The Explosion of a Ball Milling Jar

The sound of the other shoe

(1997)

By Lloyd E. Sponenburgh

Ever since I wrote the original articles on how to build a ball mill (AFN November 1995), I wondered how destructive an event it would be if a mill of my design were to explode while milling black powder. It was like waiting for the sound of the other shoe dropping – would it be catastrophic or just a mild explosion?

For three 'pyro seasons' I have been trying to arrange a test of an exploding mill. Finally, with the help of the Florida Pyrotechnics Arts Guild and its very professional safety committee, and thanks to the kind hosting and ditch-digging help of Wallace Bullock, we were able to create a test.

I had read other pyrotechnicians' accounts of mill explosions. From their stories, I generalized that such an explosion would be a pretty gentle and unimpressive thing. But my mill had that 'rocket engine'of a milling jar on it. And I didn't know – I just didn't know…

For those who are unfamiliar with the mill I'm discussing, a short redux is in order. My ball mill uses an 8-inch long piece of Schedule 3035 PVC pipe with an end cap and a reducing coupling to form the milling jar. The small end of the reducer is sealed shut with a rubber plumber's 'test cap'. The jar's empty capacity is one gallon. It holds one half-gallon of milling media – in this case, twenty-nine pounds of ¾" diameter lead balls – and one quart of material to be milled.

For the test we proposed, the material to be milled was black powder. One quart of finely milled powder weighs about six hundred grams (about 1-1/3 pounds).

To record the forces of the test, we built a 'witness box' of ½" CDX plywood 18"W x 24"H x 48"L. We assembled the box with 1-1/4" drywall screws; one every eight inches. The mill jar was positioned inside the box, suspended approximately in the middle of the enclosure on a lightweight PVC pedestal. The jar was about the same distance from the walls of the witness box as it would be from the walls of the finished ball mill enclosure with the lid of the ball mill closed.

We intended the witness box to display any damage that might occur from flying pieces of the jar or from flying milling balls. Indentations or holes in the plywood would manifest the flight of any shrapnel. We soon nicknamed the box "the coffin". It turned out to be an aptly chosen name.

Some of us feared that milling balls would be hurled with great velocity from the exploding jar. I personally believed that the rubber test cap would 'balloon', then fail, and the jar would be projected like a rocket endwise in the test box, with the contents of the jar ejecting endwise in the opposite direction. I presumed that based on my perception of the slowness of burning of finely powdered meal, as opposed to the energetic burn rate of good, grained powder.

We all got our individual surprises. As you'll see later, we should have feared dangers greater than we invented.

With the help of Wallace Bullock and his automatic shovel (a tractor-mounted back hoe) we quickly fashioned a pit to isolate and contain the explosion. We dug the pit about three feet deep, three feet wide, and six feet long; shallow, but a suitable size for a grave!

We placed the bottom plate of the witness box flat on the bottom of the pit. We charged the jar with twenty-nine pounds of ¾" diameter lead balls and six hundred grams of well milled meal powder. I milled the meal *in that jar and with that media* for three hours before the test. We used the common 75-15-10 mixture with commercial air-float charcoal and vulcanizing grade sulfur. (N*ote – this is not nearly so energetic a mix as some black powder made with 'custom' home-made charcoals, like willow or buckthorn, and not anything like as energetic as commercial grained powder!)*

A ***shielded*** Davey electric igniter (Part # SA-2001) was placed approximately centered end-to-end in the jar and lying on the surface of the pile of media, then the jar was sealed with the rubber test cap. The e-match leads were thin enough to allow the rubber cap to seal the jar as well as if they had not been present. The jar was then *carefully, slowly turned* until the mass of material inside was 'sloped' or piled up one side of the jar, as it would be during normal ball mill operation.

