the steel rod for safety.
Yuv mentioned to me that it would be a good idea to add a re-enforcing sleeve (basically a connector section or an end plug with a 25mm hole drilled) to help the end of the tube hold up to the pressure.
He also noted that it would be a good idea to file to smooth the edge of the tube so that it will be slightly conical and thus it would be easier to force the puck out.
Another good point is to use a solid pavement slab. A regular floor slab will break under the impact so don't do it at home (and for safety reasons, of course!!!).

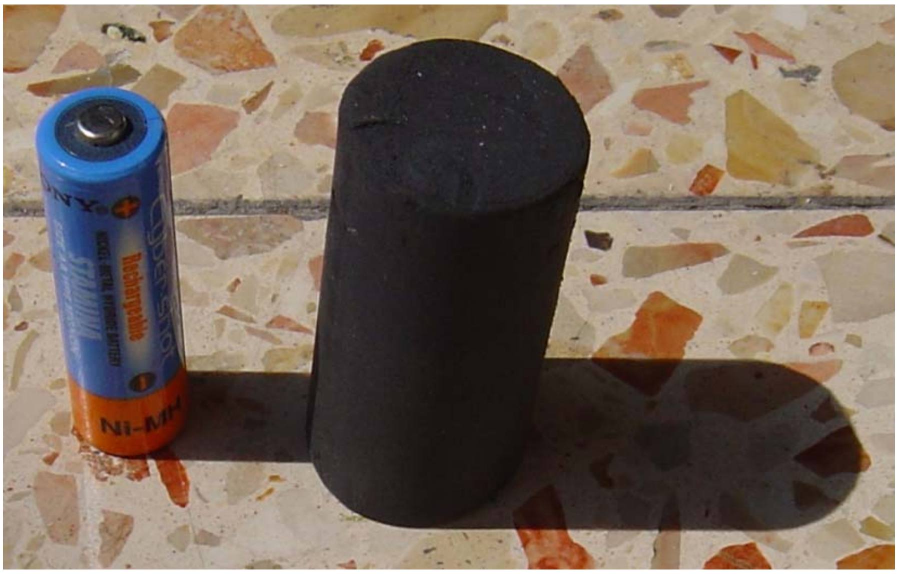
Results

I made a 200g batch of BP and saved 100gr as powder and corned the rest of it.
I "rammed" 25gr and then another 25gr on top of the first before removing my puck.
Here are my comments:

1. Use some masking tape to secure the coin in place – so you won't spill the BP (like I did the first time) if you accidentally move sideways.
2. Test your apparatus on a concrete slab you don't mind loosing. I used a heavy duty concrete slab (not the type mentioned above by Yuv – but a bigger and thicker one) and smashed it into bits with a very nice crater…
3. For protection I used an inverted steel bucket filled with sand bags.

4. To extract the grain (that is stuck pretty hard inside the tube) I prepared a wood block with a nice hole in it – the hole matched the size of the tube, but not the OD of the re-enforcing ring, that was used as a stopper. I gently rammed the second puck out using my wood block and it went out just fine.

Here is an image of my second puck:



The grain or puck is 2.5cm (1") OD and 5.4cm tall.
Its weight is 45.5gr
And its density is 1.7gr/ccm exactly which is identical to the theoretical maximal density, and this makes me very happy.

I place my BP pucks in single use aluminum cake plates (I reuse these!) and they get pretty hot and dry rather fast. Two hours are enough in a hot summer sun.
BP is stored in a safe location.

Crushing of the dry pucks is done in a stainless pot using a wooden hammer, full face mask and gloves. I always keep nearby a fire extinguisher and a 5liter bottle with a spraying nozzle.

Testing the corned vs. un-corned BP in my GVM resulted in a +10% burn rate for the corned BP. For me this extra effort is worth it – I also get my BP in small grains after the corning and this is very convenient when you want to ram your BP motors. It's much better than ramming BP motors with fine powder.

Gas Volume Meter

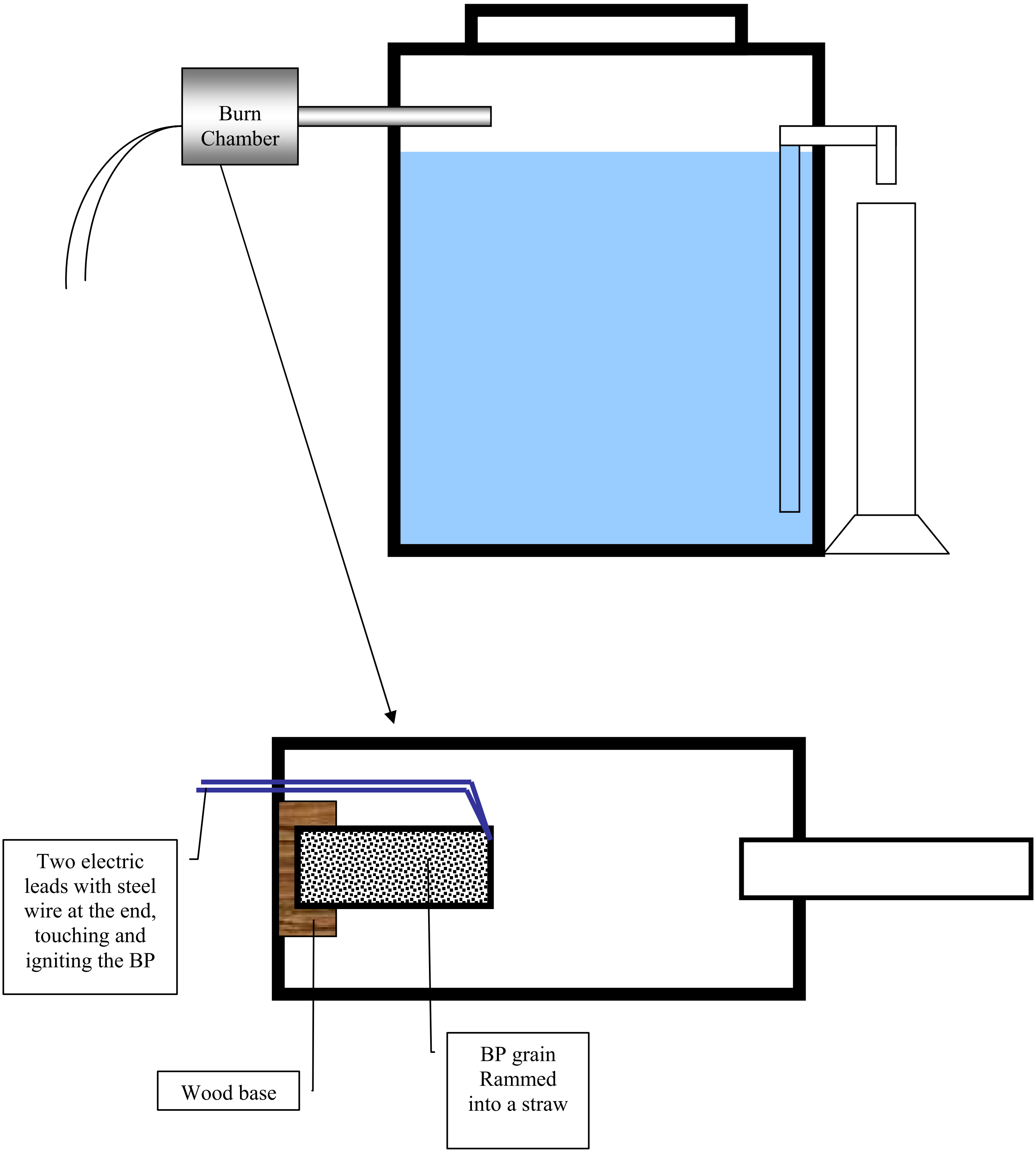
Introduction

GVM stands for Gas Volume Meter.
The basic idea is to be able to calibrate your BP with a simple tool that will tell you how much gas is produced. This means actually – how good is your charcoal (and possibly the other ingredients). Hence, you will know how good your BP. is
Another **crucial** point here is the burn rate. If the burn rate is high then even with low quality charcoal you will still get a good rocket.
However, they are usually combined. Burn rate is controlled by the time and quality of milling and processing the BP (corning, drying, etc). The more you mill, the better your BP is, the faster you dry your corned BP, etc – will affect your BP burn rate.
Hence you need at least two tools to test the quality of your BP: GVM and BRM.

The design here is a result of a long (fun, educative and very interesting) debate on R-BP forum. I wish to thank Rande, the late DJ and all the other participants in this discussion who helped a lot in the design of the system.

GVM design

My original design of GVM was very simple:



The burn chamber holds a BP grain rammed into a straw.

An e-match with no pyrogen is attached to the top of the BP grain.
As the heating element (steel wool) burns as a result of the supplied current the BP ignites and burns for some time. It is an end burner of course and as there is no nozzle or core there is no ignition spike, high pressure and rapid gas flow.

The gases flow to the main chamber, increasing the air/gas pressure.
The air pressure pushes the water out through the straw. The large volume of water compared to the volume of gas produced ensures that the total volume of water will not really change the water level in the tank a lot. This means that the column of water that is formed inside the straw is not tall enough to inflict a lot of pressure and that the air in the tank will be (after all the water get out) about 1atm. It's not exactly 1atm as air can condense. However the level of condensed air (i.e. pressure inside the tank) is about the same every time.

To test this I built a 60cc syringe that can attach itself to the system instead of the burn chamber.
Injecting 60cc of water (either fast or slow) always gave me back 55cc. The last 5cc were lost in leaks and inside pressure. The 55cc result was repetitive (i.e. I did it several times and got the same thing over and over).

OK.
This is the system I have now.
Below you can see a photo of the big version, 25liter drum and burn chamber for 5gr BP samples.

BRM-GVM

The GVM design was good but had a few flaws:
I wanted a few more things:

- 1-5gr BP sample in my tests
- Small table model
- BRM (burn rate meter) AND GVM in the same device
- Easy, simple to make and operate.
- Reliable

So…
Here is my design.
Same GVM as above only this time the burn chamber will be made of clear plastic (soda bottles used for making your own soda – heavy duty plastic and it's fittings are great).
The burn chamber is an 8mm ID aluminum tube containing a straw filled and with BP. The straw is 3.5cm long, packed (pressed) tightly with BP will be coated with 9cm long masking tape strip. The BP grain is 2.5cm long (1") and the burn rate can be easily calculated.
The burn chamber is sliced along its length so the burning will be quite visible to the naked eye. This means it can be photographed and the time will be accurately measured. Like this:

The igniter uses a small sample of BP, taken from the measured 1gr sample, so there is no addition of pyrogene of any sort. The first sparks from the igniter ignite the main BP grain and the camera can record it from start to finish.
Usually, 3 repeats per BP batch should give me a good estimation of how good is my current batch is.

To this end a clear, sturdy and rigid plastic soda bottle was placed on top of my 4 liter tank. The burn stand is on the cap of the soda bottle.
The video and sound records will tell me how fast it was.
The water spillage will tell me how much gas was produced.
And all I'll have to do would be to write those numbers down.

Here is the ignition system:

The syringe is an internal control that allows me to make sure everything is sealed.
I used a truck inner-tire as a source for my washers to seal the system.
You can see the electric wire, the holding aluminum tube, with the large opening that shows the straw covered with masking tape. At the back end there is a hole for the e-match to connect to the system.

Here is the full system:

The top soda bottle holds the sample.
The sample is partly inserted into a gray PVC tube.
The tube has two functions – it lowers the amount of gasses inside the burn chamber and allows for a better view of the burn process and it also directs the dirt away from the burn chamber, leaving it fairly clean.
The water bottle to the right will be used to measure the expelled water.
The tiny plastic pipe you see in the image has been exchanged with a larger one with an ID of about 6mm.

Results

The system was dry-tested (with the syringe) several times.
Input of 50cc gas (air) generated a 47.5cc+/- 2.5cc water output.
After several tests with a nice average of 5% constant loss in the system (happened with all the previous systems) I declared the system ready.
3 tests of my BP (grapevine charcoal, 3.5hr ball milled- see more data on my BP milling on the BP file) gave a 2.16sec burn time (2.5cm long BP grain) and an output of 360cc/gr of gas.

Corned samples tested generated the same gas volume (I didn't change the formula, just the treatment) but had a 10% burn rate increase – showing that it is well worth the effort.

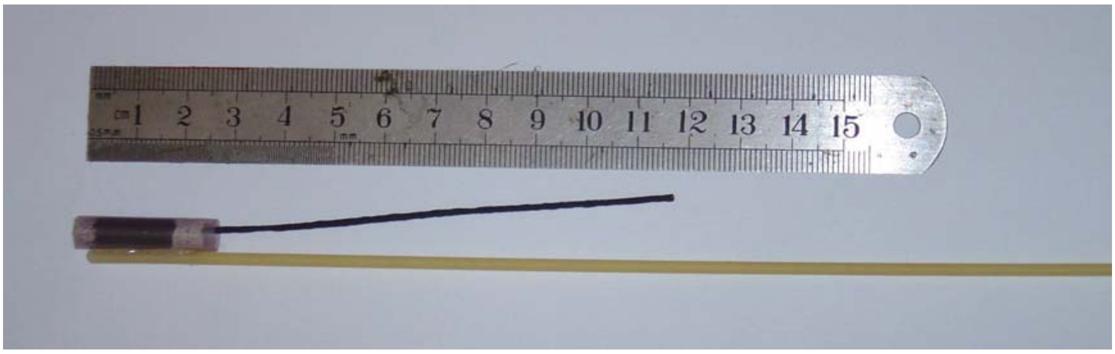
Small Thrust Meters

Introduction

The first thrust meter I used was a simple scale with a “cato guard” – a small block of wood glued below the moving plate that will prevent it from dramatically dropping down and over-pulling the springs in case of a destructive cato. A simple cardboard base with a tube on top was used as a motor cradle.
I used it once or twice (can’t recall) and it’s still functional.

I’m not discussing it.
I’ll be discussing my small thrust meters for tiny motors as Rande would say (and I’ll have to agree). As Rande requested – I’m adding this file and pictures to my site.

Why tiny scales for tiny motors?
Well…
I wanted to check my BP quality indoors.
I built a small chemical fume hood (virtually a box with a strong, but regular air vent) and this allows me to experiment indoors to some extent. Obviously I can’t fire big motors there (big means 10 and 15mm BP motors - I don’t make them any bigger).
Tiny motors (see my chapter on strawckets) such as straw-rockets or strawckets are very useful. As tiny nozzle-less motors they are fairly powerful but also VERY sensitive. Hence – lower BP quality will result in significantly lower thrust with these motors. They also use small amounts of BP so multiple repeats of the batch will not use a lot of it (a single motor uses up to 1gr PB, and usually I make them with 0.7gr BP).
Here is a strawcket ready to fly:



I had two ideas for scratch built scales – one (horizontal) is quite similar to professional systems you can see on many websites (and indeed that’s why I’ve built it) and the other one is even simpler (vertical) and I just used what I had…

Horizontal thrust meter

I'm using a simple aluminum bar a pivot point and a spring. I used whatever I had and that includes the spring.
The ratio between the long arm carrying the motor and the sort arm attached to the spring is 1:10 – this means that x force applied by the motor is x10 times applied on the spring. I can also move the spring rod and pivot point to change that ratio, which will allow me to use a variety of springs (whatever I have at hand, that is) and ratios to control the sensitivity of my scale.

The square wood "box" that contains the aluminum bar with the motor is there to assure that the motor will not tilt the system and that the rod will move downwards in a fairly straight manner.

Another piece of aluminum bar is used as a scale as you can see.

Vertical thrust meter

All you have to do is find two rods that fit each other perfectly, so that the first will smoothly run through the second. Now find a spring that fits the second one, but not the first… and you have a scale.

Note the spring INSIDE the bottom plastic tube (down at the bottom, touching the red base). The second spring is there for back up – I don't really need it, but I wanted a soft "impact" if the device is to be pushed all the way down by a cato or a stronger than expected motor.
The wood rod has two functions – it's a cato stopper and will stop the descent before any damage is done to the plastic tubes, and it is also a meter (I haven't marked it yet, but you can see my test marks in weak gray)
The top washer make sure (as much as it can) that no sparks/waste will fly into the space between the rods.

After assembling the items for this device it took me less than 30min to assemble it. It's adjustable (depending on the springs that you have), but not as adjustable as the horizontal version.

I think both systems are fairly simple and easy to make.

Data and experiments

3 motors were used as a standard test batch.

I started with core burners.
All the core burners went right off the scale.
I scaled the vertical thrust meter to up to 100gr. It looked much more like 200gr thrust. Unrealistic, of course, but still… way off the chart.
Burn time for the core burners was about 0.4sec.
A set of video clips is available for download on the video page.

End burners (2.5mm nozzle) were much more moderate.
The thrust was about 10gr (and for a 1gr motor, 0.7gr BP it's fairly good… no?).

I think this is fairly good for my needs.
I'll have to dampen the vibrations you see in the core burner mode, but it's pretty good already.

Bottom line – I've built the meters years ago and they work well.
I have found this method of testing to be very satisfactory, easy and well worth the effort.

BP rockets

Personal history and intorduction

My most favorite topic of research is black powder, or BP.
Like all propellants BP is a composition of oxidizer and reducers – in this case the "standard" ratio of BP is:
75% KNO_3
10% Sulfur
15% Charcoal

I started working with BP after 3 long years trying to get to a good working formula – by volume.
It is (converted to weight):
KNO_3-59%
Sulfur-21%
Charcoal-20%

Years later I found out what my basic mistake was and measured my formula – it was almost identical to the French rock blasting formula (by weight) which is:
KNO_3 – 60%
Charcoal – 20%
Sulfur – 20%

Back then I had no internet (wasn't available to the public yet), no pyro books to buy or even know they exist… and so on. I had to invent things from scratch. So I had some ideas of my own to try out: I made my own rocket tubes from wheat paste and newspaper, I've made tiny hummers from pistachios, small rockets from acorns, and I used all sort of tubes (yes, frightfully, metal included) for my initial rockets. Some went off and some took off. I made sure to stay well away, just in case…

Today I use a much more reliable and powerful systems, and much safer ones too!

BP motors - models

I have concentrated on small scales (relatively speaking) and I am using two sizes of motors, graded by their diameter.
1. 10mm Internal Diameter (ID)
2. 16mm ID
Why?
Two reasons: I made, and still do, small amounts of BP.
I make experimental motors and not much of pyrotechnics so I don't need a lot
I also have other limitations which led me to this choice.

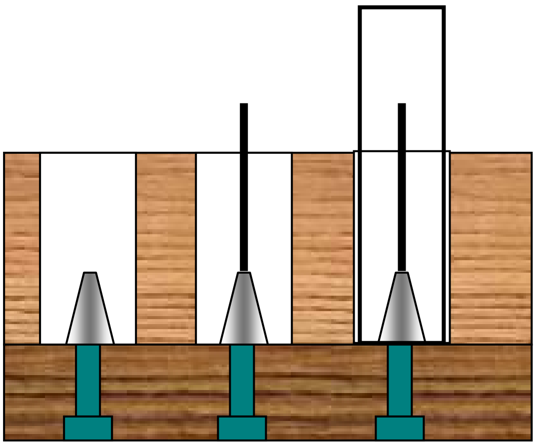
Tubes
The motors tubes are hand rolled using Elmer wood glue (undiluted) and A4 printer paper (I didn't have access to craft paper back then – it's fairly rare over here…) so I used what I had – it's actually my motto "use what you have".

To roll the tubes one must take a wood dowel with an OD (Outer Diameter) that is equal to the motor ID (internal diameter). You place the rod on a flat desk and roll the paper without any glue. Make sure the paper is wound tight, and well aligned (not conical). I then unwind it up to the first turn. I add a thick line of glue along the length, leaving 1cm free at the ends and roll it while pressing the dowel hard on the table. The tubes made this way are very reliable and Catoes - Catastrophe At Take-Off (i.e., the rocket explodes) - due to the a tube failure are very rare.

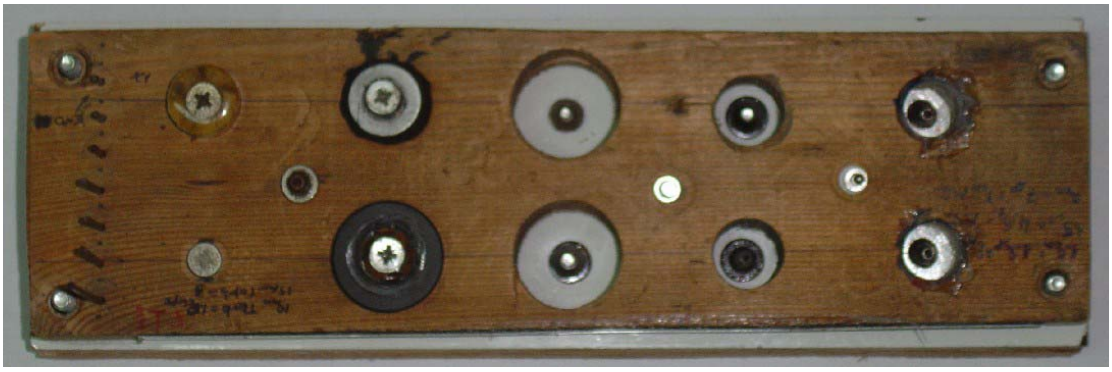
The tubes are left to dry for a day, hung up on a wire using small clips, and then they are cut into sections. Don't let the tubes dry on a table – they will get a banana shape because the drying is not even from all sides. Hang them out to dry. I don't use the edges as there is little glue there – I simply test by pressing with my fingers to see if the tube is strong enough. I place the wood dowel back into the tubes and cut them with a Japanese knife, by rolling the blade on the tube. It's a simple and fast method and you get nice and clean cuts.

The cut tube sections are placed in a ramming block.

My old Ramming block
The block had two sections – a holding section (with holes that fit the motor tube fairly tightly) and a bottom section containing pen cones or other handmade cones (~18dec half angle). The cones can hold a small 2mm OD metal rod – which is my core rod.
Here is a cut section sketch:



My block had 6 holes: 2 of the following: 13mm, 17mm and 26mm for the 10, 15, 20mm motors. The holes outer diameters fit perfectly to the motor outer diameter. Later on I added metal sleeves to hold my 10mm motors straight while ramming – this is why there is lot's of epoxy on the two right holes.
The cones are (for the 10mm motors) metal pen cones which fit tightly on my screws. For other diameters I made my own cones from bolts, or used what I had.
Also I have other attachments on the ramming block (left side) – for other types of motors/concepts I wish to test.
Last, on the left side are my core rods stuck in designated holes in the wood block.



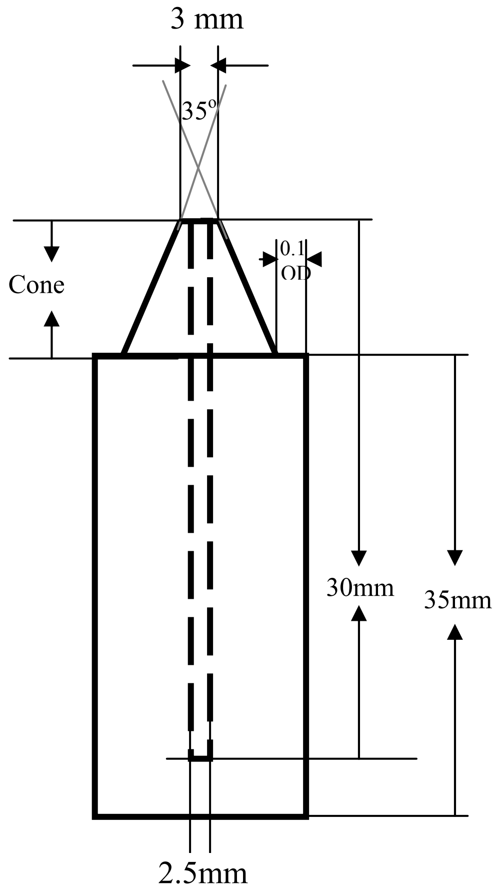
Here is a picture of the lower layer (the one that holds the cones).
You can actually see that these are metal pen cones (use what you have, and according to your budget, I say).

My apologies for the picture quality.

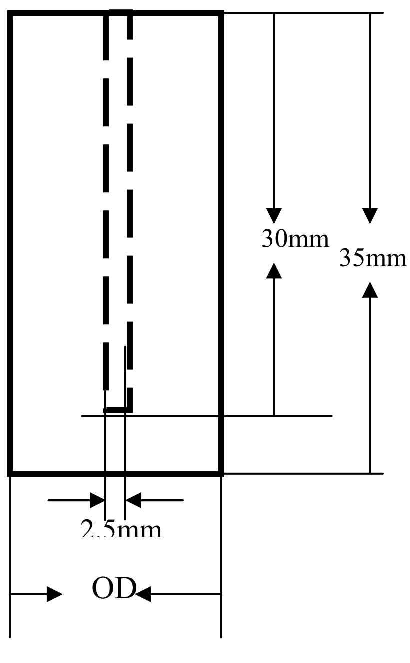
I should add here that I was very pleased with this system.
I changed it to the following system because I wanted more accurate motor designs for one of my projects. The original system cost was near zero and it served me for many years.

Designing a new ramming system

The second system was designed as a set of ramming rods and base rods.
The base rods center and hold the core rod straight and upright.
The ramming rods have an additional ramming rod (coned ramming rod) that forms a de-laval nozzle. The system OD's are 10mm and 16mm.
The coned base rods design is this:

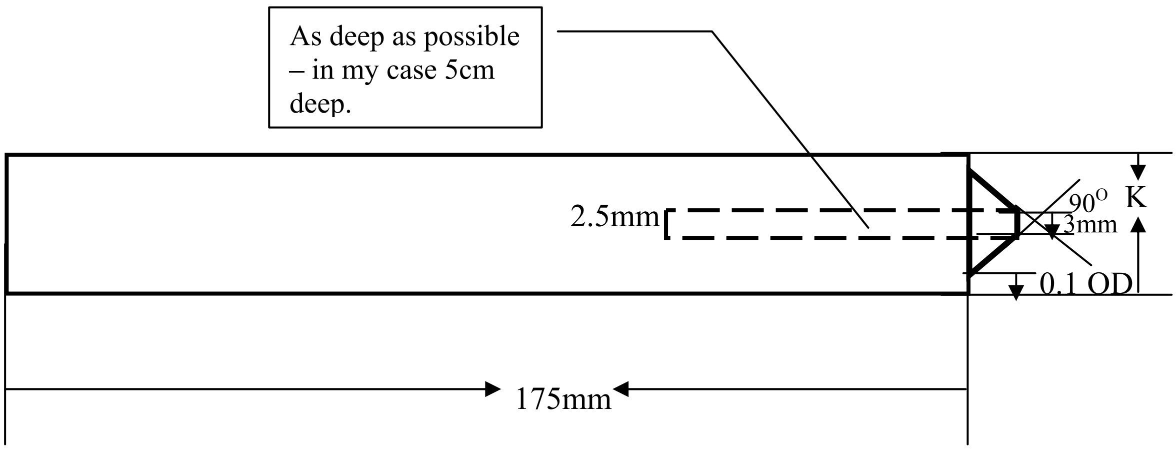


A flat base rod (for nozzle-less and so on)

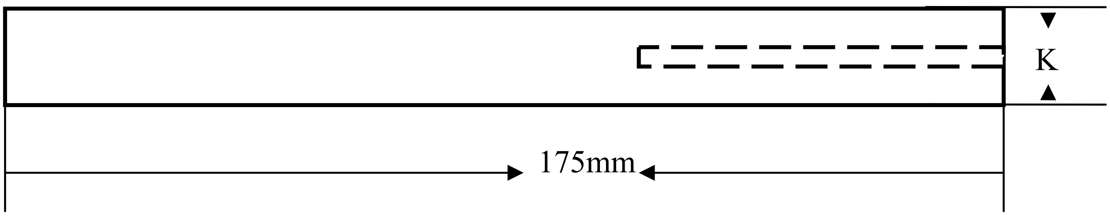


Ramming rods:

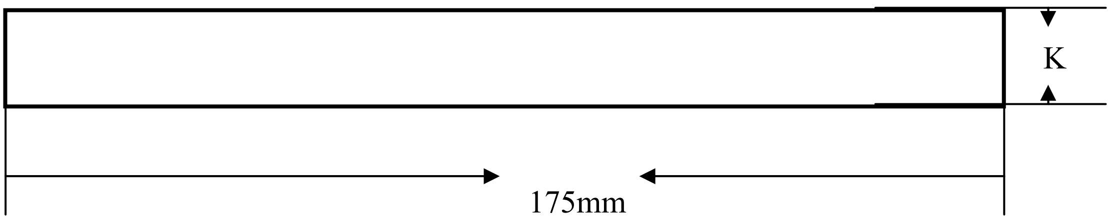
Coned rod – to make a "de laval" nozzle (or as close as possible to a real "de laval")



A simple ramming rod for cored motors



A simple, non cored ramming rod for end burners/end plugs and so on:



I know the next question:
Why didn't you just order a standard system for pressing rockets?
Answer:
I think that calibrating your spindle size is simpler, easier and much more versatile than calibrating your formula. The usual user adds more charcoal to his formula to make it burn slower to fit his spindle. I use whatever source of charcoal as I please, make any shift in the BP formula as I please and just by making 3 rocket motors with 3 different core lengths – I can calibrate my motors to work perfectly. I don't have to play with additives to my BP, and I can change my system at will…

Also- If the core rod is damaged – you can simply replace it easily. Since it's a tiny rod it will not damage your ramming rod and it won't be too costly to use a new one. You can make motors with varying cores and designs using this system and a set of unique ramming rods.

