Casting Ball Milling Media

Figure 1: Lead media after substantial usage.

Figure 2: Lead filled brass after substantial usage.

Figure 3: Lead filled brass with rounded ends.

Introduction:
Ball milling is by far the most popular method among fireworks hobbyists for grinding raw chemicals and making black powder. This method employs jars full of small balls or cylinders, known as "media" in the milling trade, which are tumbled in milling jars filled with composition.

There are several different materials commonly used to make ball mill media. All of the types mentioned below have various trade-offs, but they will all effectively pulverize your pyrotechnic materials.

Ceramic Media:
The most common commercially made media is made from various types of ceramic. Ceramic media can be purchased in a variety of shapes and sizes, including radius ended cylinders, balls, cones, ribbed balls and others. Ceramic media features very smooth and hard surfaces that optimize milling. It is also the most common option for those who can not manufacture their own media.

Some people have reported chipping problems with ceramic, but in general this is not an issue. Ball mills do not mill via impact, unless they are improperly designed, so this is generally not a problem. Media with sharp edges or other surface features prone to chipping should not be used.

The most commonly raised concern about milling with ceramic media is the risk of sparking. There are many types of ceramic media, and some may contain silica particles which could produce sparks, but for the most part this is not a problem. The key is to know the type of media that you have and purchase it from a well known manufacturer such as CoorsTek, who claim that their media does not spark.

Even when using a non-sparking type of ceramic media, milling metals such as titanium or steel could result in impurities becoming lodged in the ceramic pores, contaminating the media with impurities that introduce a sparking hazard. While used ceramic media can be purchased for under $3/lb from some suppliers, the lack of knowledge about prior use would raise concerns in this area.

Another test you can perform is to take your media into a dark room and strike it against each other to check for visible sparks. Some people have reported orange sparks during this test, while others report nothing. Note that some forms of light output known as triboluminescence actually produce "cold sparks" that are incapable of causing accidental ignition. However, any visible sparks should cause concern.

Figure 4: Ceramic media.

Lead Media:
Lead media is probably the second most common milling material, mainly because it is cheap and easy to melt and cast. Because lead is so heavy, it grinds with more force than other types of media. Lead does not produce any spark risks and can be used to mill any type of pyrotechnic compound.

The surface of lead is very porous, which reduces the grinding efficiency by trapping pockets of material that do not get ground. Because lead is such a soft metal, it tends to wear away over time. This has raised concerns by some who fear breathing the smoke generated by components made from meal powder contaminated with lead during milling.

Figure 5: Cutting 1" segments from a long brass tube.

The amount of wear and surface deformities can be reduced by using lead hardened with antimony, as opposed to pure lead. Figure 1 shows some lead media made from tire weights after two years of extensive use. The mushroomed ends show how the lead changes form over time, since they were originally flat ended cylinders. From an efficiency standpoint, there is no noticeable difference between the milling time of this media when compared to the brass media pictured below it.

Brass Media:
Brass media is also a popular choice, since brass bar stock can be purchased and cut into small segments to use as media. Brass doesn't spark, is still fairly heavy, resists corrosion and has a smooth grinding surface. The only down side is the presence of copper in the metal, which can react to form sensitive byproducts when milling certain chemicals such as ammonium perchlorate.

Figure 6: 140 segments required for one 6" jar.

Stainless Steel Media:
While not very commonly used, stainless steel is perhaps the best media available. Stainless doesn't spark, has a very smooth surface, is heavy, is resistant to wear, is resistant to corrosion and can be used to mill all types of chemicals. There are many different types of stainless, but the ideal grade should be copper free and high in nickel-chrome content, such as 310S24 or 316S16. Having a machine shop produce 140 pieces of 3/4" stainless media about an 1" long and rounded on both ends might be an expensive way to go, but the resulting media would last a lifetime and perform quite well.

Lead-Brass Hybrid Media:
The media described in this article combines the best characteristics of brass and lead, while also making the method of production easier. Brass sleeves are filled with lead, resulting in a smoother and deformation resistant media that leverages the increased weight and low cost advantages of lead.

Figure 7: Drilling out the tube holding fixture.

Figure 2 shows a flat ended cylinder shape, whereas Figure 3 shows a version where the lead was cast to give spherical ends. The rounded ends help to lock the sleeve in place, hide the sharp edge of the brass sleeves and reduce compression stress that can cause the sleeve to mushroom after a long period of use. While the rounded ends are also supposed to increase milling efficiency, there is no noticeable difference. The rounded ends also expose more lead to the grinding process, which can result in more lead contamination.

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Figure 8: Propane camping stove and melting pot.

Figure 9: Buring the gas tank to keep melting pot low and stable.

Figure 10: Using a cage to extract metal tabs from tire weights after melting them.

Casting the Media:
A typical milling jar measuring 6" diameter and about 9" long has a volume of one gallon. The proper media charge for ball milling is generally 50% of the jar volume. Using less than this amount in an attempt save on media or grind more material at once will greatly increase milling times. The 50% rule, when used in conjunction with lift bars in your milling jar, has been determined to maximize the milling efficiency by maximizing the slope of the tumbling pile of media when inside the jar (known as the "angle of repose" in the milling industry). The greater this slope is, the more aggressive the cascading action is and the faster your powder will be ground.

To make enough media for a one gallon jar, you will need to fabricate 140 individual cylinders measuring 1" long and 3/4" diameter. This will also require about 22 lbs of lead to fill all the cylinders.

