



ENERGETIC MATERIALS RESEARCH AND TESTING CENTER

801 Leroy Place Socorro, NM 87801

Phone: (505) 835-5312 Fax: (505) 835-5630 <http://www.emrtc.nmt.edu>

Results of Oxidizing Solids Testing

EMRTC Report FR 10-13

Prepared for:

Washington TRU Solutions, LLC
PO Box 2078
Carlsbad, NM 88220

By:

Graham Walsh
Research Scientist

Energetic Materials Research and Testing Center
New Mexico Institute of Mining and Technology
Socorro, NM 87801

April 12, 2010

1.0 Purpose / Background

The EPA SW-846, test method 1040 (included as Appendix A) is suitable for assessing the relative oxidizing hazard of solid substances, including solids, granular materials, and other materials that can be formed into a conical pile. Some materials bound for storage at WIPP are co-mingled with nitrate salts, which; in pure form, are categorized for transportation as oxidizers. This test series determined the amount of inert material (zeolite clay and ground high strength grout) that must be mixed into the most reactive ratio of sodium nitrate and potassium nitrate in order to classify the mixture as a Category IV (non-oxidizer).

2.0 Test procedure

All testing was carried out in accordance with EPA SW-846, Method 1040, Test Method for Oxidizing Solids; with the following variances:

1. The wire temperature, according to Method 1040, should be at least 1000°C. The wire temperature was measured on each test, in accordance with Method 1040, by direct contact with an R-type, thin wire thermocouple. In most tests, the thermocouple did not register the 1000°C minimum temperature. However, prior to testing, the heating wire temperature was verified by a direct contact measurement with an R-type thin wire thermocouple; due to the response time of the thermocouple, the time required to register the actual temperature of the wire (1015°C) was longer than the maximum time the wire would be heated in testing, which is three minutes. Additionally, the manufacturer of the thermocouples used (which are specifically identified in the Test Method), Omega Engineering, gave EMRTC specific guidance against using the thermocouple in direct contact with an electrically heated wire; as it was in the method, however, these measurements were still carried out.
2. Section 2.2 in the statement of work (attached in Appendix B), states in each subsection that 15 grams of oxidizer / inert mixture should be mixed with 6 grams of cellulose for testing. This was changed in testing to 15 grams of cellulose to comply with the 30 gram sample size required in Method 1040.

Testing was carried out in a series of steps, outlined below:

1. In order to determine the more reactive oxidizer, to be used in further testing, a series of 30 gram samples were mixed and tested per Method 1040. The sample mixtures can be found in Table 1. Six replicates were tested for each mixture.

Table 1 lists mixtures tested to determine oxidizer for use in further testing

Mixture	Sodium Nitrate	Potassium Nitrate	Cellulose
1	15 g		15 g
2	5 g	10 g	15 g
3		15 g	15 g

2. Once the oxidizer for use was determined, a comparison of mixing methods was conducted. In this test series, the oxidizer was mixed with the inert material

(these tests were carried out for both inert materials, zeolite clay and grout) using one of three methods:

- a. A wet method, where the oxidizer was dissolved in an excess of deionized water. The inert material was then mixed into the dissolved oxidizer and dried. When this mixture was dry, it was mixed with cellulose and tested.
- b. A dry method, where the oxidizer and inert material were mixed in a dry state. This mixture was then dried in an oven at 64°C for 12 hours. After drying, it was mixed with cellulose and tested.
- c. A wet-dry method, where half of the oxidizer was dissolved in an excess of deionized water, then mixed with the inert material and dried. After drying, this material was dry mixed with the remaining oxidizer. This material was then mixed with cellulose and tested.

The mixtures tested for each method are summarized in Table 2.

Table 2 lists materials tested to determine the most reactive mixing method

Method	KNO ₃ (wet)	KNO ₃ (dry)	Inert material	Cellulose
Wet	13.5 g		1.5 g	15 g
Dry		13.5 g	1.5 g	15 g
Wet-Dry	6.75 g	6.75 g	1.5 g	15 g

3. Tests were then conducted to determine the weight percent of inert material that had to be mixed into the oxidizer for the resulting mixture to test as a Category IV, non-oxidizing solid. The oxidizer was wet mixed with inert material, initially at a 50:50 weight ratio, to make a 15 g sample. That sample was then mixed with 15 g of cellulose, and tested. The oxidizer percent was increased by 10% in subsequent tests until the results of the tests were not considered as a Category IV, non oxidizing solid.
4. The mixtures with the lowest weight percent inert material to yield a non-oxidizing solid, as determined in the method above, were then tested against a potassium bromate / cellulose standard to ensure that they would not be considered oxidizers. These mixtures were tested 20 times, if any individual test resulted in a burn time less than the average burn time of the potassium bromate / cellulose standard, the testing was stopped, a new mixture was made with 5% less oxidizer, and re-tested.

3.0 Test Equipment

The test equipment met the requirements of Test Method 1040. The wire used was 22 gauge ARCOR heating wire, power was delivered to the wire using a variac. Thin, 1 mm pieces of ceramic were placed at both ends of the wire to make a 1 mm gap between the wire and tile. Humidity was kept at acceptable levels within the fume hood using a humidifier and a steam generator. The test materials were

formed into truncated cones using a 60° glass funnel. After the cone was formed on a ceramic tile with thermal conductivity, a thin wire R-type thermocouple was inserted into the pile until it was thought to be in contact with the heating wire. The temperature and humidity were recorded prior to each test, using a calibrated thermometer and a standard hygrometer.

4.0 Test Results

An initial test was run to determine the appropriate variable transformer setting to achieve a wire temperature of 1000°C. In this test, it was found, via direct measurement with an R-type, thin wire thermocouple, that a variable transformer setting of 15.5 volts produced a wire temperature of 1015°C. This variable transformer setting was used for all subsequent tests.

In accordance with the test plan, the first series of tests were conducted to determine the oxidizer for use in subsequent tests. Mixtures of cellulose and sodium nitrate (NaNO₃), potassium nitrate (KNO₃) and a mixture of NaNO₃ and KNO₃ were tested, and their burn times compared. From this testing, it was determined that KNO₃ was the more reactive oxidizer, and thus it was used in all subsequent testing. Average results can be found in Table 3. Complete test results can be found in Appendix C.

Table 3 shows the results of oxidizer comparison tests.

Cellulose (g)	NaNO ₃ (g)	KNO ₃ (g)	Average burn time (s)
15	15		47.8
15	5	10	39.9
15		15	31.7

The second series of tests were designed to identify the most reactive mixing method, be it a complete dry mix, the cellulose, KNO₃ and inert material simply stirred together as dry components, a wet mix, where the KNO₃ was first dissolved in water, then mixed with the inert material, and dried in an oven and mixed with the cellulose, or a combination of 50% wet and 50% dry mix. After testing, it was found the wet mixing method yielded the most reactive products for both inert materials, zeolite clay and grout. The wet mixing method was used for all subsequent tests. Average results can be found in Tables 4 and 5, complete test results are tabulated in Appendix C.

Table 4 shows average results from mixing method comparison using zeolite clay as the inert material.

Mixing method	Cellulose (g)	KNO ₃ (g)	Zeolite (g)	Avg Burn time (s)
Wet	15	13.5	1.5	23.3
Dry	15	13.5	1.5	45.8
Wet/Dry	15	13.5	1.5	34.9

Table 5 shows average results from mixing method comparison using grout as the inert material.

Mixing method	Cellulose (g)	KNO ₃ (g)	Grout (g)	Avg Burn time (s)
Wet	15	13.5	1.5	12.5
Dry	15	13.5	1.5	48.4
Wet/Dry	15	13.5	1.5	19.3

The wet mixing method was then used to prepare samples to evaluate the burn time of mixtures with varying proportions of inert and oxidizer to find the mixture with the highest amount of KNO₃ that was not considered an oxidizing solid when compared with the slowest burning standard from the Method, a mixture of 70% cellulose and 30% potassium bromated (KBrO₃). When zeolite was used as the inert material, a mixture of 50% cellulose, 35% KNO₃ and 15% zeolite was found to have the highest percentage of KNO₃ of any of the mixtures that tested as a non-oxidizing material. For grout, the mixture with the highest percentage of KNO₃ found to be a non-oxidizing solid was 50% cellulose, 25% KNO₃ and 25% grout. Average results are tabulated in Tables 6 and 7, complete results can be found in Appendix C.

Table 6 lists the average results for mixtures containing zeolite.

Mixture			Burn Time (s)
Standard (70% Cellulose, 30% KBrO ₃)			191.0
Cellulose (g)	KNO ₃ (g)	Zeolite (g)	
15	7.5	7.5	No reaction
15	9	6	No reaction
15	10.5	4.5	No self-sustaining combustion
15	12	3	25.5

Table 7 lists the average results for mixtures containing grout.

Mixture			Burn Time (s)
Standard (70% Cellulose, 30% KBrO ₃)			190.9
Cellulose (g)	KNO ₃ (g)	Grout (g)	
15	7.5	7.5	No self-sustaining combustion
15	9	6	49.5

No failure assurance testing was then run at the levels determined to be non-oxidizing solids from Tables 6 and 7. Each mixture was to be tested 20 times against the slowest burning standard, if any individual burn time was less than the average burn time of the standard, the material was failed. Both mixtures failed; the percentage of KNO₃ to grout was reduced by 5% and re-tested. At these levels, both materials passed. The mixtures which passed are listed in Table 8, complete data can be found in Appendix C.

