SUGAR SHOT to SPACE

MiniSShot

ProtoSShot-M Short Stack

Review of Propellant Casting Session held August 31, 2008

Rev.2008/09/17

Introduction

This report endeavours to review the outcome, in terms of “lessons learned”, of the propellant casting session that was held on August 31, 2008. The primary purpose of this casting session was to try out the new casting apparatus (Figs.1 & 2) and procedures. A secondary objective was to produce three grains suitable for the *ProtoSShot-M “Short Stack”* motor as well as one spare grain.

The procedure outlined in the casting guidance document *ProtoSShot-M Mark II and ProtoSShot Short Stack Propellant Casting Guide* (Rev.2008/08/14) was followed closely. There were only two significant deviations: the potassium nitrate was not neutralized per the document due to time constraints, and the vibrating table motor burnt out after the first grain was cast. An alternative vibrating “massager” was used when casting the three remaining grains, but was later deemed to have questionable effectiveness.

Figures 1 and 2 illustrate the new apparatus that was used for the first time during this casting session.

Participants in this casting session were Matt Campbell, Brent Dougherty, Chris King and Rick Maschek.

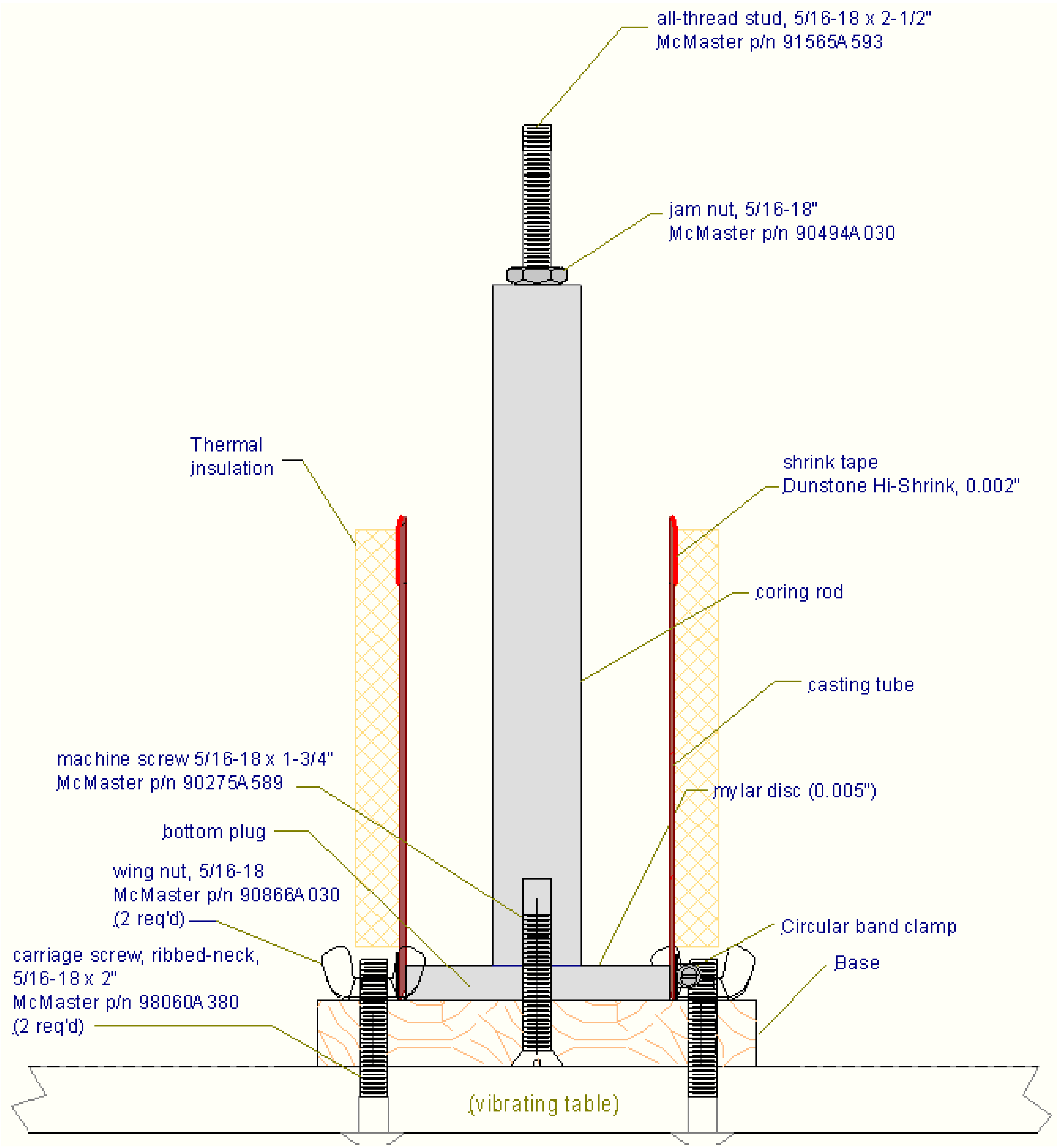


Figure 1 – Casting apparatus set-up for propellant loading operation.