The most tedious part of making a batch of media using this method is cutting the 140 sections of 1" tube. The brass tube used here were purchased in six foot lengths from McMaster Carr. The tubes are 3/4" O.D. with a .065" thick wall. The thinner tubes will not hold up under the stresses of milling and will crack off after a while, so be sure to use at least the .065" wall thickness.

Begin by marking a cutting point every 1" on the pipe, then use a pipe cutter as shown in Figure 5 to cut each segment. The pipe cutter helps to round over each end, which takes the edge off and keeps the lead from falling out once it is poured inside. If you straight cut the tubes using a hack saw or cutoff saw, the lead will get knocked out of your tubes during use (unless you make the type of media shown in Figure 12 and 13, in which case the lead overhangs the end of the tube wall). Using a piece of rubber will help you grip the tube in one hand while cutting all these segments. Figure 6 shows a couple feet of tubing converted into media casings.

Once all the tubes are cut, a fixture is needed to hold them while they are being filled with lead. This is easily made by drilling a bunch of 3/4" holes into a piece of scrap wood. Don't make the holes deeper than 1/2" or it will be difficult to remove the tubes after they have been filled. If you use a spade bit to drill the holes, you will need to fill the pointed cavity at the bottom with plaster or wood putty before you use the plate, other wise you will have big spikes on one end of your media after pouring them. The other option is to leave the holes and cut the spikes off after they have been poured.

The lead can be melted in a metal cooking pot using a propane camping stove as seen in Figure 8. A metal ladle is also required for transferring the molten lead into each mold.

Working with molten lead is a dangerous activity that requires several precautions. Because dangerous lead fumes will be generated, this activity


Figure 11: Using the ladel to pour each tube.

should only be done outside. Gloves, eye protection, a good respirator and long sleeve pants/shirt are mandatory at all times in the presence of molten lead. The lead pot should be kept as low to the ground as possible and firmly secured to keep it from getting knocked over. I prefer to bury the propane tank and surround the pot with bricks in order to lock it in place (see Figure 9 and 10).

Because I am using tire weights for the source of lead, the metal tabs must be removed after the lead is melted away. I do this by fabricating a basket out of wire screen scraps, as seen in Figure 10. The basket is filled with tire weights, then lowered into the pot using a pair of long metal tongs. When the lead melts away, the basket is removed and the remaining metal tabs are dumped out.


Figure 12: Rounded molds made with a plunge router and a 3/4" half round bit.

Figure 11 shows the holding fixture loaded with brass sleeves that are being poured with lead. Scrape away any slag on the surface of the lead before scooping up a ladle full for pouring. Since the lead will actually shrink some upon hardening, it is best to fill each tube half way and then go back and fill them the rest of the way with a second pour. When topping them off, fill them as high as possible so that the lead actually bulges beyond the rim of the tube. Avoid falling short by a small amount from the top of any tube, as adding a small second pour after the previous lead hardens usually results in a poor bond between the two layers. This can result in the added lead actually breaking away from the end during milling.

Any tubes that are not filled to the top after the lead hardens can be repaired by pouring a small amount on top, letting it solidify and then re-heating it with a blow torch until both the new lead and the lead underneath it melt together. Extra caution should be used when doing this, as trapped moisture can sometimes cause the lead to "boil" or splatter.


Figure 13: Capping both ends of a brass tube with the half round mold blocks.

Once all the cylinders are filled, they will remain hot for quite some time and the wood around them will begin getting charred. I prefer to use vice grips to remove each cylinder and throw them into a bucket of cold water so I can start the next batch. The first batch of cylinders will be a little hard to remove, but successive batches get easier.

Making Rounded Ends:
If you want to make media so that each end is rounded, a special set of rounded molds are made that fit onto each end of the brass sleeve. These molds are cut into scraps of 3/4" thick wood using the half round router bit shown in Figure 12. A plunge router with a depth stop is used to make many holes in a larger piece of wood, then the wood is cut into squares so that each square had a single rounded hole in it. Half of the molds are then drilled with a 1/4" hole, which is where the lead will be poured.

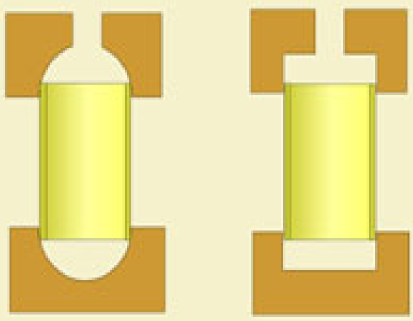
Figure 14: Two types of molds for creating radius ended media.

Figure 13 shows how the mold set is used. The sleeve is sandwiched between the two molds, which is then set into a bedding of sand while the lead is poured through the small hole in the top. Since the wood gets pretty charred by the time you make a dozen pours, the mold gets too lose after a while and must be discarded.

If you don't have a plunge router, you can still make radius ended media by using the second mold profile shown in Figure 14. This mold is created by simply drilling a cylindrical cavity and inserting the tube only partially into it. The media will have squared off ends when first cast, but these will be quickly beat into a spherical shape after using them in your ball mill. The nice thing about this method is that it lets you control the length of the lead that extends beyond each end of the tube.

It will likely take you the better part of a day to make your own batch of milling media. This may seem like a lot of work when you could just go buy some ceramic media. Then again, you could just go buy your own fireworks as well, so take pride in your hand crafted media and happy milling!