Table 8 lists the percentages at which each mixture was considered a non-oxidizing solid.

Cellulose (%)	KNO ₃ (%)	Zeolite (%)	Grout (%)
50	33	18	
50	22.5		27.5

Graham Walsh
Research Scientist
NMT / EMRTC
Socorro, NM 87801

Appendix A
EPA SW-846 Method 1040
Test Method for Oxidizing Solids

METHOD 1040

TEST METHOD FOR OXIDIZING SOLIDS

SW-846 is not intended to be an analytical training manual. Therefore, method procedures are written based on the assumption that they will be performed by analysts who are formally trained in at least the basic principles of chemical analysis and in the use of the subject technology.

In addition, SW-846 methods, with the exception of required method use for the analysis of method-defined parameters, are intended to be guidance methods which contain general information on how to perform an analytical procedure or technique which a laboratory can use as a basic starting point for generating its own detailed Standard Operating Procedure (SOP), either for its own general use or for a specific project application. The performance data included in this method are for guidance purposes only, and are not intended to be and must not be used as absolute QC acceptance criteria for purposes of laboratory accreditation.

1.0 SCOPE AND APPLICATION

1.1 This method can be used to evaluate the relative oxidizing hazard posed by a solid waste. The method is based on a "conical pile-type burning test method" adapted from the United Nations regulations and classification procedures for the international transportation of dangerous goods (see Ref. 3).

1.2 This test procedure is suitable for assessing the relative oxidizing hazard of solid substances, including solids, granular materials, and other materials that can be formed into a conical pile as described in Sec. 11.2.4. This procedure is not appropriate for evaluating oxidizing liquids.

1.3 This method is not required by the Federal regulations to determine if a waste passes or fails the characteristic of ignitability according to the RCRA regulatory definition at 40 CFR 261.21. To clarify, the test results of this method cannot be used to directly classify a waste as a D001 hazardous waste, nor can the results be used by themselves to definitively classify a waste as non-hazardous. No specific test for defining oxidizers is required by the RCRA regulations, and only a waste meeting the narrative regulatory definition at 40 CFR 261.21(a)(4) is an ignitable hazardous waste because of its oxidizer properties. However, this test method was developed to specifically illustrate the oxidizer properties of materials, including wastes, and its results provide relevant and useful information that may be applied to knowledge of a waste in determining whether a waste meets the 40 CFR 261.21(a)(4) criteria.

1.4 This method provides a qualitative means to measure the potential of a solid waste to increase the burning rate or burning intensity of a combustible substance, specifically fibrous cellulose. The burning rates for 1:1 and 4:1 waste:cellulose mixtures (w/w) are compared to the burning rates for 3:7, 2:3, and 3:2 potassium bromate:cellulose mixtures. Potassium bromate is used as the reference oxidizing standard. The three mixing ratios of potassium bromate and cellulose provide a range of burning times by which the waste is classified. The 3:7 mixture ratio provides the longest burning time, the 3:2 mixture ratio provides the shortest burning time, and the 2:3 mixture ratio provides an intermediate burning time. The burning times for the potassium bromate:cellulose mixtures are correlated to their relative oxidizing strengths, i.e., the shorter the burning time, the greater the relative oxidizing strength. If the mean burning

time for either waste/cellulose mixture is shorter than the mean burning time for the 3:7 potassium bromate/cellulose mixture, the waste is shown to exhibit oxidizer properties.

1.5 Prior to employing this method, analysts should consult the disclaimer statement at the front of the manual and the information in Chapter Two for guidance on the intended flexibility in the choice of methods, apparatus, materials, reagents, and supplies, and on the responsibilities of the analyst for demonstrating that the techniques employed are appropriate for the analytical purpose.

In addition, analysts and data users are advised that, except where explicitly specified in a regulation, the use of SW-846 methods is *not* mandatory in response to Federal testing requirements. The information contained in this method is provided by EPA as guidance to be used by the analyst and the regulated community in making judgments necessary to generate results that meet the data quality objectives for the intended application.

1.6 Use of this method is restricted to use by, or under supervision of, properly experienced and trained personnel. Each analyst must demonstrate the ability to generate acceptable results with this method.

2.0 SUMMARY OF METHOD

2.1 Aliquots of the waste sample are mixed thoroughly with fibrous cellulose in both 1:1 and 4:1 weight-to-weight ratios. An aliquot of the waste:cellulose mixture is formed into a truncated conical pile on a cool, impervious surface by means of a glass funnel. The sample is ignited by means of an electrically-heated wire inserted into the base of the pile. The burning time (in seconds) of each waste mixture is measured under standard conditions and recorded. The test is repeated five times for each waste:cellulose ratio mixture.

2.2 The burning times of the waste mixtures are then compared with the burning time for a standard reference substance consisting of a 3:7 weight-to-weight ratio of potassium bromate and cellulose. If the burning times for both the 1:1 and 4:1 waste mixtures are greater than the burning time for the 3:7 potassium bromate:cellulose standard, then no further testing is required and the results of the test are negative. If one or both of the burning times for the waste mixtures are equal to or less than that of the 3:7 potassium bromate:cellulose standard, then the waste mixture burning time is compared with the burning times for the 2:3 and/or the 3:2 potassium bromate:cellulose standards.

2.3 This test classifies a solid waste into one of four categories of oxidizers, as summarized below. Materials which fall into Categories I, II, or III may exhibit the RCRA hazardous waste characteristic of ignitability. It may be assumed that Category IV materials do not exhibit the RCRA hazardous waste characteristic of ignitability pursuant to 40 CFR 261.21(a)(4) criteria. The full determination for a material into Categories I, II, or III is not required for RCRA purposes. Any material burning at a rate equal to or faster than the Category III potassium bromate:cellulose standards is a solid oxidizer and may exhibit the RCRA characteristic of ignitability.

2.3.1 Category I -- Wastes of either mixture ratio that exhibit a mean burning time less than or equal to the burning time of the 3:2 potassium bromate:cellulose standard are classified in Category I.

2.3.2 Category II -- Wastes of either mixture ratio that exhibit a mean burning time less than or equal to the burning time of the 2:3 potassium bromate:cellulose

standard and greater than the burning time of the 3:2 potassium bromate:cellulose standard are classified in Category II.

2.3.3 Category III -- Wastes of either mixture ratio that exhibit a mean burning time equal to or less than the burning time of the 3:7 potassium bromate:cellulose standard and greater than the burning time of the 2:3 potassium bromate:cellulose standard are classified in Category III.

2.3.4 Category IV -- Wastes of either mixture ratio that do not ignite and burn, or that exhibit a burning time for both mixture ratios greater than the burning time of the 3:7 potassium bromate:cellulose standard, are classified in Category IV.

3.0 DEFINITIONS

The following definitions are intended solely as guidance to assist the user in properly classifying wastes that have oxidizing properties. Refer to 40 CFR 261.21(4) for the RCRA regulatory definition of an oxidizer.

3.1 Oxidizing substance -- Any substance which, while in itself is not necessarily combustible, yields oxygen readily to stimulate the combustion of organic matter.

3.2 Burning rate -- For the purpose of this test, the burning rate is defined as the time, in seconds, from the application of electrical power to the heating wire until the main reaction (e.g., flame, incandescence, or glowing combustion) ends. Intermittent reactions, such as sparking or sputtering after the main reaction is completed, are not considered.

4.0 INTERFERENCES

This method measures the burning rates of various mixtures of potassium bromate and cellulose which are used as standards to categorize waste mixtures under a set of uniform experimental conditions. Although no interferences have been reported for this method, several factors such as particle size, reagent moisture content, room temperature, humidity, ventilation, position of the test sample in the hood, and the position of the ignition wire within the test pile can have a significant impact on the burning rates and overall method precision. In order to obtain reliable and reproducible results, it is essential that all steps be conducted in a consistent manner under the same experimental conditions. Strict adherence to all reagent specifications (i.e., particle size, moisture content, etc.) must be observed and the test conditions must be held constant throughout the evaluation. Refer to Sec. 11.0 for more information.

5.0 SAFETY

5.1 This method does not address all safety issues associated with its use. The laboratory is responsible for maintaining a safe work environment and a current awareness file of OSHA regulations regarding the safe handling of the chemicals listed in this method. A reference file of material safety data sheets (MSDSs) should be available to all personnel involved in these analyses.

5.2 This method could involve the combustion of highly flammable materials and the generation of toxic fumes. All tests must be conducted in a suitable fume hood fitted with a pull-down sash to prevent the escape of toxic fumes into working areas. The analyst should

wear appropriate protective clothing, including a laboratory jacket or apron, safety glasses, and protective gloves. The laboratory should have appropriate fire fighting equipment (such as a Class A fire extinguisher) readily available to extinguish small fires.

