Standardization of Explosives Classification and Characterization Testing

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ABSTRACT
Accurate sensitivity and reactivity testing is essential for appropriate explosives classification and characterization for manufacturing, storage, transport and end use. This paper outlines the international effort to more fully standardize all facets of these tests to enable consistent/repeatable test data and interpretation of results.

An overview is given of the roles and responsibilities of the Explosives Testing Users Group (ETUG), the United Nations Explosives Working Group (UN EWG), and the UN Global Harmonization System (GHS). These organizations share a common stewardship to ensure the proper 1) classification/characterization of explosive substances and articles and 2) effective communication of explosive hazards to personnel.

Standardized and tailored protocols and test methods are developed as part of ETUG. ETUG participants include major international, U.S. Department of Defense (DoD), Department of Energy (DOE), and industry explosives testing laboratories and test sites. Participating laboratories collaborate to systematically minimize the variability associated with explosives testing to ensure consistent/repeatable test data and interpretation of test results. This is accomplished by 1) developing procedures and methods, 2) applying technology, 3) reaching consensus, and 4) performing periodic "Round Robin" testing.

INTRODUCTION

Accurate sensitivity and reactivity testing is essential for appropriate explosives classification and characterization for manufacturing, storage, transport and end use. The Explosives Testing Users Group (ETUG) is focused on systematically minimizing the variables associated with energetic materials testing for in-process classification to enable consistent and repeatable test data and interpretation of test results. The United Nations Explosives Working Group (UN EWG) is focused on proper hazard identification and standardization of tests for transport of explosives. The International Group of Experts on the Explosion Risks of Unstable Substances (IGUS) is a part of the UN EWG and is a group of experts who are focused on the "exchange of information on the behavior of unstable substances, with respect to production, handling, storage, and transport." The UN Global Harmonization System (GHS) is focused on the proper communication of hazards from dangerous good in all life-cycle stages. Working with ETUG, IGUS, UN EWG, and GHS greatly facilitates the proper characterization and classification of explosives for all life-cycle stages of explosives. In this paper, the details of the approach used in the Explosives Testing Users Group is highlighted with the understanding that similar approaches are used in the other complementing groups.

The Explosives Testing Users Group (ETUG) is made up of major international, U.S. Department of Defense (DoD), Department of Energy (DOE), and industry explosives testing laboratories and test sites. The ET Users Group participants collaborate to improve and standardize in-process characterization test methods for explosives, propellants, and pyrotechnic materials. Below is highlighted the approach used by the ETUG by developing standardized procedures and methods, applying technologies, and completing Round Robin testing as a verification tool for explosives characterization and classification. Additionally, as part of the ETUG, the group has created and made available an online database termed the Test Method Matrix which is also highlighted below.

1. Developing Procedures and Methods

The ET Users Group makes use of detailed procedures for explosives testing that address machine verification, site repeatability, gas analyzer verification, high-speed video application, sample receipt and preparation, and statistical data collection (e.g., Bruceton, Probit, etc.)

Machine verification is detailed with specifics in the procedure that call for standardized variables. For example, when using the Modified Bureau of Mines (MBOM) Impact Machine, the home position, surface finish, drop weight guide bar alignment, drop time, and weights are examined and verified to be consistent with the procedure.

Test samples are also standardized through conditioning and application. Sample templates are used and on-line demonstrations available for application and testing. Statistical methods are used that include the Statistical Relative Comparison Method and the Chart Significance Method, each of which easily facilitate statistical based decisions on whether test results are indeed different from each other or not (Guymon 2014) .

2. Applying Technologies

The ETUG Charter includes sensitivity and reactivity testing to further establish standardized procedures and methods. Sensitivity testing analyzes the ability to initiate from an energy stimulus, and includes friction, impact, ESD, dust explosibility, auto-ignition temperature, and etc. These tests require participants to simulate in-process energy stimuli and conditions, where all data is submitted in engineering units. Reactivity testing investigates propagation characteristics after ignition, including rapid burning, deflagration, or detonation. It requires participants to simulate in-process energy stimuli, configuration, and conditions.

