



Inert KNSB Propellant Development

Experimental - Part I

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Objective:

To determine whether sodium chloride (NaCl), in the form of table salt, would serve as a suitable substitute for potassium nitrate in the manufacture of “inert” propellant based on potassium nitrate/sorbitol (KNSB). Inert propellant is intended to be a safe (non combustible) substitute for genuine propellant and is typically meant for use in the trial testing or practicing of casting operations.

An experiment conducted at an earlier date indicated that NaCl/Sorbitol of standard 65/35 ratio produced a slurry that was paste-like and of a much higher viscosity than KNSB propellant, and as such, would not serve as a suitable substitute. This earlier experiment was done using milled table salt. The first objective of the current experiment is to see if a different NaCl/Sorbitol ratio would produce a suitable inert propellant. The second objective is to see if “as obtained” (non-milled) table salt could produce a suitable inert propellant. The rationale behind the second objective is the obvious convenience of using table salt without the need for first milling it.

Procedure:

Particulars of the four experimental 60 gram batches that were prepared are shown in the table below:

| Batch no. | Mass ratio NaCl/Sorbitol | Mass NaCl (grams) | NaCl form | Mass Sorbitol (grams) |
|-----------|--------------------------|-------------------|-------------|-----------------------|
| Batch #1 | 60/40 | 36 | milled | 24 |
| Batch #2 | 55/45 | 33 | milled | 27 |
| Batch #3 | 65/35 | 39 | crystalline | 21 |
| Batch #4 | 70/30 | 42 | crystalline | 18 |

Milled NaCl was ground in *Braun* coffee grinder for 10 seconds per batch.

Crystalline NaCl was “as obtained” *Sifto* table salt

Sorbitol was “as obtained” (measured moisture content 0.74%)

After combining both constituents, batches were blended using a rotating mixer

(<http://members.aol.com/nonillion/pix/mixer2.gif>) for a period of 1 hour.

The milled salt was of a powdered form closely representing the milled potassium nitrate that is typically used for production of KNSB propellant. Crystal size of the “as obtained” salt was determined by use of a 100X magnifier and a glass disc with etched 1 mm gratical lines. Crystals were found to be cubic in shape (see Figure 1) of typical dimension 400-500 micron along each side. This is much coarser than the particle size that results from milling (typical max. 50-80 micron).

All batches were heated in a cast aluminum 1000 watt *Tall-Fry* “deep fryer” with thermostatic control normally used for KNSB propellant production.

Temperature measurements of the heated slurry were obtained by use of a K-type beaded thermocouple interfaced to a digital multimeter.

Results:

Due to the relatively small batch size (60 grams each), the powdered mixtures tended to “melt” quite rapidly, and it was challenging to try to maintain a constant, uniform temperature. As such, it was not possible to get accurate readings of the slurry temperature. Stated temperature ranges are therefore to be considered as approximate only.

Note that the term “melt” is intended only as a descriptor -- the sodium chloride remains largely as solid particles suspended in a matrix of molten sorbitol.

Batch #1 (60/40 milled salt/sorbitol)

The powdered mixture quickly melted. The colour of the slurry was a translucent white initially. Some slight caramelization began to occur. The temperature of the slurry was then measured and found to be in the range of 150° - 160°C., indicating some degree of overheating. The slurry was then poured & scooped into a paper cup and set aside for curing. After 24 hours, the material appeared to be fully cured (non-viscous). After 48 hours, no slumping was apparent.

Batch #2 (55/45 milled salt/sorbitol)

Greater care was taken to heat up the mixture more slowly. The mixture soon fully melted. The colour of the slurry was a translucent white and remained as such. The temperature of the slurry was then measured and found to be in the range of 110° - 120°C. The slurry was then poured & scooped into a paper cup and set aside for curing. After 24 hours, the material appeared to be fully cured. After 48 hours, significant slumping was apparent.