6.0 EQUIPMENT AND SUPPLIES

The mention of trade names or commercial products in this manual is for illustrative purposes only, and does not constitute an EPA endorsement or exclusive recommendation for use. The products and instrument settings cited in SW-846 methods represent those products and settings used during method development or subsequently evaluated by the Agency. Glassware, reagents, supplies, equipment, and settings other than those listed in this manual may be employed provided that method performance appropriate for the intended application has been demonstrated and documented.

This section does not list common laboratory glassware (e.g., beakers and flasks).

6.1 An ignition source -- An inert metal wire of platinum or nickel that can be electrically heated to approximately 1000 °C and formed into the shape shown in Figure 1 (e.g., a 30 ± 1 cm in length, 0.6 ± 0.05 mm in diameter, 22 guage, ARCOR nickel/chromium heating wire, PN 66258-102, from Fisher Scientific, or equivalent)

6.2 Low-heat conducting, non-combustible, impervious ceramic tile or equivalent material, of sufficient size to support a 70-mm diameter test sample -- This tile will be used as a platform to conduct the burning rate tests for the reference substances and waste mixtures.

NOTE: A complete burn mold for this test (Figure 2) is available from Associated Design and Manufacturing Co.; Lorton, Virginia, 22079.

6.3 A thermocouple -- To measure the temperature of the ignition wire (e.g., an Omega thin wire thermocouple, PN P13R-010, or equivalent). Instead of a thermocouple, an infrared thermometer may be used.

6.4 A calibrated thermometer to measure room temperature.

6.5 Standard sieves, 0.150-mm, 0.300-mm, and 0.500-mm (Tyler screen scale equivalent of 100-, 48-, and 32-mesh respectively).

6.6 A 60 ° glass funnel, sealed at the narrow end, with an internal diameter of 70 mm -
- This funnel is used to form the reference standards and waste mixtures into truncated conical piles with a 70-mm base.

6.7 Stopwatch capable of measuring 0.1 sec increments.

7.0 REAGENTS AND STANDARDS

7.1 Reagent-grade chemicals must be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 Potassium bromate (KBrO₃), crystalline (CASRN 7758-01-2).

CAUTION: Potassium bromate must have a nominal particle size range of 0.15 to 0.30 mm. It should be sieved through the 0.30-mm sieve followed by the 0.15-mm sieve. Light crushing and grinding is permissible to achieve the desired particle size if necessary. Carefully dry these reference substances at 65 ± 2 °C for 12 hr and store in a desiccator until used.

7.3 Cellulose fibers, with a fiber length between 50 and 350 µm and a mean diameter of 25 µm, to be used as a combustible substrate with the reference reagent and samples. Dry in a layer no more than 25 mm in thickness at 105 ± 5 °C for 4 hr and store in a desiccator until required. Each batch should be used within 24 hr of its preparation. The water content should be less than 0.5% by dry mass.

7.4 Reference standards

7.4.1 Potassium bromate and cellulose reference standard (3:7) -- Each reference standard is tested five times to determine the mean burning time. Each trial is conducted with 30 ± 0.1 g of mixture. In a 500-mL beaker or other suitable glass container, mix 60 g of potassium bromate (Sec. 7.2) and 140 g of cellulose (Sec. 7.3). The materials must be thoroughly mixed to assure a homogeneous mixture. Mechanical mixing devices may be used to assure complete mixing. The reference substance should be stored in a desiccator until the test is conducted. The 200 g of reference material will provide enough material for five trials using 30 ± 0.1 g of material, plus an additional 30-g aliquot of material, if needed. This reference standard has the longest burning time.

7.4.2 Potassium bromate and cellulose reference standard (2:3) -- If needed, prepare in the same manner as described in Sec. 7.4.1, except mix 80 g of potassium bromate with 120 g of cellulose. This reference standard has an intermediate burning time.

7.4.3 Potassium bromate and cellulose reference standard (3:2) -- If needed, prepare in the same manner as described in Sec. 7.4.1, except mix 120 g of potassium bromate with 80 g of cellulose. This reference standard has the shortest burning time.

8.0 SAMPLE COLLECTION, PRESERVATION AND STORAGE

8.1 Sample collection

8.1.1 Samples should be collected in clean glass containers fitted with PTFE-lined screw caps.

8.1.2 This procedure requires a minimum sample weight of approximately 260 g. It is recommended that more than 500 g of sample be collected to allow for retesting or confirmation of initial test results, if necessary.

8.2 Sample preservation -- No preservatives are added to the sample. The waste is tested at ambient laboratory temperature.

8.3 Sample storage -- Samples should be stored at or below ambient laboratory temperature (20 ± 5 °C).

8.4 A holding time for oxidizing solids has not been established. The sample should be tested as soon as possible to avoid any further chemical or physical changes.

9.0 QUALITY CONTROL

9.1 Refer to Chapter One for additional guidance on quality assurance (QA) and quality control (QC) protocols. When inconsistencies exist between QC guidelines, method-specific QC criteria take precedence over both technique-specific criteria and those criteria given in Chapter One, and technique-specific QC criteria take precedence over the criteria in Chapter One. Any effort involving the collection of analytical data should include development of a structured and systematic planning document, such as a Quality Assurance Project Plan (QAPP) or a Sampling and Analysis Plan (SAP), which translates project objectives and specifications into directions for those that will implement the project and assess the results. Each laboratory should maintain a formal quality assurance program. The laboratory should also maintain records to document the quality of the data generated. All data sheets and quality control data should be maintained for reference or inspection.

9.2 The mean burning time for each reference standard is determined using a minimum of five separate trials each time the test is performed. Perform each evaluation as described in Sec. 11.0 and average the results of the trials. It is not necessary to determine the burning time for all three reference substances as long as the waste can be properly categorized (Sec. 2.3). For example, if a waste does not ignite or has a burning time greater than that of the 3:7 potassium bromate:cellulose standard, no further testing is required and the burning times for the 2:3 and 3:2 potassium bromate:cellulose standards need not be determined. Should the waste exhibit a burning time less than the 3:7 potassium bromate:cellulose standard, prepare and test the 2:3 and/or 3:2 potassium bromate:cellulose reference standards as needed.

9.3 Each waste is evaluated in 1:1 and 4:1 weight-to-weight (waste:cellulose) ratios. The burning time for each waste mixture ratio is evaluated in five separate trials and the average burning time is calculated for each waste mixture ratio by dividing the sum of the burning times by five.

9.4 Each waste is categorized based on the shortest mean burning time for either waste mixture. For example, if the mean burning time for the 1:1 waste mixture is 55 sec and the mean burning time for the 4:1 waste mixture is 28 sec, then the 28-sec burning time is compared to the mean burning times exhibited by the reference standard(s) in order to make the appropriate oxidizing classification.

10.0 CALIBRATION AND STANDARDIZATION

10.1 Determine the mean burning time (in seconds) for each reference standard using a minimum of five separate trials according to the procedures contained in Sec. 11.0. The mean burning times for the standard(s) must be determined each time the test is performed. The mean burning time for each reference standard is obtained by dividing the sum of the five burning trials by five.

10.2 The burning time for all three standard reference mixtures need not be determined, as long as the waste can be properly categorized, as described in Sec. 2.3.

11.0 PROCEDURE

11.1 Waste preparation

11.1.1 Carefully dry the waste to be evaluated at 65 ± 2 °C for 12 hr and store in a desiccator until used. Each batch should be used within 24 hr of its preparation.

WARNING: Extreme care should be exercised when drying waste samples with unknown properties. It is possible that the waste may combust or react violently upon heating.

11.1.2 Evaluate the particle size of the waste, in order to assure consistent burning rate times and to assure the complete mixing of waste and cellulose. The waste should be cut, crushed, or ground so that the particle size of the sample to be tested is no larger than 0.5 mm (passes through a 32-mesh sieve).

11.1.3 Waste:cellulose mixture (1:1) -- In a 500-mL beaker or other suitable glass container, mix 100 g of waste and 100 g of cellulose (Sec. 7.2). The materials must be thoroughly mixed to assure a homogeneous mixture. Mechanical mixing devices may be used to assure complete mixing. This will provide enough test material to conduct five burning rate trials using 30 ± 0.1 g of material per trial, and an additional aliquot if needed.

11.1.4 Waste:cellulose mixture (4:1) -- In a 500-mL beaker or other suitable glass container, mix 160 g of waste and 40 g of cellulose using the procedure described in Sec. 11.1.3.

11.2 Burning rate test

11.2.1 Weigh five separate 30.0 ± 0.1 g aliquots of the 3:7 potassium bromate:cellulose reference standard (Sec. 7.4.1) into five separate glass beakers or other suitable containers.

11.2.2 Position the ceramic tile (Sec. 6.2) in a fume hood approximately 20 cm (8 in) from the front of the hood in an area of laminar airflow. Air flow across the test sample should be minimal (approximately 0.5 - 0.7 m/s), but sufficient to prevent the escape of fumes or smoke into working areas.

11.2.3 Position the ignition wire over the center of the ceramic tile. The ignition wire is formed into a 40-mm circular loop (see Figure 1), and positioned approximately 1 mm above the test surface (see Figure 2).