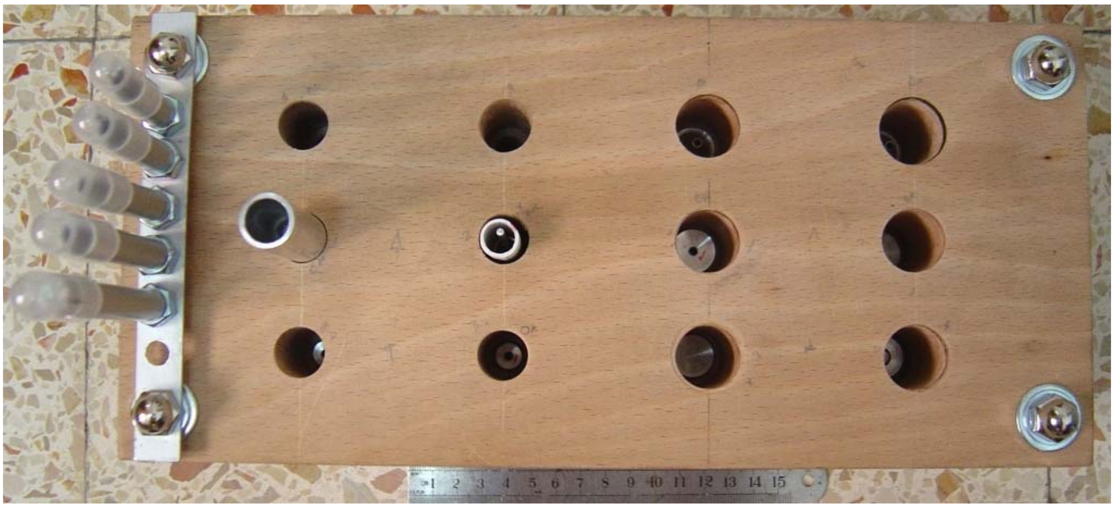
NEW Ramming tools and system

At 2006 I ordered a set of stainless steel (310-24, non sparking stainless steel) tools. The reason is that I cannot make very accurate motors with my old system, especially when making long motors (over 7cm tall) as they start to bend and look much like a banana even if they still fly OK.

Here is an image of the base cones and 10mm ramming rods. I have two sets – 10mm and 16mm. The inside core of the base rods has been adjusted to 2.4mm and its 3cm deep from the top of the unit (I had to fix a lousy lath work - don't ask, it's a long, sad, story). And the inside core of the ramming tools has been adjusted to 5cm, same ID. I had to do these by hand, and I tell you – stainless is NOT as soft as everyone says it is.

The ramming rods in the image are 10mm, I didn't take the image of the 16mm set, as it's identical.

Below is the complete system, ready to make motors:



The system is made of three hardwood plates.
The bottom plate is 2cm thick and has no holes in it (of course), except for the screws. The mid plate is 3.2mm thick and holds the base rods (the coned/flat rods that form the nozzle of the motor). These extend 3mm + nozzle above the plat surface. The holes are 16 and 10mm to fit the base rods OD. The top plate has 16 and 19mm holes drilled in it. The 19mm holes are for the 16mm motors (that are 19mm OD), and the 16mm holes hold the sleeves (16mm OD, 12mm ID) for the 10mm motors (12mm OD, of course). The tubes on the left hold the core rods in place, so I can turn the system upside down (to clean it) and still the core rods will be in the tubes.
You can see an aluminum sleeve on the left side, a motor tube (6cm tall) in the middle with a protruding core rod in it. The ruler at the bottom gives you an estimation of the system size. It's 15x30cm to be exact. I will use it to make all sorts of motors, including Rosetta motors (3 and 4 cores in a single grain).

Motor preparation

Generally speaking, my tools are all handmade, except for the new ramming set.
I ram my rockets with a 1kg rubber mallet, although I will switch to dead blows in the future.

Once the tube is in place some Kitty litter grit [EVER CLEAN brand, containing 3% mineral oil premixed] is added and rammed and then the BP is rammed in a few steps, each step is about 1 ID tall. The BP is poured inside the motor tube and then (depending on the core rod length) I choose and insert the wood dowel. I ram 4 times successively before taking the dowel out and adding more BP or clay. Each 10mm rocket contains about 3gr of BP. The top section is a kitty litter clay section or plug. I am not giving any exact quantities as I never did measure how much my scoop holds – I simply added a handle to a used 0.45" cartridge and this is my scoop. After ramming the BP quantity is packed roughly into 1OD length.
The nozzle requires 1.5 scoops. Each BP step is a single scoop
The end plug also uses 1.5 scoops

End burner

Core burner

The motors come in two formats – either core burners or end burners.
The core burners are rammed with a core rod that long enough to reach the clay plug - 1/2 OD. The end burners are rammed with a core rod that protrudes about 0.5cm above the top of the nozzle section.
Two motors take about 7 minutes to make. Ideal.

The motors specs

My standard 10mm motor core burner

The motor is usually 5cm long.
The nozzle is 3.5mm ID
Core is 2.4mm ID and 2.5 cm long, the grain is 2.5cm long
The burn time is about 0.5sec
The speed and acceleration are impressive
Apogee: ~100m

My standard 10mm motor end burner

The motor is usually 5cm long.
The nozzle is 3.5mm ID
Core is 2.4mm ID and 0.5 cm long, the grain is 2.5cm long
The burn time is about 5sec
Liftoff is slow but nice with lot's of sparks
Apogee: 90m vertical flight

My standard 16mm motor end burner

The motor is usually 7.5cm long.
The nozzle is 3mm ID
Core is 2.4mm ID and 0.5 cm long, the grain is 5cm long
The burn time is about 7.5sec
Liftoff is slow but nice with lot's of sparks

My standard 16mm motor core burner

The motor is usually 7.5cm long.
The nozzle is 6mm ID
Core is 2mm ID and 5cm long, the grain is 5cm long
The burn time is about 1sec
Liftoff is impressive.

Common questions

Why stick with such small (10mm) motors?

- It's easy to test your batch with such a motor without wasting too much BP.
- It's ideal size to test new ideas with it as a single sample without wasting BP.
- If you want to make many motors to test a new idea or method – that's the one.
- Testing can be done in a relatively small place.
- No fire hazard (the motor casing falls to the ground a long time after the grain has ended its burn, and there is no external fire).
- Wonderful way to test your paper rolling skills, clay additives and manufacturing methods.

For example:
Making clusters out of these motors is simple and easy, but you have to solve a lot of ignition timing and problems. To this end it's easy and fast to make many motors of this size and see what you can do. After you get a good ignition setup and it works nicely – than it's time to upscale.
Another project – staging – also required a delicate timing issue as well as mounting issue and so on. Again these motors provide a good tool to examine these questions.

Straight upward flight of BP motors

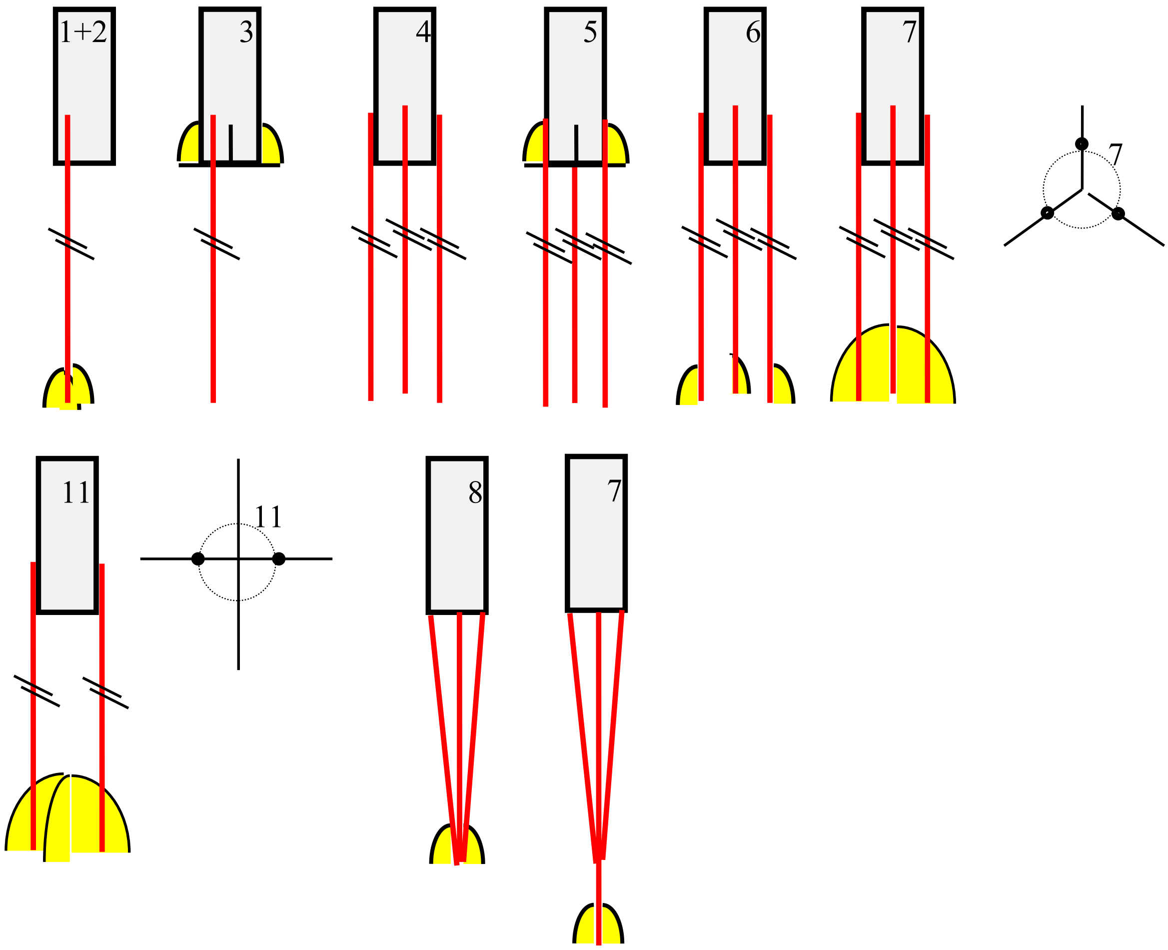
If you wish to measure apogee for a bottle rocket you usually encounter a very simple but annoying problem – the rocket flight will be affected by the wind. It will also be affected by the shape of your guide stick, the nozzle (if it's not perfect – and it's not!) and many other small problems. Also the single stick also shifts the center of gravity and this result in a change in trajectory. Don't believe me? – use a heavy stick on a small rocket and see what I mean.
Of course you can make stingers and they do have a spin which gives them a nice vector that makes sure they fly fairly straight… but I'm talking about bottle rockets here.
Well… after a long debate with Arocket and a few ideas of my own I finally got a nice list of items to try out.

Trying to make bottle rockets fly straight up

All motors are end burners.
Why end burners?
They are much more affected by the wind/other factors than core burners.
The reason is that core burners are much faster and the wind factor has less time to affect them. For the same reason I also chose small motors with less mass (and hence more wind/nozzle/etc effects on the trajectory.

1. A single stick and big fins attached at the bottom of the stick.
2. A single stick and small fins attached at the bottom of the stick.
3. A single stick and small fins attached at the bottom of the motor.
4. Three sticks to balance themselves and center the gravity center.
5. Three sticks with fins attached to the bottom of the motor.
6. Three sticks and three fins at the bottom of the sticks.
7. Three sticks and four fins (cross shape) at the bottom of the motor
8. Three sticks joining at the bottom and the fins are attached at the bottom of the sticks, also joining each other.
9. A motor with straws instead of sticks (less weight and each straw is actually a circular fin) – as in suggestions no. 1-4.
10. Three long fins (from popsicles) to act as fins and as balancing sticks at the same time.
11. Two sticks and four fins holding the bottom of the sticks
12. Options 1-12 only nozzle-less motors instead.

See the drawings below.



Flight results

Rockets no. 8 and 11 were the best. The flight was not necessarily vertical (due to my short launch rod) but was very straight.
My launch rod is 1m long. A 1.5m long launch rod should do it, and also a longer launch lug that must be well aligned with the motor!!
Rockets 3, 5 spiralled away and shifted direction quite often. The rest weren't as good.
I had No. 1 cato (completely demolished the system) and I'll have to complete the set (I really neglected this project, didn't I?)

Now that I'm commenting on this – I once built rockets with just fins. No stick, no nothing – just a motor and large fins around it. Crazy flight is a good name for it. Almost got hit…

Summary

Fins should be generally down, at the bottom of the stick and not up around the motor. No surprise – that's why rocket enthusiasts build their professional rockets with fins down the bottom.

The actual reason for this is that the wind factor below the center of gravity has a lesser effect on the trajectory than in an opposite case (I hope I put it right – if not please correct me).
For a more detailed and better understanding of concepts – read books about it.

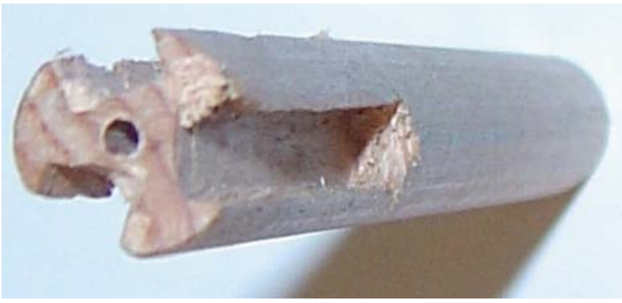
Rosetta BP motors

Rosetta motors (RM for short) are motors that have more than one core in their grain. This results in a very high and early thrust peak.
Although I have no use for such motors – I think it will be very interesting to try and make them using BP and KNS (sorbitol nitrate propellant).

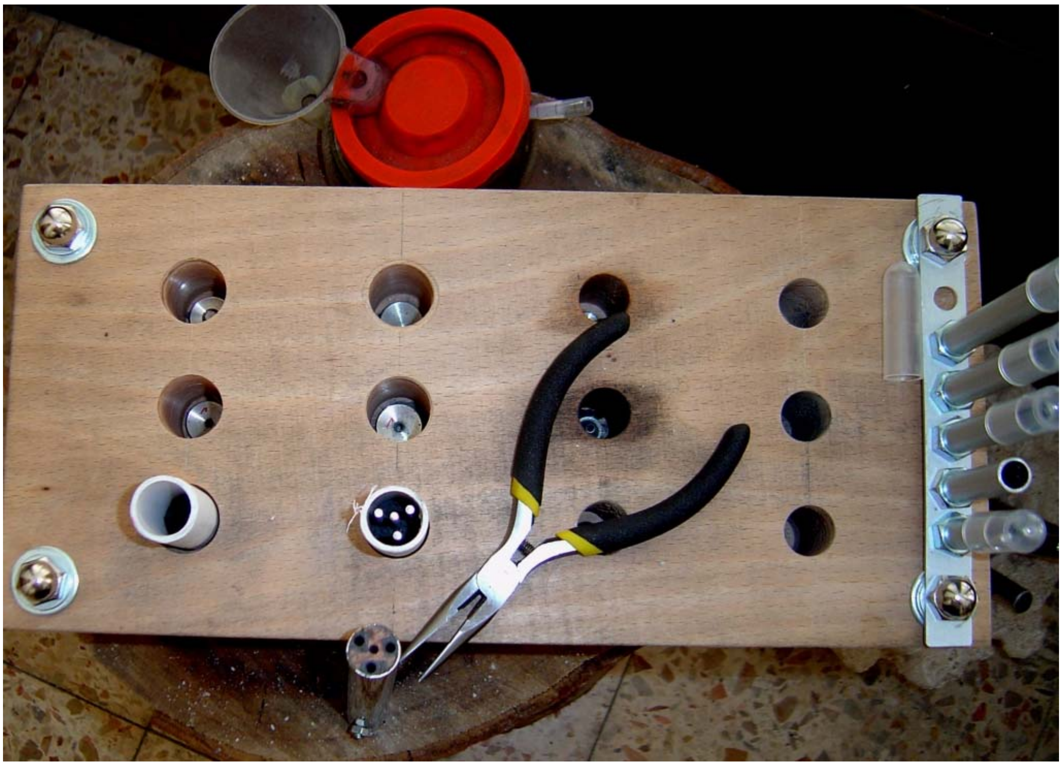
A simple hand made tool

The simplest way (from my point of view) would be to make only the ramming rod in the rosetta format, without a unique base. This is due to the fact that I don't own a lath and hence I'm limited to handmade items.
Drilling one hole (for the core rod) in a wood rod, making sure it's well centered and runs along the wood axis is very hard. Making 3 without a mistake is far harder and almost impossible without some sort of tool such as a bench press (which I also don't have).

The first thing I did was to drill the vertical, centered hole in the wood ramming rod.
I chose a 14mm OD wood dowel that is inserted into a 16mm OD brass rod (nickel plated).
After I got a "core" that was just right I used my caliper to measure and mark 3 lines 120deg apart from each other. I then marked straight lines along the rod and carved away the wood at these spots with my handy Dremmel tool.
The carved areas which you can see in the image below fit perfectly to three plastic tubes that I had (like all of us I collect what my wife calls "junk").



Some epoxy did the trick and the system was secured.
I drilled the top of the rod and inserted a screw secured with a bolt to make sure that the wood will not try to move inside the metal tube.



Making the motor

The next step would be to make a motor. I have not made this motor yet, but I have made others, with a single core, based exactly on this concept. Hence, I know it will work properly.

A 16mm ID rolled paper tube is used for this.
The first step would be to ram a nozzle as usual – but use tools that are made for end burners.
Next, a standard amount of BP is inserted into the tube.
The core rods are inserted into the new ramming rod.
The ramming rod is inserted horizontally into the motor tube.
After some shaking to make sure the rods have settled on the top of the nozzle the ramming begins.
After the first quota of BP has been rammed the BP will hold the core rods in place.
Ramming proceeds as usual until the last 0.5cm length of the rods (or any length desired.
At this point the rods are carefully and gently removed out of the BP grain.
A paper circle is inserted and the last spoon of BP is rammed on top, followed by a clay plug which is rammed into place.
That's it.

Update June-2007

I just made my very first Rosetta motors.
It went just as I planned (no big surprise after my experience with the double/staged core burner in a single tube).
Here is the final results after the rods were extracted:

Yep. It's a lousy pic, but it does the job – you do see the four cores, right?

Ignition

To ignite the holes at the same time the simplest way would be to drill the nozzle with a proper drill so that all the cores are exposed.
A small amount of granular BP is added on top of the BP grain.
Then a small piece of aluminum foil is used to seal the nozzle, held by a rubber band.
The fuse or E-match goes through the aluminum foil.
As the fuse ignites the thin layer of granular BP on the foil it will do two things:

1. It will blast the foil away.
2. It will ignite the grain surface and this will lead to a rapid ignition of the cores.

Motors in reality

In theory the motor is very powerful.
It should produce the same power output of an endburner of the same size that burns 7seconds in 0.2second. Thus it will produce a massive thrust and pressure peak.

Sadly, I have till now (may09) I haven't been able to make them even get off the launch pad. I am about to try another concept in motor ignition:
I will use the same system I used for igniting clusters (see the clusters section) and see how it goes. Basically I'll stick a quick match all the way up to the motor core top and ignite all of them at once.

Staged motors

Why a bottle rocket double stager you ask?
Why not???
It's a small challenge and its fun too…

Points to consider

- Each motor has to have his own stick for stabilization
- Ignition must be 100% reliable
- The two motors have to sit tightly one on top of the other – and disallow any vibrations from the booster burn to break apart this connection
- As always – it has to be dirt cheap, simple to construct and light weight

Choosing the motors

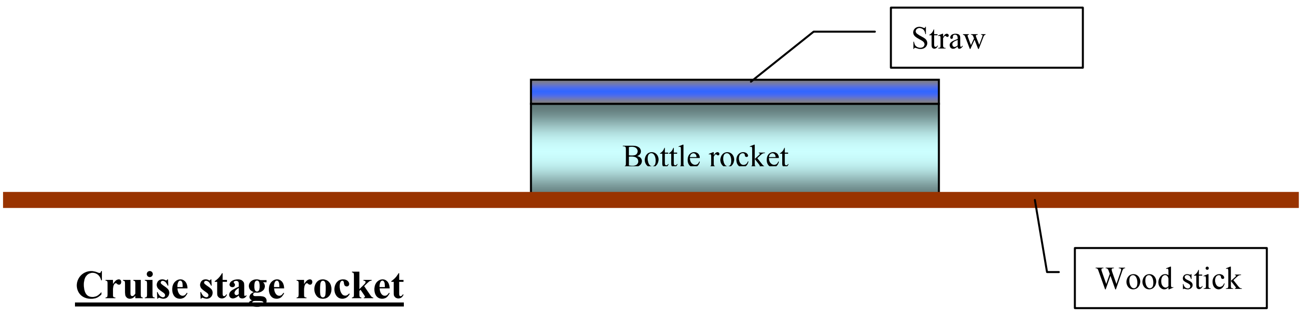
Preferably the first stage or booster must be stronger than the top stage so it will be able to give the top stage a descent speed before the top stage (or cruise) begins its burn.
To this end I have chosen my 10mm motors.
The bottom motor (booster) will be a core burner and the top one will be an end burner.

Tools and equipment

1. hot-melt gun
2. 3.5mm ID straw (so the sticks will slide easily in it)
3. 2 wood sticks (barbeque sticks)
4. 2 motors: end burner and core burner.
5. Black match

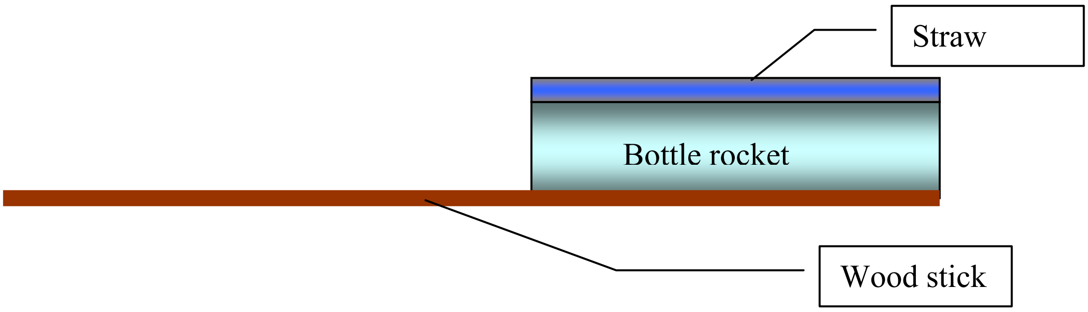
Booster stage rocket

The booster is first glued with a stick.
The stick must protrude at least 5 cm above the top of the motor.
At 180deg – opposite to the stick – a 3.5mm ID, 5cm long straw is glued (using hot-melt of course)
I usually drill two holes in the top plug of the core burner to pass the fire (using the black match) to the second motor. One hole will probably do it, two are better.



Cruise stage rocket

The end burner, cruise rocket is also glued with a stick (only this time it's as usual and the stick does not protrude upwards) and again with a straw.

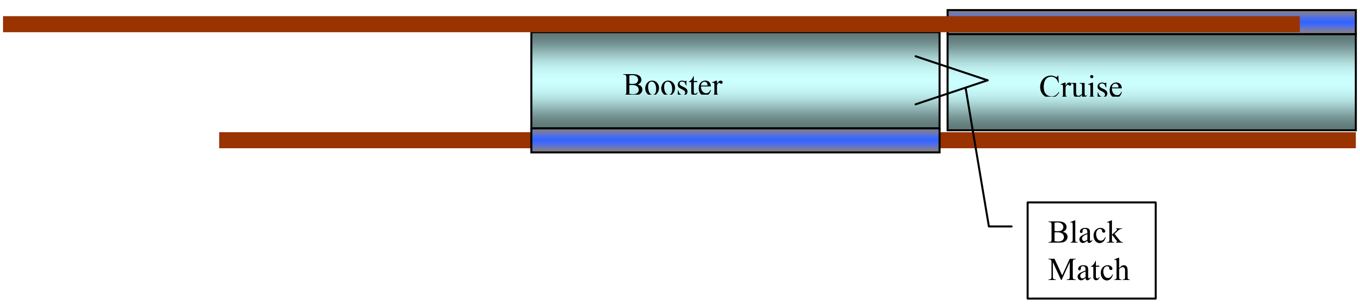


Assembly

The black match is inserted into the holes drilled in the top plug of the booster motor. Two holes mean you have a better chance that if one black match fails the other will prevail.

The Black match doesn't have to be very long – I usually use a 3cm long black match, fold it in the middle and insert both ends into the holes.
I then slide the cruise motor stick into the straw of the booster and slide the extended stick section of the booster into the cruise straw.
While doing so I try and make sure the black match protruding from the booster top goes into the cruise motor.

Last thing to do is to add a fuse to the booster section and secure it with some cotton. The motors are now ready to go.
To make sure they don't come apart while driving to the launch site I use paper based masking tape and secure them together with a nice 10cm long strip. The masking tape is removed, of course, before the launch.



That's it.
Slide the Boosters stick into your launch tube and ignite the fuse…
If you wish for effects – you could stick a star between the motors as well as a payload on the top of the cruise motor.

Double stager in a single tube

The idea is to form two core burning grains in the same tube.
This way you won't have to align and join two motors.
Also, this design has an edge over the regular dual system.

Think of this:

Regular dual motor system	Single tube double core burner
First booster must carry: 2 nozzles 2 tubes 2 grains 2 plugs Second booster must carry 1 nozzle 1 tube 1 grain 1 plug	First grain burn carries: 1 nozzle 2 tubes (1 tube x2 the length) 2 grains 1 plug Second grain carries: 1 nozzle 2 tubes 1 grain 1 plug

Hence, the double stager single tube system carries less weight overall.

Motor preparation

In my 10mm model system I used a 10cm long tube (instead of my usual 5cm long tube). Use a tube twice the length you usually use.
Ram your nozzle and first cored grain, as usual.
Ram the "delay" grain/section – about 1 OD of full grain section.
Pour 1 standard volume of BP to be rammed, and place the core rod in the "center" of the tube.
Fit the ramming rod and ram as usual. The first BP increment will now hold the core rod in the center for the rest of the ramming.
Before ramming the plug, GENTLY take out the core rod and place a piece of paper on top of the BP grain (so it won't get filled with the clay).
Ram the clay.
Done.

A cut section would look like this:

Tips

I highly recommend a strong metal/plastic/paper(best) tube to hold the motor tube in a straight position during ramming (mine got a little bent because I don't have such a tube, but this doesn't bother them too much - I have previous experience with regular but long BP motors, both end and core burners).

My experience with this system

I made 2 such motors and they both functioned beautifully.
Very nice launch – you can see the first stage "roar to life" and lift the system up and away, see the sparks during the delay section and then hear and see the second kick in and climb up up and away.
Another good idea would be to add a payload to see how high the motor went.

BP motor clusters

Why a make a cluster of BP motors?
After you make a dual spiral cluster – you will understand why – they are simply LOVELY! They take off with a blaze, two showers of golden sparks flying around each other in a perfect spiral in the sky, and also a very straight trajectory up up and away…
Clusters with more than two motors are also very very simple to make and are lots of fun. Clusters can also allow you to assemble a triple stager or more using the same motors all along. For example – a triplet of motors carries a spiral dual motor cluster which carries on top of it – a single motor. Pure fun.
And – it's not hard at all.

Points to consider

- Ignition must be 100% reliable – in all of them, at the same time!
- As always – it has to be dirt cheap, simple to construct and light weight

Choosing the motors

From my experience – stick with the end burners.
The flight with core burners is so fast and so energetic that you won't have enough time to see the beauty of the flight itself – and this is the point here.

For a dual spiral motor – you will need two motors of course.
I will represent this system, as well as a drawing for a triplet system. You can use as many motors as you wish – but it gets awkward after 5 or so…
I have used five motors in a single setup and it was just lovely – but the spiral system beats any other cluster when it comes to beauty.

The spiral cluster

The tools and equipment list is just as good for a dual spiral cluster as well as for a triplet cluster.

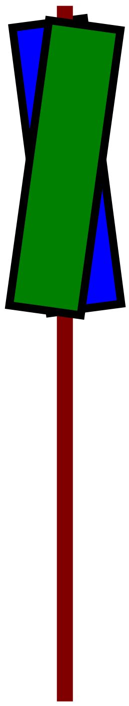
Tools and equipment

1. hot-melt gun
2. 1 wood stick
3. 2 motors: end burner and core burner.
4. Black match
5. Quick match
6. Granular BP

Take one motor and glue it to the top of the stick– make sure the stick is glued all along the length of the motor. Apply hot-melt on top of the stick and attach it to the

motor. Glue the motor at an angle – you don't need an exact angle-meter, nor do you need more than a few degrees tilt.
Glue the other motor on the other side of the stick, with the same tilt – only in the other direction.
Look at the drawing (I'll try and make some dual motors in the near future and add pics to this file).

The stick is the brown verticle line
One motor is colored blue and the other – green.
See what I mean?



