TEST REPORT

BURST CHARGE POWDERS EQUIVALENCY TESTING

SEPTEMBER 13, 2018

SMS-5278-R1, REV 0

PREPARED FOR

NATIONAL FIREWORKS ASSOCIATION
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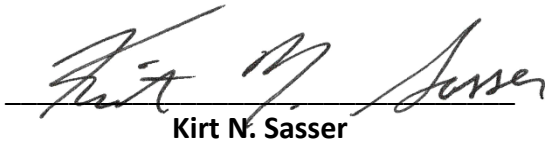

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REFERENCES

1. United Nations (UN) Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Sixth revised edition, 2015

I. OBJECTIVE

The National Fireworks Association (NFA) requested that Safety Management Service, Inc. (SMS) perform testing of some standard burst charge formulations using a new test method developed to help distinguish the reaction behavior of burst powders for aerial fireworks shells. Three samples were examined in the new test method.

II. SUMMARY AND CONCLUSIONS

The test results are summarized in Table 1. The Burst Charge Containing Metal (12.5% Al) and the Whistle Composition had Equivalency Levels of 15 mm and 18 mm respectively. The Flash Composition's Equivalency Levels exceeded the limits of the test (i.e. > 22 mm).

Table 1: Burst Charge Powder Equivalency Test Results

Burst Charge	Equivalency Level
Burst Charge Containing Metal (12.5% Al)	15 mm
Whistle Composition	18 mm
Flash Composition	> 22 mm

III. SAMPLE DESCRIPTION

Three samples were compared in this testing: (1) a Burst Charge Containing Metal; (2) a Whistle Composition; and (3) a Flash Composition as seen in Table 2. A picture of each sample is provided in Photos 1-3

Table 2: Burst Charge Samples Tested

Burst Powders	Chemical Constituent	Weight Percentage (%)
Burst Charge Containing Metal	Potassium Perchlorate	68.5
	Aluminum, Indian Blackhead (< 53µm)	12.5
	Charcoal	11.4
	Sulfur	7.6
	Total	**100%**
Whistle Composition	Potassium Perchlorate	70
	Sodium Benzoate	10
	Corn Starch	20
	Total	**100%**
Flash Composition	Unavailable	NA

Photo 1: Burst Comp Containing Metal (12.5% Al)