11.2.4 Place $30.0 \text{ g} \pm 0.1 \text{ g}$ of reference substance into the glass funnel. Tap the funnel gently to settle the material in the funnel, place the ignition wire and ceramic tile on top of the funnel, and then invert the funnel and sample to cover the ignition wire and ceramic tile. Remove the funnel. The reference substance should be in the form a truncated conical pile with a base approximately 70 mm in diameter, centered over the ignition wire so that the wire is completely covered by the test sample. Refer to Figure 1 for placement of the conical pile and ignition wire.

11.2.5 Measure the burning time of the 3:7 potassium bromate:cellulose reference standard by turning on the electric power and heating the ignition wire to at least 1000 °C, but no greater than 1050 °C. The temperature of the ignition wire may be measured as follows using a thermocouple: Make sure that the ignition wire is flat on the

platform. Bend the thermocouple wires so that the tip of the thermocouple can be held by the pressure of the bent thermocouple wires against the ignition wire. Clamps may be used to hold everything in place. Place the thermocouple near the middle of the Y-shaped ignition wire, maintaining contact. Apply power and adjust until the required temperature is reached. (An infrared thermometer may instead be used to measure wire temperature.)

Begin timing when the power is applied to the wire and continue timing until the end of the main combustion. Once the pile is ignited, turn off the power to the ignition wire. Record the total burning time in seconds. Repeat the burning time trial four more times, using a fresh 30.0 ± 0.1 -g aliquot of reference standard for each trial, and calculate the mean burning time. Allow the ceramic tile to cool to ambient temperature between time trials. In order to ensure consistent data, all tests must be conducted under standard test conditions, which include a temperature of 20 ± 5 °C and a relative humidity of $50 \pm 10\%$.

11.2.6 Measure the burning times of the 1:1 and 4:1 waste:cellulose mixtures as described in Secs. 11.2.1 through 11.2.5. Each waste concentration is evaluated with five separate time trials and the average burning time is calculated. The shortest mean burning time for either waste concentration is used to categorize the waste.

NOTE: If the first two trials of each waste/cellulose mixture result in no ignition, then the unknown can be classified in Category IV (non-oxidizer) without further testing.

11.2.7 Apply power to the ignition wire as described in Sec. 11.2.5 until observable signs of combustion are evident. If the waste mixture does not appear to ignite, continue heating the ignition wire for a period of at least three minutes. If the waste fails to ignite after this period of time, no additional trials are required and the results of the oxidizing test are negative.

CAUTION: This procedure compares the mean burning time exhibited by a waste to that of standard reference materials having known burning characteristics. It is therefore critical that the test be conducted in a consistent manner in order to assure reliable and consistent results. Care should be taken to assure that all test conditions are held constant to the extent possible. The position of the ceramic tile within the fume hood and the position of the ignition wire within the conical pile should be the same for all trials. Recognition of ignition and termination of burning must be applied in a consistent manner for both reference substances and waste mixtures.

If the burning times for both the 1:1 and 4:1 waste mixtures are greater than the burning time for the 3:7 potassium bromate:cellulose standard, then no further testing is required and the burning times for the 2:3 and 3:2 potassium bromate:cellulose standards need not be determined. If one or both of the burning times for the waste mixtures are equal to or less than that of the 3:7 potassium bromate:cellulose standard, then prepare and test the 2:3 and/or 3:2 potassium bromate:cellulose reference standards as needed (Sec. 11.2.8).

11.2.8 If needed, measure the burning time for each of five aliquots of the 2:3 potassium bromate:cellulose standard (Sec. 7.4.2) and the 3:2 potassium bromate:cellulose (Sec. 7.4.3) standard as described in Secs. 11.2.1 through 11.2.5. Calculate the mean burning time for the standards.

11.3 Criteria and method for assessing results

The results are assessed on the basis of:

- whether the waste mixture ignites and burns; and
- the comparison of the average burning time for the shortest of the two (2) waste mixtures with those of the reference standards.

12.0 DATA ANALYSIS AND CALCULATIONS

A waste sample is categorized by comparing the shortest mean burning time for either of the waste mixtures (1:1 waste:cellulose and 4:1 waste:cellulose) with the mean burning times exhibited by the standard reference substances. Category I wastes have the highest oxidizing strength, while wastes in category III have the lowest oxidizing strength. Any wastes that do not ignite or burn within three minutes, or have burning times greater than the 3:7 potassium bromate standard, are not considered oxidizers under this test, and are placed in category IV. Use the table below to make the appropriate classification.

If the Shortest Mean Burning Time in Seconds for Any Waste Mixture Is...	Then the Waste Is:
Less than or equal to that of the 3:2 potassium bromate:cellulose standard	Category I (oxidizer)
Less than or equal to that of the 2:3 potassium bromate:cellulose standard and greater than that of the 3:2 potassium bromate:cellulose standard	Category II (oxidizer)
Less than or equal to that of the 3:7 potassium bromate:cellulose standard and greater than that of the 2:3 potassium bromate:cellulose standard	Category III (oxidizer)
Greater than that of the 3:7 potassium bromate:cellulose standard or does not ignite or burn within three minutes	Category IV (a non-oxidizer)

13.0 METHOD PERFORMANCE

13.1 Performance data and related information are provided in SW-846 methods only as examples and guidance. The data do not represent required performance goals for users of the methods. Instead, performance goals should be developed on a project-specific basis, and the laboratory should establish in-house QC performance criteria for the application of this method. These performance data are not intended to be and must not be used as absolute QC acceptance criteria for purposes of laboratory accreditation.

13.2 In an evaluation of the standard reference oxidizer/fuel mixtures, the burning rates for the 3:7, 2:3, and 3:2 (w/w) potassium bromate:cellulose mixtures were determined. Separate aliquots of 30 ± 0.1 g of each mixture were formed into conical piles and ignited by

means of an electrically-heated ignition wire. Each reference mixture was tested with a minimum of six separate trials. Table 1 summarizes the mean burning times and standard deviations exhibited by each of the three reference mixtures. These data are provided for guidance purposes only, and the actual burning times obtained by any laboratory may vary, depending on the specific experimental conditions (see Ref. 4).

13.3 Table 2 gives example burning times of two sample mixtures and the three standards. All data were taken from Ref. 5, and these data are provided for guidance purposes only. A comparison of the data in Tables 1 and 2 reveals that the absolute burning time for the standards can differ significantly between laboratories. The cellulose, the potassium bromate, the preparation steps, and the ambient laboratory conditions are all contributing factors to the burning time. However, a sample is not classified according to its absolute burning time, but rather is classified based on its burning time relative to the standards analyzed each time that samples are tested. Thus, even though there will be differences in burning times between laboratories, the procedure will yield correct classifications of waste samples.

13.4 Table 3 gives example burning times of two waste samples and the three standards. These tests were conducted at EPA's NEIC laboratory. The data show that neither of the unknown samples were classified as a solid oxidizer by the test. Both unknown samples were dried sediment from waste ponds at a facility producing hexaaminecobalt(III) nitrate. Unknown Sample No. 1 contained only 0.6% (w/w) of this compound, however it was tested because it contained 21.9% (w/w) total nitrate. Unknown Sample No. 2 contained 120.4% (w/w) hexaaminecobalt(III) nitrate and 10.5% (w/w) total nitrate. The data from the three standards compares the burn rates determined by the NEIC laboratory to values obtained by the study addressed by Ref. 4. Very good agreement was obtained between the 3:7 and 2:3 potassium bromate:cellulose standards. Greater relative differences were shown between laboratories on the 3:2 potassium bromate:cellulose standards. This probably is due to the use of different ignition wires or power sources. These factors could affect the time, once electrical power is supplied, that elapses before the ignition wire reaches a temperature that ignites the test mixture.

14.0 POLLUTION PREVENTION

14.1 Pollution prevention encompasses any technique that reduces or eliminates the quantity and/or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in laboratory operations. The EPA has established a preferred hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address their waste generation. When wastes cannot be feasibly reduced at the source, the Agency recommends recycling as the next best option.

14.2 For information about pollution prevention that may be applicable to laboratories and research institutions consult *Less is Better: Laboratory Chemical Management for Waste Reduction* available from the American Chemical Society's Department of Government Relations and Science Policy, 1155 16th St., N.W. Washington, D.C. 20036, <http://www.acs.org>.

15.0 WASTE MANAGEMENT

The Environmental Protection Agency requires that laboratory waste management practices be conducted consistent with all applicable rules and regulations. The Agency urges

laboratories to protect the air, water, and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any sewer discharge permits and regulations, and by complying with all solid and hazardous waste regulations, particularly the hazardous waste identification rules and land disposal restrictions. For further information on waste management, consult *The Waste Management Manual for Laboratory Personnel* available from the American Chemical Society at the address listed in Sec. 14.2.

16.0 REFERENCES

1. Hasegawa et al, "Characteristics of the Conical Pile Type Burning Test Method for Determining the Potential Hazards of Oxidizing Material," *J. Loss. Prev. Process Ind.*, Vol 2, p 135, July 1989.
2. Title 49, Part 173, Appendix F, Guidelines for the Classification and Packaging Group Assignments of Division 5.1 Materials.
3. United Nations, Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, ST/SG/AC.10/11/Rev 2, Section 34, Classification Procedures, Test Methods and Criteria Relating To Oxidizing Substances of Division 5.1, Test O.1: *Test for Oxidizing Solids*, 1995.
4. Science Applications International Corporation, Final Report for the Evaluation of Method 1040, submitted to the US EPA, Office of Solid Waste, June 1998.
5. John Fowler of NEIC, Personal Communication to Oliver Fordham, OSW, July 1999.