Ignition

This is the most crucial part of the system.
If one motor does not ignite the flight will be erratic, slow and unpleasant to the viewer, not to mention disappointing after all the time and work invested.

First you will need a thin quick match.
I make my own by placing a set of two thin (1-1.5mm OD) black match strings on a piece of masking tape (along the length). Then I roll the masking tape (paper based) as tight as I can on the strings. A 10cm long (4") quick match should be enough.
Other types of tape will probably do the job (avoid nylon based masking tape) – use/test what you have. Even plain old paper will work. Masking tape is convenient and easy to obtain (I have many types of these in my drawer).
The masking tape must be 2cm shorter than the black match – so you can have protruding ends of black match about 1cm each from either end of the quick match.
Test this method to see that your black match performs nicely as a quick match.

Two quick matches are placed in the nozzles of the motors.

The match must be tightly secured to the motor!!! This is CRUCIAL.
Why tightly secured? – read on.
Take a small piece of Aluminum foil and make a small tube.
Roll one end of the tube on a regular black match/visco or whatever fuse you choose.
Now you should have a metal "cup" with a fuse going through the bottom of the cup.
Fill with some granular BP and place the quick match ends in this cup. Press with your fingers on the top of the cup to tightly secure the Al. foil cap to the quick matches.

How does it work?
Upon ignition (you ignite the black match/visco going to the aluminum cup) the fire goes from the black match to the granular BP.
The granular BP ignites very rapidly expanding the cup and actually blowing it apart or opening it wide open. It also ignites the quick fuses.
As the cup is now open and no longer holds the quick matches it will fall to the ground. The quick matches pass the fire rapidly to the engines. Ignition.
BUT – If one quick match has a flaw and is slightly slower from its neighbor – than comes the advantage of the secured quick matches to the motors.
As the first motor ignites and provides thrust - it will lift the cluster. This means it will lift the other motor too, along with its damaged, yet burning quick match. In due time (should be very fast anyway) the other motor will also be able to ignite as the quick match is attached and will pass the fire.

Let's compare this to a set of electrical igniters:
Let's assume that one of our two igniters has a flaw and takes 0.1 sec instead of 0.01sec to ignite the motor. What happens is that the first motor that has already ignited will lift the system – and the second igniter (not hot enough yet) will fall to the ground. The cluster will launch – on a single motor. The second motor will never have a chance to ignite anymore.

Of course the same principle goes for bigger clusters with 3 or more motors in the cluster. This is even more crucial if you choose to use core burners – as they will burn and ignite so fast that a single motor that did not ignite in the same split of second – will never ignite unless it has it's own quick match attached.

Crucial points

- Make sure the quick match fits tightly into the motor nozzle – you should be able to hold the motor from the quick match. If it doesn't – press into the gap some cotton. Tightly.
- Make sure the aluminum cap is not glued and does not stick to any of the quick matches. If it is glued it may drag a quick match with it and the motor will fail.
- Not much granular BP is needed in the cup – 1/2 volume will do nicely. I usually roll the cap on a 1cm (~0.4") wood rod. Spiraling one of the tube ends around the visco/black match is all that is needed to secure the cup form – no glue is needed.
- Your quick match must be tested to be of high quality and even, fast burn.
- When making larger "clusters" – make sure your stick is still balancing the cluster just like a regular bottle rocket.

Triple, quadruple and penta-clusters

In these clusters I simply choose a long enough stick.
Long sticks, btw, can be freely obtained from the roadsides – miniature versions of bamboos grow here freely and wildly.
Back to clusters.
It’s a bit complicated to glue more than 2 motors at an angle, and it requires a bigger base so I simply glue them aligned with the rod. Simple and fast.

Well… that's it.
Try it and enjoy – I highly recommend the spiral dual cluster.
Triple motor clusters, four and five motors are just the same but these are also lots of fun. Don’t forget to use only end burners. Use core burners or you won’t see a thing – the setup will blast away so fast you won’t believe it can do that… I know... I’ve seen it do that.

Colored BP motor

As far as I know, it's impossible to color BP due to the following reasons:

1. Low burning temp (1,800c)
2. "Wash out" of the color due to the sparks, smoke.
3. The color is produced INSIDE a motor casing... how much of it can escape from the nozzle??? - Very little I suspect. With the exception of nozzle-less motors DJ's designed.
4. Chemical incompatibility [minor] - you can't add chlorate, for example, to BP motors (with the exception of people with a death wish).

Well... I say - If you simply can't do it – find a way around it! (i.e. cheat!).
And I'm cheating!
I have tried several configurations, but as I'm limited to Mag-colors I had to consider the potentially dangerous chemical reaction between Mg and sulfur.
After several tests and bangs I got to a "formula" that works, with **any** color composition.

Method

Ram/press your Bp motor on a short wood dowel so the nozzle is simply a clay ring with a hole in the center. Make sure you leave some extra sleeve (say ~1 OD length) below the nozzle.
It should look like this:

This is an end burner, of course.

Drill the nozzle to its final OD and insert a drill bit (bottom first). Grease it if you like (not crucial with my color comp... but I don't know what you are using!).
The section of the drill bit that is in the sleeve must be a smooth full rod (bottom section of any drill bit).

Now - mix your favorite color mix using NC laqour as a binder.
While it's wet and mushy - fill the sleeve (with the drill bit stuck inside).
Fill it completely. You can make a nozzle shape with some sort of cone, if you wish.

The comp will probably burn faster though, due to the high surface area, but will also produce more light.
Allow to dry somewhat and extract the rod.
Allow the color comp. to dry.
The finished item will look like this:

* in red – the color composition.

Fuse the motor so that ONLY the BP ignites, and not the color composition.
Don't forget to add a stick and you're done.

Upon ignition - The hot BP gasses ignite the color mix.
As the color mix is right at the bottom of the motor - you can easily notice the nice color, as well as lots of sparks from the BP.

My tests

My system is simple.
10mm motor setup and the sleeve for the color comp. is 10mm long.

I've used a white color comp that is fairly simple for the preliminary tests [Sorry, can't recall the source] with the following formula:
70 KNO_3
30 Mg
NC laqour bonded (1ppb/100ml acetone).
No prime

Other compositions I plan on using are based on Lancaster:
55 oxidizer (Ba / Sr / Na(?)) NO_3
17 PVC
28 Mg powder
Bonded with NC, (for cut stars - primed with BP-Mg - 30% Mg).

A lovely colored flight of the motor.
The motor had a 6mm ID nozzle or throat (no nozzle, actually).

Safety

As your possibly (potentially) BP-incompatible color mix is (or should) NOT touch the BP, (touching the clay plug) – no problems should occur.

Non-the-less - the motors must be kept in a secure location - and apart from other sensitive/flammable/etc. compositions until you are perfectly sure of the safety of your system.

Tips

1. Calibrate your motor - end burners are highly recommended.
2. Calibrate your binder - you want the color mix to burn during your motor burn, not faster, not longer (fire hazard).
3. Adjust the thrust and nozzle ID of your motor. Don't add too much charcoal grit for sparks, as this may "wash out" the color effect. I don't add any charcoal grit at all for these motors.
4. Crucial - cover your fuse to the motor!!! You don't want the composition to ignite before the BP does.

Nozzle-less version of the colored BP motor

Ram your nozzle-less motors as usual, just leave a sleeve for the color.
Secure the core rod in the nozzle and fill with color composition.

Safety note

YOUR COLOR MIX MUST BE FULLY COMPATIBLE WITH THE BP OR OTHER PROPELLANT OF CHOICE!!!
For example, If you are using Mg stars like I do - MAKE SURE YOU USE SULFUR-LESS BP!!!
Your BP should be 80KNO3-20Charcoal (it's just fine, but needs a longer core).
Sulfur-Mg incompatibility may cause your motors to auto-ignite!!!

Universal use of this system

As you see this system can be used in a variety of motors and propellants / color compositions. It's simple and does not take too much time.
There is a price, though - which is a lowered thrust. All in all – I think it's worth the price.
Even the serious rocketry guys with the high tech casings and all the lovely tools could use it – by adding a cardboard sleeve on top of their graphite nozzle (or by carving another graphite nozzle) - but they won't. Rocketry guys (myself included) are into performance, and we (myself included again) are into color and beauty). As for me - I love both worlds and I enjoy both.

<u>*Last but not least*</u> –
I would like to dedicate this colored BP motors article and system to our beloved, remembered and cherished friend - the late DJ.
I think he would have loved it.

Pencil rocket

Years ago I got stuck with very little BP (had to make more) and even less time.
I was also noise limited (didn't want to wake up the neighbors) and I wanted to make a rocket.
It had to be fast, easy and from whatever I had at hand.
I had a pencil, some aluminum foil and black powder (and a fuse – back then I used to roll my fuses).
Weird enough it didn't take me long to make a working rocket.
Shortly after that I added a nice nozzle to the design and these little things used to fly like little aluminum bats from hell…

I just saw Jimmys whizzers movie and this reminded me of that nice project (I think I made the last one about 16 years ago…), so I decided to write about it. It's a cute project for the kids, and it uses very little BP so the danger is minimal.

Remember, as always, the basic safety rules – gloves (as this is a gentle, manual procedure I use thick cotton gloves), full face mask, a water bucket and an escape route. Aliquot you're BP – don't use a 1kgr container while making these rockets (or any other project) – use a small container and keep the stock far from your work site. Each rocket uses about 2gr of BP so 50gr should be more than enough.

Ingredients

5cm wide, 10cm long three layered aluminum strip (regular) or 1 layer heavy duty aluminum foil.
A sharpened pencil with the tip of the graphite snipped off.
Two more pencils with a flat bottom (take the eraser off). Make sure there is no sharp tip at the other side or you will regret it!
Black powder – powder form
Cello-type.

Here is an image:

Making the rocket

Roll the aluminum on a pencil – as tight as possible. It should be tight but still allow you to insert and extract your pencils. I used to simply roll the foil on the pencil, but Jimmy's method is far better – fold the foil over the pencil and (extra 2cm) and then start to roll it. If I got the principle right – this will prevent the foil from unwinding due to the pressure. The nozzle (see below) has the same job – but there is no harm in extra precautions. [Am I right Jimmy?]
Secure it with a thin clear cello-type strip, ~5cm long.
Now you should have a nice tube (hexagonal, to be exact).

Insert one pencil (flat side first) about 0.5-1cm deep. Accuracy is not crucial.
Insert the other pencil (flat side first) at the other side until they touch.
Separate them by 0.5cm or so (requires some experience).

Like so:

Twist and turn one pencil clockwise (or anti-clockwise, as you please) until you will get a nice, twisted and tight nozzle. If you did this right the nozzle will have a small inner diameter hole running through. For this to happen you need to space your pencils just right. You will need some hands-on-experience, but it's not hard.
If you closed it too tight – unscrew a bit it and skip to the next step.
Press the two pencils one against the other – this will form the final shape of the rocket.
You should now have a nice "quasi bell shaped" nozzle, or to be more exact – a hexabell-shaped-nozzle. If you like it this way – keep it.
It will fly just fine!
If you choose to use the sharpened edge of the pen instead of a flat one you will be able to make a cone nozzle and get better performance (not that big a deal with these little motors).

Take out the top pencil, add some BP and press it with the pencil.
Continue adding more BP till you reach 0.5cm of the top of the tube.

Fold the top of the tube and secure it with some cello-type. If you would like to have a more esthetic looking top – make 4-6 slits in the top of the tube and fold them to get a nice top.

To make a coned nozzle – after ramming the BP:
Take out the bottom pencil out and insert the sharpened pencil with the cone in front into the nozzle.
Twist the aluminum and tighten it to get a nice nozzle.

Add a pasta rod as a stabilizing stick.
Insert a fuse and launch.

And finally the finished item (It's a mock - no BP inside, just for the image sake):

Straw rockets - strawckets

Strawckets are a combination of straw+rockets.
It started out with a McDonald straw (which has an ID of 8.5mm).
I was eating their big-mac and thought I could really make use of that tube…
But what?
Well… we could make a rocket out of it.
Aha… but that will have to be a core burner, right?

Well… this was a looooong time ago and in the meantime I managed to make end burners and core burners of these straws.
McDonald straws rockets were named McRockets
Regular straw rockets are named strawckets.
I have several size strawckets – 6mm, 4.5mm, 3mm ID rockets.
They are simple, fun and take very little time to make.
These rockets are ideal for thrust tests on new propellant formulas and many many other items. They can be ignited in a small chemical fume hood and there is no need to rush to the field. Tests can go on even if it's raining cats and dogs out there…

McRockets & Strawckets – preparation

Tools + consumables/combustibles

1 small (50gr?) hammer or a small hand press (which I use now)
Straws (start with the 6.5mm)
Wood ramming rod (one without a central core, and one with) or pressing apparatus.
BP
Kitty litter clay, powder is best.

Simple ramming block

To make a stand simply take a wood block.
Drill a 6mm ID hole – vertically.
Imbed a small segment of a 6mm OD stick in it.
Make two – one with a hole and one without.
Use a sharpened pencil tip to make a cone, if you wish.

Ramming the motors

Place your straw on the ramming block and ram some kitty litter.
You don't need much – and you can also avoid it at all, these little rockets function just great as nozzle-lesses (DJ's invention, scaled down).
Ram a 6mm length plug – either BP or clay.
All in all – you don't have to use clay if you don't want to.
If you don't have a metal/plastic sleeve for these little motors – you can ram them without the sleeve. It takes time and expertise to use the right amount of force: Just to get the rocket tube to "bulk up" in the increments, but not to rupture it. Ram gently.

Core burners

For core burners a 2cm long core rod (2mm wide) will do just fine.
If you rammed a core rod (with a tiny 2mm ID core, as above), your work is almost complete – glue (hot-melt) a pasta rod (use the long hollow brand – they are more durable and won't snap easily), and insert a fuse.
If you used a clay nozzle – drill its nozzle with a 3mm drill bit.
You don't need to do anything else – go outside and launch.

The straw will melt at the end and the stick will fall off. In fact it's hard to find any remains from these rockets, except for the charred pasta rod, that falls back. The tube remains are too small to find.

End burners

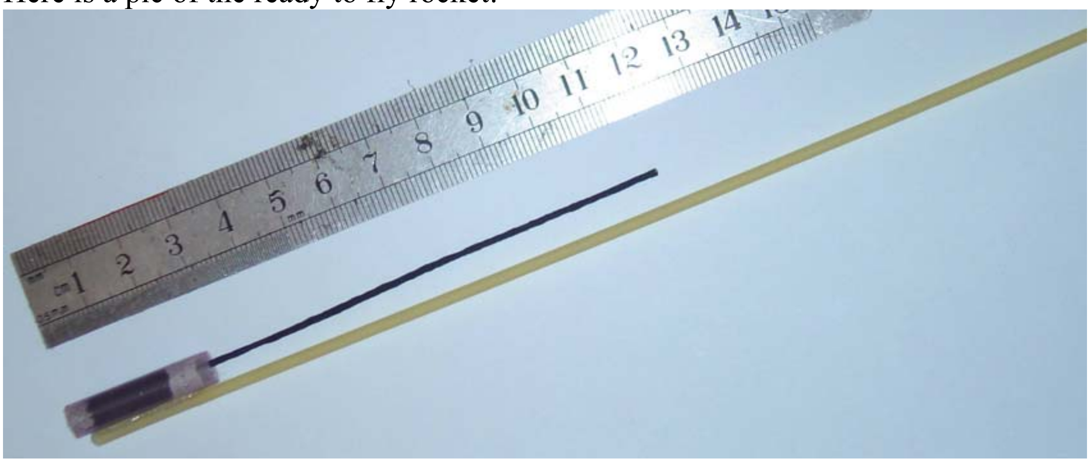
Same process as above.
Use a clay nozzle – 3-4mm long will be just fine (without a cone, that is).
Drill it to 2.5mm.
Coat the rocket body with a paper based masking tape (2-3 layers will work just fine) and add a stick and fuse.
Done.

It's a lovely flight.
A small star or some flash at the top (leave some extra tube in that case, and don't make a clay plug – a BP plug will do just fine) makes a nice effect. Even tiny stars will work out fine.

Thrust

When I measured the thrust of these little rockets I was pretty impressed: 10gr for the end burners and a 30gr spike of the core burners.
I make them 3cm long, 1.7cm long grain core or end burners.

Here is a pic of the ready to fly rocket:



This one was made with a sleeve and it is very smooth.

Tubelesses

I once left a motor out in the rain. Gladly it wasn't too wet – the paper tube got all loose and wet, but the BP grain was still OK. So I dried it up and thought of cutting it for stars. When I broke it in half I got a half with a hole and a half with a core. So I ignited the cored one… just for fun (I hot-melt a stick on it) and it took off! It reached about 3m tops but it was nice!! This is how I began to work on tubelesses.

Tubelesses are actually a small grain of BP, with an internal core, burning and flying on its own. No tube/casing, no nozzle and no plug. The fly just fine without all these…

Tools

I have completed a full metal ramming system (not lath work, good old improvised stuff, steal epoxy and so on - lath work is too expensive for me - it's my first all metal tool...!!! usually my tools are wood based, hand drilled/made. The system is made of an aluminum tube 10mm ID and a ramming rod ~9.5mm OD with a centered core (I broke 2 drill bits on that one). The core holds a core rod in place – which allows me to use any length of core rod I choose. Basically speaking, it's an upgraded star pump.

Drawing:

Aluminum tube – gray
Wood dowel (actually metal, but I have wood dowels for this too) – wood texture.
Core rod - black

Concepts:

Basically the stronger the grain/motor the longer (in millisecond or so) it will hold up to the pressure of the burning/expanding grain inside. Hence, a good binder can be of use. To this end I have tested a list of binders/adhesives that may be of use and are commonly available. If anyone as a good suggestion and IF I can find the reagent here I will be happy to add it to the list.

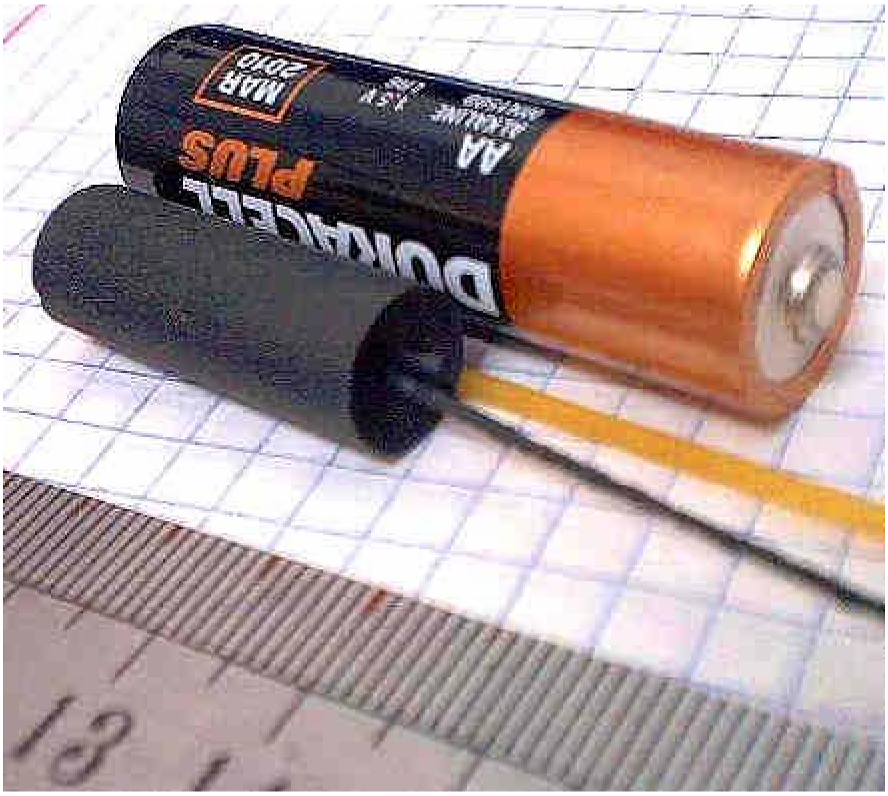
Propellant

A high quality BP (willow charcoal, 75, 15,10, ball milled for 3.5hr, dry time: 2hr) is used for these motors. The BP is used in powder form, added with binders. The binders are added by grinding the BP+binders in a mortar and pestle until the mix is totally homogeneous - and then some more. Added doubly distilled water or other dissolving reagent, mixed thoroughly and then rammed. The ramming process is done only one time per motor - no successive ramming. Each test motor contains approximately 3-3.3gr of BP, so the 10gr batch yields 3 motors.
The grains come out of the tool smooth and nice, no cracks of any kind.

The finished motors are set to dry for 2hr in the sun. The motor is very rigid after drying. Each motor is inspected pre-launch for cracks.

The motors are:
10mm OD
~3cm long
2cm long core, 2.4mm ID
(see image on my web page, index page)

Preparations for flight:
Hot melt a pasta rod (the thin, hollow kind are best)
Insert and fix a fuse.
Done



Sorry for the low grade image. It was my first digital rocketry image ever…

Testing for binders – results:

Binder	**Binder [%]**	**Water [%]**	**Result**	**Extraction from pump**
Tap water		5	Poor flight	hard
		10	Good flight	Easy
		15	Good flight	Easy
Dextrin	5	5	OK: 2 took off, 1 catoed	Hard
Corn starch	5	10	OK: 2 took off, 1 didn't fly	Hard
Potato starch	5	10	OK: 2 took off, 1 didn't fly	Hard
DDW		5	Catoes, all of them.	Hard
		10	Good flight	Fairly hard
Flour	5	20	Poor flight	Ok
	5	15	Lousy.	Ok
NC laqour*	5ml		1 was amazing – fast, long flight 1 catoed and 1 didn't take off at all.	Very easy
50% ethanol	5		Good flight	Ok.

* My 2% NC laqour is made by adding 1 ping pong ball in 100ml of acetone.

So far I have had good flight results.
However, the flights are fairly slow, except for the NC based, and I need a better binder. One that will not interfere with the burn rate.

Downscalling

Why downscale these?
Well… if I downscale them I'll be able to test them in my fume hood.
To this end I've used my strawckets tools (using a tiny hand press). To make the preparation of these motors easy I've uses a straw sleeve that's been sliced almost all the way along its length.
The motors were about 0.5gr each, 14mm long and with a 10mm long core that is 2.4mm. The result is tiny, little and very cute motors. You can look at the pics in the next page.

I pressed them with 5% NC laqour, 3% Guar Gum or 5% of 50% ethanol as binders (five motors per binder).

The tubelesses were tested.
Sadly the intense fire didn't allow me to take good measurements (I need to add a stop-marker to my thrust meters). I can tell you that these little things have a thrust time of about 0.1sec and total burn time of up to 0.4 sec with a peak thrust of 30-50gr. All of them worked just fine.
This gave me a small hint - It is possible that my ramming wasn't good enough and tiny cracks and pores existed in the finished motor. Hence the unexpected catoes.

Here are the images:

Sorry for the fuzzy pic, but you get the point…

Launch report

The little motors fly just fine, with a small thin pasta rod as balance.
I did further tests on the solvent and binder, testing Guar Gum and NC laqour 5% as well as water for control.
All were fine, but clearly the NC binder was superior to the rest.
Hence, 5% NC laqour is ideal for our needs and this actually completes the tests.
The tests, of course were done both on the small scale ones as well as the regular motors.

So why NC is ideal?
As the NC binder is a propellant on its own it does not shift the redox balance of the propellant formula too much. The solvent doesn't contain water to a great extent and hence there is less chance for the formation of nitrate crystals, which result in poor burn characteristics.
Also, the acetone evaporates fairly quickly which leaves tiny pores in the propellant grain, even if one considers the massive ramming or pressing applied to make the grain, and thus the surface area and burn rates are increased.

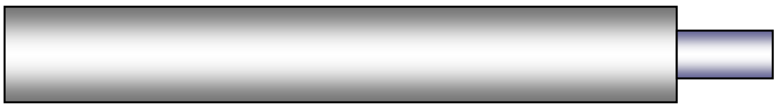
I suspect that 10% will do even better… I'll give it a try.

Wingless tourbillions

Wingless tourbillions do not require wings as they use the thrust to spin as well as elevate themselves off the ground.
They are easy to make and require very little handling.
They do not use adhesives to protect the cardboard and hence could be used immediately after making them.

Motor Construction

As usual my model is 10mm cardboard (hand rolled) tubes cut to 4cm (1.5") long sections.
Why 4cm long? – Because that's usually my leftovers from the motor sections cutting.
First I place a cup (0.45' cartridge) of kitty litter (supplemented with 5% mineral oil) in to the tube. I ram it once, with a ramming tool I've made for this.
The ramming tool for the nozzle has a 7mm (1/3") long, 5mm (0.25") OD protruding rod to form the cavity.
Like this:



Ram the entire amount of clay in one time – no successive ramming is needed, nor will it work. **I use the same concept for my stinger missiles** and hence I need not fuss with fireproofing chemicals (or the time they need to dry…).
The BP is rammed successively, as usual, with ~1OD length each time, and a clay plug is rammed at the end.
A 2.5mm (0.1") hole is drilled at the end directly towards the middle.

BP mix

When I first did this my BP was lousy but the tourbillions worked just fine.
Years later I wanted to make a few more items with effects but all I got were catos, and other weird effects, but no lift or proper spin.
I found out the reason – my BP is simply too fast.
To this end I add 10% fine grit charcoal to the mix. It slows the burn and provides lot's of lovely sparks too. Two birds in one shot - or should I say one tourbillion?

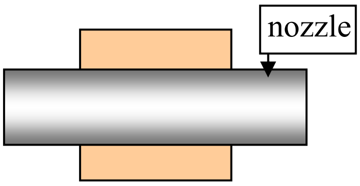
Balance I

The "nozzle" is fitted with a drill bit and tipped at an 11degrees angle downward.
The motor is hot-melt glued to a flat cardboard plate 2*2cm (0.75*0.75").
While the motor is attached to the plate it also holds the drill bit inside the nozzle – which is now a "needle" set in the proper angle (blue line in the drawing below)

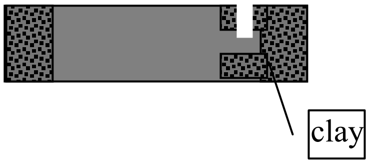
I used a plastic angle meter for this.

The zero mark on the angle-meter leveled with the nozzle the drill bit hides the angle number. This is tricky as you have to hold it in position till the hot melt holds – but it's just for a few seconds. Don't do it if you are in a rush – you will miss and the angles will vary. **A 2 degree shift will ruin the effect.**

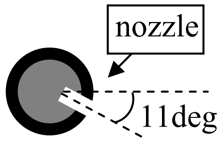
Top view

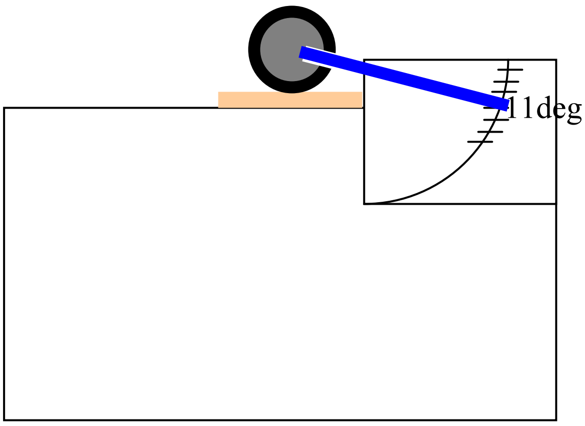


Cut section



Forward cut





Balance II

The disadvantage of the first system is that you need a flat, smooth, plate to launch these from. The slightest mishap in the beginning of the flight/spin means that these will fail eventually.
To this end I've designed the second system.

The same cardboard base (approx. 2x2cm) is punctured at the center.
I press a 6mm wood rod into a metal tube 6mm ID. This makes a nice smooth hole.
Next I place a 6.5mm OD, 6cm (2.4") tall straw through the hole and secure it from the top (i.e. where the motor is about to be. Minutes amounts of hot-melt glue are needed at this point. I also fill up the straw at the top.

To make sure the straw is at 90deg to the cardboard plate I use a section of a pen as a pipe to hold it.
Then, while the system is still set it place, I place the motor on top, and glue it.
Before the glue hardens I aim the motor at the proper angle (same trick with the drill bit).
The result – is a straw at 90deg and a plate on top of it, forming a base for the tourbillion motor.
This system is placed on a wood rod 5.5mm OD, which allows the tourbillion to spin freely until it has enough power to lift on its own.

Basic concepts:

1. Exact angle measurement is critical. +/- 1 deg is OK, but no more!
2. As the burn-cone inside the motor is being generated – the gas from the initial phase will spin the tourbillion, then – when the cone has formed and uniform burn begins and reaches full thrust – the tourbillion will start to liftoff.
3. Check your BP – too hot is not good, nor if it is too weak.
4. Additives (such as Al flakes, charcoal grit and so on) can be added – but don't overdo it.
5. The nozzle ID should be the minimal nozzle ID possible. If you add a burn rate enhancer to the mix – expect a cato if you don't enlarge the nozzle ID. Example - Mg powder will increase the burn rate.

Effects:

1. Make the nozzle perpendicular to the ground and it will not fly but rather spin on the ground.
2. Change the angle **and** nozzle ID to get slower or faster flight speed (still under construction – sorry, no details yet).
3. Addition of some BP lift and a star instead of a plug is nice, and my favorite.