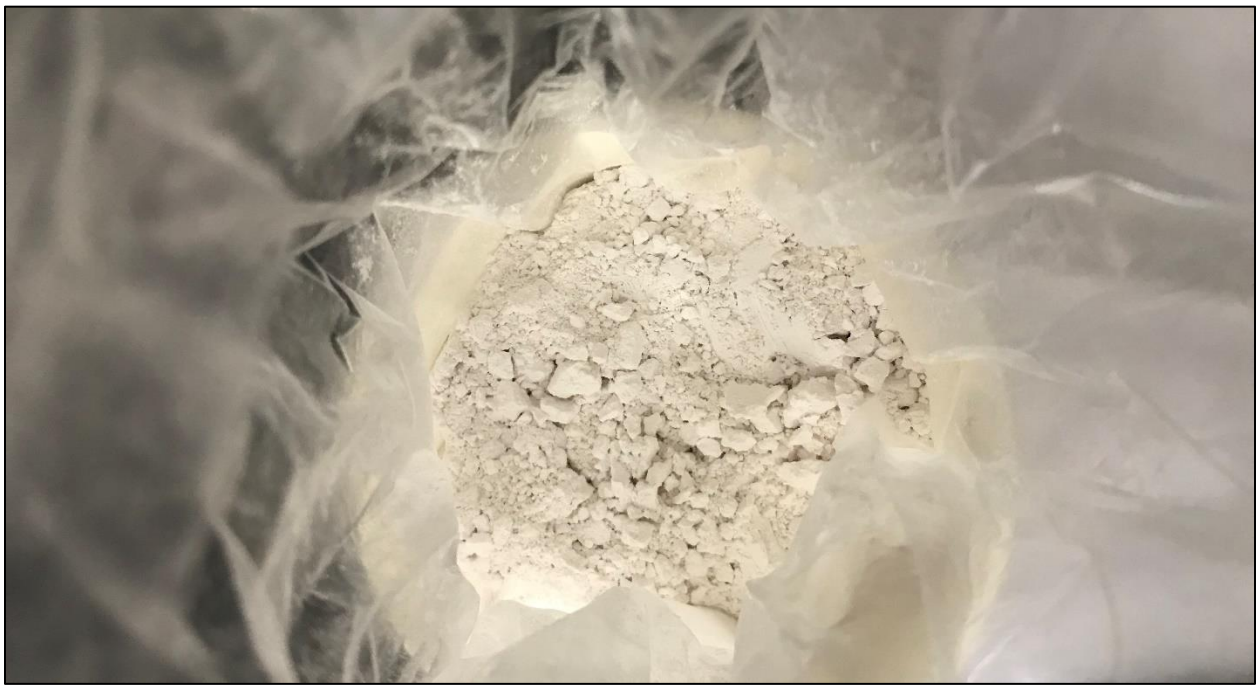

Photo 2: Whistle Comp (70/10/20)

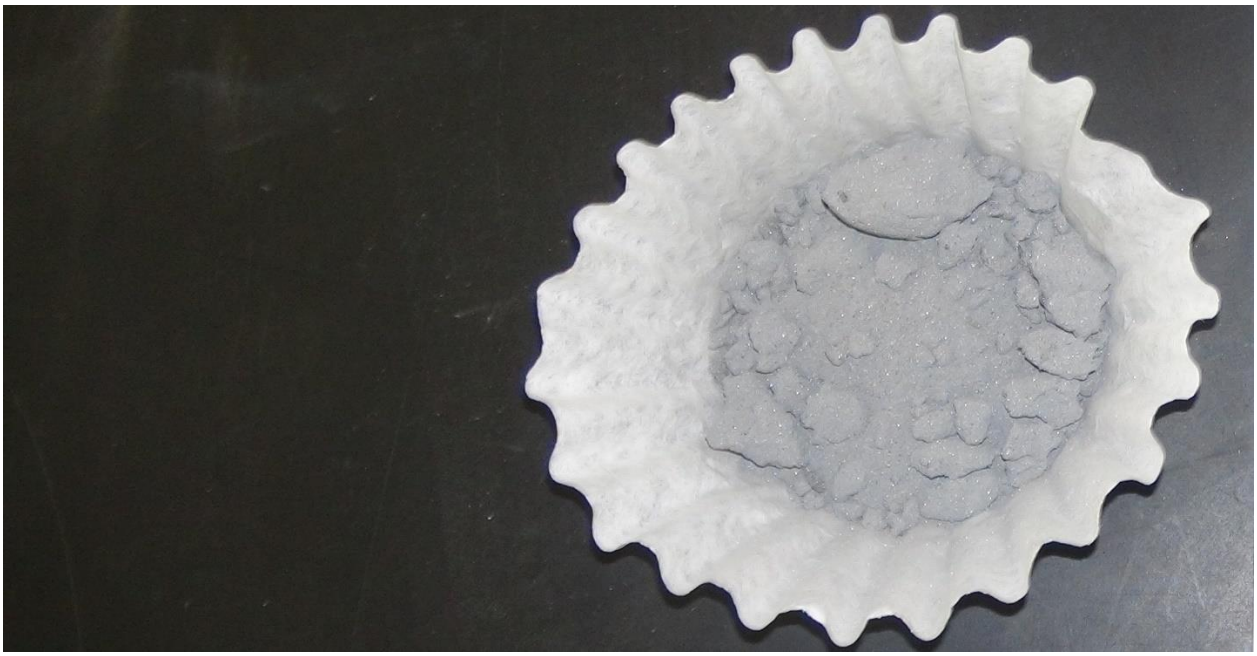

Photo 3: Flash Composition

IV. TEST DESCRIPTIONS AND RESULTS

A. Burst Charge Powder Equivalency Test

1. Test Description

This test is used to compare the relative energy output of burst (or break) charge powders as compared to each other.