17.0 TABLES, DIAGRAMS, FLOW CHARTS, AND VALIDATION DATA

The following pages contain the tables and figures referenced by this method. A flow diagram of the procedure is included after the figures.

TABLE 1

EXAMPLE MEAN BURNING TIMES (IN SECONDS) AND STANDARD DEVIATIONS
OF THE STANDARD REFERENCE OXIDIZER/FUEL MIXTURES

Oxidizer:Fuel Ratio	Mean Burning Time in Seconds \pm SD
3:7 Potassium Bromate:Cellulose	64 \pm 14.8 ¹
2:3 Potassium Bromate:Cellulose	28 \pm 8.2 ²
3:2 Potassium Bromate:Cellulose	16 \pm 0.7 ²

¹ Results based on six trial burns.

² Results based on seven trial burns.

All data are taken from Ref. 4 and are provided for guidance purposes only. The burning times for the standard mixtures must be determined each time the test is conducted.

TABLE 2
EXAMPLE BURNING TIMES OF VARIOUS MIXTURES

Test No.	Burning Time (sec)				
	Sample/Cell. 4:1	Sample/Cell. 1:1	KBrO ₃ /Cell. 3:7	KBrO ₃ /Cell. 2:3	KBrO ₃ /Cell. 3:2
1	11	38	105	58	10
2	14	--	105	50	11
3	10	--	129	56	8
4	13	--	103	56	12
5	14	--	118	60	10
Mean	12	38	112	56	10
Std. Dev.	1.8	--	11.2	3.7	1.5
%RSD	14.6	--	10.0	6.7	14.8

Conclusion: Since the 4:1 sample/cellulose mixture burned at a rate between the 2:3 and 3:2 KBrO₃/cellulose standards, the sample material is a DOT 5.1 oxidizer and falls within Packing Group II.

Subsequent chemical analysis of the sample found that it was approximately 55% sodium chlorate with the remaining material being mostly sodium chloride. Sodium chlorate is a known oxidizer and in its pure form is listed in Packing Group II.

All data are taken from Ref. 5 and are provided for guidance purposes only. The burning times for the standard mixtures must be determined each time the test is conducted.

For comparison, the DOT reference values for the standards are:

3:7 KBrO ₃ /cellulose	100 sec
2:3 KBrO ₃ /cellulose	54 sec
3:2 KBrO ₃ /cellulose	4 sec
4:1 pure sodium chlorate/cellulose	5 sec

TABLE 3

EXAMPLE RESULTS FROM SOLID OXIDIZER TEST ON WASTE
FROM PRODUCTION OF HEXAAMINECOBALT(III) NITRATE

Test No.	Standards Burning Time (sec)		
	KBrO ₃ /Cell. 3:7	KBrO ₃ /Cell. 2:3	KBrO ₃ /Cell. 3:2
1	53	25	7
2	67	24	6
3	73	29	6
4	60	30	7
5	82	32	7
Mean	67	28	6.6
Std. Dev.	11.2	3.4	0.5
Ref. Value	64	28	16

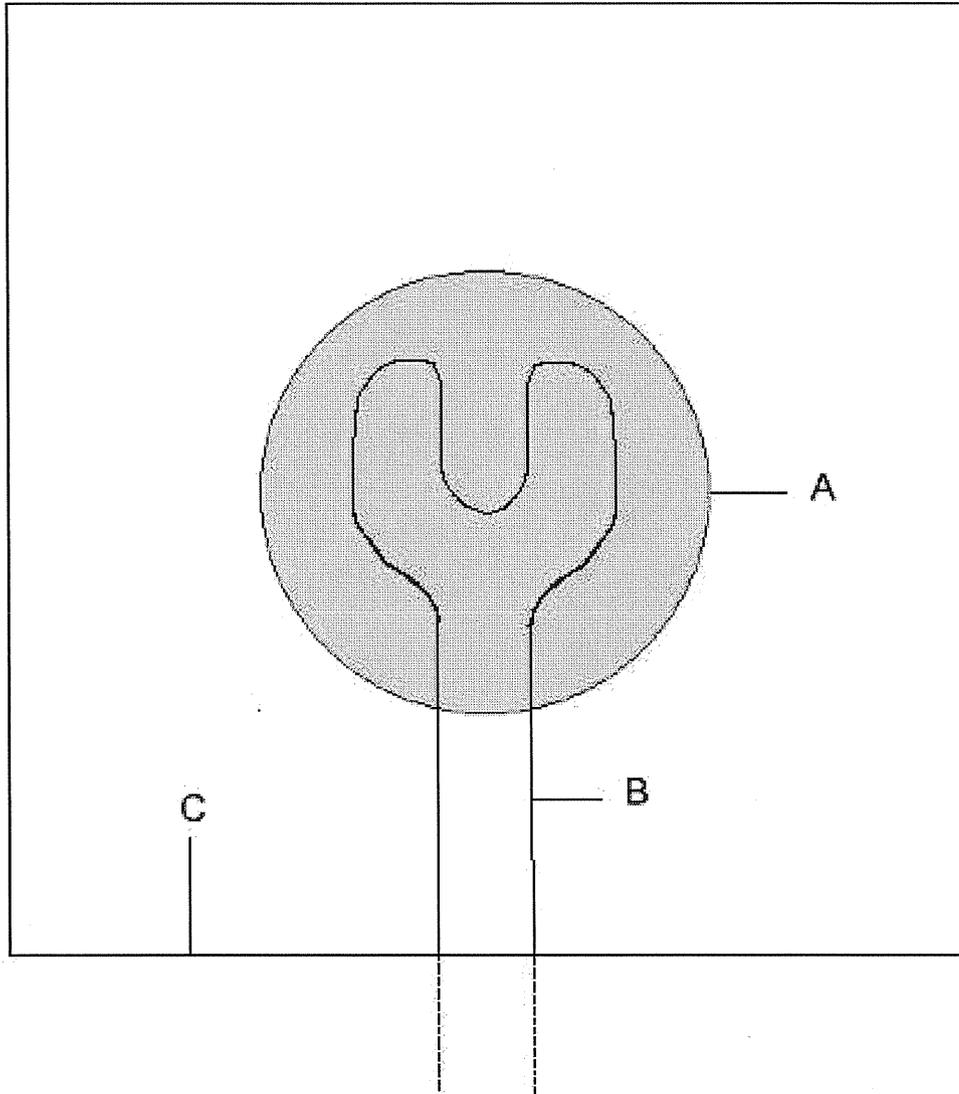
Sample/Cellulose Mixture	Test No. 1 Sample Burning Time (sec) by Sample Type		
	Unknown No. 1 Sample	Unknown No. 2 Sample	Hexamine Cobalt (III) Nitrate Sample
4:1	>180	>180	124
1:1	>180	>180	24

Ignition wire: Nickel chrome wire, ARCOR PN 66258-102

Single test only on Unknown #1 and #2 because they did not ignite.

Single test only on the Hexamine Cobalt (III) Nitrate because of limited supply and high cost.

