

**Date: 5 Feb. 2006**

Experiments relating to Item 6c. "Liquid phase sorbitol/KNO<sub>3</sub>/H<sub>2</sub>O mixture"

Ref: [http://www.sugarshot.org/downloads/pdt\\_investigations.pdf](http://www.sugarshot.org/downloads/pdt_investigations.pdf)

**Purpose of this Experiment:** Trial run of apparatus & improved process including propellant residual water measurement. **No vacuum applied.**

Masses prepared:

Sorbitol: 110 grams

KNO<sub>3</sub> : 508 grams

H<sub>2</sub>O : 150 grams (based on 338.5 gram solubility of KNO<sub>3</sub> in 100 ml. H<sub>2</sub>O at 115C.

Due to difficulties encountered with first trial run, a larger amount of sorbitol and KNO<sub>3</sub>/H<sub>2</sub>O solution prepared. Only a fraction of the amounts are actually used for this experiment.

Sorbitol was "as obtained" from pvonly.com

KNO<sub>3</sub> was "as obtained" K-Power fertilizer

Three deep fryers were used. One for melting sorbitol, one for heating the KNO<sub>3</sub>/H<sub>2</sub>O solution, and one for combining & drying operation. The latter was of cast aluminum construction.

Temperature measurements made with K-type thermocouple connected to a multimeter.

Deep fryer #1 (Sorbitol) set at 260 F (130 C)

Deep fryer #2 (KNO<sub>3</sub>/H<sub>2</sub>O) set at 240 F (115 C)

Deep fryer #3 (Combined) set at 260 F (130 C) Tare mass measured at 1860 grams.

Powdered sorbitol placed in deep fryer, turned on, and allowed to melt. Did so in less than two minutes. Temperature of melted sorbitol was measured at 135-140° C.

The H<sub>2</sub>O and approximately half the KNO<sub>3</sub> placed in deep fryer, stirred well, turned on, and heated. After all KNO<sub>3</sub> had dissolved, the remainder of the KNO<sub>3</sub> was added. After about 5 minutes, all KNO<sub>3</sub> appeared to be dissolved. The thermostat had to be adjusted downward to prevent boiling and frothing. Temperature at boiling was measured to be between 113 – 114° C. About 10 ml H<sub>2</sub>O added to replace that lost by boiling.

A portion of the melted sorbitol was then poured into a pre-heated stainless steel transfer container placed onto a digital scale. Total mass of sorbitol transferred was 105 ± 1 grams. A portion of the KNO<sub>3</sub>/H<sub>2</sub>O solution was then poured into the same container, to the tune of 252 ± 1 grams. A glass stir rod was then used to mix the two constituents, then the contents poured into the pre-heated third deep fryer. Immediately much boiling occurred. The temperature was measured at 123° C, and found to remain at this temperature for several minutes while the water was boiling off. After about 6 minutes, the degree of boiling greatly subsided and the temperature of the slurry rose to 145-

150°C. The appearance of the slurry was not typical of conventional KNSB slurry. The slurry had a slight yellowish tinge, and appeared almost “spongy” or aerated. This could have been a result of the release of steam during the boiling process. After another 5 minutes of heating, nearly all bubbling ceased and the slurry became more firm and conventional looking. The viscosity was, at this point, “scoopable”. Heating was then stopped. Two strands were then produced for burn rate testing. The heating vessel & contents, strands, and stainless steel transfer container were then weighed. The masses were as follows:

Heating vessel & contents: 2166 grams  
 Two strands: 3.9 grams  
 Transfer container & residual contents: 83.4 grams  
 Transfer container, tare: 80.6 grams.

A sample was ignited. Hard to ignite, but once ignited, burned fiercely and in a very stable manner, typical of conventional KNSB.

Analysis:

Mass of KNO<sub>3</sub>/H<sub>2</sub>O/sorbitol placed in third heating vessel:

$$m_o = 252 + 105 - (83.4 - 80.6) = 354 \text{ grams (rounded to nearest gram)}$$

Mass of KNO<sub>3</sub>/H<sub>2</sub>O/sorbitol at end of heating period:

$$m_f = 2166 - 1860 + 3.9 = 310 \text{ grams (rounded to nearest gram)}$$

$$\Delta = 354 - 310 = 44 \text{ grams.}$$

Mass of H<sub>2</sub>O originally in mixture

$$m_w = 252 (150)/(150 + 508) = 57 \text{ grams.}$$

Therefore, residual water in propellant = 57 – 44 = 13 grams, which represents 13/310 = 0.04 or 4%. This must be considered approximate as the masses of water boiled off and subsequently replaced were estimates. As well, resolution of the digital scale used for most measurements greater than 200 grams was ±1 gram.