Spinners

Spinners are a small fun project, similar to caduceus rockets.
I thought one day that there must be a good use for Popsicle sticks…
And here it is:

Drill a 6.5mm hole in the middle of the stick.
Secure (with some hot-melt) a 6.5mm OD straw in the center of the hole.
A hot-melt secured rod forms an elevated spot and hence angles the motors with respect to the stick.

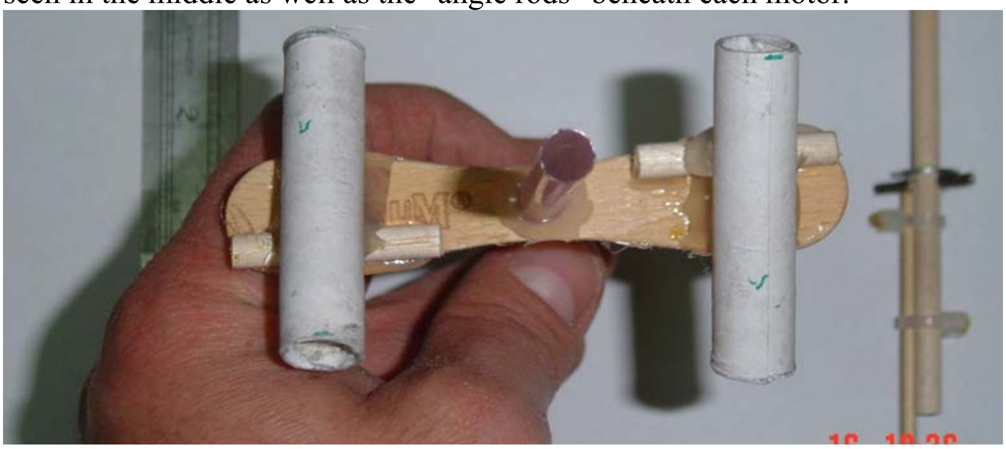
This angle will control the speed of elevation.
I'm not looking for a caduceus rocket system that lifts up rapidly (although it's a lovely effect on its own) - I'm looking for a "saucer" of sparks lifting slowly from its launch rod…

Except for the hot-melt the motors must be secured tightly to the system.
I highly recommend a long good cotton string and numerous ties.
Tie the motors into their place in the spinner system and then use hot melt.

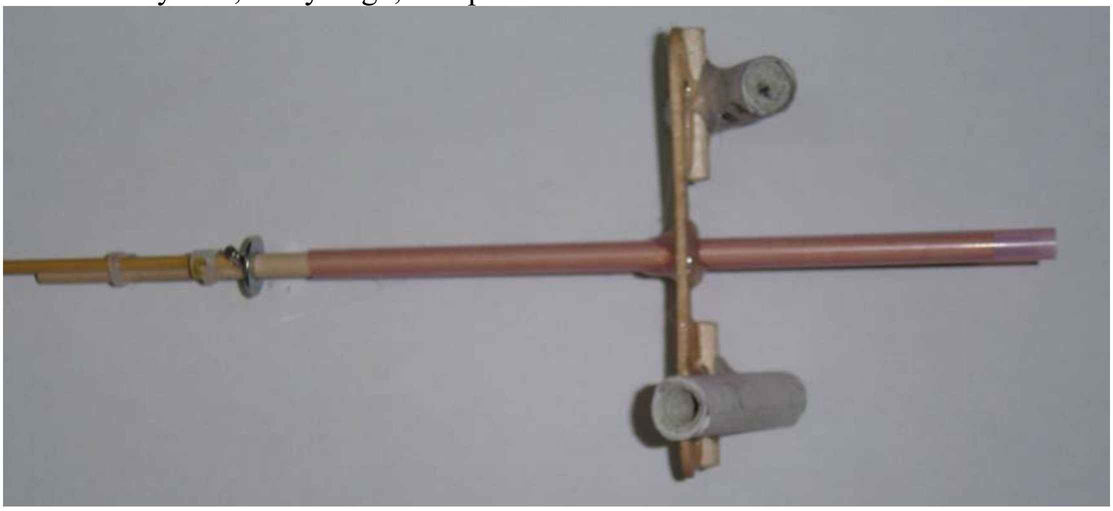
Ignition is done with quick match.
A simple and fairly fast way of making homemade quick match is simply done by placing two strands of black match on a masking tape and wrapping them tight. A hole (created with a sharp knife) in the middle allows me to insert a regular black match fuse.

Currently I've built only two of the systems and none has flown "correctly". In the first a motor "got loose" and although the system used only one motor it worked just fine – spiraling away in somewhat an odd manner.
In the second a motor catoed and this didn't help at all…

These are pics from my first attempt (only hot-melt glue binding).
On the right you can see the launch rod – a washer is placed at the bottom so the spinner will be able to spin on the pad freely and with little friction. A skewer at the bottom of the launch rod is used to secure the rod to the ground.
The two motors here are my standard 10mm ID (5cm long, end burners). The straw is seen in the middle as well as the "angle rods" beneath each motor.

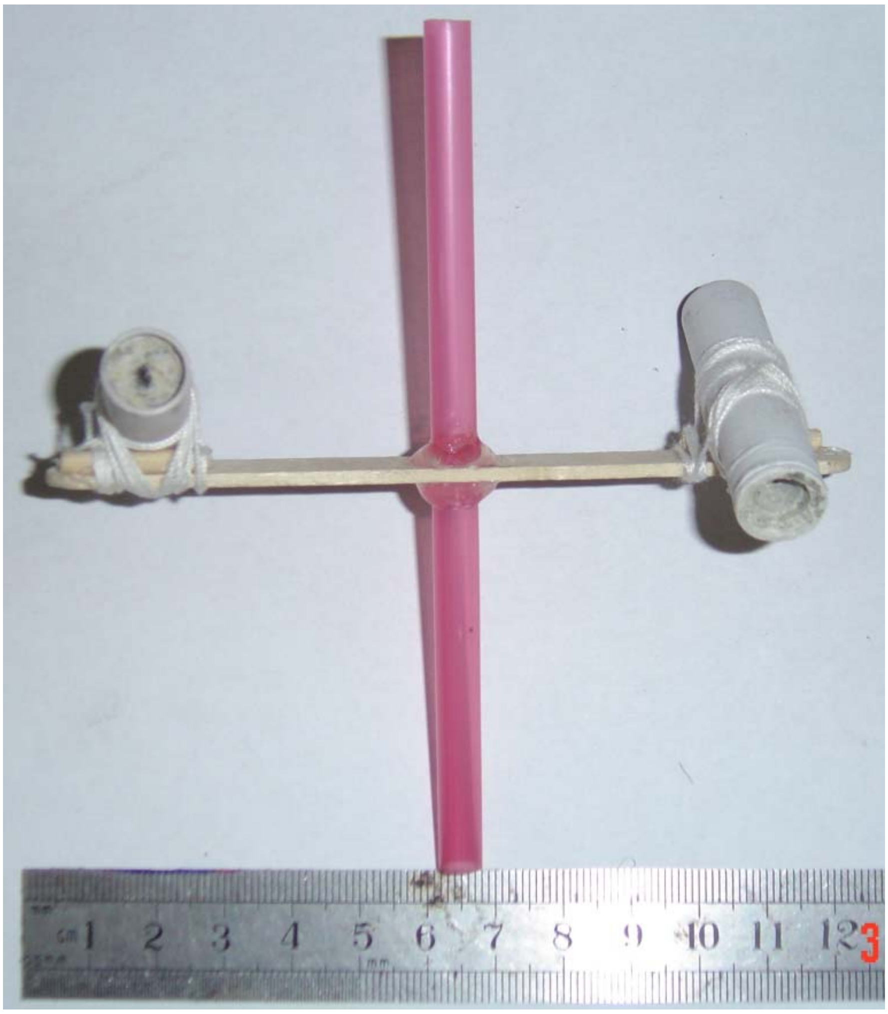


This is the system, ready to go, except for the fuses.



Update

Well… so far I tried a few spinners.
The first (as you can see above) didn't hold one of the motors well enough…
Although it lost a motor at the beginning of the launch it still spun nicely.
A second spinner held the motors with two nylon ties (per motor) and lot's of hot-melt.
The second suffered a cato (a fairly rare occasion, I should say), and of course it didn't handle it nicely… I assume that the tight restraint had something to do with the cato and so I thought of a third way:
I'm tying down the motors to the stick, and adding a nice layer of hot-melt on top of that. You can see a picture in the next page that shows the ties all around the motors.
This one worked just fine.
I tested the angles required and a 45deg angle was ideal for spin/liftoff, no surprise.



Looks nice… doesn't it?
And it works too!

VTVL rocket design for BP motors

Usually making a rocket take off vertically is not complex… as you know.
Making it land vertically is extremely complex and hard to do.
Armadillo are doing this, and I can't even imagine the cost of the tools they need and buy…
http://www.armadilloaerospace.com/n.x/Armadillo/Home

If one can't buy/get/obtain the tools and know-how to do the things he wants to do – then he must do it with what he has.
And so I did (and I still do).

Basics

It's very straight forward.
IF your rocket has very long legs, very flexible legs (to function as springs and absorb the impact) and very heavy legs (relatively speaking) then once the rocket is up there the center of gravity is very low, and then the rocket can't flip and fall down. It has to fall down feet first, or legs first.

As usual with my work – I scaled everything down to fit my 10mm OD motors.
The rocket was made of a tube (to contain the motor), a plastic head (unused plastic tube), three legs and a chute. The legs were fitted with a weights at the bottom (three nails each).
I didn't want to deploy the chute so I used a simpler approach – it covers the body and sticks to it during launch, and deploys automatically as the rocket starts to drop.
All this sounds complex – right?
A picture is worth a thousand words. See the two bottom ones.

Ready for launch (without a motor):

<u>Launch report</u>

The rocket was tested once, a few of years ago.
It functioned perfectly, with a very lousy BP end burner (I was testing BP mixes and I accidentally used the wrong motor instead of the good one I intended to use – and it was of poor quality). The max apogee was about 10m and she dropped a few meters away from me, very smoothly.

Crude Altmeter

How can one check how high his/her rocket got to?
Of course you can buy a digital/electronic or other types of altimeters.
But what if your rockets are too small for this and you are still curious?
One way - according to Estes - is their AltiTrak altimeter device. It's not accurate by any standard – but it does give you a general estimation. If a few rockets give you the same number – than you are in the ball park.

Another method by Dustin brown from PML is a more physical method: He attaches a fair sized flash charge to his rockets and tracks them in the sky using a video camera. He then analyzes the time from the flash to the bang and makes a simple calculation: 330m x time in seconds = apogee in meters.

I wanted to make my own altimeter.

The ESTES AltiTrack system

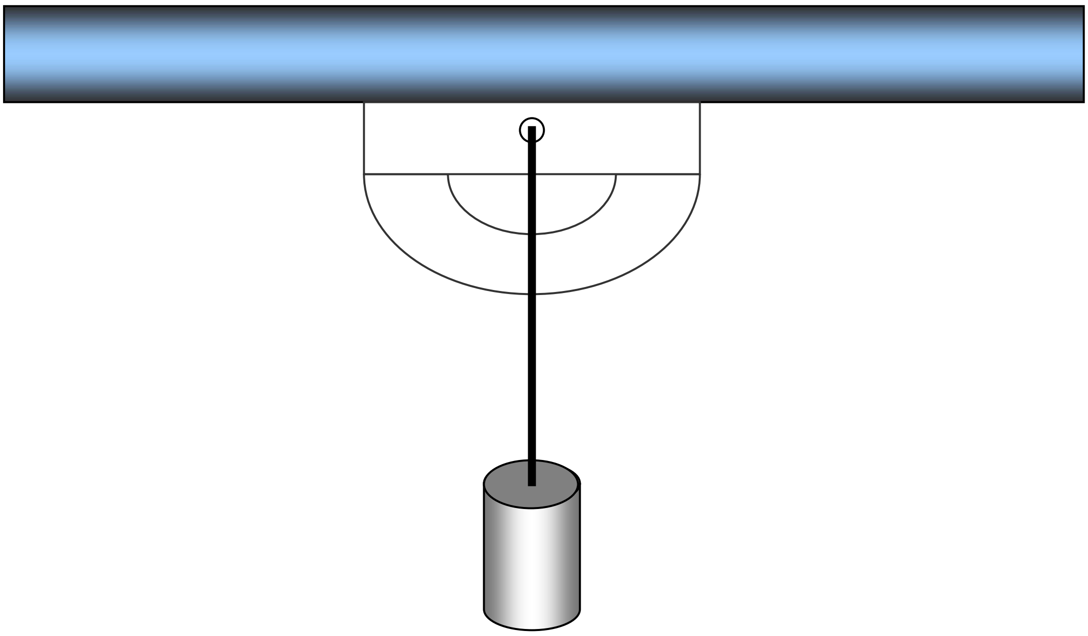
That's not ideal but it's nice.
So – to measure my 10mm ID motors (and the even smaller ones) I built a mock up system.

Building your own altimeter

The system is very simple.
You will need:
1 30cm (1ft) or so PVC tube
1 protractor (flat plastic kind for school)
1 lead weight
1 metal rod, thin
Hot-melt glue

Glue the protractor to the middle of the PVC tube, along the length.
Drill a hole in the protractor and attach the metal rod to the protractor, in a way that will allow it to move freely. Glue the lead weight to the metal rod. Done.

A sketch of the crude homemade altimeter



When the altimeter is horizontal the mark on the protractor is 90 deg.
This is our zero.
You will need a friend to check the apogee with this device.

Give your friend the Zippo to light the rocket on command and step back 50 or 100m (the farther you step – the more accurate the calculation is). Under ideal conditions you would use another friend with an identical device at a 90deg angle to you, same distance from the launch site… but we live in reality… so simply make 5 or so motors and the average will be OK. Let's hope the motors will not fly all in different directions and far away from the vertical line…

So – tell your friend to light the rocket fuse/ematch.

Track your rocket while it's climbing up and away (a bright star payload is highly recommended).
When you see it reach apogee – freeze, hold the lead weight rod with your finger so it won't move, tilt the device to the side and mark the number.
Below there is a list of angles vs. distance with regard to your distance from the launch site.

The calculation is simple:
From the viewer to the rocket up in the sky and to the launch site there is a virtual triangle.
Tangent of the degree you measure is equal to the distance from you to the launch site divided by the altitude of the rocket. We know the distance, and we do know the angle and hence we can calculate the apogee.
The table is in the next page

Table of angles vs. distance from the viewer to the launch site

Protractor Recorded angle 90deg=horizontal	50m Distance from launch Apogee [m]	100m Apogee [m]	angle	50m Distance from launch Apogee [m]	100m Apogee [m]
89	0.9	1.7	54	36.3	72.7
88	1.7	3.5	53	37.7	75.4
87	2.6	5.2	52	39.1	78.1
86	3.5	7.0	51	40.5	81.0
85	4.4	8.7	50	42.0	83.9
84	5.3	10.5	49	43.5	86.9
83	6.1	12.3	48	45.0	90.0
82	7.0	14.1	47	46.6	93.3
81	7.9	15.8	46	48.3	96.6
80	8.8	17.6	45	50.0	100.0
79	9.7	19.4	44	51.8	103.6
78	10.6	21.3	43	53.6	107.2
77	11.5	23.1	42	55.5	111.1
76	12.5	24.9	41	57.5	115.0
75	13.4	26.8	40	59.6	119.2
74	14.3	28.7	39	61.7	123.5
73	15.3	30.6	38	64.0	128.0
72	16.2	32.5	37	66.4	132.7
71	17.2	34.4	36	68.8	137.6
70	18.2	36.4	35	71.4	142.8
69	19.2	38.4	34	74.1	1483
68	20.2	40.4	33	77.0	154.0
67	21.2	42.4	32	80.0	160.0
66	22.3	44.5	31	83.2	166.4
65	23.3	46.6	30	86.6	173.2
64	24.4	48.8	29	90.2	180.4
63	25.5	51.0	28	94.0	188.1
62	26.6	53.2	27	98.1	196.3
61	27.7	55.4	26	102.5	205.0
60	28.9	57.7	25	107.2	214.5
59	30.0	60.1	24	112.3	224.6
58	31.2	62.5	23	117.8	235.6
57	32.5	64.9	22	123.8	247.5
56	33.7	67.5	21	130.3	260.5
55	35.0	70.0	20	137.4	274.7

Protractor Recorded angle (90deg=horizontal)	50m distance from launch apogee[m]	100m apogee[m]
20	137.4	274.7

19	145.2	290.4
18	153.9	307.8
17	163.5	327.1
16	174.4	348.7
15	186.6	373.2
14	200.5	401.1
13	216.6	433.1
12	235.2	470.5
11	257.2	514.5
10	283.6	567.1
9	315.7	631.4
8	355.8	711.5
7	407.2	814.4
6	475.7	951.4
5	571.5	1143.0
4	715.0	1430.1
3	954.1	1908.1
2	1431.8	2863.6
1	2864.5	5729.0

I tested several times my small BP motors with this method. The end burners reach an apogee of 90m. Nice.

NITRATE-SUGAR MOTORS

KNS motors

Introduction

At 2002 I started to make KNS motors (KNS in my case is KNO3-sorbitol, unless stated otherwise).
I did quite a lot of tests as I wanted a system that will allow me to stick the core rod inside, forget about it until the propellant "cures" and then take it out – basically minimal work and maximal result.
I won't list the experiments that I did but I will list my current system.
Most of the system was developed by Yuv, and I will credit him from time to time.

Propellant

You can choose your favorite propellant.
There is a wide range of fuels and mixes: Sucrose, sorbitol, dextrose, maltitiol, and other sugars including additives: syrups, iron oxides, charcoal, titanium and so on. Even a honey based KNS was generated.
The additives range from your regular catalysts (usually ferric oxide) and opacifires (usually charcoal air float or lamp black) to liquidizers such as propylene glycol, glycerol and other additives.

I originally chose the 65 KNO3 : 35 Sorbitol mix.
The reason is simple: The ratio has been examined and is widely used. Sorbitol is fairly cheap (not very cheap, not as sugar, but still affordable), and it doesn't caramelize like sugar. It also requires a lower melting temp, which means it's slightly safer to handle and was available at the time.

Motor design

The motors are as simple as it gets. This is Yuv's design.
A 15mm ID PVC tube (19mm OD)15cm long, filled with KNS and has a 13cm long core. Neither nozzles, nor plugs are used or necessary.
The tube is a plain thin walled PVC pipe used for electrical wiring and it is very cheap. It is NOT a water pipe (schedule40), and you don't need such a pipe – too heavy and too expensive.

Preparing KNS motors

Melting the propellant

A stainless steel pot is placed on top of my hotplate which is set to 120c.
100gr of KNS are added.
The Sorbitol, obviously doesn't need any milling as it will work just fine.
The KNO3 is grit and looks and feels like very fine sand. I don't mill it – no need, as most of it is actually fine powder (I discovered this when I tried one day to screen it to see the ratios of powder/grit). They will burn and fly just fine.

I thoroughly mix the two after weighing the chemicals, screen the clamps and grind them.

A few minutes after adding the mix to the hot stainless pot the KNS is molten and I mix it well to ensure it is homogeneous.
I have a metal angle to tilt the pot a bit, and shift (with a metal spoon) the KNS to the lowest point in the pot.

Filling up the motor case

A syringe with is attached directly to the PVC tube. The fitting is tight and this allows me to suck up the hot, molten, KNS directly into the motor tube.
The syringe has been adapted with a rubber cone that has a second plunger that runs freely through it. The plunger has a free moving large head and the rising propellant lifts the head and seals the airway, thus disallowing the propellant flow into the syringe. This way the plunger stops the molten KNS from entering the tube/syringe and also tells me that the tube is now full and it's time to insert the core rod.
Here are my latest ones - two syringes (each adapted to another motor tube OD):

The lower one is used on 15mm ID motors.
The top one is used on 21mm ID motors (Jimmy's spin burners, to be exact).

I pull up the hot KNS into the PVC motor tube, clean up the bottom end (the end I dipped into the hot KNS) and seal it with nylon based masking tape – just place a square of 2" masking tape on the top of the tube and tighten down.
Then it's time to insert the core rod.

Core rods – Teflon coated

The rods must be prepared before the casting process begins.
I use 4mm 304 stainless steel rods. These won't rust in time (hopefully…).
I roll at 45degrees some Teflon tape on them, all along the length.
I then roll some plain cello-tape at the top and fill with BP mixed with some NC laqour. The last part is no exact science – take some BP powder and pour some NC

laqour until you get a crumbly BP mix. I push the rods into the mix and fill the cello-tape tubes with it. Allow to dry.
Just mark 13cm from the top of the BP grain and you're done.

Here is a picture of such a rod, fully prepped.

The black tip is the BP-NC grain (you can see the cello-tape). Note the Teflon winding at approx. 45degrees.
I chose this format of core rod and design due to two simple reasons:
1. The Teflon ensures easy extraction of the rod.
2. The BP grain stays stuck inside the core, and allows easy and reliable ignition.
See the ignition chapter.
Note: the Teflon tape must be of high quality. There are two brands. One is almost transparent, very thin film, and the other one is much thicker. Buy the thick one. The thin one tend to get stuck in the core rod (it doesn't bother the motor ignition/flight though). The thick brand is actually re-usable as it comes out whole and clean.

Core rods – BPNC coated

BPNC stands for BP+NC laqour.
Ball mill a high grade BP (good charcoal) to get a fine powder.
Screen it to make sure you don't have any lumps/grit/dirt in it.
Find a long and acetone-durable container that has a screw cap that will not allow the acetone to evaporate. It has to be deep enough to contain your core rod.
Fill that container with BP + 55% (w/v) of 10% NC laqour.
Mix well and your BPNC dip is ready. It should be honey consistency.
OK. Many people stop here and ask – what do I mean?

Example:
To 100gr of BP add 55ml of NC laqour
The NC laqour should be 10% concentration which means 10gr of NC in 100ml of regular acetone (or better one, if you have any). If you don't have powdered NC – use ping pong balls. Every ping pong ball weighs 2gr and comprises of 99% NC. Hence you need 5 ping pong balls in 100ml of acetone to get a 10% NC laqour. If you have a really high quality, water free, acetone you can go down to 2% NC.

So why 10% NC, why not a lower concentration?
Answer:
After making a few sets of BPNC coated rods I got annoyed by the fact that the BP sinks so fast down to the bottom of the tank. I tested various concentrations of NC.
I also wanted a system that will be able to utilize regular acetone (which contains some water) without the pin-hole effect (tiny holes generated by the absence of water in the acetone). Hence, I tested higher concentrations of NC laqour using ping pong balls.
Bottom line – 10% NC (i.e. 5ppb's in your 100ml regular acetone) will do the trick.
The BP won't set so fast (it takes at least 48hr to see a slight sign for sedimentation - perfect for my needs).
Better yet – the new mix is so thick you need to dip your rod only once.

Last but not least – as the mix is very thick it will dry in an odd – but very useful fashion – it will create a dry skin that you can touch, shift and play with. Below that skin you have a really liquid mix. This skin allows the mix to dry evenly, smoothly and form a very tough coating layer.

Back to rod dipping -
To protect your core rods dip them into the BPNC.
Make sure you mix the BPNC well before you start dipping them.
The BP will sink to the bottom of the container over time.
When you extract your core rod from the mix make sure to slowly twist it between your fingers. This twisting action releases a lot of access BPNC and leaves a nice even coat.
Let it drip for a second or two.
Allow the coated rod to dry while hanging vertically (down) or the wet BPNC will stick to the table/paper/whatever you left it on. It needs only a minute in the free air to loose enough acetone and start to harden. How do you know that? – it won't be shiny-black anymore.
Store in a safe location – remember: it's BP!

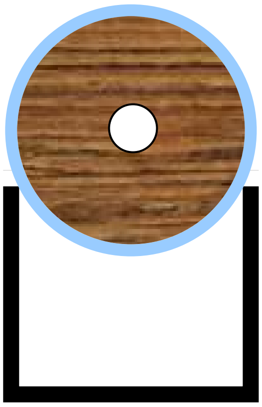
To use these core rods simply stick them into the KNS motors as far as the coat goes, centering them (see below). Cast your propellant into the mold.
Allow the propellant to cool and harden (takes a day or two).
Hold the core rod with a vice and twist the motor.
This will easily release the core rod from the BPNC coat and will enable you to pull out the clean core rod.
The BPNC sticks to, and coats, the inside of the motor core.
It will also act as a good prime and enable you to ignite your motor core easily.

Tips:
Make sure your core rod coat is even.
If not – scrape it off (toss the shavings) and re-dip.
If the mix is getting too thick – add more acetone.
If you made a proper mix and you still get the pin holes – you have too much water in your acetone.
You can either buy a high grade acetone, or add calcium chloride to your acetone.

Centering the core rod

This little gadget is Yuv's invention – a simple tool to work with.
A tube (same PVC tube, same diameter) is held on a U aluminum beam.
A drilled wood tube is inserted (just drill a piece of wood using a "cup" drill bit).
The inserted wood section has a central hole. Insert it and fix it inside the PVC tube.
Now you have a centered hole to hold your core rods.

This is a mid section diagram:



Sliding the newly filled motor into the fixed and centered core rod is easy and fast.
Here is a demo:

After getting the core rod inside (13cm), I usually add a wood peg and store the system upright. The peg makes sure the core rod doesn't keep on sinking deeper or shifts sideways. It takes about 15minutes for the propellant to cool enough so it will be able to hold the weight of the core rod on its own. Once the KNS is at room temperature, I roll some masking tape on the nozzle end (with the core rod still in the KNS), and secure it tightly, to make sure it's air tight.
Remember to take any access Teflon tape off or it won't stick to the rod…
I store these motors in a triple zip lock bag.
After a day or more I usually take out the rods (use vice, turn 1/4 turn and pull – easy!) and place another section of masking tape on the "nozzle" end, just for safety.
For long storage I keep the motors inside a double zip-lock bag, and inside an air tight cookie box.

Fuses & ignition

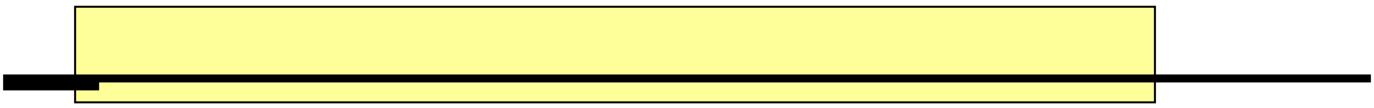
Igniting the motor is fairly simple.
All I have to do is to ignite a BP grain at the top of the core and that will do the rest.
No problems, right?
Wrong – you have to make sure NOT to ignite the walls of the core - just the top.

Of course there is the simple Ematch possibility… but I prefer not to use it.
Why?
Because it takes a longer time to make Ematches than fuses.
Here is my method for the fuse.

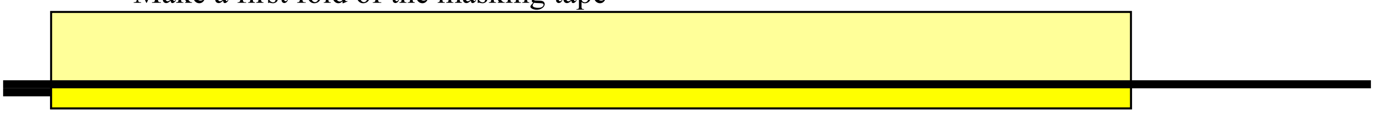
Masking tape protected fuse
Take a 1" masking tape and cut a 14 cm long section.
Place it on the table, sticky side up.
Place a 2mm thick black match fuse along the length (use a 1-2mm thick 30cm long black match). Fold the top end of the black match. Fold the masking tape over the black match so that there is a void, or tunnel formed around the match.

OK, some will ask, Why not use quick match and that's it?
The reason for this is that it will burn very fast, and amazingly it will have enough power to lift the motor. I used two thin (1mm) black match fuses once and the result was that the motor jumped off the pad, fell to the ground and only then ignited and took off – the fuse literally lifted the heavy motor (and stick!) on its own. In another case I saw the motor leap (3m or so in the air) out of the launch tube, hover in the air for a split second and then ignite and take off up into the sky. This is NOT funny, nor safe.

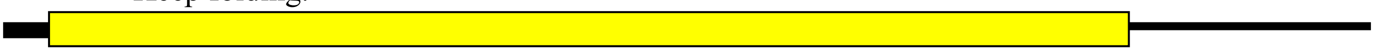
Here is a sketch of the steps:
Place like this (5mm from the side of the masking tape). Fold the top of the match.



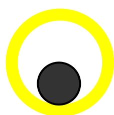
Make a first fold of the masking tape



Keep folding.



Cut section (enlarged):



Do take into consideration that the enclosed section of the fuse will burn VERY FAST! But with virtually zero lift power.

Advanced fuse
Due to the hygroscopic nature of the motors they often swell a bit and the ID core is getting smaller.
Hence tubes made of paper or gummed tape rolled on a 2mm rod are better.
I roll a 2cm wide, 15cm long regular A4 paper on a straight 2mm OD steel rod. The tube generated is 3.5mm OD.

I them bind the top and bottom ends of the new tube with Cello Tape. This leaves some "loose" paper that is actually useful as it stops the fuse from falling out of the motor core.