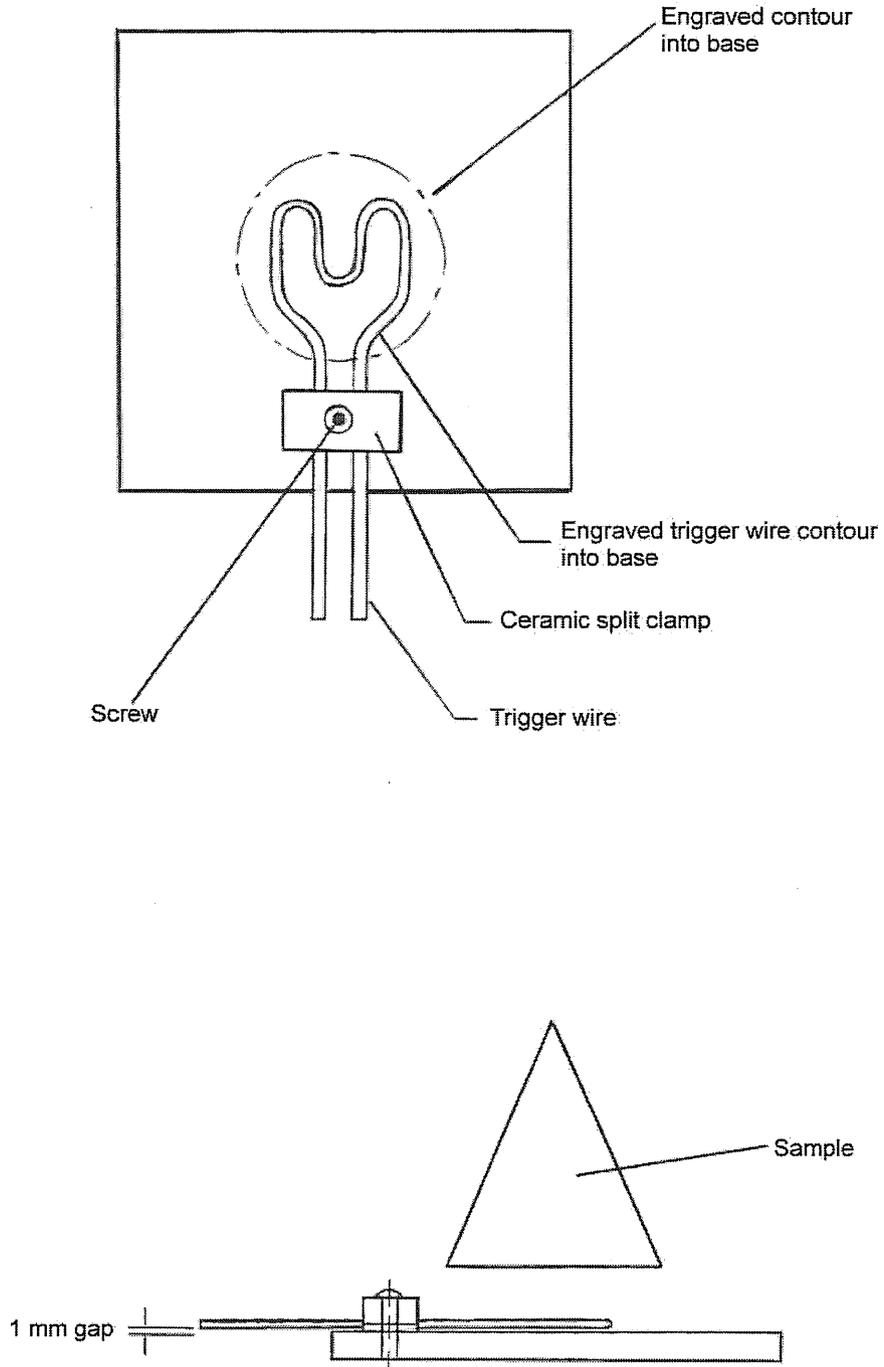
FIGURE 1
TEST PLATE AND IGNITION WIRE
(not to scale)



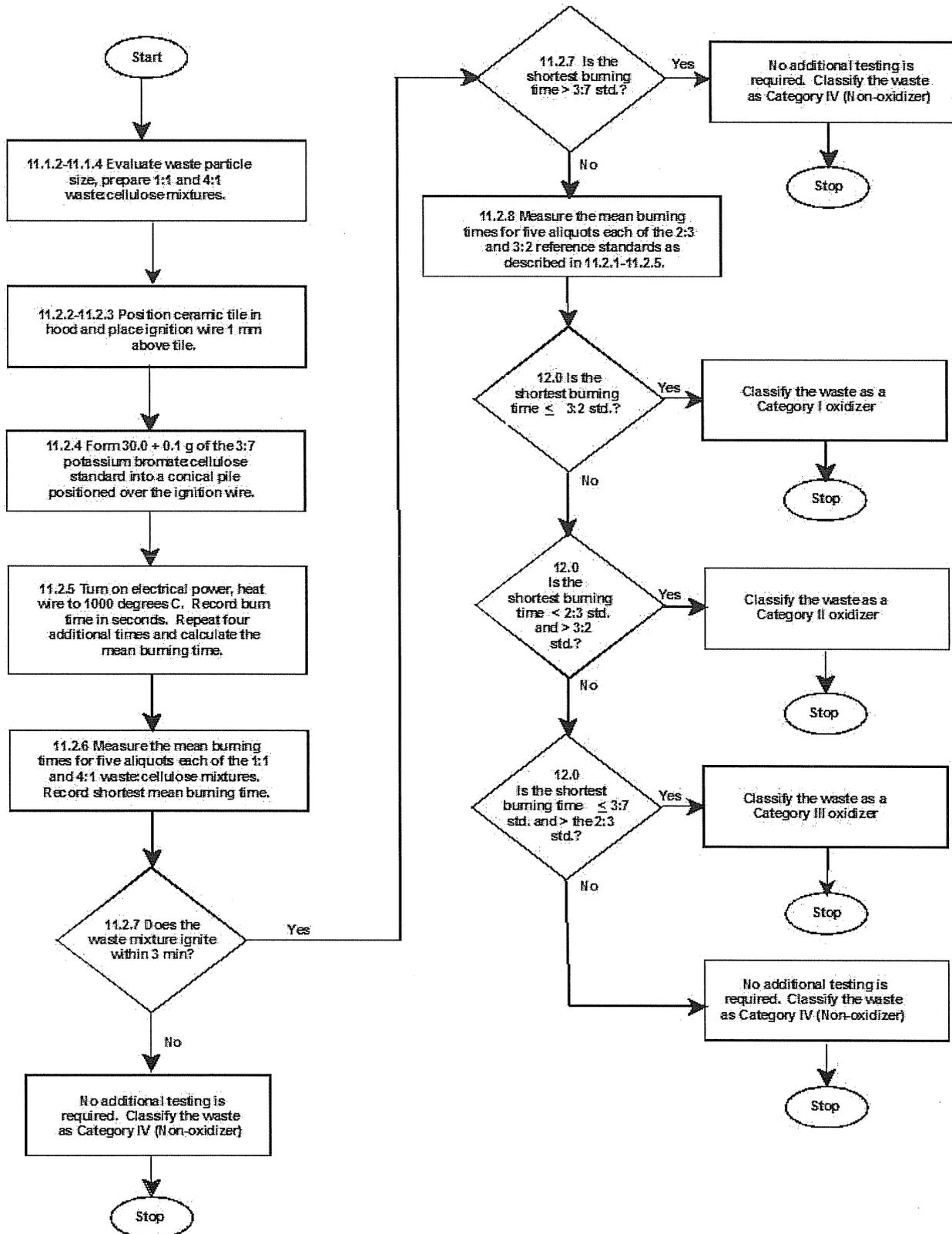
- A = Outline of the base of the 70-mm conical pile
- B = Approximate position and shape of the ignitor wire
- C = Ceramic tile or other non-combustible material, approximately 150 mm on each side

FIGURE 2

BURN MOLD WITH IGNITION WIRE POSITIONED APPROXIMATELY 1 MM ABOVE THE TEST SURFACE
(not to scale)



TEST METHOD FOR OXIDIZING SOLIDS



Appendix B
Statement of Work
Oxidizing Solids Test Plan



ENERGETIC MATERIALS RESEARCH AND TESTING CENTER

801 Leroy Place Socorro, NM 87801

Phone: (505) 835-5312 Fax: (505) 835-5630 <http://www.emrtc.nmt.edu>

Oxidizing Solids Test Plan

Prepared for:

Washington TRU Solutions LLC
PO Box 2078
Carlsbad, NM 88220

By:

Graham Walsh
Research Scientist

Energetic Materials Research and Testing Center
New Mexico Institute of Mining and Technology
Socorro, NM 87801

January 6, 2010

1.0 Purpose / Background

The EPA SW-846, test method 1040 (included as Appendix A) is suitable for assessing the relative oxidizing hazard of solid substances, including solids, granular materials, and other materials that can be formed into a conical pile. Some materials bound for storage at WIPP are co-mingled with nitrate salts, which in pure form, are categorized for transportation as oxidizers. This test series will determine the amount of inert material (zeolite clay and ground concrete) that must be mixed into the most reactive ratio of sodium nitrate and potassium nitrate in order to classify the mixture as a Category IV (non-oxidizer).

2.0 Test procedure

All testing shall be carried out in accordance with EPA SW-846, Method 1040, Test Method for Oxidizing Solids. This testing shall be completed in multiple stages, as outlined below. Sections 2.2 – 2.4 shall be conducted twice, once using zeolite clay as the standard matrix, and once with ground concrete as the standard matrix. Washington TRU solutions shall identify the type of zeolite clay to be used in testing, and a vendor from which it can be acquired.

2.1 Determination of Nitrate for Use – 3 tests, 6 replicates each

- 2.1.1 Test 1 – Mix 15 g NaNO_3 / 15 g cellulose. Find average of 6 burn times.
- 2.1.2 Test 2 – Mix 5 g NaNO_3 / 10 g KNO_3 / 15 g cellulose. Find average of 6 burn times.
- 2.1.3 Test 3 – Mix 15 g KNO_3 / 15 g cellulose. Find average of 6 burn times.
- 2.1.4 Determine which mixture is most energetic oxidizer (shortest burn time). This mixture will be referred to as the oxidizer and shall be used for all subsequent tests.

2.2 Find the most reactive mixing method -3 tests, 6 replicates each.

- 2.2.1 Test 1- Dissolve 13.5 g oxidizer in water; mix with 1.5 g standardized matrix. Dry. Mix 15 g oxidizer/standardized matrix mixture with 6 g cellulose. Find average of 6 burn times.
- 2.2.2 Test 2 - Mix 13.5 g oxidizer /1.5 g standardized matrix /15 g cellulose dry. Find average of 6 burn times.
- 2.2.3 Test 3 - Dissolve 6.75 g oxidizer in water; mix with 1.5 g standardized matrix. Dry. Mix 8.25 g oxidizer/ standardized matrix mixture with 6.75 g dry oxidizer and 15 g cellulose. Find average of 6 burn times.
- 2.2.4 Determine which mixing method produces the most energetic mixture (shortest burn time), use that mixing method for all subsequent tests. If there is no difference in burn time, the dry mixing method will be used in subsequent tests.