2. Apparatus and Materials

The apparatus consists of a Koenen non-reusable steel tube (UN Series 1b), which is equipped with a closing plate with an orifice (Photos 5 & 6) and installed in a protective fixture. Upon ignition of the sample using an electric match, the decomposition gases escape through the orifice. If the orifice is not of sufficient size, the gases rupture, burst, or fragment the tube. The closing plate with the orifice is made of heat-resisting chrome steel with venting hole diameters from 2.0 to 22.0 mm. A steel threaded collar and nut hold the orifice in place during the test. The dimensions of the tubes are provided in Figure 1.

Photo 4: Koenen Tubes and Orifices

Photo 5: Tube/Orifice Assembled

The overall concept for this test is that substances that are more energetic and have burn rates that are relatively fast will require orifices that are much larger than substances that have slower burn rates. If the venting or orifice hole is sufficiently large, then the material will burn within the Koenen tube and vent out the specified orifice hole. If the venting or orifice hole is insufficient, then the Koenen tube will rupture (fragment or burst). Equivalency levels (which correlate to a vent size) are established when three trials at a given orifice size are performed with no tube rupture or fragmentation. In general, substances that require a larger orifice size such that the Koenen tube does not rupture, have a much faster burn rate than those substances that do not rupture with smaller orifice diameters. The assembled test unit is placed in a protective fixture. Photos 7 and 8 are representative photos of the protective test fixture used with the Koenen tube and collar/orifice assembly.

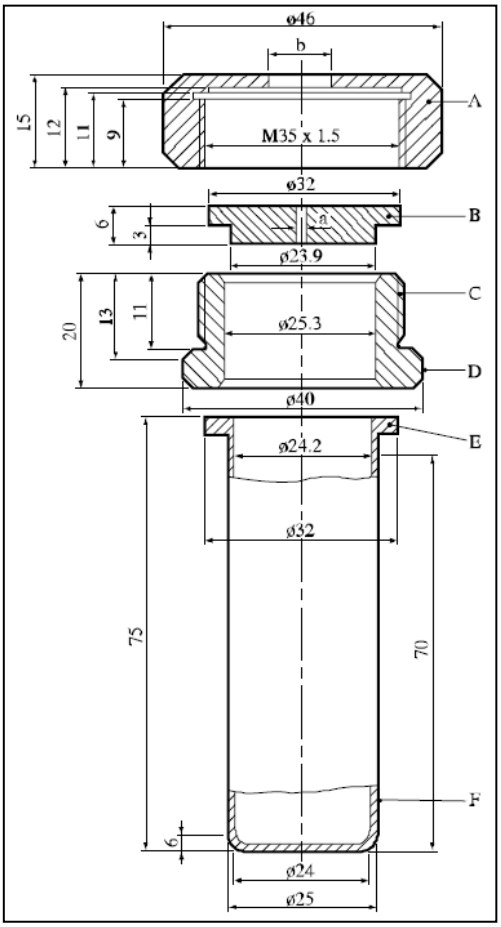

Figure 1: Koenen Tube (mm)

Photo 6: Protective Fixture for Electric Match Ignition

Photo 7: Protective Fixture for Electric Match Ignition

3. Procedure

Five (5) grams of the test substance are weighed out and placed in the bottom of the test tube. A vent size is selected, and the orifice, collar, and nut are assembled, and the test assembly positioned in the protective fixture. The fixture is positioned such that the operator approaches from the back side for safety purposes. The operator then positions an electric match (Photo 9) through the vent hole and down into the powder. The electric match is functioned, and the test tube is examined for damage. If the tube does not rupture, the vent size is decreased and the process repeated until a rupture occurs. If the tube ruptures, the vent size is increased and the process repeated until a rupture does not occur. The test is then repeated until 3 trials are performed at the smallest vent size without rupture occurring. This is then determined to be the Equivalency Level for this powder and can be compared to other powders performed using this same method. Additional details of the electric matches function in this system are presented in the Appendix.