*This particular, **potentially dangerous** concession to accuracy is why a shielded e-match was used. If any milling balls were to fall upon the match while the jar was being turned, we didn't want them to ignite the match by impact. The plastic shield on the match prevents any but extremely vigorous impacts from igniting it accidentally from friction or impact.*

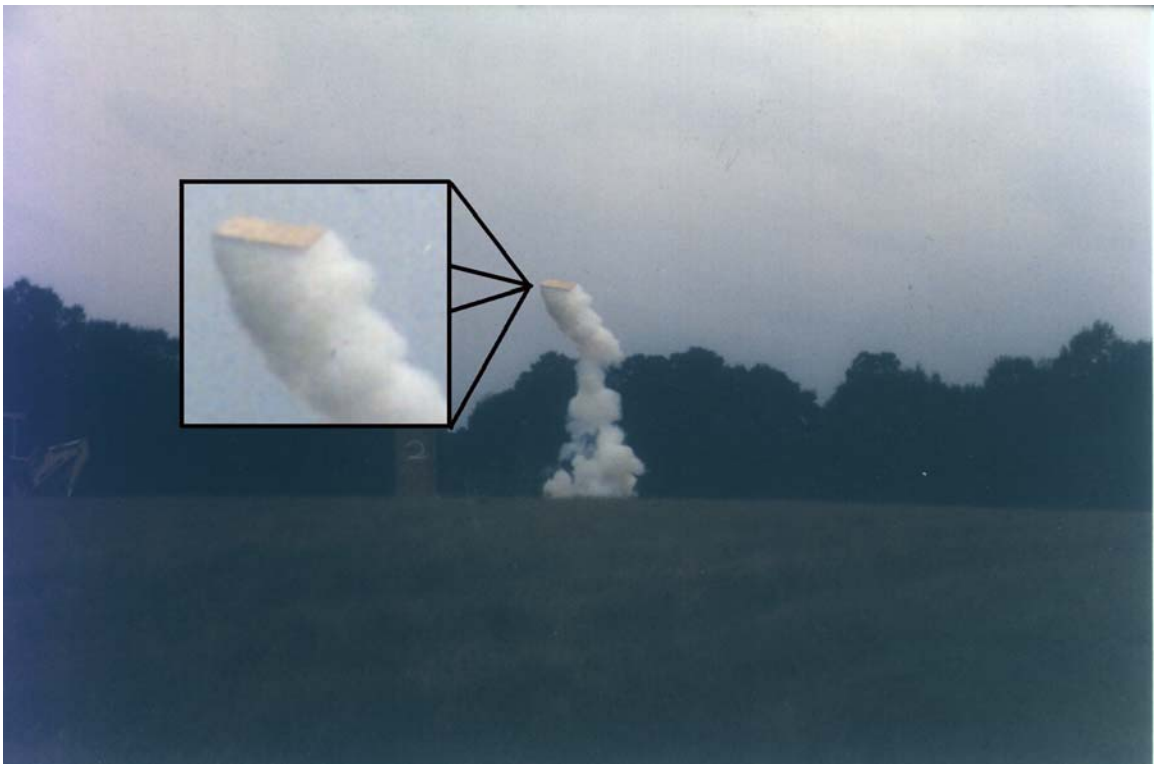
Once we conditioned the jar for the test, we poised it upon its perch in the center of the witness box and closed the box. A shunted length of shooting wire was spliced to the e-match leads, and we spooled out two hundred feet of wire to the viewing site. Joe Ruggieri kindly loaned us an "authentic blasting box" with which to perform our ceremony of destruction.

The milling jar on its support before closing the witness box.

The ‘coffin’ in its ‘grave’, ready to explode.

Our safety crew made radio calls around the range announcing the test about to happen. Shouts of “look out” and “look up” were heard here and there about the field. We counted down together, and I twisted the crank on the blaster.

For the tiniest (probably only mental) fraction of a second I thought, “Nothing’s happened.” No sooner had I thought it than I was greeted by a gut-thumping ***BOOM*** much deeper and more ‘throaty’ than a mortar’s muzzle blast – and we saw a wide, tall column of smoke rising from the test pit. Atop this forty-foot white pillar rode the intact top of the witness box, as prettily as if the smoke had been a fountain of water!