2.3 Find oxidizing solid pass / fail point -up to 7 tests, 6 replicates each.

- 2.3.1 Test 1- Mix 9 g KBrO_3 with 21 g cellulose (standard from test method). Find average of 6 burn times.
 - 2.3.2 Test 2 - Mix 15 g of a test mixture consisting of 50% oxidizer and 50% standardized matrix by weight, with 15 g cellulose. Find the average of 6 burn times.
 - 2.3.2.1 If average test mixture burn time is greater than the average standard burn time, this mixture would not be classified as an oxidizing solid. Repeat test series, increasing the oxidizer concentration in the test mixture by 10% until the average test mixture burn time is less than the standard burn time.
 - 2.3.2.2 If average test mixture burn time is less than the average standard burn time, this mixture would be classified as an oxidizing solid. Repeat test series, decreasing the oxidizer concentration in the test mixture by 10% until the average test mixture burn time is greater than the standard burn time.
 - 2.3.3 Use iterative process to determine the weight percent oxidizer at which the test mixture would be classified as an oxidizing solid. Use the mixture with the highest oxidizer concentration that would not be classified as an Oxidizing solid for all subsequent tests.
- 2.4 No failure assurance -2 tests, varying replicates.
- 2.4.1 Test I-Mix 9 g KBrO_3 /21 g cellulose. Find average of 6 burn times.
 - 2.4.2 Test 2 -Test mixture as determined in 2.3.3 above 20 times. Ensure that none of the 20 burn times are shorter than average from 2.3.1.
 - 2.4.3 If this fails, reduce the oxidizer concentration in the test mixture 5% by weight, and re-test.
- 3.0 Test Equipment
All test equipment shall meet specifications called out in EPA SW-846, Method 1040. All tests will be recorded, using a video camera.
- 4.0 Meteorological Data
Ambient temperature and humidity will be recorded by hand at the beginning of the day and once testing had concluded for the day, or when there is a significant change in atmospheric conditions.
- 5.0 Test Results
All test results will be given to Washington TRU Solutions upon the completion of testing in the form of a written report, to be provided within thirty days of testing. Washington TRU Solutions will also be given copies of the video from testing.

Appendix C
Data from Oxidizing Solids Testing

Time 8:30 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series NaNO3/Cellulose Section 2.1

Overall	Cellulose	Oxidizer (NaNO3)	Inert
%	50%	50%	N/A
Mass	15g	15g	N/A

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	3.29	400	00:47.15	18.0	37%	
2	30 g	4.39	906	01:03.19	18.5	35%	
3	30 g	4.23	291	00:44.81	18.5	31%	work properly
4	30 g	5.54	954	00:54.37	17.0	28%	
5	30 g	5.42	842	00:41.91	17.5	28%	
6	30 g	5.32	1133	00:44.16	18.0	28%	
Average				00:47.765			

Time 9:40 AM
 Operator AC/GW
 Variac Setting 15.5 V

Test Series NaNO3/KNO3 + Cellulose Section 2.1.2

Overall	Cellulose	Oxidizer (KNO3)	Oxidizer (NaNO3)	Inert
%	50%	33.33%	16.67%	N/A
Mass	15g	10g	5g	N/A

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	5.10	202	00:34.72	18.5	20%	
2	30 g	5.34	371	00:42.78	17.0	37%	
3	30 g	4.29	826	00:47.37	18.0	33%	
4	30 g	4.42	538	00:51.00	18.5	33%	
5	30 g	4.23	913	00:29.53	17.5	33%	
6	30 g	4.11	951	00:33.78	18.1	35%	
Average				00:39.86			

Time 11:30 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series KNO3 + Cellulose Section 2.1.3

Overall	Cellulose	Oxidizer (KNO3)	Inert
%	50%	50%	N/A
Mass	15g	15g	N/A

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	3.45	176	00:45.35	19.0	35%	
2	30 g	4.07	123	00:27.03	22.0	30%	
3	30 g	4.30	742	00:28.88	21.0	28%	
4	30 g	4.54	272	00:33.00	21.4	39%	
5	30 g	4.07	960	00:27.28	20.3	28%	
6	30 g	5.10	997	00:28.40	21.0	30%	
Average				00:31.66			

Time 12:10 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.1 - Wet Mix

Overall	Cellulose	Oxidizer (KNO3)	Inert (Zeolite Clay)
%	50%	45%	5%
Mass	15g	13.5g	1.5g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	5.14	71	00:25.16	22.0	31%	
2	30 g	5.48	83	00:22.84	22.0	33%	
3	30 g	3.98	819	00:22.16	21.3	30%	
4	30 g	4.88	849	00:22.59	21.8	35%	
5	30 g	5.01	618	00:21.16	22.4	37%	
6	30 g	5.82	70	00:26.13	22.0	40%	
Average				00:23.34			

Time 2:05 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.2 - Dry Mix

Overall	Cellulose	Oxidizer (KNO3)	Inert (Zeolite Clay)
%	50%	45%	5%
Mass	15g	13.5g	1.5g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	5.44	840	00:43.15	23.0	50%	
2	30 g	6.11	53	00:48.41	22.8	50%	
3	30 g	7.69	839	00:49.96	22.8	50%	
4	30 g	5.57	791	00:42.34	23.0	43%	
5	30 g	6.20	799	00:42.65	23.0	50%	
6	30 g	6.45	690	00:48.16	22.8	50%	
Average				00:45.78			

Time 2:50 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.3 Wet / Dry Mix

Overall	Cellulose	Oxidizer (KNO3)	Oxidizer (KNO3)	Inert (Zeolite Clay)
%	50%	22.5%	22.5%	5%
Mass	15g	6.75g (Wet)	6.75g (Dry)	1.5g (Wet)

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	4.57	735	00:38.06	21.4	55%	
2	30 g	6.23	846	00:38.22	21.7	52%	
3	30 g	5.08	781	00:31.97	21.3	55%	
4	30 g	5.29	120	00:36.43	21.5	55%	
5	30 g	4.89	800	00:28.38	22.0	54%	
6	30 g	5.33	806	00:36.31	21.5	53%	
Average				00:34.895			

Time 9:45 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.1 KBrO3 standard 3:7

Overall	Cellulose	Oxidizer (KBrO3)	Inert
%	70%	30%	N/A
Mass	140g	60g	N/A

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	6.20	543	03:31.00	19.8	50%	
2	30 g	6.44	164	02:46.03	18.9	49%	
3	30 g	6.42	233	02:53.91	18.0	43%	
4	30 g	7.60	361	03:07.62	19.2	41%	
5	30 g	7.16	260	03:23.87	19.2	41%	
6	30 g	6.41		03:23.65	19.4	42%	
Average				03:11.00			

Time 10:00 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.2

Overall	Cellulose	Oxidizer (KNO ₃)	Inert (ZEOULITE)
%	50%	25%	25%
Mass	15 g	7.5g	7.5g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	N/A		No RXN	18.5	49%	
2	30 g	N/A		No RXN	17.7	42%	
3							
4							
5							
6							

Average

Time 11:00 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.2.1

Overall	Cellulose	Oxidizer (KNO ₃)	Inert (BEQUITE)
%	50%	30%	20%
Mass	15 g	9 g	6 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	15.1 OFF	952	No sustained RXN	18.8	55%	
2	30 g	1:15 Back On	580	No RXN	17.0	47%	
3	30 g	N/A					
4	30 g						
5	30 g						
6	30 g						

Average

Time 11:35 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.2.1

Overall	Cellulose	Oxidizer (KNO ₃)	Inert (PERLITE)
%	50%	35%	15%
Mass	15 g	10.5 g	4.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	16.61 OFF	1024	No Self Sustaining	17.9	46%	
2	30 g	21.16 OFF	821	No Self Sustaining	17.2	43%	
3	30 g	45 Back On		Combustion			
4	30 g						
5	30 g						
6	30 g						

Average

Time 12:00 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.2.1

Overall	Cellulose	Oxidizer (KNO ₃)	Inert (ZnO/LiTE)
%	50%	40%	10%
Mass	15 g	12 g	3 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	8 OFF		829	18.5	45%	
2	30 g	30 Back On	9.54	846	17.5	40%	No further RXN
3	30 g		8.36	808	18.3	44%	00:30.72
4	30 g		8.95	301	18.3	40%	00:21.38
5	30 g		10.26	767	19.0	40%	00:27.00
6	30 g		10.58	615	19.1	41%	00:24.97
Average				00:25.452			00:23.19

Time 1:00 PM
 Operator AC/GW
 Variac Setting 15.5 V
 Test Series 40% test Kitty Litter/KNO3 - Dry mix

Overall	Cellulose	Oxidizer	Inert
%	50%	20%	30%
Mass	15 g	6 g	9 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	WIRE DID NOT HEAT			19.2	48%	
2	30 g	Wire On/Off	540	No sustained RXN	19.9	55%	
3	30 g	Wire On/Off	811	No sustained RXN	18.7	43%	
4	30 g						
5	30 g						
6	30 g						
Average							