Photo 8: Ignition Source – Electric Match

4. Test Configuration

Three samples were compared in this testing; a burst charge containing metal, a whistle composition, and a flash composition (see Table 1). Trials were performed with these substances using 5 grams per trial. A new tube is used for each trial. Five (5) grams of the test substance are weighed out and placed in the bottom of the test tube. A vent size is selected, and the orifice, collar, and nut are assembled, and the test assembly positioned in the protective fixture.

5. Test Results

The results of the tests are shown in Table 3. The Burst Charge Containing Metal (12.5%) had an Equivalency Level of 15 mm. The Whistle Composition's Equivalency had an Equivalency Level of 18 mm. The Flash Composition's Equivalency Level exceed the limits of the test (i.e. > 22 mm).

Table 3: Burst Charge Powder Equivalency Test Results – Electric Match Ignition Source

Burst Charge	Orifice Size (mm)	Trial	Results	Pass/Fail
Burst Charge Containing Metal	15	1	Tube undamaged	Pass
	8	1	Tube ruptured	Fail
	10	1	Tube undamaged	Pass
	10	2	Tube ruptured	Fail
	12	1	Tube ruptured	Fail
	15	2	Tube undamaged	Pass
	15	3	Tube undamaged	Pass
Whistle Composition	22	1	Tube undamaged	Pass
	20	1	Tube undamaged	Pass
	18	1	Tube undamaged	Pass
	12	1	Tube ruptured	Fail
	15	1	Tube ruptured	Fail
	18	2	Tube undamaged	Pass
	18	3	Tube undamaged	Pass
Flash Composition	22	1	Tube ruptured	Fail

Photos 10-13 show typical results of undamaged tubes and ruptured tubes.

Photo 9: Burst Charge Containing Metal – 15 mm Orifice - PASS

Photo 10: Burst Charge Containing Metal – 12 mm Orifice - FAIL

Photo 11: Whistle Composition – 18 mm Orifice - PASS

Photo 12: Whistle Composition – 12 mm Orifice – FAIL

V. APPENDIX

A. Test Method Background

As previously mentioned, this test method was developed to help compare the relative energy outputs of burst charge powders for aerial fireworks shells. The use of an electric match and the consequences to the desired objective were evaluated in the development of the test method. Two obvious details with the use of the e-match are the reduction of vent area from the e-match leads and the energy released by the match head. A short discussion of these details is provided in the following:

1. Vent reduction by e-match lead wires

As the objective of this test method is to give a relative comparison of the energy output of the burst powders, the reduction of vent area due to the electric match leads is inconsequential as the reduction is constant. The area taken up by the leads is small enough such that the effective vent area is always larger as the orifice diameters increase. The cross-sectional area of the electric match lead wires occupies a lesser percentage of the vent hole as the diameter of the vent hole increases.

For example, the insulation on the lead wires of the Daveyfire SA 2001 A/N 28Br electric matches used in this study each have a diameter of 1.25 mm, or a cross-sectional area of 1.23 mm^2. The paired, or "zipped" wires have a combined area of 2.46 mm^2. The cross-sectional area of the 22 mm orifice is 380 mm2. The percentage of the vent area occupied by the lead wires is then,

$$(2.46\ mm^2 / 380\ mm^2) \times 100\% = 0.65\%$$

The area percentage occupied by the lead wires for the 18 mm and 15 mm orifices is 0.97 and 1.4 %, respectively. These reductions in area are considered insignificant as the system is the same for all powders being evaluated.

2. Energetic contribution of the electric match to the energy released by the burst charge sample

The pyrotechnic composition in a Daveyfire A/N 28Br electric match head has a mass of 80 mg and a heat of explosion comparable to those of the three burst charges tested. Thus, the energy contribution from the electric match head to the burning of 5g (5,000 mg) of a burst charge sample equates to approximately,

$$(80\ mg / 5{,}000\ mg) \times 100\% = 1.6\%$$

This is also judged to be insignificant, having little effect on the test results as once again, this value is constant, and the results are comparative in nature from sample to sample.