The explosion, with the lid of the witness box in flight.

There were wide eyes, grins, and knowing nods among the viewers; this was *neat stuff*! Our crew was already trekking back to the test pit when the witness box lid finally touched down. It had flown higher than fifty feet, and landed about fifty feet from the test site.

As soon as we saw the devastation in the pit, we ***knew*** we had a duty to inform others of what could happen. If we did nothing else, we had to get out the word that milling black powder indoors or near dwellings was ***a bad idea!***

Evidence of a cataclysm in the pit.

The explosion had completely shattered the mill jar. I was partly exonerated in my opinion about the jar taking flight, because the base of the jar had flown the length of the box with enough velocity to imprint the PVC pipe company's logo and end-cap nomenclature on the end plate of the witness box.

Imprint (with readable nomenclature) of the jar's end cap in the test box walls. Note, oddly, that the cap struck somewhat off-center from the main force of the explosion. This indicates that the jar did not disintegrate uniformly.

However, the jar must have been in the act of shattering to bits at that very instant it struck and passed through the end plate, because no piece of the jar (or the thicker and stronger fittings) larger than a few square inches was found anywhere. No visible 'strike' of the intact jar was seen in the dirt walls of the pit just outside the box. Pieces of PVC were embedded in the pit walls. The guys who had bet the jar would explode violently and completely were correct.

The biggest surprise was that the lead milling media did not fly far from the blast. We recovered just over 60% of the milling balls. The ball recovered furthest from the pit was only fifteen feet from the explosion's center. It's reasonable to assume that some balls went further, but they did not travel with much speed. Even those balls that impacted the soft clay walls of the pit left only shallow impressions. I think that the lead milling media would not pose a serious risk as projectiles in such an explosion. I think that lighter media like ceramic or glass *would* be a hazard.

But there is a *serious* risk of shrapnel from the milling jar. The day of the test, we found pieces of PVC over seventy-five feet from the pit. Remember that they had to travel up *and* out to get out of the test pit. During subsequent trash cleanup, pieces of plastic were found over one hundred feet away.

Every piece of plastic was razor-edged! Most pieces had knife-like points. Pieces of PVC were embedded deeply in the test pit walls. The plywood witness box – made of

tough Southern Yellow Pine plywood – was deeply gouged and cut where the plastic struck.

We didn't include a roasting chicken in our test, like the C.P.S.C. does when it wants to show the newspapers how dangerous M-80's are. But we were convinced that the plastic shards would have easily penetrated a person's abdominal wall. They certainly would have shredded and maimed the hands or face of anyone unlucky enough to have been close to the exploding jar.

The test was a sobering reminder that this art of ours can be dangerous if we don't control it. The rule of fireworking to "minimize, isolate, and contain" applies as much to milling black powder it does to mixing flash.

What did we learn? Personally, I learned that six hundred grams of black powder is *a lot of explosive.* I guess it never impressed me that much before. It does now.

Never mill more material at one time than you must.

We learned that, while PVC makes a cheap and effective milling vessel, it can be very dangerous if a mill explodes. We confirmed what we have been teaching:

Never mill pyrotechnic mixtures indoors or near a dwelling.
ALWAYS start and stop your mill remotely.
If possible, place your mill in a strong, separate building or bunker.

I hold the same opinions about a 'less dangerous' milling vessel, like a rubber tumbler. The shrapnel hazard might be reduced, but the force of the explosion we saw was great. A person's being near it would have been a bad idea. Caps, clamps, and closure hardware could become projectiles as dangerous as the PVC fragments we saw. Treat any milling vessel as a potential bomb.

Our test confirmed what we already knew intuitively and from industrial history -- milling black powder is dangerous. If you mill your own powder, mill in a safe, remote location no less than one hundred feet from any occupied buildings. Start and stop your mill from a safe distance.

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