Time 8:35 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.1

Overall	Cellulose	Oxidizer (KBrO3)	Inert
%	70%	30%	
Mass	21 g	9 g	

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	7.66	191	03:01.48	15.0	48%	
2	30 g	6.26 OFF 14 ON 20	N/A	03:24.19	16.3	43%	
3	30 g	7.95	589	03:02.25	17.5	43%	
4	30 g	10.89	711	03:52.82	16.3	41%	
5	30 g	9.41	680	02:50.00	17.0	40%	
6	30 g	10.54	588	02:54.78	17.8	40%	
Average				03:10.92			

Time 9:30 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.1

Overall	Cellulose	Oxidizer (KNO3)	Inert (grout)
%	50%	45%	5%
Mass	15 g	13.5 g	1.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	4.51	846	00:11.78	15.9	43%	
2	30 g	4.61	675	00:11.56	18.1	40%	
3	30 g	4.7	760	00:12.44	18.2	40%	
4	30 g	4.35	N/A	00:11.16	19.4	40%	
5	30 g	4.39	736	00:13.13	16.5	40%	
6	30 g	4.17	820	00:14.75	17.5	52%	
Average				00:12.47			

Time 10:05 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.2

Overall	Cellulose	Oxidizer (KNO3)	Inert (grout)
%	50%	45%	5%
Mass	15 g	13.5 g	1.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	7.17	859	00:48.94	18.6	43%	
2	30 g	5.76	970	00:50.22	19.0	42%	
3	30 g	7.39	877	00:45.25	15.3	41%	
4	30 g	5.79	1013	00:44.12	18.5	56%	
5	30 g	6.39	1037	00:44.03	18.7	50%	
6	30 g	6.42	937	00:57.78	18.2	41%	
Average				00:48.39			

Time 11:00 AM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.2.3

Overall	Cellulose	Oxidizer (KNO3)	Oxidizer (KNO3)	Inert (Grout)
%	50%	22.5%	22.5%	5%
Mass	15g	6.75g (Wet)	6.75g (Dry)	1.5g (Wet)

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	5.01	N/A	00:22.53	18.4	55%	
2	30 g	5.76	956	00:19.31	18.4	43%	
3	30 g	6.23	1039	00:17.16	19.0	50%	
4	30 g	5.48	949	00:16.16	19.0	50%	
5	30 g	5.58	941	00:18.97	17.1	40%	
6	30 g	6.17	925	00:21.65	18.4	42%	
Average				00:19.30			

Time 11:35 AM

Operator AC/GW

Variac Setting 15.1 V

Test Series Section 2.3.2

Overall	Cellulose	Oxidizer (KNO3)	Inert (Grout)
%	50%	25%	25%
Mass	15 g	7.5 g	7.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	N/A	775	No RXN @3 min	18.2	45%	
2	30 g	N/A	790	No self sustained	18.3	43%	
3	30 g						
4	30 g						
5	30 g						
6	30 g						

Average

Time 12:00 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.3.2.1

Overall	Cellulose	Oxidizer (KNO3)	Inert (Grout)
%	50%	30%	20%
Mass	15 g	9 g	6 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	39	796	00:55.00	18.6	59%	
2	30 g	10.92	56	00:50.47	19.6	55%	
3	30 g	30.26	787	00:48.75	18.6	42%	
4	30 g	11.11	69	00:35.00	18.8	49%	
5	30 g	N/A	826	00:58.00	19.0	43%	
6	30 g	21.61	470	00:50.04	N/A	N/A	
Average				00:49.54			

Time 2:00 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series 2.4 KBrO3 STD

Overall	Cellulose	Oxidizer (KBrO3)	Inert
%	70%		30%
Mass	21 g		9 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	14.17	42	03:16.97	23.4	40%	
2	30 g	8.76	56	02:46.19	24.0	55%	
3	30 g	9.51	51	02:29.12	23.6	42%	
4	30 g	9.91	43	02:42.56	23.9	59%	
5	30 g	11.20	500	02:36.50	23.9	55%	
6	30 g	8.55	593	01:30.66	24.0	59%	

Average

Time 3:30 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.4.2

Overall	Cellulose	Oxidizer (KNO3)	Inert (Zeolite)
%	50%	35%	15%
Mass	15 g	9.5 g	4.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	13.20	N/A	00:35.07	23.9	49%	Fail
2	30 g	13.48	787	00:37.85	24.0	40%	Fail
3							
4							
5							
6							

Average

Time 4:15 PM

Operator AC/GW

Variac Setting 15.5 V

Test Series Section 2.4.2

Overall	Cellulose	Oxidizer (KNO3)	Inert (Grout)
%	50%	25%	25%
Mass	15 g	7.5 g	7.5 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30 g	36.7	121	00:53.13	23.2	40%	Fail
2	30 g	17.42	677	01:13.97	23.5	43%	Fail
3							
4							
5							
6							

Average

Time 9:45 AM
 Operator AC/GW
 Variac Setting 15.5 V

Test Series Section 2.4.3

Overall	Cellulose	Oxidizer (KNO3)	Inert (grout)
%	50%	22.5%	27.5%
Mass	15 g	6.75 g	8.25 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1		On/Off Multiple 30 Times	582	No Self Sustained RXN	19.1	40%	Pass
2		On/Off Multiple 30 Times	284	No Self Sustained RXN	20.3	51%	Pass
3		On/Off Multiple 30 Times	N/A	No Self Sustained RXN	21.2	41%	Pass
4		On/Off Multiple 30 Times	792	No Self Sustained RXN	22.5	46%	Pass
5		On/Off Multiple 30 Times	645	No Self Sustained RXN	21.6	47%	Pass
6		On/Off Multiple 30 Times	700	No Self Sustained RXN	21.6	52%	Pass
7		On/Off Multiple 30 Times	733	No Self Sustained RXN	21.1	50%	Pass
8		On/Off Multiple 30 Times	685	No Self Sustained RXN	22.2	45%	Pass
9		On/Off Multiple 30 Times	738	No Self Sustained RXN	21.5	55%	Pass
10		On/Off Multiple 30 Times	710	No Self Sustained RXN	21.6	52%	Pass
11		On/Off Multiple 30 Times	670	No Self Sustained RXN	22.2	55%	Pass
12		On/Off Multiple 30 Times	800	No Self Sustained RXN	22.5	55%	Pass
13		On/Off Multiple 30 Times	783	No Self Sustained RXN	21.4	55%	Pass
14		On/Off Multiple 30 Times	652	No Self Sustained RXN	21.3	50%	Pass
15		On/Off Multiple 30 Times	539	No Self Sustained RXN	22.8	55%	Pass
16		On/Off Multiple 30 Times	30	No Self Sustained RXN	21.2	55%	Pass
17		On/Off Multiple 30 Times	133	No Self Sustained RXN	23.9	55%	Pass
18		On/Off Multiple 30 Times	788	No Self Sustained RXN	21.9	55%	Pass
19		On/Off Multiple 30 Times	685	No Self Sustained RXN	21.2	55%	Pass
20		On/Off Multiple 30 Times	577	No Self Sustained RXN	22.4	58%	Pass

Average

Time 10:15 AM
 Operator AC/GW
 Variac Setting 15.5 V
 Test Series Section 2.4.3

Overall %	Cellulose	Oxidizer (KNO3)	Inert (Zeolite)
50%	15 g	33%	18%
Mass	9.75 g	9.75 g	5.25 g

Test	Mass	Time wire off (s)	Temp wire off (°C)	Burn time (m:s)	Ambient T (°C)	Ambient H	Comments
1	30	On/Off Multiple	980	No Combustion	22.5		54% Pass
2	30	On/Off Multiple	656	No Combustion	22.7		55% Pass
3	30	On/Off Multiple	38	No Combustion	22.2		54% Pass
4	30	On/Off Multiple	44	No Combustion	22.1		48% Pass
5	30	On/Off Multiple	803	No Combustion	22.4		55% Pass
6	30	On/Off Multiple	109	No Combustion	22.4		56% Pass
7	30	On/Off Multiple	120	No Combustion	22.0		50% Pass
8	30	On/Off Multiple	38	No Combustion	22.3		55% Pass
9	30	On/Off Multiple	42	No Combustion	22.6		48% Pass
10	30	On/Off Multiple	32	No Combustion	23.4		50% Pass
11	30	On/Off Multiple	32	No Combustion	24.0		47% Pass
12	30	On/Off Multiple	36	No Combustion	24.2		50% Pass
13	30	On/Off Multiple	41	No Combustion	22.0		50% Pass
14	30	On/Off Multiple	887	No Combustion	22.6		55% Pass
15	30	On/Off Multiple	624	No Combustion	22.4		51% Pass
16	30	On/Off Multiple	734	No Combustion	22.4		55% Pass
17	30	On/Off Multiple	25	No Combustion	22.2		58% Pass
18	30	On/Off Multiple	30	No Combustion	21.3		58% Pass
19	30	On/Off Multiple	28	No Combustion	21.8		56% Pass
20	30	On/Off Multiple	894	No Combustion	22.1		56% Pass
Average							