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Explosive Limit of Armstrong's Mixture

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When investigating the cause of an accident, it was necessary to learn something about the lower explosive limit with regard to phosphorus content in Armstrong's Mixture. A short literature search did not produce the needed information; thus a brief laboratory study was undertaken. Because the results of the study may be useful regarding safety and because they may be intrinsically interesting, this short article was prepared.

Armstrong's Mixture is both a very sensitive and very explosive pyrotechnic composition, potentially making it extremely dangerous.[1–3] Its practical use is limited to manufacturers of toy caps, although from time to time hobbyist experimenters are reckless enough to experiment with it. Davis[4] reports the formula for Armstrong's Mixture as given in Table 1. However, hobbyist experimenters often do not include the lesser two ingredients. There is little hope of mixing the ingredients in the dry state without their exploding, and dangerous reactions may occur even in the wet state.[3]

Table 1. Formula for Armstrong's Mixture.

Ingredient	Percent by Weight
Potassium chlorate	67
Phosphorus (red)	27
Sulfur	3
Calcium carbonate	3

In this study, to duplicate conditions of the accident, mixtures containing only potassium chlorate and red phosphorus were examined. Mixtures, containing from 2 to 30% red phosphorus, were prepared wet, using an additional 40% water. One-gram quantities of the mixes (dry weight of ingredients) were applied wet over the tips of electric matches in sample holders, see Figures 1 and 2. For each composition, three test samples were prepared. After drying for two days, the test samples were placed between two free-field blast gauges, one at a distance of one foot and the other at two feet, see Figure 3. Upon activating the electric match, the explosive output (as a blast wave) was recorded digitally for later analysis.

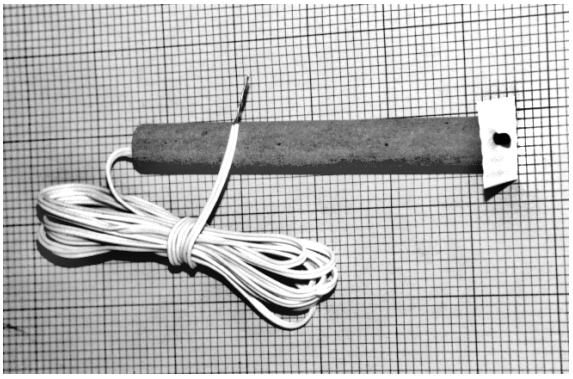

Figure 1. Test sample holder, made using a 5/16-inch ID paper tube with an electric match glued in place and protruding through a square of heavy filter paper.

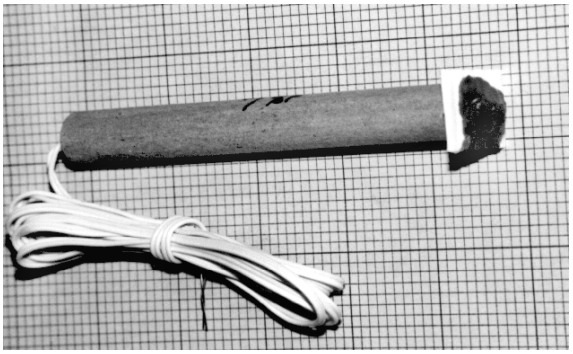

Figure 2. Test sample holder with a 1-gram sample applied over the electric match tip.

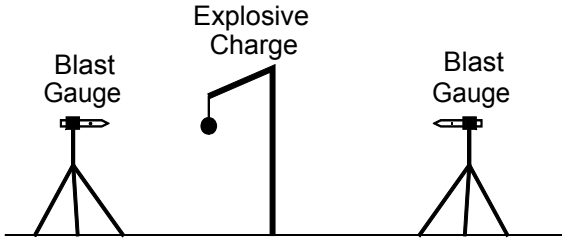

Figure 3. Drawing illustrating the set-up of blast gauges to measure the explosive output of the test samples (not to scale).

One method of reporting explosive output is in terms of TNT equivalent under specific conditions. For example, in these measurements, the maximum output for a sample was found to produce a TNT equivalent of 27%. For this sample, the explosive output (air blast wave) of 1 gram was found to be equivalent to that expected to be produced by 0.27 gram of TNT. The average results from the series of test mixtures are graphed in Figure 4 and demonstrated in Figure 5.

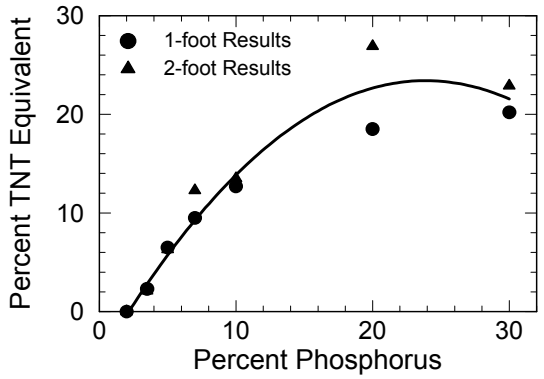

Figure 4. A graph of the TNT equivalent as a function of red phosphorus content. Air blasts were measured at 1 and 2 feet from 1 gram, unconfined test samples.

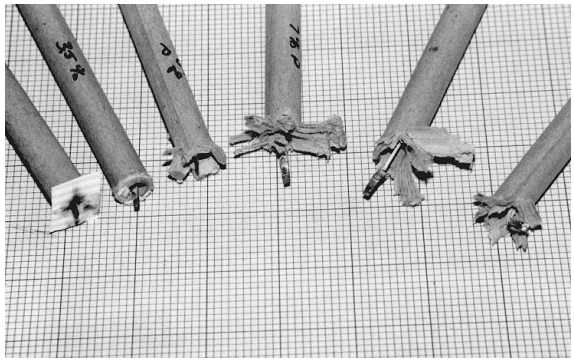

Figure 5. Representative examples of damage to the test sample holders for 2, 3.5, 5, 7, 10, and 20% red phosphorus mixtures, shown from left to right.

Note that in the case of 10 and 20% red phosphorus test mixtures, nearly one inch of the end of the support tube was blown off by just one gram (0.04 ounce) of material. For an unconfined pyrotechnic in such a small quantity this is impressive. (Considering the extreme sensitivity of these mixtures, this is just plain scary.) Note also that even small percentages of red phosphorus produce explosive results and would certainly be disproportionately more explosive in larger amounts.

Acknowledgments

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References

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4) T. L. Davis, *The Chemistry of Powder and Explosives*, Angriff Press (1941) p 105.