Lately, I bought some "party straws" as they are defined by the manufacturer. These are 3mm ID, 3.5mm OD and 15cm long and are perfect for this purpose.
I simply place my black match fuse in it, fold the ends and stick them hard into the straws. They will stand up to the heat generated, except for the straw's rear end.
Here is an image of such fuses:
The top fuse is covered in a straw sleeve – to protect it from damage during transport.

The middle one is the plastic fuse and the bottom one is the hand rolled paper fuse.

Note – making the rolled fuse with gummed craft paper tape is a better idea than A4, I simply didn't have any back then...

Ignition notes

The method above (fuse and BP-NC grain) will ignite a regular KNS motor reliably. However, when dealing with experimental KNS motors everything and anything can happen.

If you don't want to use the pre-made BP grain method my advice is that you make a very thick ("angora" – fluffy hairy string used for knitting) – based black match. Simply cut it into short 1.5cm sections, insert a section and ram it down the core.
A fuse, as mentioned above, or any Ematch will ignite this fuse and that will do the trick.

Thermite ingition

If nothing else works you will need something hotter.
Mg-CuO thermite will do the trick.
Mix 4.5 units of CuO (copper oxide) and 1 unit of Mg (units by weight of course).
Both chemicals must be finely powdered – separately!
Don't store. Mg is sensitive to moisture from the air and it may ignite (not reasonable, thermite needs lot's of heat, but still – safer is better. Keep in an air tight container for short terms. I usually make a little (~ 1gr – you don't need much!) and burn the rest after the launch.
This mix will ignite quite easily!!!
A black match will ignite it.
A bare e-match will ignite it, and even steel wool based E-match will ignite it.
Fast, easy and very good.
It's very hot too – if you try this, make sure you are well protected as you will copper plate anything in the vicinity.

It also radiates UV light (like most burning metals) – so use eye protection.

You can add water-free NC laqour to this mix and make a thermite dip.
Dip your e-match heads in it (instantly dry, btw) and these little thing will work just fine on KNS motors.
I usually coat them with some nail varnish after the match is dry – this enables it to withstand the moisture in the air for longer times.

Launch

I'm lazy, and these are usually experimental motors.
This means that there is some odd chance that a motor will ruin a perfectly good rocket that took me quite some time to build… so I'm using a stick.
The motor is tied down to the stick with cello-tape (forget about hot melt). The stick is a reed, found plentifully along small water sources.
Cut a slit in the masking tape covering the nozzle, insert the fuse and ignite.
That simple.

Liquid KNS system

A couple years ago, when I was first introduced into this fascinating sweet propellant (thanks Yuv!), I imagined the KNS as a clear liquid, runny and nice and easy to handle…
Of course it's not… It's porridge like and very hard to work with. It takes me about 5 hours to make 10 motors with a regular sorbitol nitrate propellant.
So far I can't say I'm disappointed, but I can't say I'm also very happy with all that hard work…
I have tried many additives, trying to liquefy the KNS. I did a lot of experiments:
I tried adding water, glycerol, propylene glycol, mixture of sugars with potassium nitrate, water and glycerol with or without propylene glycol and so on.
I have not reached anything reasonable.

Serge, on the other hand – did reach a good liquid mix.
Mixing NaNO3 , KNO3 and sorbitol or sugar at different formulas gave a wonderful result and a liquid KNS.
http://airbase.ru/users/serge77/index.htm
[click on the "translate to English with Babel fish" link below the page heading].

To examine the potential in Serges formulas for my motor type I made a series of tests.
The conditions were standardized so each propellant batch and formula got the same treatment as far as I could verify.
Each batch was 50gr weighed, mixed well, and placed on a heavy duty steel pan. It was melted at 120c (or if it wasn't willing to melt than at 140c and up to 170c). After the propellant has molten, It was properly mixed and then poured into standard motor tubes. Ignition was identical (see above pages) in all cases. Burn rate tests were also conducted in a standard 10mm ID, 5cm tall cardboard tubes.

I did not write all of the experiments, for example the liquid runny test for each sugar and KNS formula (length of drip at a 31deg angle on a teflon coated aluminum plate), 1atm burn rate tests, motor casting simulators and so on. I don't list them here since it will take too much space, but if you are interested I will send you a copy.

These experiments took about 6 months, so a considerable amount of effort was put into the system tests.

Liquid KNS tests results

I have tested the following formulas (see the formulas in the next page).
Please remember that I use a very small motor size and thus the formula I need must be extra runny. The big rocket boys don't need it that thin, as they have a lot of space to cast their propellant.
Hence my scale: Runny, Medium, Regular (i.e. very liquid and good for my needs, medium liquid and not so good for my needs but others can easily use this, and regular like standard KNSB, respectively).

Propellant formula	Liquid state	Full size motor test
Serge0	120c- Very runny	**Poor flight, low thrust.**
Serge0+1% BIO	120c- Very runny	**VERY good flight!**
Serge0+1% RIO	120c- Very runny	**Unknown – to be tested.**
Serge0+1% YIO	120c- Very runny	**Poor flight, low thrust.**
Serge1	120c- Very runny	**Poor flight.**
Serge0+1% BIO	120c- medium	**Poor flight**
Serge0+1% RIO	120c- medium	**Poor flight**
Serge0+1% YIO	120c- medium	**Poor flight**
Serge0+0.5% BIO	120c- medium	**Poor flight**
Serge0+0.5% RIO	120c- medium	**Poor flight**
Serge0+0.5% YIO	120c- medium	**Poor flight**
Serge0+1% BIO+2.5%PG	120c- Runny	**Unknown – to be tested.**
Serge0+1% RIO+5%PG	120c- Runny	**Unknown – to be tested.**
Serge0+1% YIO+2.5%PG	120c- Very runny	**Unknown – to be tested.**
Serge2	120c- Medium	**Poor flight**
Serge2+2-5% PG	120c- Medium	**Poor flight**
Serge2+2-5% Gly	120c- Medium	**Poor flight**
SergeDx	120c- Very runny	**Didn't even leave the pad!**
SergeDx+1% BIO	120c- Very runny	**Very poor flight**
SergeDx+1% RIO	120c- Very runny	**Very poor flight**
SergeDx+1% YIO	120c- Very runny	**Very poor flight**
SergeDxS		**Very poor flight**
SergeDxS+1% BIO		**Very poor flight**
SergeDxS+1% RIO		**Very poor flight**
SergeDxS+1% YIO		**Very poor flight**
Scott PG	120-160c regular	**Untested**
Scott Gly	120-160c regular	**Untested**
Serge-Fr	120c-medium	**Untested**
KNSB+2% Fairy soap	120c- regular	**Didn't ignite, no matter what!**
KNSB+1-5% water	120c- medium	**Burned well**
KNSB+1-5% PG	120c- medium	**Burned well**
KNSB+1-5% Gly	**120c- medium**	**Burned well**

Formulas

Serge0- KNO3 35% : NaNO3 30% : Sorbitol 35%
Serge1- KNO3 35% : NaNO3 30% : Sorbitol 20% : Sucrose 15%
Serge2 - KNO3 35% : NaNO3 30% : Sucrose 35% : +1% water
Serge Dx - KNO3 35% : NaNO3 30% : Dextrose 35%
Serge DxS - KNO3 35% : NaNO3 30% : Dextrose 20% : Sucrose 15%
Serge FR - KNO3 35% : NaNO3 30% : Fructose 35%
Scott PG - KNO3 65% : Sucrose 35% + 2-5% Propylene glycol (PG)
Scott Gly - KNO3 65% : Sucrose 35% + 2-5% Glycerol (Gly)
KNSB – regular KNO3 65% : 35% Sorbitol.

Additives:
BIO – Black iron oxide (Fe3O4)
RIO – Red iron oxide (Fe2O3)
YIO – Yellow iron oxide $Fe(OH)_3$
PG – propylene glycol
Gly – Glycerol

Liquid KNS - Summary

After testing all the formulas (except for the hard to cast ones – I won't use them anyway, so why bother?), the best one is the Serge0+1% BIO.
This is not a surprise since the sorbitol was the most liquid of all the sugars. It ran on my slanted Teflon coated surface 8cm while sucrose ran 2cm and dextrose and fructose ran 4cm. So Sorbitol allows you to form the most liquid formula.
I am currently building an improved horizontal setup just for these motors.

I must say I had very high hopes for the dextrose based fuel since it is now cheaper than before, and much cheaper than sorbitol. I also hoped to get better results with sucrose+sorbitol or sucrose alone, but alas both failed me. They simply don't work well under my systems characteristics.

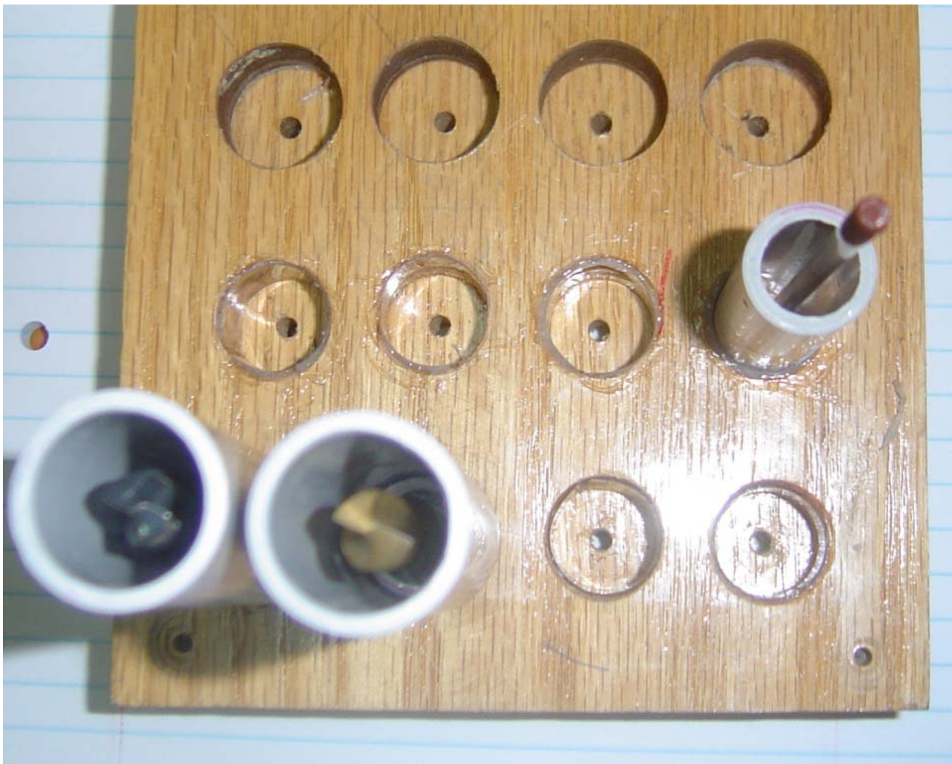
I have also noticed that YIO is a very good liquidizer and tends to help liquefy the KNS formulas I used it in – but it is also a poor catalyst in my test system.

On the other hand – since my motors are nozzless and since Serges formulas are extremely sensitive to the catalyst type and perform poorly in my system this forms a very good platform to test catalysts.

I recently got some TiO2 and I will test it to see how well does it work as an opacifier (it reflects IR rather than absorb them so it should do well in combination with BIO).

Upright casting system

This is my low tech upright system for liquid KNS motor casting:



I used a short tube (on the right) to show you the centered is the core rod (I know it doesn't look like it – but it is).
The bottom sections show my centering tool for 10mm drill bits.
See next section for Jimmy's spin burners and you will know why...
I have used the system with Serge's mix and it works nicely.
To avoid KNS running between the wood plates, messy and sticky – pour some flour, sawdust or other types of powder that you have at home into the tube and shake.
These will seal the gap and will not allow the KNS to pass through.
Pour, and have fun.

TIP of the day:
If you don't have a circular angle cutter (like me) - buy a simple steel tube cutter that will allow you to cut the tubes at a 90deg angle and straight.
The "regular" KNS (not liquefied) motor tubes don't matter if the cutting is a bit off, but the standing rig will make your life harder if the tubes aren't standing properly.

James Yawns SpinBurners

This is another one of Jimmy's wonderful inventions.
Jimmy used drill bits and cork screws instead of rods…
http://www.jamesyawn.com/spinburner/

I loved the idea and wanted to try it out for size.
But, unlike Jimmy, I'm lazy.
I wanted a simple way of inserting the drill bit into the KNS.
So I coated it with Teflon tape.
I used my 15mm motors (shorter, of course) and 7mm drill bits.
Here is the drill bit core rod:

Four layers of Teflon tape on the grooves and ridges of the core rod gave me this nice looking, nonstick tool. Indeed – it was very easy to extract them. But they did leave some tape inside. Still there was no problem igniting them with a very thin e-match coated with copper oxide-Mg thermite dip.
I made another one as tubeless and it also functioned very well.
The KNS was added with 1% of ferric oxide and 1% of charcoal (willow, air float).
Very fast burn. Sorry, I don't have any images or videos.

Another tool I built for these motor is this one:
It's a single helix core rod, with a 4mm steel rod as base and a spiral of electric wire

around it. It allows me to change the pitch and other parameters of the tool as I please. Not perfect, but interesting.

I also bought a wood drill bit that is single helix and it will be tested shortly.
I'll try to add a picture of it.

Note:
I experimented with the drill bit coats.
Alas, even titanium drill bits are not BPNC safe – they rust away fairly fast. Hence the BPNC coat is off the list. I also tried simple NC coat but although the NC seemed to peel off the core easily before casting – it was impossible to remove it with the propellant grain afterwards (I had to toss the grain). So the Teflon coating is the best and only solution I have to this problem.
Had I had a lot of copper oxide or magnesium I would have tried it as a core coat… but I don't.

Cement nozzles for KNS motors

I'm using quick cement (used for fixing damaged water pipes) which can solidify even underwater. Tests with regular and liquid KNS formulas have shown that the nozzles withstand the thrust and heat and erosion. Here are my homemade tools:

An experiment with Serge0 formula, a motor with 10cmX4mm core also performed just fine. I didn’t use any additives. Post launch examination showed no erosion of the cement nozzle (I tried to enlarge it at the launch site – it was impossible to drill through, so I was not surprised by this result).

KNW and rKNS

A few years ago I heard (and saw a nice web page) of a NASA project using hybrid motors that apply LOX or NOX and wax.
Well…. If hybrids can do it – why can't solids do it?
Hence my initial idea of wax-nitrate motors.

Standard paraffin candle wax is usually a 14mer hydrocarbon chain.
This results in a stoichiometric ratio of 1:4.2 wax:KNO_3.
So I experimented with it, testing also various ratios below and above this "ideal" ratio, testing it with and without additives.

The end result was annoying – the wax acts as a heat sink.
It melts and absorbs the heat, and you can't get any ignition (no, I haven't tried chlorate and I don't intend to).

I have tried additives and fuels such as hot-melt glue, sulfur, ferric oxide, black iron oxide, yellow iron oxide, aluminum at various grades, magnesium, charcoal and so on. I even tried out a hot-melt glue-nitrate motor, with all the additives I have and could think of. It didn't help.

So if wax can't be used as the main reducer, what about wax as an additive?
This opened the era of the rKNS or rammable-KNS experiments.
Actually, the plain rKNSU is of course the regular and famous "5 cent sugar rocket".

I ball milled KNSU (65% KNO_3, and up to 30% sugar) and added 5% or above wax.
I saw that below 50% wax as a reducer you can't melt and cast the mix.
You have to ram or press it.

Hence I tested additives.
The current list is:
Wax, paraffin.
Hot melt
Vaseline
Mineral oil
Propylene glycol
Glycerin

These additives were tested in varying concentrations from 35% to 5% total.
Standard strawcket motors were prepared with these and are of the following dimensions:
6mm ID, 6.5mm OD, 3cm long, 2cm long 2.4mm core.
Wax samples were first placed on a hotplate to melt and then mixed with the rest of the ingredients; the other reducers were mixed directly.

Results

Ramming/pressing process
Pressing regular KNSU is very easy, but extracting the core rod is very hard.
It is as hard as pressing/ramming a motor full of kitty litter and trying to get the core rod out. Try and see.
Additives do help here:
Mineral oil and Vaseline (5%) allows for an easier release of the core rod.
Propylene glycol and glycerol (5%) have the best effect in core rod release so far – very easy.

Partial list of propellant Performance
Regular KNSU burns nicely, as expected.
35% wax as reducer: 65% nitrate – the motor does not burn at all. The grain melts. The same goes for hot-melt or mixes of wax and hot-melt and Vaseline.
At 10-5% wax (and the rest sugar) the motor ignites and generates a nice flame above the nozzle, but the thrust is very low and burn rate is too slow (24sec).
10-5% Vaseline is also fairly poor as an additive; much like the wax and it too generates a nice flame after the nozzle.
5% Mineral oil (paraffin oil) is very good - the burn rate is a bit longer but the thrust peak is fairly close to that of the regular KNSU.
5% Propylene glycol generates a very poor motor performance, about 1/3rd of the regular KNSU peak thrust.
5% glycerol is very close to mineral oil and the original KNSU profile, so far unaffecting the burn rate.
Here is an image of the core burner (nozzless) motors:

Motor tests results
Eventually I have focused my efforts on propylene glycol, glycerol, mineral oil and regular KNSU as control. End and core burners were made using 5% additives and tested on my horizontal thrust meter.
Core burners with KNSU, mineral oil and glycerol generate an "off the scale" peak thrust, estimated at around 40-50gr for 0.2sec or so.
End burners generated a modest 5gr thrust on all these formulas.
It should be noted that the end burners showed spikes in the thrust, in the case of KNSU, more in the mineral oil formula, and very low in the case of the glycerin.

Also, when breaking down motor for propellant re-use I noticed that the pressed KNSU and KNSU-oil grains were very hard, almost rock hard, while the KNSU-glycerin is a bit softer. Also the propellants themselves tend to "cake" or agglomerate – except for the glycerin added propellant. This makes scooping the propellant for reaming/ pressing very easy.

Future plans

Testing 10mm ID motors.
Testing hard waxes.
I just got two samples of ross wax. These waxes melt at 140 and 160c each.
I hope they may be of use for this research.

PYROTECHNICS

Black Match

Black match is a widely used fuse type in the hands of the amateur.
It's easy to make and fairly reliable.
This is my way of making it.
I have explored many routes along this way, making 7 or more systems to make black match. Several string types, from 1mm OD to 4mm OD have been tested and are capable of generating good black match.
My goal was: string goes in, match comes out, less work and more match in as little time as possible.
Black Match will also be referred as BM, shortly.

Black match wet mix

After testing various mixes, getting fungi (mold) to grow on the mix I got to this formula, and additives - with the kind help of John Collins and other PML members.

- Black powder – high quality ball milled BP. Nothing less is acceptable from my experience – If you put junk into your black match machine you will get junk at the other end!
- +3% dextrin (grind with some dry BP with the binder using a mortar and pestle, and add to the rest of the BP batch.
- 55% v/w (i.e. 55cc of liquid per 100gr of BP) of 20% ethanol is added.
  The ethanol will make sure nothing "grows" on the mix and ruins the quality of the future black match. **Most Important: The using 20% Ethanol instead of water will also prevent the leeching of the nitrate into the fuse (which udually will result in an uneven mix on the fuse and a loss of the BM activity due to lack of nitrate which has been taken by the first few meters of the fuse.** It will also stop formation of large nitrate crystals, which will ensure the homogeneity and proper function of the fuse (even burn rate)
- Additives suggested by John Collins (were tested and found to be good) -
  1% Boric acid (to avoid bacteria)
  1% Copper sulfate (to avoid fungi)
  The additives did not affect the BP and BM (black match) quality

System design

If you take a canister and run a string through it – it will locally drain the liquid (soak it up) from the BP mix and the result will be a "tunnel" of BP that allows the clean wire to run through a semi-dry BP mix.
To avoid this I have assembled my system on top of a hair clipper machine (with the blades taken off for match safety (the blades snipped my black match the first time…)
The clipper vibrates and this makes sure that no "tunnels" are formed.
Stainless steel rings force the wire to run inside the mix (see images).

Both the inlet and outlet holes (in the cap) have screw caps.
There are several caps – storage caps (sealed) close the system and do not allow air/water/ethanol vapors to leave the system. There is also a major cap for the entire box I use in order to store the black match slurry for long times.
The operational outlet caps – with different holes ID inside for different string types – the cap hole ID is a bit larger than the string OD. For a very thin black match I use a 1mm string, and a 1.5mm hole is drilled in the exit cap; for a 2mm cotton string I use a 2.5mm exit hole in the exit cap (regular fuse for rocket ignition); and for the "Angora" brand string (very furry string half cotton contents) I'll use a 4mm exit hole to obtain a very thick black match.

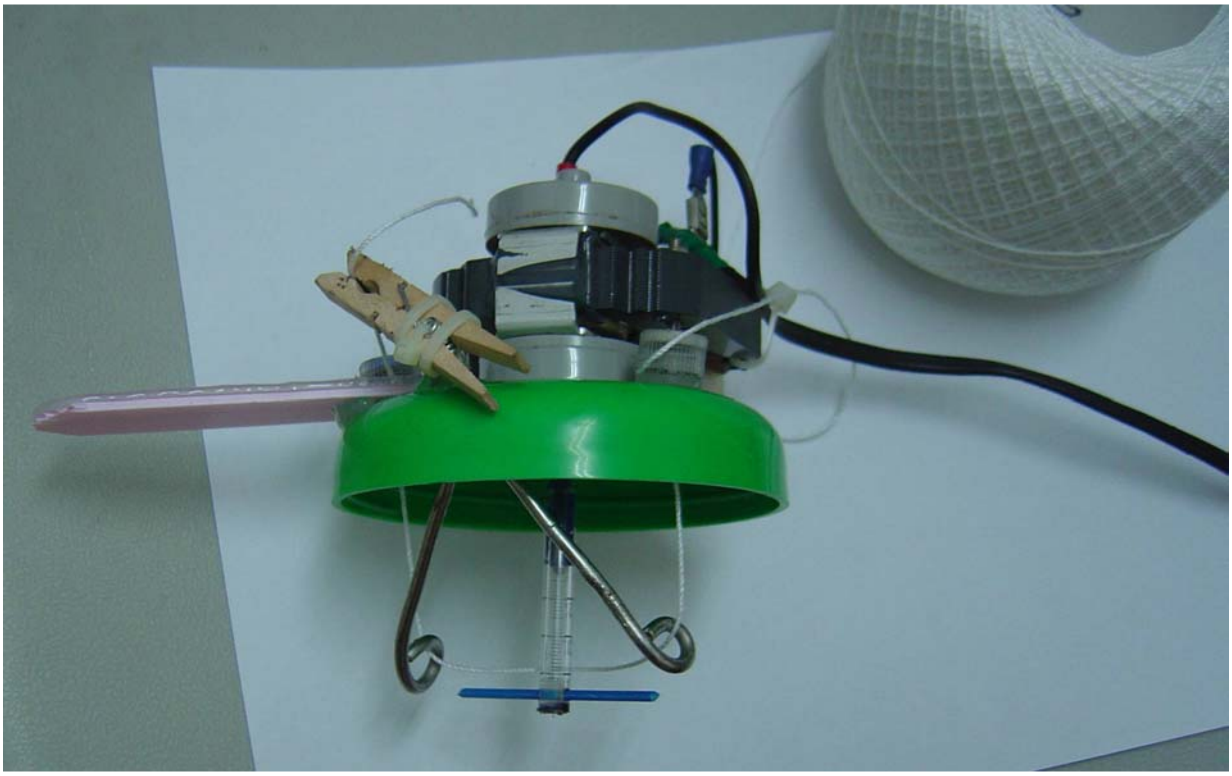
I used a V shaped stainless steel wire bending the ends to form the hooks at the ends of the V arm. The V wire is attached to the cap. This makes replacing the string, or rewiring the system (if the string dropped into the container) very easy.

From time to time, even with the hair clipper options the string doesn't get enough BP coat. The reason is that the mix is drying, setting and doesn't adhere nicely to the string. A quick shake helps mix it better. This always happens just before you need to add some more 20% ethanol. So I added a motor and converted it into a stirrer.

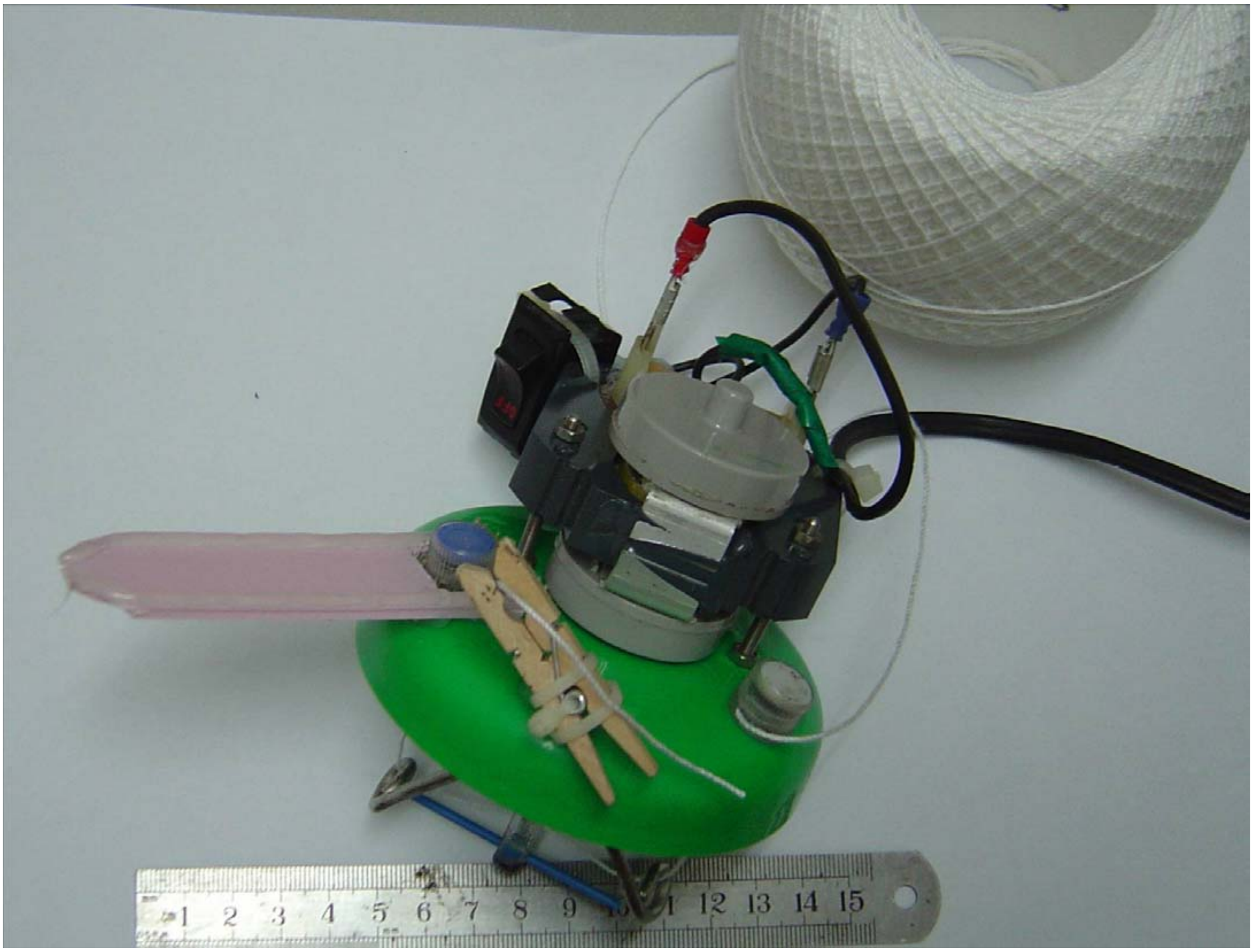
This will also helps me shorten the handling time: Instead of taking the whole thing to the table, open the lid, add the ethanol, mix well, close and get back to making black match – I'll be able to just add the ethanol through the inlet hole, turn the motor on for a second or two and back to black match making.

I even made a smaller system (sorry, not in the images currently) for testing various additives. The smaller system can be hooked with a plastic tie to the main one and I'll be able to use it with only 5-10gr of BP each time.