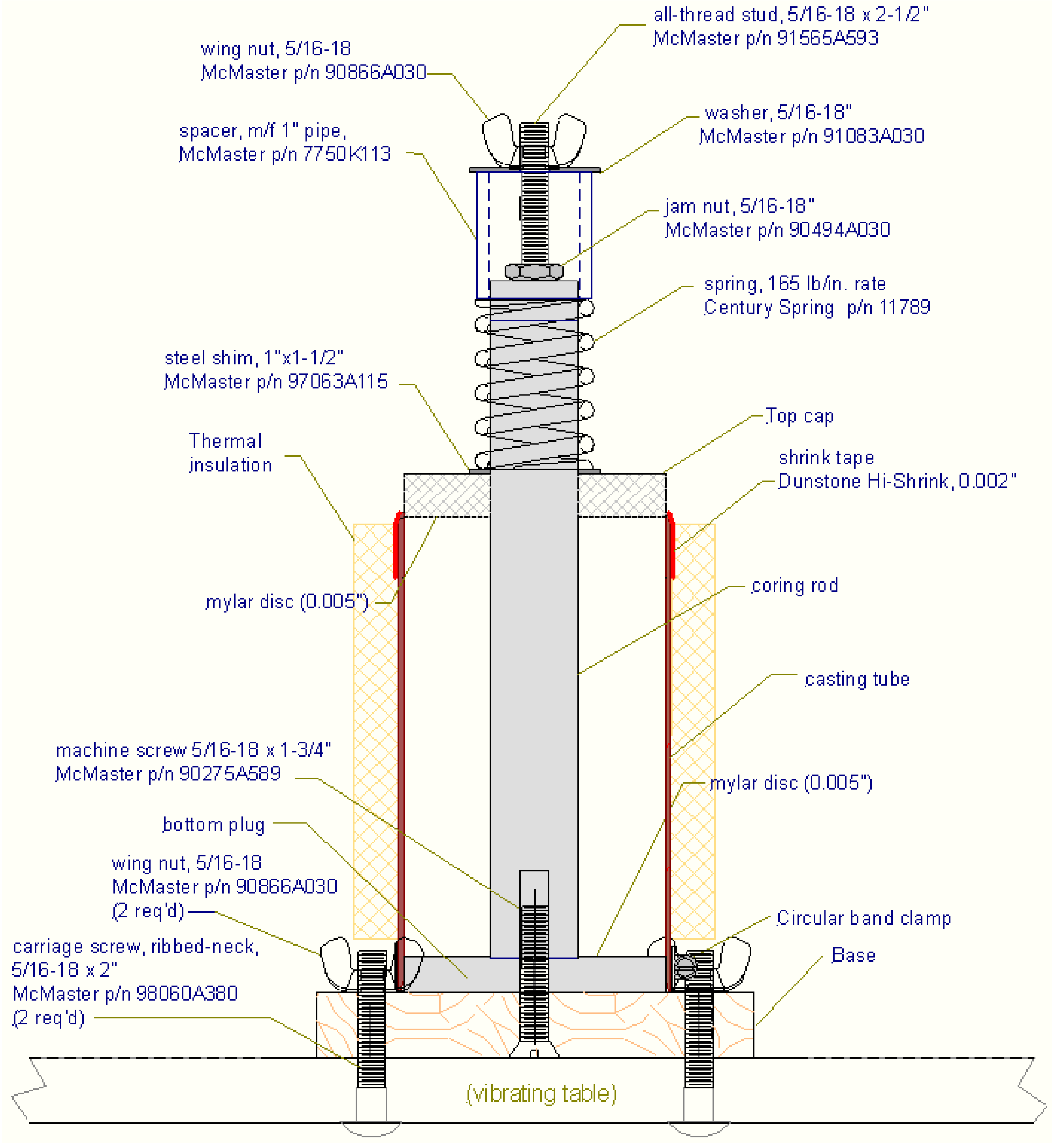


Figure 2 – Casting apparatus set-up for clamping propellant during curing.

Discussion

Things that worked well

Overall the casting operation went well and the casting document served as an accurate and useful guide. The components of the casting apparatus fit together and assembled well, for the most part. As expected , the vibrating table was very effective in settling the propellant in the casting tube. It was unclear, however, as to whether the vibration-induced motion of the propellant was effective in eliminating air bubbles. The propellant viscosity appeared to be less than the previous casting operation held in April 2008. It was unclear as to why this was so, but it may have been due to differences in the potassium nitrate stock. The following summarizes what went well:

1. The procedure outlined in the casting document was good.

1. Vibration helped with loading the slurry into the casting tubes.

2. Vibration appeared to aid air removal from the slurry.

3. Insulation blankets worked well.

4. Intumescent paint did not interfere with casting .

5. Shrink tape was effective in keeping casting tubes clean.

6. Bottom Plugs and Top Caps fit well in the casting tube.

7. Mylar discs were effective in preventing propellant bonding.

8. The propellant loaded into the casting tubes by pouring.

Things that did not work well

During setup, it was found that the coring rods did not fit through the hole in the Top Cap and it was necessary to slightly enlargen these holes. Measurements of the pH of the potassium nitrate showed it to be highly alkaline. Due to time and other constraints, pH balancing was not performed properly and the resulting slurry was a light tan colour indicative of thermal degradation of the impurity. During the casting operation, the vibrating table motor began to smoke and burnt out shortly thereafter. As such, only the first grain cast was subjected to proper vibration. A “massage” tool was used on the subsequent grains (only) after the propellant was poured into the casting tubes in an attempt to dispel any trapped air. The grains that resulted from this casting session were discoloured and had defects, as described in the following summary of things that did not work well:

1. Coring rod was too tight a fit through Top Cap central hole.

2. Top Cap tended to tip and bind in casting tube when spring pressure applied.

3. Casting tubes had to be express-delivered (expensive) to arrive on time and had to be painted at last minute compromising drying time.

4. pH balancing attempt of KNO_3 was not effective (documented procedure was not followed).

5. Too many casting tubes on the vibrating table – tended to get in the way during casting.

6. Vibrator motor failed after only a single casting.
7. Forgot to apply mould-release on one of the coring rods.
8. Propellant chipped on bottom surface during coring rod removal (reference Figure 3).
9. The grain top surfaces were not smooth as expected (reference Figure 4).
10. The propellant density was much lower than expected (reference Table 1).
11. Order of casting was not recorded.
12. Coring rod attachment screws tended to loosen during vibration.

Discussion of Issues and Suggested Corrective Actions

The following is a list of corrective actions that can be implemented in order to overcome the things that did not work well:

1. Have the remaining batch of Top Caps made suitably larger.
2. Make certain that the Top Cap is placed evenly on top of the propellant surface and make a visual inspection to ensure it does not tip.
3. Logistics in preparation of the casting sessions need to be better managed.
4. Procure a neutral pH batch of potassium nitrate to eliminate the need for pH balancing, which is probably of limited effectiveness anyway.
5. Have the vibrating table hold only a single grain segment.
6. Use a more powerful motor for the vibrating table and do sufficient testing of the table beforehand to ensure motor is durable.
7. The requirement of adding mould release to the coring rods should be documented in the casting guide to eliminate the likelihood of forgetting this step.
8. The propellant chipped on the bottom surfaces because the coring rods were not to blueprint (had a chamfer at each end). This and other similar issues can be resolved by making sure all parts are made to blueprint.
9. The grain top surfaces were not smooth possibly because the propellant had begun to set by the time the full clamping pressure was applied. This was done 10 hours post-casting, which was the maximum specified in the casting guide. Clamping should instead be performed as soon as the propellant begins to cool and no longer has a tendency to ooze out of the mould due to the application of clamping pressure.

   Another possible reason for uneven top surfaces is that the clamping pressure may have been insufficient. The springs have a load rating of 165 lbs/inch and when fully compressed, produce a force of 140 lbs. This translates to the propellant being subjected to a hydrostatic pressure of 40 lb/sq.in. Springs with a higher load rating may be beneficial.
10. The propellant density values (see Table 1) were significantly lower than expected. This could be due to a combination of reasons.
    - trapped air due to lack of proper vibration during casting

- insufficient propellant clamping (see #9).
- Impurities in the potassium nitrate may have generated micro-bubbles when heated.
- Challenge of accurately measuring grain length considering irregular top and bottom surfaces.

To improve the density values, the following suggestions are put forth:

- further investigate what frequency of vibration is most effective in eliminating trapped air and implement this change to the vibration table.
- Use a potassium nitrate stock that has an acceptable (neutral or slightly acidic) pH value.
- Consider vacuum-treating the propellant slurry prior to casting.

11. A notation should be made in the casting guide to record the order of casting with respect the serial number marked on each casting tube.
12. To prevent the attachment screw from loosening due to vibration, thread-locking compound should be applied to the screw threads prior to assembly.

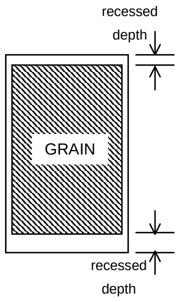
Figure 3 – Bottom surfaces were chipped during coring rod removal.

Figure 4 – Irregular propellant top surfaces.

MINISSHOT GRAIN DENSITY CHECK

Casting tube inner diameter = 3.000 inches
Core diameter = 1.002 inches

Grain ideal density = 1.841 gram/cc



Grain s/n	Mass of casting tube (grams)	Mass of casting tube + propellant (grams)	Length of casting tube (inch)	Recessed depth End 1 (inch)	Recessed depth End 2 (inch)	Grain length (inch)	Mass of propellant (grams)	Grain density ratio (actual/ideal)
1	47.4	864.9	5.50	0.344	0.394	4.762	817.5	**90.6%**
2	49.9	845.3	5.50	0.406	0.394	4.700	795.4	**89.3%**
3	53.3	876.2	5.50	0.313	0.394	4.794	822.9	**90.6%**
4	47.6	868.7	5.50	0.391	0.394	4.716	821.1	**91.9%**
5								
6								
7								
8								
9								

Table 1 – Results of propellant density check.