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After leaving the propellant samples & strands overnight in the open air, it was found that the propellant was very slightly sticky to the touch, and was fully cured (rigid). However, the texture was slightly “waxy”, unlike the previous day’s sample which was fully hard.

Two strands were then burned to determine ambient burn rate:

Strand #	L1 (cm)	L2 (cm)	t1 (sec)	t2 (sec)	r1 (cm/sec)	r2 (cm/sec)
1	1.25	2.40	5.52	10.34	0.226	0.232
2	1.15	2.27	4.98	10.12	0.231	0.224

These strands burned at approximately 9% lower rate than KNSB prepared by the conventional melt & cast method (0.250 ± .05 sec.). This could be a result of the residual moisture content.

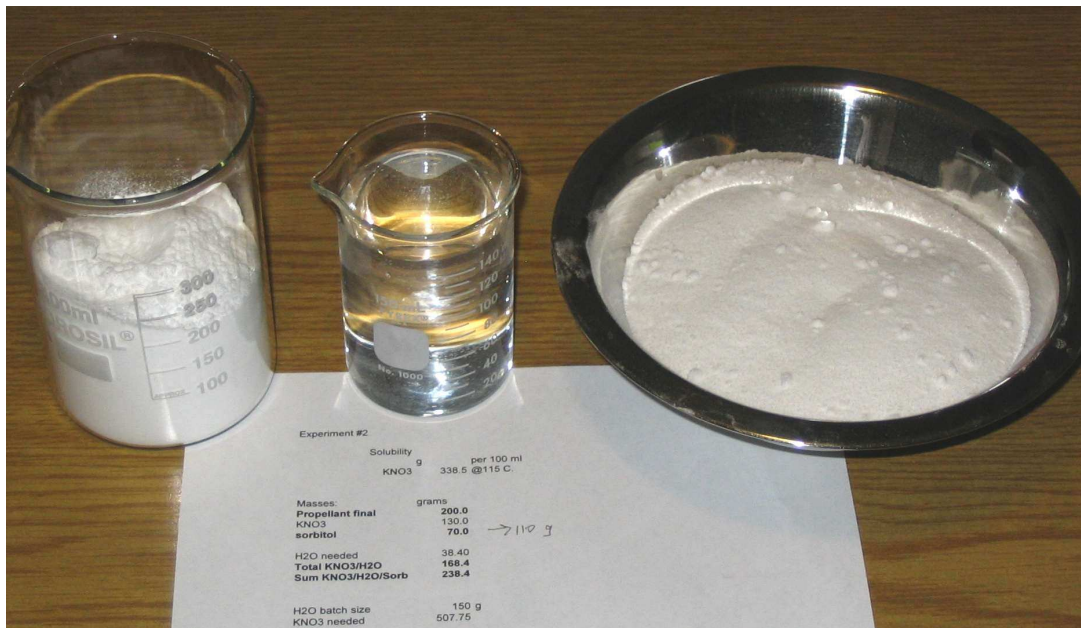
To obtain a more accurate estimate of the residual moisture present in the resulting propellant, a tiny sample was ground to a fine granular form using a coffee mill. The sample was then sifted using a flour sifter to remove larger granules. The sample was placed into a tared stainless steel cup, and weighed. The cup was then placed into a sealed container with calcium chloride and placed in a preheated oven at 140°F. (60°C), with the oven turned off for safety. The sample was left to dry for 4 hours.

Mass prior to drying = 4.53 grams

Mass after drying = 4.43 grams

Moisture removed = 0.10 grams, or 2.2% of the original mass.

As such, the residual moisture estimate for this batch of propellant is 2-4% range.



Chemicals used in experiment. Left to right: sorbitol, H2O, KNO3



Left to right: Sorbitol in heater,  $\text{KNO}_3/\text{H}_2\text{O}$  in heater.



Transfer vessel with  $\text{KNO}_3/\text{H}_2\text{O}$ /sorbitol solution



A sample of the propellant burning

Video (2.2 Mbyte)

<http://sugarshot.org/downloads/prop-burn-ex2.avi>



A sample of the granulated propellant used for residual moisture measurement