Technology is very useful for assessing and standardizing sensitivity and reactivity testing. For example, gas analyzers can be incorporated with impact, friction, and ESD tests. Gas analyzers measure the CO concentrations given off during testing and can detect 1+ ppm changes. Gas analyzer specific software can be coupled with software that can determine whether a test is a “Go” or “No-Go”.

High speed videos (HSV) can be used in impact, friction, and ESD sensitivity tests. HSV can detect the on-set of a reaction from light or the excessively rapid expulsion of material termed jetting. For ESD testing, GoDetect-ESD (Patent numbers 9,202,145 and 9,654,742) uses HSV and with image processing algorithms to automatically detect reactions based on specific criteria such as buoyancy, brightness, shape, uniformity, and color. This reduces the factors of human error in detecting reactions and also provides video documentation.

High speed video also aids is the assessment of various reactivity tests (e.g., determine fragmentation velocity/energy, reaction duration, etc.)

3. Round Robin

A significant part of Round Robin testing is determining the criteria that defines agreement or disagreement between test facilities. Due to variability (either biased or random), results from each laboratory or within the same laboratory may differ. The criteria to say that the results are different or not is statistically based. The ET Users Group has adopted the Statistical Relative Comparison (SRC) Method (Guymon 2014) to determine if differences in the sensitivity test outcomes are indeed significantly different (“ETUG Round Robin Testing” 2018).

After participants have completed testing as instructed by the procedure and methods, a statistical comparison of results is used to determine if results between laboratories are statistically different. The SRC Method uses a t-value, which is a measure of the difference between results, with higher values indicating greater disagreement. When t-values are greater than 3.75, it indicates a statistically significant difference (Guymon 2014). The SRC Method can be used with Probit, Bruceton, SEQ, Langlie, or other adaptive test methods. A Chart Significance Method (also adopted by the ET Users Group), is used to determine statistical significance for trials completed at a given energy level.

4. ETUG Test Methods Matrix™ (TMM)

The ETUG Test Methods Matrix™ (TMM) is a tool used to ensure that accurate sensitivity and reactivity testing is used for explosives classification and characterization throughout all life cycle stages. It is a publicly-accessible

database that outlines the purpose, key test parameters, and indicators (including pictures and videos) for each sensitivity and reactivity test for both In-Process and UN test methods ("Test Method Matrix" 2018). The database also serves as a repository for the specifications for the parameters and indicators along with the documentation of their origins. The objectives of the TMM are to document the technical basis for "in-process" and UN Tests, and to provide an informal tool to facilitate technical discussions.

The TMM consists of an In-Process Classification section, which outlines the purpose, key test parameters, and indicators (including pictures and videos) for each sensitivity and reactivity characterization test prescribed in the ET Users Group technical standard "ETUG-GS01-15: ETUG Standard for In-Process Hazard Classification of Explosives." Provided in this section are also in-process decision trees to determine which tests are used ("In Process Classification" 2018). In-process classification utilizes key process parameters such as composition, physical state, configuration/confinement, quantity, conditions, and initiation stimulus. The database steward for the In-Process Classification is the ETUG.

The TMM includes a UN Manual Classification System section for testing and criteria ("UN Manual Classification System" 2018). This section is based on the test series listed in the UN Manual and are also included in the database since many of the in-process tests use similar or the same test parameters. The International Group of Experts on the Explosion Risks of Unstable substances (IGUS), comprised of members of the United Nations Explosives Working Group (UN EWG), has stewardship over this section.

The ETUG Test Methods Matrix™ is considered a "living database" that will be continually enhanced by gathering additional origin information, expanding example test photos and videos, and strengthening 1.5 and 1.6 portions of the test database.

5. Summary

The international effort to more fully standardize sensitivity and reactivity testing is done through developing procedures and methods, applying technologies, undergoing Round Robin testing, and collaborating with multiple domestic and international related groups. Standardized testing is based on sound principles that result in accurate, repeatable test results and user confidence. The use of the ETUG TMM facilitates technical collaboration and is a key tool in the standardization of testing. In-process classification and characterization are essential and required for proper facility siting, risk assessment, and risk management.

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