Enough typing – here are the images:

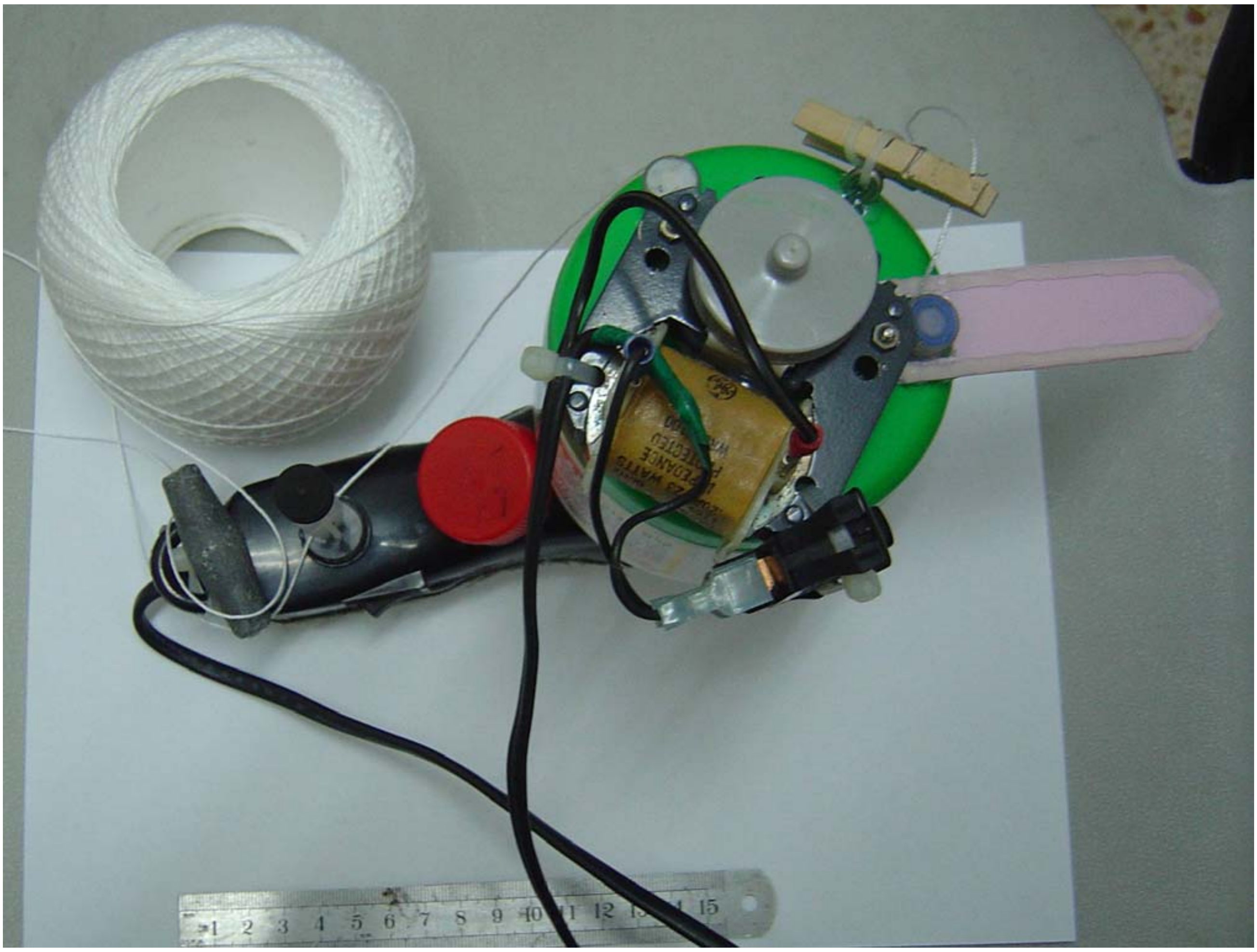


This is the cap.
It actually contains all the important parts.
You can see the electric motor on top (110v, 60mA, 23W if you are so interested in the specs), the hooks below that run the wire through the mix (and you can see the wire too), the mixer/stirrer head (attahced to the motor, of course) and the wet black match path (pink plastic sheet that guides the wet BM to the pegs).



This is the lid again, but top view:
The VOG knitting string goes through the inlet cap (white), runs through the stainless steel hooks, mix, and back up to the exit cap (blue storage cap, in this case. The exit caps are identical, but have exit holes of course). The peg holds the wire so it won't slip back to the mix (if I'm forced to stop during the operation). The Peg is secured to the top section of the V shaped stainless steel wire that ends with the plastic ties.

In the next page you can see the full system.



This system has a far greater capacity than my old one. I holds up to 100gr of BP. Usually 50gr of BP will give about 3 rounds of black match, which are 36meters, and still you will have some leftover BP. Although I don't plan on making tons of black match so this will enable me to make thicker black match string, with a single fill of the can. Obviously the thicker the string the more black powder mix it consumes.

Making the initial mix

I add a fresh batch of mix (usually 30gr + additives + solvents). I recommend that you mix it in a nylon bag, kneed it well, cut a corner and pour it into the container.
Every 6 meters of black match a volume of 2.5cc of 20% ethanol is added and the system is mixed with a top motor. This makes sure the mix doesn't get too dry. This method doesn't force you to wet the string first, but both methods work nicely. I simply prefer intake of a readymade string without pre-treating it.

String types

I have tested a wide variety of string types.
I try to stick to the golden rule of using a cotton string (which burns a lot better than synthetic ones).
I have had good success with the following strings:

1. Colored knitting string, 1mm thick, cotton
2. VOG knitting string, 1.5mm thick, cotton
3. Angora knitting string, 4mm thick, 50% cotton.

Drying the Black Match

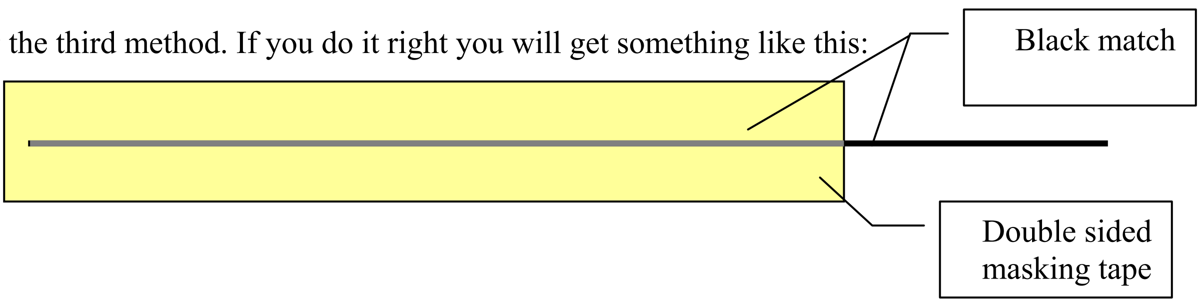
Now… how to hang the black match to dry?
I use a vertical standing flat wood door, with pegs on it, and horizontal nylon wires. The wires make sure the sticky fresh BM does not cling to the wood door.
I simply hold the new black match on the top peg, pull 1.2m of black match and secure it with the lower peg, snip and repeat.
This system is space & time saving and allows to dry lots of BM.
Here is the top section (in red script there is a note for me to refresh the black match mix with more 20% ethanol).

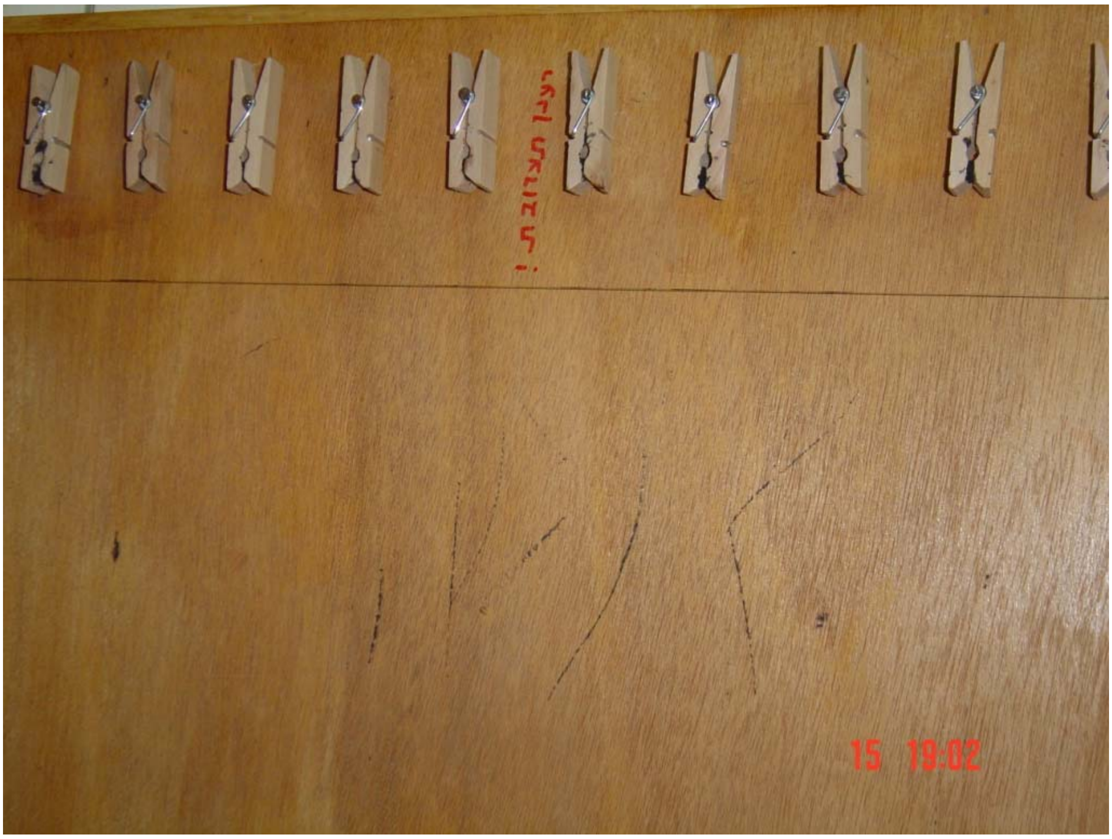
Testing the match

There are some ways to test a match.
The criterion, in my opinion, is that it should be water resistant (to some extent so it will function in the damp evenings) and it should pass through nozzles and narrow places. The first criteria can be measured in a humidity chamber (see below).
The second criteria can be tested by several methods:

1. Let the fuse burn through a 10cm long thin aluminum tube (Yuv's way)
2. Let the fuse burn through a very long and narrow clay nozzle.
3. Place the fuse on a paper based masking tape (15cm long fuse, 10cm bonded to a 20cm long tape), fold the rest of the tape on top to form a second layer of tape (sticky to sticky sides) and secure the match with your fingernail so there will be no cavity around it – the tape must stick to it from all sides. If it reaches the other side (i.e. pass the whole 10cm) it works.

I'm using the third method. If you do it right you will get something like this:





You can see a black nylon line below the pegs (black from the sticky black match – no worries the BMs don't stick to it – they just leave a mark). I spaced the nylon lines about 20cm from each other.

Experimenting with Adhesives

Just before building this system I started experimenting with additives.
I can give you just the initial tests results so far, and I'll have to do many more experiments (which is why I made the smaller system for tiny batches).

I have so far examined:

1. Corn flour [5% in 30% ethanol]
2. Potato starch (potato flour) [5% in 30% ethanol]
3. NC laqour [5% and 10% NC in acetone]
4. Homemade dextrin (corn starch based, overcooked) 3%
5. Commercial dextrin 3%
6. Guar Gum 3%
7. Acacia gum (aka gum Arabic) 3%
8. A 1:1 mix of acacia gum and guar gum final concentration 3% and 5%.
9. Commercial Redgum 3% and 5%
10. Commercial ironing starch
11. SGRS – to be tested.

Corn flour and potato starch did well in my tubelesses and generated good and fairly reliable rockets. However, they proved to be very bad for black match.
Experimentation with these binders ceased.
Commercial ironing starch was also tested (the label did not include the ingredients, but stated it's all natural, and scented). I added enough of the liquid to the BP batch to make it liquid, and made a fuse. It burned well, but not through holes or in contact with anything else (place on a plate and it stops burning).
It works well as an ironing starch...

NC laqour was clearly better at 10% as the match was more consistent and smooth, but it wasn't able to form a quick match. 5% was able to burn in a quickmatch properly so it was chosen. 5% of acacia gum and redgum degraded the BP ability to burn fast enough and pass the nozzle simulator test.

NC at 5% is great for black match.
It generates a fuse with a very even, smooth burning, with an even burn rate and very hot fire. One big problem with it is the acetone – the whole place reeks of acetone.
It also evaporates very fast and forces the use to add more acetone every 2m or so.
To this end I've built a model that fits the needs of an NC based black match machine.
I'll publish it as soon as I finish testing and modifying it.
The NC BM is much hotter than any of the other types (5% NC) so it has a good potential… once the evaporation problem is solved and over (it is).

As for Guar gum and acacia gum both had good results!
3% of Guar Gum or acacia gum were added to the BP and mixed well.
About 50% w/v of 20% ethanol was added later to obtain a good, fairly thin paste.
It was easy to make the fuse (just like dextrin) and it dried as fast.
It burns just like dextrin and a quick match with this fuse is a fast burning, flash through quick match as you would expect and need it to be.
I also tested it using my regular masking tape test – and it works well.
Although some people said that guar gum is good for extrusions and not fuses – it still is very good for fuses.

Humidity chamber

In order to evaluate and compare the binders I've made a humidity chamber.
It is a small box with a towel paper bottom and a small elevated surface that holds the BM fuse above the wet paper. The box is closed and the humidity rises. After some time the box is opened and the fuse is tested.

Black match samples 3,4 and 6-9 made with all of these at 3% were tested in the humidity chamber. They all survived and functioned after 50 minutes but failed after 60 minutes. The best ones were my homemade dextrin and NC laqour based, which survived 55 minutes.
Hence, I am currently using my homemade dextrin and BPNC.

Burst charge

Introduction

Unlike some people that use flash powder, KP, H-1, whistle composition or other burst formulas – I lack the chemicals to do so.
It also makes me very nervous making large amounts of flash (usually I make up to 1gr, and that's on rare occasions).
Hence, I'm limited to either rice hulls or polverone.
So far I haven't made any polverone, and hence I won't describe it here until I try it myself.
This leaves us with rice hulls.
Sadly, I was unable to locate and buy rice hulls locally, but came up with a good substitute which I will describe in the next pages.

Hulls

Although I have made many efforts to find and purchase rice hulls locally, I've been unable to get any. I know they are used in the wine industry and I called and asked - but no one was willing to sell or give me some.

I have tried out some other substitutes such as flat flower shaped pasta, and other things, but they were not very efficient. Most of them leave a charred, sometimes still smoldering residue falling from the sky. This is a fire hazard, and not ideal.

I have two parrots (budgerigars) at home…. The small cute ones…
And one day, as I was cleaning their cage I thought of the hulls problem.
Hulls are used because they are concave, very thin and burn instantly, and due to their shape hold a lot of BP.
And then I looked at what I was cleaning - and throwing away – it was parrot food hulls. Parrots eat Millet which is a round type of seed, and they toss a lot of nice, clean Millet hulls, which are essentially the same thing as rice hulls: very thin envelope that holds BP.
While rice hulls are a bit elongated the millet hulls are more round, but the concept remains the same.

Years ago I got a tiny amount of professional rice hulls burst charge (and I kept it).
So I used it then to compare it with my first homemade batch of Millet hulls.
It was a success!
They both burned fast, easily, leaving a light weight fully burned residue.

I then started to make millet hulls as my burst charge for rocket payloads.
But making the hulls by hand (shaking them in a box with black powder) resulted in a low quality burst charge as they would often clump and generate nice balls of hulls and BP mix. Even after applying all the tips from PML members (thank you guys!).

One day I saw a video of a Japanese company (Hanebi, I think) that made rice hulls with a star roller. This was just after I built my own star roller.
Of course I had to try it out myself.

After a few initial tests I got great results and developed a simple, fast and easy process with far better results than the mixing box method.
Just the thing for a lazy man (me).

Millet hulls preparation via a star roller

1. Ball mill 80gr BP with 3% Dextrin, dry and screen it.*
2. Weigh another 20gr of ball milled BP - without the dextrin.*
3. Weigh 20gr of millet hulls (tip: it fills a standard polystyrene cup)**
4. Wet **half** of the hulls with hot tap water in a nylon bag.
5. Shake for a minute or two to make sure the hulls are all wet.
6. Drain the water and squeeze the bag as hard as you can to get rid of as much water as possible.
7. Add the other half of the hulls into the bag and mix well, shaking and kneading the hulls by hand. This makes sure the hulls are all wet, but not too wet and saves the long draining time. This is crucial step as too-wet hulls will wet the BP and you will get a BP-hulls paste and not separately BP filled hulls.
8. Pour the hulls into a star roller bowl (see my star roller below).
9. Start spinning (60rpm) and add BP+dextrin (I use double spoons of baby food measuring cups).
10. At first the wet hulls stick to the bowl so mix them with a spoon.
11. Keep adding more black powder in intervals. Once the black powder you just added has been incorporated in the hulls, add more.
12. After about fifty grams of black powder (with dextrin) have been added the hulls will form and start to roll nicely.
13. If clumps form – break them with the spoon as the roller rolls on.
14. Take samples of the hulls with the spoon from different areas of the mixing wave of hulls to make sure they are all even and smooth. If you have clumps – keep breaking them.
15. Finish off with a final volume of BP (the 20gr BP without the dextrin).
16. Allow the hulls to keep rolling for another minute or two.
17. Dry in the sun (I use aluminum cake plates)

*The black powder must be in fine powder, and of good quality (i.e. good charcoal)
** A ratio of 1:5 rice hulls to BP is used.

The 100gr batch you see in the images below took about 15 minutes to prepare:
5min preparing the hulls
~10min in the star roller

This method is now used routinely in my bench.

Here are some images of the finished product.
Most of the batch is nice and oval hulls (the exterior of the hulls is smooth and BP doesn't stick to it, as you can see).

STARS

Stars, if you don't know, are small cubes/balls made of a pyrotechnic mixture.
The lovely (small or big) colored spots you see in a firework show are burning stars.
I am no pyrotechnic expert and this is just how I do things.
I also lack lots of needed chemicals and hence I am forced to work with certain compounds that I do have. I also make very tiny volumes (limited by the small amounts of chemicals that I do have).

What I can do is to build small rocket payloads. The payloads that I use are scratch built, simple, cheap and easy to obtain.
This section will discuss my stars: types of stars, methods of preparations and storage, testing and rocket payloads.

I DO NOT recommend the metal star formulas given below.
It is much safer to use AP or KP formulas
Why don't I use my own advice? Because I don't have any KP or AP.

Star compositions

Metal star composition

These formulas were taken from Wouters page (collection of pyrotechnic compositions).
These Mg formulas are highly dangerous and prone to spontaneous combustion due to the Mg reaction with nitrates and/or possible moisture from the air. I DO NOT recommend these formulas. Please use safer and more standard formulas. I use these because that is all I can use and I make only 10gr at a time and store each formula in a different isolated fireproof container (see more below).

Metallic colored stars composition

This is the original colored star formula I tested:

Red star #9
Source: rec.pyrotechnics. Post by Andrew Krywonizka. Composition from Lancaster[2].
Comments: Produce as a pressed star

Strontium nitrate................................55
Magnesium..28
PVC..17

For Green I simply replace the strontium nitrate with barium nitrate.
I haven't tried yellow yet (using sodium nitrate) nor orange (sodium/strontium nitrates 1/4 respectively), but I intend to.
I don't have any purple or blue formulas that fit my possibilities and hence I will not discuss such formulas.

White star composition

For white star I converted the following formula:

Flash #2

Source: rec.pyrotechnics, Listed as ‘Ellern #121' in Ellern [4].

potassium perchlorate.............................70
Aluminum (dark pyro)..............................30

I used KNO_3 instead of the KP which I don't have, and Mg instead of Al. Hence, the formula is:

KNO_3 – 70
Mg powder – 30.

It’s a lovely, blinding white.

NC laqour

NC laqour is the binder I use.
1 ping pong ball (2gr) is sliced and inserted into a 100cc container full of acetone generates a 2% NC laqour solution once it dissolves into the acetone.
The acetone you use must be dry!!!
Commercial acetone contains water. The water will react with the Mg. This is not a good idea.
A good friend gave me some $CaCl_2$ which is used to dry items fast.
Even the commercial $CaCl_2$ is soaked with water to some extent.
Hence, I baked the $CaCl_2$ at 400c (on a hot plate, max temp) for 3 hours.
I allowed to cool on the floor (fairly fast) and inserted it into two nylon bags (each sealed separately and placed the bags in an air tight container.
Some of the $CaCl_2$ was added to my acetone stock. I left almost no air in the acetone container.
This method was given with the kind help of PML members and by John Collins.
John crucial point was – don't store the acetone in a metal container. Use plastic (polypropylene).
Make sure you don't leave the acetone stock container or the NC laqour container open for long times as it will soak up water from the air.

Preparation of metal stars

Fume hood and/or full face mask, leather gloves and apron and a good quality respirator are a must! A bucket of water and a water tap near bye are a must!
Be prepared as the mix may ignite. You must have an escape route that you can use in case something happens.
As I work with 10gr at a time – If something happens (ignition, bubbling of the mix which may happen if there is water in the mix) I simply step back (fire) or simply toss the mix into the bucket of water (if it bubbles).
The Mg, KNO_3 and PVC (if needed) already are in powder form.
If not – I will grind each one **separately** before mixing all of them together.

NEVER grind a pyrotechnic composition!.
This can and will result in an accidental ignition or explosion of the composition. This may cause severe damage to you and your surrounding and may even result in death!

Once the ingredients have been weighed and are in powder form (separately, each in its own container) I first add the reducer (Mg) into a mortar.
I add NC laqour and wet the Mg well. 50% of the final mix weight in cc will do the trick. Stir a bit.
After the Mg is thoroughly wet I add the PVC and KNO_3 into the mortar and gently mix with a wood spatula.

NEVER grind a pyrotechnic composition!.
This can and will result in an accidental ignition or explosion of the composition.

The mix should be thoroughly wetted, and if it starts to dry – add more acetone.
After the composition has been thoroughly mixed I allow for it to dry a bit (until it gets fairly solid – like plasteline).
At this time I pour/scrape it out on a flat surface (glass would be good) and cut it into small squares 7mm wide x 7mm long x7mm high (which gives a total "diameter" of 9mm). The end product is a square cut star.
10gr of mix will result about 40 stars, which is more than enough for my needs.
Allow the stars to dry on the cutting board for about 30m-1hr in the sun.

Charcoal spreader stars

I am aware of the fact that pine charcoal is highly recommended for stars that emit lot's of golden sparks (they spread the charcoal sparks and hence the name).
I don't have any, although I can make some.
I find it simpler, to use barbecue charcoal and simply grind it.
I grind it either with a mortar and pestle (small amounts) or simply place it in a paper bag and use a wood mallet to break it to finer pieces. I sift the charcoal through a system of two nets: coarse mosquito net and flour net.
I use the sifted material through both. The coarse net provides me with fine charcoal grit (great for these charcoal spreaders) as well as charcoal powder (same use).

Charcoal spreader composition

This is my own composition.
I started with another mix and got to this one from trial and error.
Units are, of course, by weight.

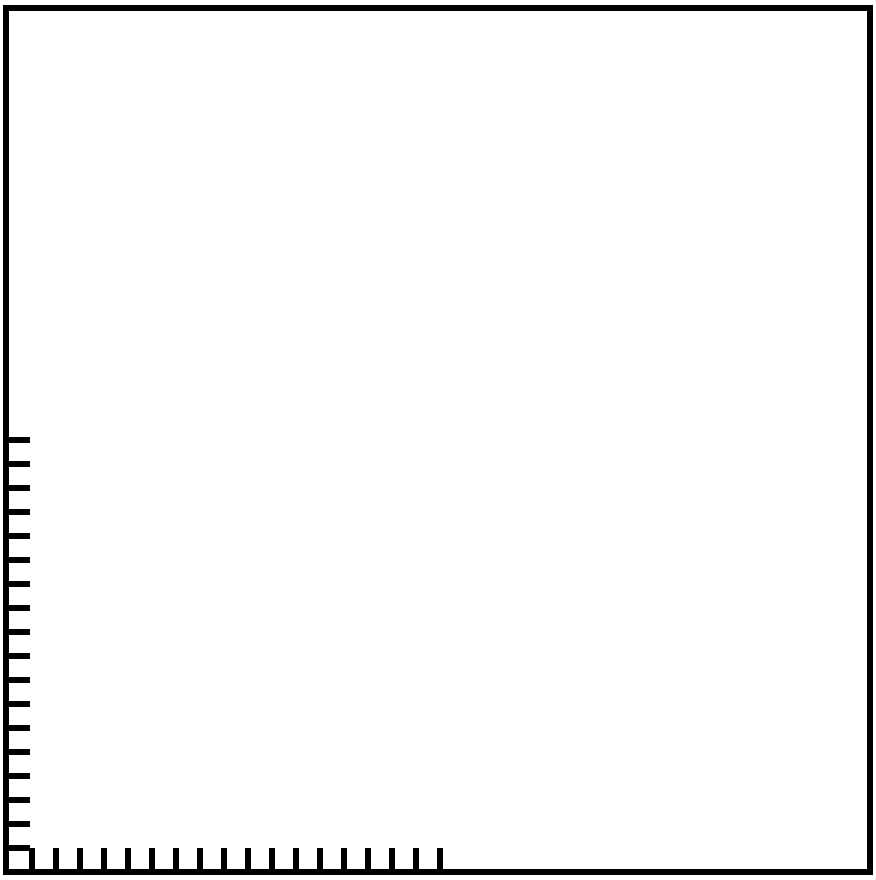
55 units KNO_3
10 sulfur
25 charcoal powder
5 charcoal grit.
+5% dextrin
Wetted with 30% ethanol.

Note:
I have substituted successfully the 5 charcoal grit with powder, getting 30units of powdered charcoal. The dextrin is a bit clumpy so I grind it by hand with some of the composition before mixing. Mixing is best done in a nylon bag by hand (kneading) – first when the composition is still dry (to thoroughly distribute the dextrin) and also after it's wet.

Star preparation methods

Sketch of cutting board

This is a simple glass or Formica plated wooden board.
Anything will do as long as it will not be dissolved by acetone or alcohol, and it must be smooth.
Each mark is 7mm apart from the next one.
I make 7x7x7mm stars as they fit my needs just fine.



After Ned started to write his wonderful articles on skylighter (www.skylighter.com, look for articles), I have built a similar system to the one he shows there for cut stars. This board is simpler and also less time consuming to build but is messier and requires some time to clean it well. Ned's method is simpler.

I chose this system for colored stars since I have very little amounts of the required chemicals and I have to use a little at a time. This fits my needs. I use this system only for colored stars.

Pumping charcoal stars

I use this method for charcoal spreaders. Not for colored stars.
After the composition has been thoroughly mixed (dry)
I add 20% volume per weight (e.g. 20cc to 100gr of mix) of 30% ethanol.
I keep kneading it until I feel it's homogenous.

My pumps are syringes with the top taken off.
Some of them have been equipped with a stopper that disallows me to push the piston completely out and/or with springs. I plan on adding the stoppers to all of them – I just have to find the time for it. Springs are more complex – I use what I have.

Below is a picture that will save me a thousand words.

I pull the syringe piston about 1.5 OD back, fill and press hard to make sure the composition is packed tightly – and then push the star out of the pump.
Sound simple right?
It is.

It's just plain hard after you try to do that with 100gr mix and a 9mm syringe (2.5cc syringe) you will see what I mean – plenty of stars but very annoying.
Dry in under a hot summer sun for two hours.

Rolled stars

I have a hand driven star roller…. But…
Rolling stars by hand is tedious and takes a LONG time…
This is my new electric star roller – homemade, of course.

This is a 220v motor attached to a large (my scale, of course) bowl. The black magnet you see attached to the bowl was a mixing experiment (trying to mix better the contents of the bowl (of course there is another magnet inside). A small fan cools down the motor.

As you can see I used the bowl large diameter as a spinning wheel or gear to slow down the RPM. It runs at 55rpm.

What you can't see in the picture is the hinge.
I originally attached it to a 90deg angle iron and bent it to the proper angle (by experimenting).

I tested the "proper" angle using small marbles, but as I discovered, the optimal angle varies when you shift from the light weight cores to the heavy stars.
I found this the first time after I added a spoon of star cores to the turning bowl and those got to fly all over the place, as the angle was too low

To this end I've built a pivot that is easily adjustable.

These are my cores
Small pasta beads are used as cores.
I forgot to add a charcoal spreader batch image, but that's not that crucial, is it?

I also developed a process to make a large batch with even star size:

Make/buy a small container that can hold your cores, with holes that will allow you to sprinkle the cores, just like adding salt and pepper to your salad. I used a film canister and made lots of holes in it using a scalpel.
Add some solvent into the box to make sure the star cores are wet and shake well.
I use a lousy liquor that is basically some food dye and 30% ethanol (I got it for free, and it works just fine). I prefer using 20-30% ethanol as the ethanol does not allow the nitrate crystals to form.

Place a small amount of star mix in the bowl and start the engine.
Now sprinkle the cores directly over the powder.
As soon as the cores hit the powder they are coated and will not stick to each other.

My standard batch is one spoon of baby formula (Similak). It contains about two hundred cores.

From that point I keep spraying the solvent and adding more powder. In the beginning I start with small quantities (half a spoon of powder and small squirts of solvent), and then quickly upscale. I make sure to wet the small stars and sprinkle them with the powder. The entire process (two hundred cores, 200gr of star composition, takes about 20 minutes.

One Key note:
The angle of the bowl is crucial.
As the cores are lighter in weight they spin at a different angle than the heavy stars.
Hence changing the angle during the preparations gives better results.
My stars are usually in the range of 9mm OD being 90% of the star product, very few (one or two) double stars are rarely seen, and the rest of the stars are either slightly larger or slightly smaller. This is a very good distribution with a fairly high Gaussian peak. I'm very happy with these results.

Cheap Isolation boxes

Safety is the no. 1 law.
I tend to explore star formulas as well as rocket propellant formulas (with my tiny list of available chemicals – tiny in number as well as in volume). My biggest concern is how safe is it to store some composition. I have to make sure it is not moisture sensitive or auto-combustible (aka death mix). Obviously I don't make sensitive compositions and I never make anything that is known to be dangerous (for example sulfur and chlorate mixes), and I always follow the well known list of "do not mix". Most of the time I simply burn all the remains after the tests – as most of my tested compositions are useless and there is no need for it anymore.
In the rare event that I do find something interesting - I need a way to find out if the formula is safe for storage in a long run.