Batch #3 (65/35 crystalline salt/sorbitol)

The mixture took a fair amount longer to become completely melted, compared to the two earlier batches. The texture was noticeably “gritty”, reminiscent of concrete. The colour of the slurry took on a very slight yellowish hue. The temperature of the slurry was measured and found to be in the range of 130° - 140°C. The slurry was then poured & scooped into a paper cup and set aside for curing. After 24 hours, the material appeared to be fully cured. After 48 hours, no slumping was apparent.

Batch #4 (70/30 crystalline salt/sorbitol)

This mixture took even longer to melt, and was thicker in viscosity than the three previous batches. The texture was noticeably “gritty”. The colour of the slurry took on a

slight yellowish hue, more so than batch #3. The temperature of the slurry was measured and found to be in the range of 150° - 160°C.

Discussion:

It is important to point out that the viscosity of KNSB propellant is strongly related to the particle size of the potassium nitrate and to the residual water content. As such, the usual viscosity range is quite large, from “pourable” to “scoopable”

For the first three batches, the viscosity of the slurry was of a similar range to that typically seen for genuine KNSB propellant.

The 55/45 ratio suffered from slumping, suggesting that it may not be suitable for certain applications. However, this may simply be a result of residual moisture of this particular sample, which may not be present in larger batches that require longer heating times (consequentially, more moisture is driven off).

Both, the 60/40 formulation made with milled salt, and the 65/35 formulation made with crystalline salt behaved quite closely to genuine KNSB with regard to casting characteristics. The “gritty” nature of the latter formulation, combined with the greater amount of heating required, suggests that the 60/40 formulation would constitute a generally better inert propellant.

The fourth batch (70/30 ratio) was thicker in viscosity than normal KNSB propellant. This, combined with the relatively high temperature needed to make the mixture fluid, suggests that this formulation is not particularly suitable as an inert propellant.

Three of the specimens (batches #1-#3) are shown in the photo in Figure 2, taken 48 hours after casting.

Conclusions:

With the use of milled table salt, a suitable inert propellant can be produced when used in a 60/40 salt/sorbitol ratio. A “fine tuning” of the salt/sorbitol ratio could produce inert propellant that closely matches the range of viscosity, and pouring/scooping behaviour, of the KNSB propellant.

The use of “as obtained” table salt produced a product that resembled the slurry of genuine KNSB propellant in terms of overall viscosity. It is not known if the gritty nature of the product would lessen its suitability.

It is possible that a finer crystalline salt, such as “popcorn salt”, might be a good choice for producing an inert propellant when used in a 60/40 ratio, without need for milling.



Figure 1 – Photo of table salt crystals.
(Ref. <http://www.cwpost.liunet.edu/cwis/cwp/clas/bio/salt.jpg>)

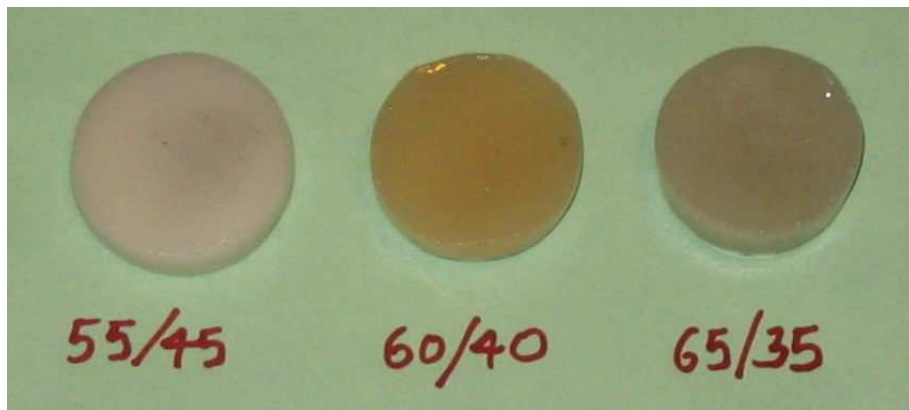


Figure 2 – Three specimens of experimental “inert” propellant after 48 hours.
Note the slumping of the 55/45 formulation.