I always make a 1gr test batch of each formula, and if it has been found useful – a 2gr storage batch is prepared to be used for the compound stability test. I store the batches in a safe place – locked and far away from flammables, people or pets. But I also want to protect my samples from each other – in case one ignites I don't want the others to follow.

How can this be done?
The storage box that holds each sample has to be:

1. made of cheap materials, widely available
2. fast and easy to build
3. Easy to handle
4. Function properly

The isolation boxes are designed to contain stars of unknown type, but not a lot of stars as this is an un tested batch. I usually keep these compositions in two tubes – one is open and one is sealed (to see if they are sensitive to humidity). I store them for a long period of time (3 years), and even then I always suspect them. The fact that some mix has not auto-ignited on its own during my test does NOT mean that it will never do!

Even after a compound has been certified (i.e. deemed "fairly safe") I never exceed a 10gr batch size. Even these compounds are kept in such containers.

Over the years I have designed several systems to this end.
I have ended up with two systems: an underwater system or the "wet system" and an interlocking cup system or the "dry system".

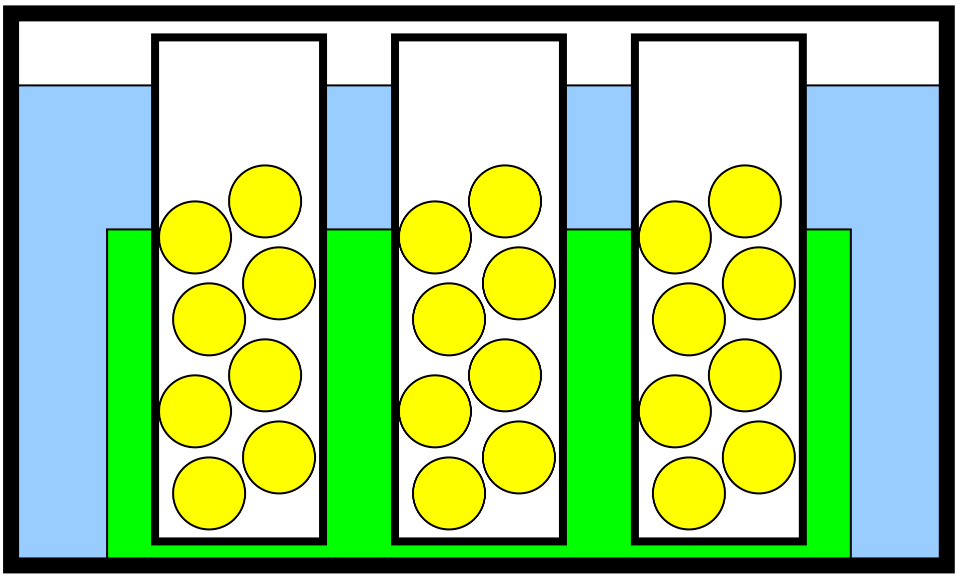
The underwater system

Underwater system – is designed to be self fire-extinguishing.
The stars are placed in a water and air tight container that has two large holes below the water line. The holes have been sealed with a thick nylon strip and hot melt glue. This results in a wall (the nylon coated area) that is very sensitive to heat and pressure. If the stars ignite – they will burn through and/or expand the nylon sheet to its breaking point. Hence, they will be drowned instantly with lots of cold water.

System advantages:
1. Un-ignited stars will never be able to ignite.
2. The stars will not fully ignite and burn – very little smoke output
3. No sparks or flame is emitted from the accident area.
4. Very safe and easy to use

There is one problem however – this system cannot be used with metallic based stars. Mg or Al will react with the water generating highly flammable hydrogen gas which can cause an explosion.

Cross section of the wet system

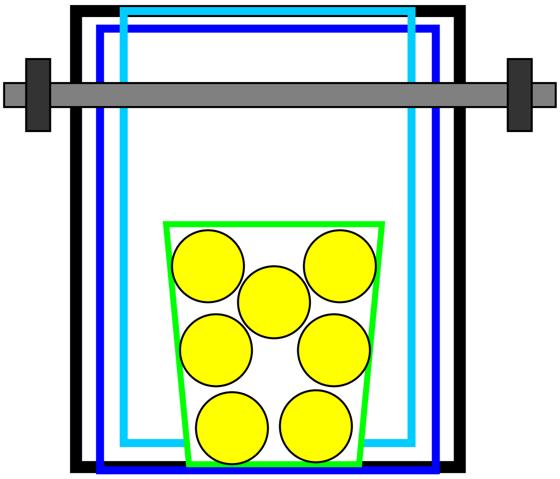


A big plastic box holds enough water (2 liter).
The plastic tubes are held upright with a (green) holder.
The lid of the plastic box prevents them from floating around, and I have added some lead weights to the bottom to make sure they sink instead of float.
The stars are inside the plastic tubes and as the tubes are air-tight the humidity in the tubes is kept low.
The main tank lid is not locked.
The idea is that if a tube ignites the gasses will be able to easily open the lid and escape – with no resulting explosion or damage to the box itself.

The interlocking cups system

This system is made of three types of tin cans – food grade tin cans.
The system allows air/gasses to be expelled out of the system (no pressure spike is allowed) but disallow any stars to be blown out of the system.

Cross section of the dry system



The big box is actually a can of canned tomatoes or baby food (depends on what I can get). It is connected (hot-melt or via an aluminum pin) to a canned mushroom can (the smallest). These two form the top of the system.

The bottom is a medium sized pickled cucumbers and it has a plastic cup attached that contains the stars (also connected with some hot-melt).

The system is locked by a long screw and two bolts at the ends.
To open I just remove one bolt and take out the rod. The cans have marks that tell me how to orient them so that I can lock the system again later.

The long screw makes sure the system will not be opened by the gas pressure of burning stars. I have tested the system with lots of stars (approx 40-30gr) mixing magnesium bases stars with charcoal spreaders that provide a lot of gas and sparks. The hot gasses have moved it (it flew a 1m high and 3m long path) – but only few sparks and colored star fragments were able to escape. It was red hot though.
Even if one of these boxes would ignite in a storage place – other boxes will shield their contents from the sparks and heat.

Here is the system opened:

Usually, I use some hot melt glue to place a small plastic cup here to hold the stars.

And here it is close:

Payloads

No doubt that every pyrotechnician would like a payload on a rocket (stars, shells and other fun configurations).
Rocketry fans and professionals also need a rocket payload (high tech speed/altitude/cameras/etc equipment).
These two groups just disagree on the payload kind and type.
I'm suggesting a "mid line" – stars for apogee detection (as I'm using extra primitive tools)... Nevertheless, I must confess that I do use pyro payloads for fun as well…

So this section is discussing payloads.
If you are looking for elegant, spherical, exactly-as-they-should-be payloads – attempts are discussed at the bottom of the section. However, this is not my expertise and don't expect expert tips.

As you can understand from the above I believe that almost any container can be used for shell building purposes. As you will see in this file, I make payloads out of almost everything. However, I highly recommend you to refrain from using glass and metal but all forms of paper and most forms of plastic will be just fine when using rice hulls and not flash. I would NOT use flash and PVC plastic containers – a rain of sharp plastic fragments is no fun.
Look around – there are countless forms of cardboard and plastic containers that could be used for simple and fun shells.
The options are limitless – depending on your sources.

OK… some will ask – why not make a nice, symmetrical shaped shell, lot's of sophisticated novel effects, new motors and their effects - just as it should be…?

Good question.
If you're displaying your skills to other pyro guys – go for it.
They will appreciate the skill, time, knowledge, efforts and all that work.
But -
If your display is for your non-pyro friends – don't bother.
They don't and they won't have a clue nor care as to:

- How many hours all that work took (that burns in 30sec up in the sky)
- What makes it symmetrical / colorful / fly / work so nice
- How did you do it.
- Etc.

Hence, in such cases: the simpler, the more colorful, and the less time consuming effects – the better.

Payloads - general

The rockets must have a type of fuse to pass the fire to the payload.
I usually drill two holes in my end plugs to make sure that at least one of the two fuses ignites the payload section. This takes a few more seconds – but I've never had a mishap with it so far.
I have had a few "blanks" in the past with single fuse systems… so I highly recommend the double fuse.

Simplest payload

When using small BP motors, like I do, drill holes at the top of the plug for the fuses, and insert the fuses (I usually insert one fuse – with both ends secured inside the holes.
Take a 2" wide paper based masking tape and roll around your rocket plug area twice. I use a metal rod that has the same OD as my rocket (12mm) and roll about 1cm (0.4") of masking tape on my rocket and 1-2mm (0.1" top) of masking tape on the metal rod at the same time. This way I can pull away the metal rod and it will detach itself quite easily. This results in a nice round tube of masking tape.
Fill with some BP grit, a star or two (don't spill any BP on the masking tape – use a funnel!) and seal the masking tape "tube" by pinching it to a flat surface.
Upon ignition the sealed area will open (unless flash is used) and launch the stars.
This is so simple and fast that it is one of my most favorites.

PPB shells

Ping pong ball shells. Well known shells and widely used, so I won't write much about these shells. This is a tip given to me from Doc Barr and others on PML (Thanks Doc!, guys). Excellent method. Too bad my cheap PPB supplier ran out of PPB's…
How to: Cut a triangular hole in one side of the ppb. The hole should be big enough to allow you to insert your stars easily, but not very large (less than a quarter of the ball surface). Cut a smaller hole opposite to the first one – and pass your quick-match through it. Secure the quick match with some hot-melt.
The quick match has to be well protected all the way to the tip.
Fill the ball with stars and allow for some space in the middle to be filled with rice hulls or rice hull substitute.
To close the lid – take another ppb and cut it to 4 large triangles.
Using hot-melt simply glue the larger triangle over the hole.
Another useful "glue" is NC laqour - I used it with good success.

Kinder egg shells

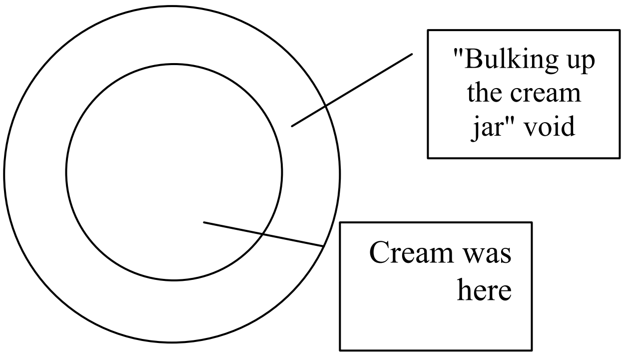
The old kinder egg shells are lovely.
They are my most favorite – small and simple.
They have two parts – major "body" and a "cap".
Just drill a hole at the bottom of the major half and add a quick match.
Fill with 3 10mm stars, a layer of rice hulls, and keep on filling.
Place the cap and secure. Lock it all up with some cello-tape around the rim. That's it.

FCS payload

FCS or Film Canister Shell is a well known payload in the field of pyrotechnics.
If I'm not mistaking, Doc Barr is the expert in these little great items.
What I do is as follows:
Drill a hole at the bottom of the canister and pass through a quick match.
Secure the quick match with some hot-melt.
The quick match has to be well protected all the way to the tip.
I fill the canister with my 10mm (0.4") stars (5 fit nicely on the rim of the canister) and top that with a single layer of hulls (see my millet hulls). I repeat the procedure to get about 4-5 layers of stars.
The canister lid is filled (rim only) with hot-melt glue and sealed tight.

Cream Jars

This is my most favorite "big" payload item!
I like cream jars – they have a wide rim and a central void (where the cream used to be). If you take the bottom of a cream jar you would usually see something like this:



To make a useful shell out of this item:
Drill a hole through the bottom of the jar and secure a quick match through it.
The quick match should reach the center of the cream chamber.
I simply pour in the stars and rice hull substitute in layers and screw the lid on.
It's that simple.
It will not give you a symmetrical break… but it's going to be a nice one.

Cream Jars – double burst

To really use the cream jars to their full potential you can use also the "bulking up void" – the rim void.
To do this I simply add two holes in the side and attach two quick matches that lead to the void at 180deg apart. The rim void is filled with black powder coarse grit, rice hull and stars.
The fuse leading to the cream void must be slower.
I simply inserted a homemade visco to a rubber tube (empty dual electrical leads tubes work nicely) and that's it.
This means that the rim void will "burst" before the main void does. It will nicely "burst" backwards to the flight trajectory (void) and then forward (main chamber) if you do it right.

The jar does survive the effects and it (theoretically, if you can find the bottom section and lid) can be re-used.

Urine cups

Yes… the same urine cups you give samples in.
I got a couple from a friend (unused, if you must ask).
I drilled the lid and fixed a quick match in it and filled the cup.
A small wood rod allowed me to make some room for the fuse.
Screwing the lid was quite sufficient confinement to allow most of the stars to ignite (I didn't count) and provided a nice burst and fairly loud bang.
This was a single attempt – but it was very satisfactory.

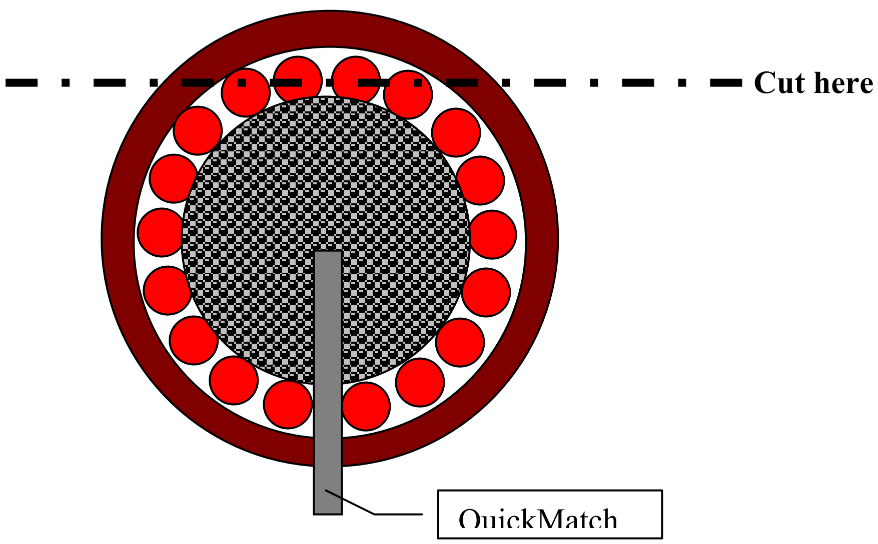
Tennis ball shells - symmetrical burst attempts

One day I was talking to a fried that plays tennis.
And it hit me – tennis balls are small (5cm or 2" inner diameter), even and very strong. Why not use these as shells???
First one needs a good glue to re-attach the sliced halves or other sections.

I have tested many glue types and found 3 good brands, listed according to their strengths (tested by hand):
1. The best (by far) was blue rubber glue from car tier repair shops. This glue is smeared on both surfaces and allowed to sit for a minute or so, until it is no longer shiny (but still "wet") and then make contact with the other hemisphere.
2. Quite good was the regular contact cement – apply the glue and contact the hemispheres. Don't let the glue dry separately and them attach the hals(as you would normally use it) but use wet and then allow the glue between joined halves to dry..
3. Black rubber glue specific kind

I decided to use two methods for these shells:
1. Hemispheres (cut into two halves)
2. Scalping (the tennis ball)

Here is a drawing of a shell inside:



In the first method I'll use standard methods of filling the tennis ball with stars around the inside surface and then filling the inner void with rice hulls substitute.
In the second method I sliced off the "top" of the tennis ball so there is little place in that section and the tennis ball interior volume is almost intact. I'll fill half of the shell as above, insert a sphere of tissue paper coating the rice hull substitute (with a protruding quick match) and insert it into place. Then I'll easily add the rest of the stars and push them to their final position.

In both methods, in an attempt to create an even break I added small slits (8 of them) at a cross formation that will tear open and widen when the internal pressure rises (at burst).

Final comments

I did a lot of tests and a lot of configurations.
Sadly I must admit in defeat. I am unable to make these little fun items break symmetrically (without flash). Of course the fault is due to the high elasticity of the tennis ball…
Still it was a fun project and an interesting one.
I learned a lot about glue types and bought a few new glue types to add to my collection.
I had lots of fun.

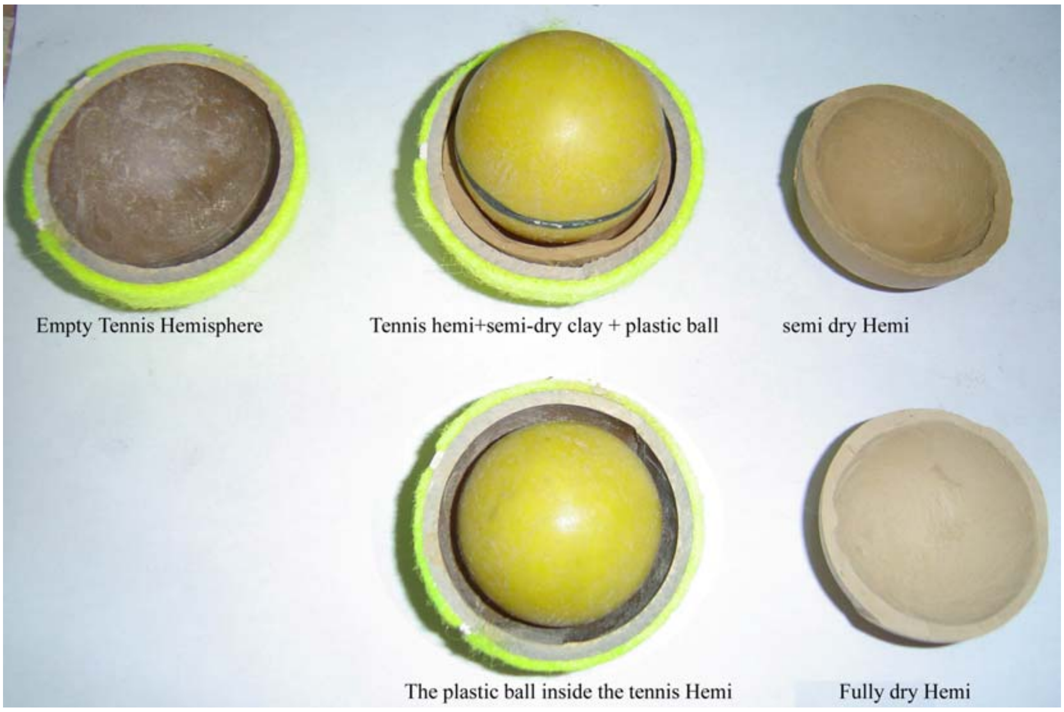
Clay hemispheres

I had some wet clay around (I used it for the desktop star tester) and I had some extra. I didn't have anything to do with it so I started thinking: I have tennis balls, a small plastic ball, that's a little smaller… 1+1=2, hence, clay hemis (short for hemispheres). So I took some clay, made a flat pancake, and placed it inside one half of a tennis ball. I then coated the small plastic ball with saran and pressed it into the clay, up to the midline. Then I pressed the ball against the tennis ball hemi. The ball came out easily and I peeled off the saran.

After about 8hr the clay was fully dry (it's summer and a hot summer too). The clay shrank and the hemi was free and did not adhere to the walls anymore.

The nice thing about it is that these spheres are environmentally friendly, including their bio-degradable paper coat… ;)

Here are some images.



I used Elmer wood glue and A4 printer paper strips or gummed tape (simpler but not cheaper) as the coat for the shell (I didn't have a source of brown craft paper initially). I built a small roller (that holds on to a 5cc syringe) for even elmer coat on the paper strips. I won't go into the details for now.

Launch report

The effect was near symmetrical, and was lovely.

Walnut shells

As digital cameras are taking over in our lives the old films are going to disappear. This means that the film canisters will also disappear and with them the film canister shells. I chose walnuts.

Why go nuts about it?
They hold 8-10 10mm stars (my standard size).
The shell is rigid and easy to handle
Cost is very low, and they are tasty too….
And of course they are biodegradable.

Store your walnutsells in pairs. If you don't you will have a mess and it's hard to tell them apart.

Take the two halves and fill them with stars.

Add rice hulls on top (I'm using Millet hulls, as you can see).

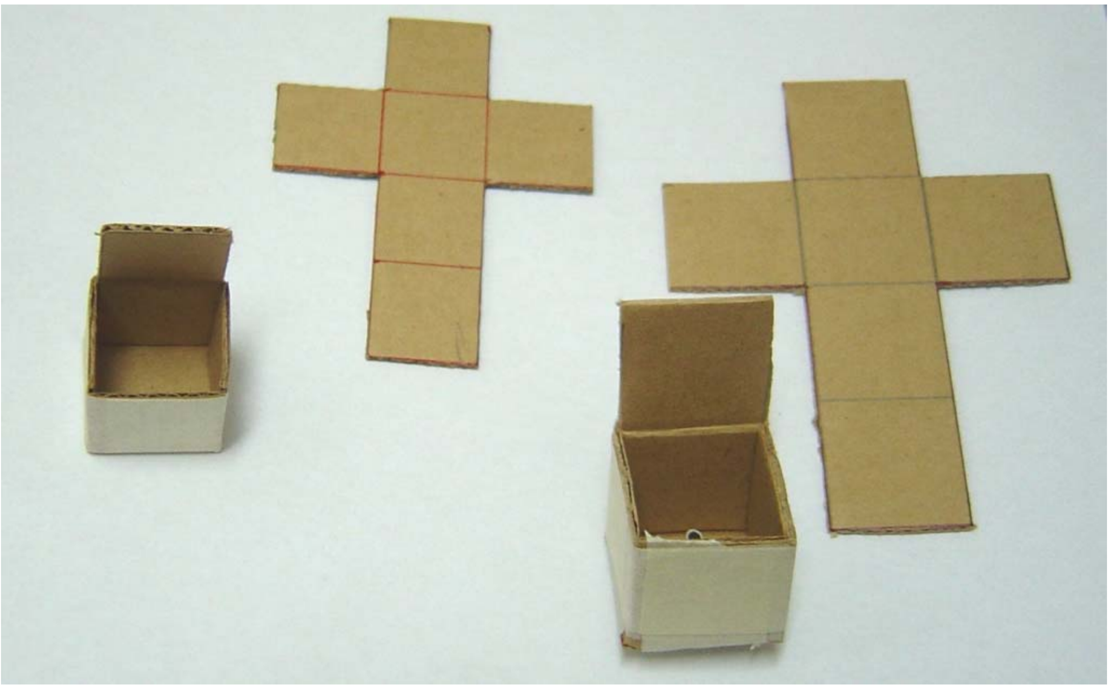
Add a fuse of your choice (I use quickmatch) and secure it with some hot-melt to the shell (orange line). Cut a square piece of masking tape (I use clear masking tape) so that it will cover most of the shell surface (red frame). Place it on the hemi with the fuse. Make sure the ends have properly adhered to the outer shell.

Sorry for the lousy quality.

Cover the edges of the other half with hot-melt glue.
Flip the masking tape secured hemi and lock the two halves together tightly, until the glue will cool enough to hold them.

The whole process takes about 5 minutes.
Not as fast as FCS preparation, but close enough.
I tested lots of coats. The best one was A4 paper with Elmer wood glue.
I already have prepared a simple glue coating machine that applies glue to one side of the paper strip. I'm using A4 printer paper, slicing it along the length 3 times (1/8 width). I heavily coated one of these shells with paper strips and I hope that this fairly thick coat (2-3mm, at least 10 wraps in every direction) will do a fair job and provide a nice break.
So much for just plain fun, but this is not realistic.
The next shell is the simplest and best alternative for FCS's.

Cube shells



Make your cross mold and cut accordingly new crosses.
Fold and secure with masking tape. The ones you see here are 3x3x3 and 2.5x2.5x2.5.
They work nicely and are easy to fill and use.
Yuv's tip – make the entry hole for the fuse in a corner.
This makes sure your coating process is easier and faster.
It's also better for a rocket payload to be pointy and create less drag.

FAST cube shells

Sept. 2007 update -
Cutting crosses from cardboard is an annoying task.
There must be something better – right? Yes there is.

Follow these instructions:
Cut a rectangle of cardboard that is X wide and 4X long (X is the box side length).
For example – a 2.5cm by 10cm long is what I use for my 2.5x2.5x2.5cm cube shells.

Now fold it in two, open and fold each half in two again. All folds should be in the same direction. Example: if you had folded a cardboard that is black on one side and white on the other, so that the black doesn't show up anymore, keep folding the blacks.

Open and use some gummed tape (gTape, for short) to secure the ends to each other.
Now what do we have?
A cube with the top and bottom missing, just the walls, right?

Use some more gTape: glue two strips of gTape at 90deg of tape at the "bottom side" making a bottom for your cube shell.
That's all there is to it.
Just fill it with your stars, place a fuse at one corner and use the same method to make the "roof" of the cube. Now start rolling on more layers of gTape.
The method I currently use is to roll one side, tilt at 90deg and roll again, tilt again at 90deg (covering the cube from all sides) – every time making a double layer of tape.
I repeat the procedure twice (i.e. eight layers of tape on each face of the cube – and if you don't believe me – count or do the math).

I use millet hulls for break and these work nicely.
As for the ideal coat thickness - this is just the beginning:
I have tested a wide variety of coats: 2, 3, 4 layers per roll X 8, 12, 16, 20 and 24 total layers. That translates to a lot of shells.
The best shells, the closest ones to symmetrical break were 3 layers per roll and 12 coats total. I believe the cubes may, under the pressure, in the very last millisecond before burst form a nice round sphere… John Collins disagrees with me… so we are having fun arguing about this. It remains to be seen. I'll keep on trying…

Bottom line – if you are looking for a simple method to make cheap and simple shells for your non-pyro friends, then this is the way to do it (in my humble opinion of course). \

Firing cube shells from a mortar

I have thought about it and I have a solution to the problem:
A thick cardboard disc with or without a thick gummed paper sleeve/skirt will form a platform that holds the cube shell in the mortar, stores the gas and blasts it up in the air.
A thin but strong rope will be attached to the platform so it can be re-used. The rope will be long enough to allow the platform to lose speed enough so that the rope won't tare.
This idea has been implemented and will be shortly tested. I will update this file with the results.

Quick and easy Gummed tape hemispheres

Hemispheres are usually made by pressing a male mold into a female mold with freshly glued cardboard sheets in between. The sheets take the form of the mold and a hemisphere emerges.
I don't have a press and it seems to me that the regular process using paper Mache will take too long for my needs. To this end I have developed a new system for making paper spheres. In this demonstration I'm using 32mm OD balls and 5cm wide (2") gummed tape. The final shell is fired from a 4cm ID mortar, or launched as a rocket payload.

You will need:
Gummed craft paper tape
A ball the size you wish for your sphere inner diameter
Scissors
Water

How to make them:

The tape glue seen here is activated with water. The tape is rolled on the ball to form a cylinder. The first roll is without water so the tape won't stick to the ball, and another roll with water.

The ball is placed at the center of the cylinder and in the future I will build a small base just for this. Currently this is made by placing the ball in the center of the gummed tape cylinder by hand. It works.
Now cut small nicks in the cardboard, about 1cm deep and 1cm wide. Four to six of them are required. This will form a structure like a flower petals.

Folding these petals, one after the other does the trick. To activate the glue make sure you wet the **outside** of the first petal and NOT the inside of the following petal. This way the petals are glued one to the other, and not to your ball mold. A better way to do that is to make sure that the outside of the new ball is the sticky side and not the inside. An even better idea (as I was told by a PML'er) is to use the tape sticky side out. I can't recall who it was (sorry, and thank you), but he was right.
This is how it should look:

Once both sides are done, hold the new sphere between your palms and roll, just like you would do to round a piece of play dough. Roll tightly, as hard as you can. You can also roll this on a flat surface too.
Cover the holes (if you have any) with a small piece of tape.

Now make another cylinder of tape at a 90deg to the first one.
Before you start working with this piece of tape fold it along its length and mark the midline with a pen or marker.
This time there should be no exposed surface of your ball mold and hence you can use a wet tape and the process is faster and easier.

Here it how it looks when done.

Perfect it's not, but it is round and nice.
Allow to dry overnight and then cut along the midline you marked before.
Open the two spheres and glue them together with a small piece of tape (so they will be perfectly aligned and ready to be filled.

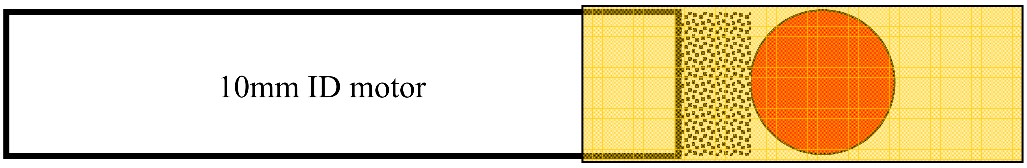
Presto. All you need now is to fill it with and finish the shell and launch it.
After filling with stars and burst I usually add a few more coats (around 6 or so) and add a fuse. Done.

Note:
From past experience I'm sure this shell can be easily done with craft paper (or even A4 paper strips) and Elmer wood glue if you don't have this type of gummed paper.

Star Ignition tester

Introduction

The project started, as usual, from a basic need – I needed to test my rocket propelled stars ignition and resolve problems.
Usually I simply roll a double layer of paper based masking tape on my 10mm ID, 12mm OD rockets, add a fuse (in advance) and some granular BP and a star. Then I simply crimp the sticky masking tape and that's it.
Like this:



At the time I had priming problems using my Mg colored stars.
It was also winter and my launch area is a 20min drive away – not reasonable to go, launch a single star, or set of stars, and get back for more tests… and so on.

Eventually, the solution was simple:
BP without sulfur was ball milled to fine powder (80:20).
35% Mg (weight) were added to the BP and bonded with NC laqour.
Usually for a 10gr colored star batch I add about 5gr of BP coat. On the top side, just before cutting the stars.
I simply add enough NC laqour to the star mix until it is dough like and then I make a small flat square cake which is 7mm tall. I pour on top of this cake the BP+Mg mix and that's it.

But to get to this simple solution I had to come up with some way to test the star priming inside my fume hood.

There were several problems:

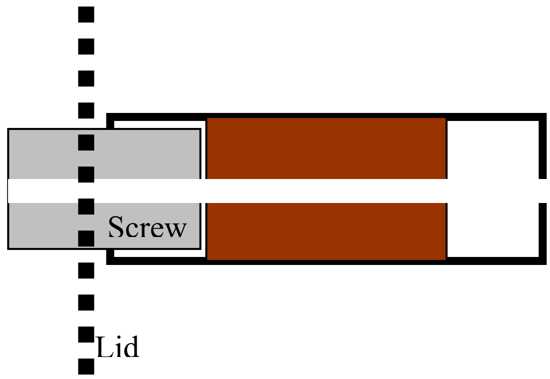
1. My fume hood is made of wood and I didn't want to burn holes in it.
2. I needed a system that would mimic the rocket heading I use
3. The system had to be cheap, easy to handle and prepare and effective.
4. Work well even if it's rainy out there… ;)

A fume hood star ignition tester

Take a "heavy duty" coffee can.
Drill holes in one side of the can (no need for more) so the gasses could escape easily, and so you could also see the color too.

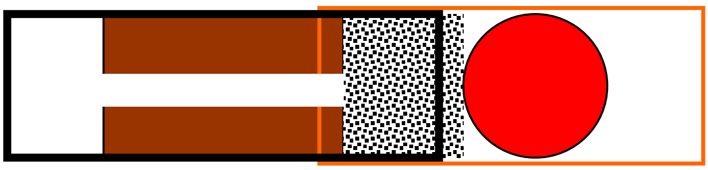
The holes must be smaller than the star in total. For my 7x7x7mm stars I drilled 5mm ID holes in the can, about 20 of them.

In the lid I added a screw with a hole in it – so I could pass a fuse (black match) to the "head".
An aluminum tube 12mm OD, 10mm ID was fitted on top of the screw mentioned above. It was fitted with a wood insert (also drilled thorough so the fuse could pass through it).



Not really fancy, nor too complex to make.

To use – the aluminum tube is rolled twice (exactly as I would do with a motor) with a paper based masking tape – about 1cm of masking tape rolled on the tube and the rest form a new open tube, filled with BP and a star.
Like this:



And then the tape is sealed.
The fuse is inserted through the screw and tube. The coffee can body is screwed back into the can lid and the fuse is lit.
If all goes well the star will ignite and burn inside the box. It will never, in theory, (and so far they have never) leave the box, but instead burn at the bottom of the box.

I had my share of blind firings using this system until I reached the satisfying prime that I'm using today and it's been great ever since.
The ease of this system is that you can apply the prime on a hot afternoon and when you get the time – to test the stars without leaving the house or annoying your neighbors every time. It doesn't matter if it rains outside or not – I can do the tests I wish with various prime types at any given time.

Assembly and cleaning are easy and take only a few seconds.

You CAN see the color of the star you made – through the holes.

One important note – use a heavy lead or other weight on top of your tin can – or it will hop inside your fume hood.
I'm not adding a video of such a test as it will be a waste of web space – but if you are interested ask me and I'll make one and send it to you by mail.

Here are a picture of the setup I use.
This is a bottom view, so you can see the legs of the system, the fuse hole and the holes in the can:

Desktop Star Color Tester

Introduction

Any pyrotechnics master will tell you – stars are BEST tested while flying in the night sky. Some compositions may not even burn properly or give a proper color in a ground test.

Why?
I'm no expert but I'm told that as the star falls in the night sky it has a wind factor that provides oxygen, speeds up the burn rate and removes the gasses it emits. This allows for a clear color view and good burn characteristics, which are obviously different than those of a star burning on the ground.

To this end there are several methods to test a star. It has to be in flight so -
Some use a star tester stand – basically a tube, some BP lift and a star. Some use mini-rockets, as so do I, some launch it from a star gun (steel or cardboard tube) and so on.

But – this is annoying.
You have to drive to the launch field (or go out back if you're lucky) and it's impossible to launch on a rainy day with heavy rains – bottom line it takes money, petrol and time.

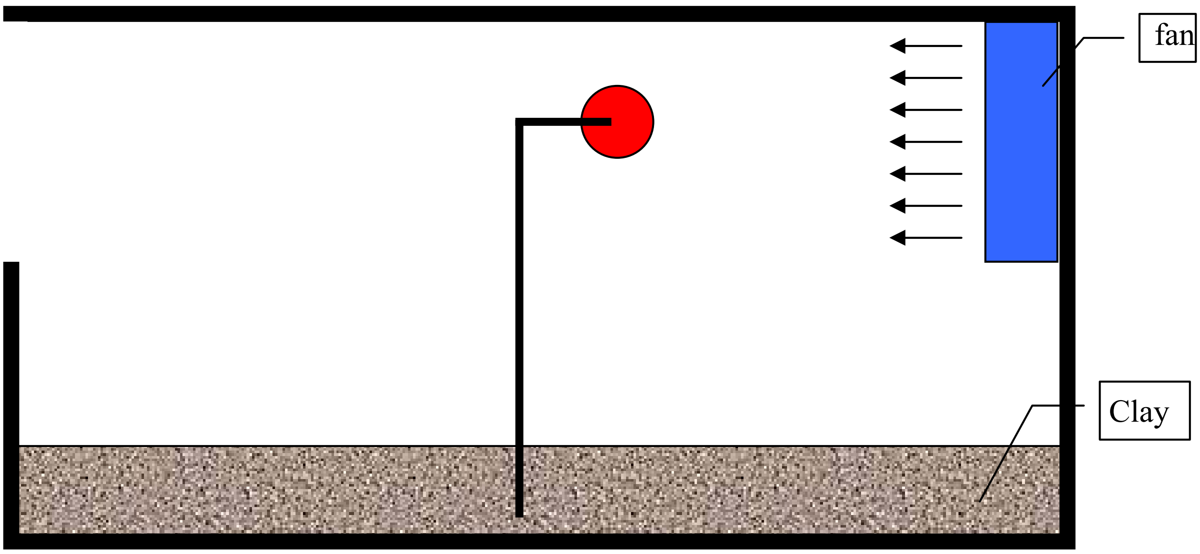
So what am I offering?
A device that will test stars on your desktop/bench (inside a fume hood if it's indoors) or in open air near your garage.
It has to be low cost, easy to manipulate and reliable.
It has to accommodate a small star you can make, buy or get (it can be up-scaled for larger star setups, btw).

The basics

If you choose to work indoors the first and most essential thing you will need is a hood, a chemical fume hood to be exact.
It's fairly simple – a wood/plastic box with a fireproof bottom like clay or tiles or wood + metal/clay cover. Make a nice hole and attach a vent using a long tube (same one used for laundry dryers to take the hot air out). Make sure there are no turns in the tube (as much a possible) – more turns means slower air movement and less/slower gas flow.
My hood is made of wood and I simply coated the bottom with heavy duty aluminum foil and burn everything in a clay base that I've made, or in a ceramics dinner plate.
I use it for a wide variety of things – testing new fuse batches, testing small motors and so on. All small items can be tested there. Even small flash samples (0.1gr – not more!) are possible.

The star tester

My star tester is made of a computer power supply unit.
It has a nice strong box and a small vent. The box is used as a frame and the vent blows air towards the star – mimicking the star flight in the night air. The metal box is cut at one side and place a Plexiglas window. The bottom is fitted with a wood plate and clay cover. The clay protects the wood and the wood holds a steel rod. The rod is bent at a 90deg angle at the top and a star can be placed on top of it.
A small hole at the top or side allows to insert a fuse (black match / visco).



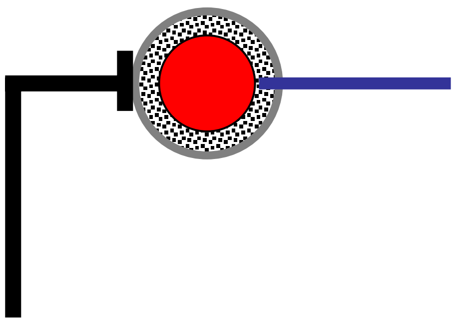
Here it is:

Ignition of the tested star

Obviously a simple fuse (point contact and point ignition) would be the simplest.
It will give you a good color test (which is the reason for building such an item in the first place) – but it will not provide a good overall ignition comparison test.

If you would like to check an overall ignition simulation you could try this:
Take a metal/wood rod the same OD of the holder rod in the tester, and place it in your star hole. Make a small cup of aluminum foil and fill with some (very little) granular BP. Secure a thin fuse along the metal rod touching the star and fold the foil, while making sure the star is covered all over with granular BP.
[An alternative could be to dip the star in NC laqour or other pyro-adhesive and dip it again in grit-BP, which will stick to its outer surface]
Twist the foil so that it holds on to the fuse/rod.
Take the rod out and insert the system on the tester system. Ignite.

Something like this:

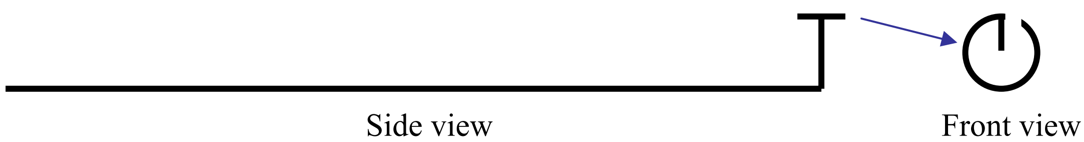


Fuse in blue
Star in red
Al. foil envelope in gray and BP grit inside.
Steel rod in black.

To test ignition like in a real shell: high pressure, shock waves, impacts with other stars and all that – it's a bit more tricky but can be done:
Build a shell!

Securing the star

The simplest way to hold the star while burning is as follows:
Take a paper clip and straighten it to obtain a fairly straight wire.
Fold it at a 90deg angle (see the image) and use pliers to twist the end to the following shape:
Make a circle (with small pliers) and bend the end at a 90 deg angle.
It should look like this:



Assuming that your star is NOT sensitive to the heat of hot-melt glue – THIS MUST BE TESTED IN ADVANCE!!! – place a small pearl of hot sticky hot-melt glue on the metal circle and secure your star. Add some hot-melt from the back side if necessary – to properly secure the star.

Stick your fuse directly onto the star and add some hot-melt on top of the fuse so that it will drip onto the star and bind them both. As soon as the fuse ignites the star the hot-melt drop will fall off.
Cello type can also be used to bind the visco/black match to the star – but hot-melt is faster and easier.

Using the star tester

Just slide away the Plexiglas window, and place the star +steel rod into its place.
With some masking tape, cello-type or hot-melt glue to secure the fuse to the star.
Close the window.
Turn on the fume hood vent
Turn on the star tester fan
Ignite the fuse.
That's all there is to it.
A video camera would be very useful – it can tell you the burn time, show you the burn progress frame by frame (using the Microsoft movie editor, for example), allow you to strip a single image and save it to compare the color with other stars, and so on.

Bottom line -
It's working nicely!

Flash tester

Safety

I do NOT recommend you to use flash or make flash.
Al-KNO3 based flash is unstable and can go off without warning. Al reacts with the nitrate and this will cause auto-ignition at an unexpected time (and without warning)!
Permanganate flash is also auto-decomposing and is considered unstable and very dangerous.
KP-Al is considered safer, but still it's **extremely dangerous** and will cause severe damage without much provocation.

Flash is the most dangerous composition in the pyro field and it must be handled safely.
The flash mixes I make are NEVER over 1gr (for two reasons – I wish to keep my 10 fingers and I have tiny amounts of the required chemicals).
I rarely do make or use flash for these reasons.
As always – full face mask, hearing protection, leather gloves, and a fire extinguisher are a must. I ware cotton cloths and watch out for static electricity.

Introduction

I have to admit – I love pyrotechnics, I love rocketry even more – but I hate bangs.
I have sensitive ear drums and I really dislike bangs.
My friends always find this amusing…

So…
One day I wanted to crudely compare flash.
I wanted to compare some KNO3-sulfur-Al flash (VERY dangerous – I really don't recommend this one) to permanganate-Al flash (again – not recommended and very unstable), and also KP-Al (considered safer, but as always – a serious hazard).
I also thought that other metal additives/compositions would be interesting.

To this end I designed about 5 systems and one by one, they failed - until the last one.
The first four were rigid and were designed to withstand the force of the explosion.
The crackers were 4.5mm straws, 4cm long (see below).
All these systems were demolished on the first trial, with less than 0.1gr of flash.
Then, one day, I was inspired by a McDonalds cup – soft and flexible.
Soft and flexible might be better than strong and rigid, I thought…
I tried it – dipping a cracker into the cup (with a water protected fuse) - and it left a huge stain all over the place. I had to clean the bathroom for over an hour!
Bottom line – the cup survived… and this lead me to the current, working, setup.

Underwater test rig

Design

My design is based on a flat metal plate (coffee can metal plate).
The bottom of the plate was glued to a flat piece of Styrofoam, to cushion the impact on the bottom of a bucket (full of water, of course).
A heavy weight makes sure it will rest on the bottom of a bucket and stays there too.
An insulated wire ends with an Ematch - the folded ends of the wire hold a steel wool wire are used for best results. The wire goes through a small rectangular block of epoxy that holds the flash containing straw.
The electrical wires run thorough a 40cm long plastic sleeve (from another electric wire, with its internal wires removed) and this makes sure they stay dry. The sleeve goes from the surface of the water all the way down to the system.

As you know - a picture is worth a thousand words… it's on the next page.

The straw is placed on the epoxy rectangle (not seen, as it's covered by the straw). The wires (not seen) go through the plastic sleeve (white) and into the metal pipe. The sleeve is secured with lots of hot-melt (also inside the metal tube). This allows the wires running through the system to stay dry.

Ignition

As you already understand E-matching is a key word here.
BUT – no pyrogen, just bare wire. Why? Because this will shift the results, as you don't know how much pyrogen is in the match.

Your system must not rely on fuses – they will get wet, they will surprise you and they will annoy you, even if they are theoretically water proof.

Preparation

First, make lots of straws tubes by "welding" the ends: take a plier, hold the straw tight with just a millimeter of straw protruding, and warm that strip of flat straw with a lighter. It will melt and stay that way (this method was developed by Dan Pollino).
Prepare your Ematch – place a steel wool and fold the ends of the wires over it to form a bridge. Cut the access steel wool.

I take the composition, fill to 3/4 of the straw and set it aside.
Place the straw on the systems cone.

If it's not holding properly I can always secure it with some hot-melt.
The hot-melt does not bind the epoxy cone and it will drop off with not too much resistance, which makes it easy to clean and replace it after placing a new straw…

I immediately sink the system into a bucket full of water and use my 12v transformer to do the rest - a white bright flash is seen, a few bubbles go up, and you can hear a very faint "thump". You can feel a weak shockwave if you're barefoot.

Tips

Don't use nichrome wire. Use thick (sort them out from the fine) steel wool wires. NiCr wire will burn through the straw before it will ignite the flash – and water will rush in.

If your steel wool wire isn't igniting the flash (Al. conducts the electricity to some extent) apply a constant and very small amount of BP powder on top of the wire – that will react with the wire first…

After each experiments – snip the ends of the wire and prepare a fresh Ematch from the new ends.

Results

KNO_3-Al flash is the weakest.
Permanganate flash is equal to KP flash.
Additions of flake Al, grit Mg, grit Al, fine Mg – only ruin the effect (I had high hopes of a flash and burning flakes/grit… no such luck). These tests, btw, were repeated in the open air.

Firecrackers

Introduction

As you already know, I'm not fund of loud bangs.
This is kind of weird for a pyro hobbyist – but I'm much more of a rocketry lover, and this fits - rocketry people don't like to see their rockets go "boom".
Anyway – back to the subject – from time to time I get this tingling feeling in my fingers and then I know I have to do something about firecrackers…

If I ever try to list all my experiments in this subject the file will be very long (it is very long – I keep full record of all the things I do). I'll give you the short version.

Goal

Simple, VERY cheap, easy to make and, of course, from highly available items.
I found the ultimate (for me that is) tube – a straw.
McDonald straws are 8.5mm ID, Regular straws come in 3 sizes: 6mm ID, 4.5mm ID and 3mm ID.
I made firecrackers with these using either flash powder - which I'm a bit scared of flash powder I limit myself to 1gr of flash at a time (say once or twice a year – I told you I'm not a bang lover), or grit BP. The BP has to be in fine grit – the finer the better.

Making firecrackers using straws

My Tube ID vs. Tube length rule of thumb

There is a rule of thumb which I have discovered during my underwater experiments.
Tube ID X 9ID tube length = optimal bang decibel.
For a 4.5mm cracker I used a 4cm long straw.
Fill 3/4 of the tube and no more.
Filling less or more than 3/4 makes a big difference, although the difference between filling 1/2 to 3/4 isn't that bad.

Ingredients

Straws of several sizes
Black match – as thin as you can make it. Visco will do the trick too probably. I never used it. My black match (the thin version) is 1-1.2mm OD.
Hot melt
Masking tape (paper based)
Black powder grit / flash powder

Making the firecracker

Take the straw and cut it.
I have tested the length of the 4.5mm ID straws – the optimal length is 4cm.
3mm ID straws – 3cm long
4.5mm ID straws – 4cm
6mm ID straws – 5.5cm

Take your hot-melt gun and glue one end – 3-5mm thick plug will do the trick nicely. I place then with the hot-melt plug down on top of a piece of paper, allow the hot-melt to cool and simply take them off the paper.

While the tubes plugs are cooling off I start to cut strips of masking tape. I use the thin brand (1/2" wide) and cut 0.5-1" long strips.
I have 10cm (4") sections of black match already prepared and I simply fold the last 1.5cm and roll the masking tape on the double stranded black match section.
This section will act like quickmatch – please take it into consideration.

After the fuses are set and the plug has cooled off it's time for assembly.
I fill the tubes 3/4 full with the BP grit or flash and insert my fuse. Before inserting the fuse place an O-ring of molten hot-melt glue around the front edge of the masking tape. Insert the fuse and twist slightly to allow the hot-melt glue to hold all around.
That's it.

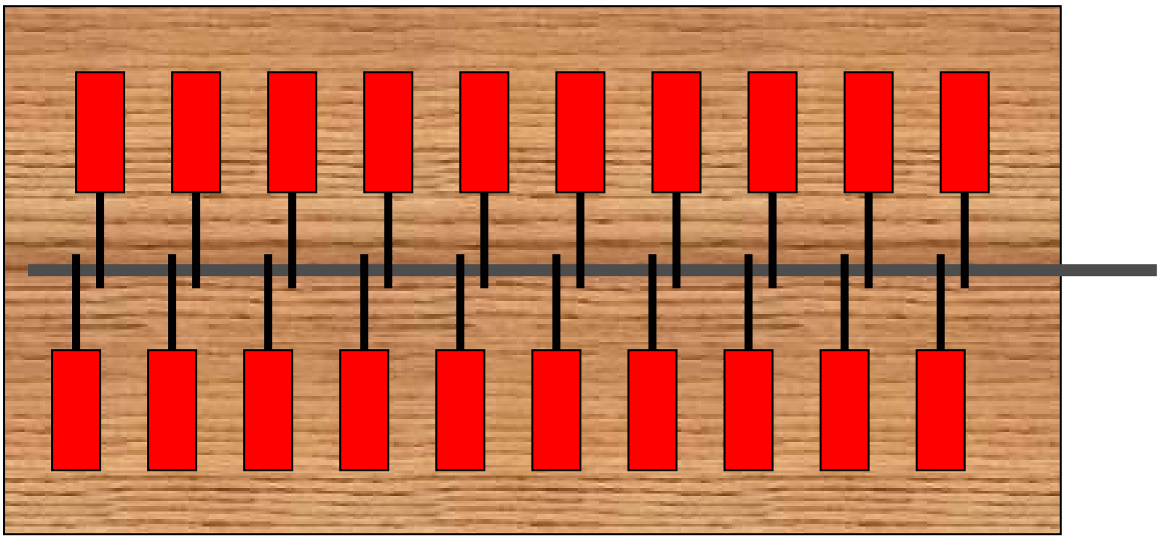
Firecracker strings I

So you made a bunch of these little fun items and you want them to go one after the other… Hand stringing firecrackers doesn't sound like much fun to me…
So here is the simpler way:

Take a flat cardboard/tile/wood/whatever flat surface you have.
Plug that hot-melt gun back into the socket
Get a long visco/black match/some powdered BP near bye.

After the hot-melt is ready to go – place a tiny dab of hot-melt at side of a firecracker and glue it to the board, so that the firecracker is placed along the board with the fuse pointing towards the middle line of the board. Repeat this with all your firecrackers. The distance of each firecracker from the next one, as well as the method of ignition, will determine how fast they will go off.
Now place your black match/visco/BP powder train along the middle line of the board and (safely) ignite it. I recommend that you secure the visco or black match in some way, either to the fuses of the firecrackers or to the tile/cardboard. A few spots of hot-melt along the fuse will do the trick.

It should look (more or less) like this:



The gray line represents your black match fuse that ignites all the firecrackers.

Firecracker strings II

I'm lazy.
That's why I like to invent – it saves me time and money and its fun too.

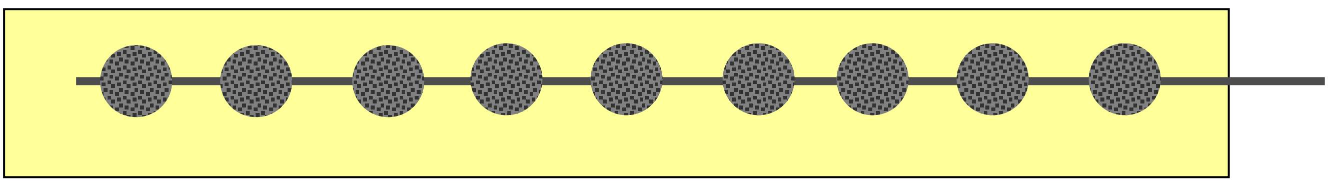
Tools and ingredients
Paper based masking tape (wide version – 2" or 5cm) or heavy duty masking tape (the brand with the gauze imbedded inside).
BP fine grit / Flash
Black match/Visco.
I recommend a thin version of black match (~1mm OD for paper based masking tape and thicker versions for the heavy duty masking tape)

Place and hold (with other small strips of masking tape) a long line of masking tape on your work area, with the sticky side up, of course.
Stick a longer black match along the length of the masking tape.
Place small piles of BP or flash, on top of the black match lead, along the length of the masking tape.
Place another strip of masking tape on top of the first one, sticky side to sticky side.
Press gently. Press on the black match wire tight (in areas where there is no flash/BP grit) to slow down the burn rate.
When you ignite the extruding black match it will burn fairly fast inside the masking tape and ignite the flash/BP.

Tricks and fine tuning
1. The further the "piles" of flash/BP grit are from one to another – the more time interval you get from one "pop" to the other.
2. Paper based masking tape tends to "open up" due to the force of the burning flash/BP – make sure you have a distance of at least 2" or 5cm between the spots. The stronger masking tape will hold better and you can use shorter distances and it will also provide a bigger bang.
3. You don't need a lot of flash/BP grit for these – I use a soda straw (6mm ID) that is 1cm or ~1/2" long to make my "piles".
4. Make your first tests with fine BP grit and then move on to flash.

Your mileage may vary depending on the type of the masking tape, the glue strength and your BP/flash quality/type. Hence, please remember to calibrate your setup.

The strip of masking tape with the black match string and piles of flash/BP grit should look like this (just before you place the top section on):



The beauty of this method is that you have virtually no limitation on the length of the firecracker string, you can time the "pops" and you can combine several strings as you please. Also it's a fast and easy method to play with, and it's a fun project for kids (I recommend that you use BP grit with kids).

MISCELLANEOUS

Balloon Rocket

I was playing with my kid the other day – he loves balloons – and I started thinking:
Why don't balloons fly in a straight line???
Well… a floppy flexible and constantly "on the move" nozzle is one reason for sure.
Another reason is probably the lack of guidance.

I can fix that, can't I?
After all – I'm not a rocket scientist for nothing (even if I am slightly ignorant, tiny scale amateur rocketry lover)

So –

1. I took a thin plastic tube, approx. that ID of the balloon "nozzle" and secured that in place with a rubber band.
2. I took a couple of sticks (don't ask why I didn't use one… I just grabbed whatever was close to me in the heat of the moment)
3. The first rubber band at the bottom of the "nozzle" was used primarily to seal the balloon "nozzle" to the plastic tube. It was also used to secure the sticks in place.
4. Another rubber band to secure it to top section of the plastic tube.

This rubbery setup allowed me to turn the plastic tube sideways and fill the balloon with air - and then return everything to a good-to-launch orientation (along the axis) hold it for a few seconds till it's steady and not flopping around – "3,2,1, launch!".

Here it is:

I can't really say that all the flights were very straight – but I did get a few straight ones. Anyway it's far superior to the normal random balloon flight.

It's a lovely toy for kids, easy to make and fun indoors as well as outdoors.
You could add a small straw (masking tape it to the balloon) and a string to guide it…

Safety notes

1. Do remember to secure the bottom of the stick(s) with a blob of hot-melt/sponge or something else soft – so no one gets hurt if the balloon-rocket hits anyone.
2. While using indoors – make sure that there are no fragile precious/expensive/irreplaceable items waiting out in the open in the launch room ("launch chamber"???) – those balloon rockets can go wild sometimes…).

Update

In the meantime I have experimented with lots of tubes, nozzles and all sorts of things. I now have a better understanding of how to make the rockets fly much straighter:

1. The tube you use must be longer than the balloon nozzle extension.
2. You must tie down (with a rubber band) the most upper section of the balloon so that when you inflate it you will have an almost symmetrical sphere – not an oval balloon but a ball. This will make sure it will not tilt on its side and flex as it flies (well… as much as possible).
3. The larger the plastic tube you use – the better, and the faster it will fly.
4. **The optimal tube for these balloons is a 5cc syringe – cut the top and bottom with a sharp knife (be carefull) or saw them off. Make sure the ends are smooth and nice.** Thin paper tubes are also great – but they have a high ware and tear due to the high humidity conditions… ;)
5. Use of rubber band – 3 tight turns at the top will ensure there is no leakage from the side and the air will go only through your nozzle. 3 more turns to tie the stick – going down (don't tie the stick at one point – it will be unstable and so will be the baloon-rocket).
6. Use a **double-long stick** – one hot-melt glued to the other to get a long stick

Follow these rules and you will have a really nice, straight flying balloon rocket.

Also – it's a great fun test to tie weights (paper clips will do just fine) to the rocket, until it "stays still" in the air. I have one of these and it's fun to see how they hover in the air for a second or two… the paper clips are, in fact, a good thrust meter.

Balloon-CD hovercraft

A good friend introduced me to these items and I thought I should write about this one just in case you didn't hear of it, and especially if you don't have kids.
It took me about five minutes to build one and my kids love it.
Go borrow a plain water screw cap off one of your water or soap bottles. Choose the ones you can pull and get soap/water.
Hot melt it to a used and useless CD, and center it.
Using a rubber band secure a balloon to the cap.

How to use it

Clear a nice long table.
Open the cap and inflate the balloon through the other side of the CD.
Once the balloon is full press on the cap and seal it.
Place the hovercraft on the table and pull to open the cap – air will rush through the cap, passing through the hole in the CD and will spread evenly, and lift the craft. Now push the craft (in the base, push the cap, not the balloon) and it will glide gently on the table until the balloon will run out of air.

Tip of the day

Go to the local library/book store and buy a good book - pyro or anything else you prefer.
Grab a snack and something to drink.
Make one hovercraft per kid and give these to your kids.
Clear the table and show them how to use it.
Don't forget to tell them they can write their names on it, paint and add stickers.
You have now at least 1hr to yourself – read your book, eat the snacks and drink your beverage and relax...

p.s.
I'll try and add a picture soon..

Water rocket

I always wanted to make a water rocket, but never got to it.
After reading James Yawn's great page (great site too, one of my most favorite sites on KNS motors) I decided to make one.
James has a great way of simplifying things – such as the nozzle issue.
So I will leave it up to his nice water rocket page to explain the details.
http://www.jamesyawn.com/h2o/index.html

My water rocket is supposed to be (still untested) a VTVL – vertical take off , vertical landing (legs first). The heavy legs will make sure it will land feet first, and the chute makes sure it stays vertical. I have made a smaller version of this concept years ago and it worked nicely.

I'll say no more – the next images will do the rest.

Images

END