SYNCHRONIZATION OF IM AND HC: THE NAVY PERSPECTIVE

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Abstract

The US Navy's Naval Ordnance Safety and Security Activity (NOSSA) is charged with the development and evaluation of Insensitive Munitions (IM) advanced technologies, managing the Hazard Classification (HC) program to enable the safe transport and storage of ammunition, explosives and related components, monitoring of the developments or trends in energetic materials, weapons or ordnance systems, ship or aircraft systems that influence or could adversely affect ordnance safety, their applications, and the safety impacts to the DON of those developments. Recently, NOSSA has combined the IM & HC personnel into one assembly to facilitate the synchronization of the IM & HC testing and application of testing requirements for each facet. This paper will present the US Navy's perspective of the harmonization of IM and HC functions.

Insensitive munitions (IM) Background

In 1979 Vice Admiral John D. Bulkeley, the President of the Navy Board of Inspection and Survey, was concerned about the survivability of the new Navy combat ships. He was particularly concerned about ships built with aluminum superstructures and ordnance magazines located above the water line. He requested and then listened with interest to a NAVSEA presentation on new explosive materials technology. Admiral Bulkeley agreed that the explosives being developed by the Navy laboratories could improve ship survivability in combat. He wrote [1] to Admiral R.L.J. Long, the Vice Chief of Naval Operations to recommend that the Navy initiate a program to exploit this new technology and make "Insensitive Ordnance" available to the Fleet.

Though he is probably unaware of it, Admiral James D. Watkins, who became the Secretary of Energy in President Bush's (Bush 41) administration, coined the name "Insensitive Munitions". After he relieved Adm. Long as the Vice Chief of Naval Operations, Adm. Watkins signed a Navy Operational Requirement document calling for the development and exploitation of "Insensitive High Explosives". The goal was to make "Insensitive Ordnance", a term coined by VAdm. Bulkeley, available to the Fleet [2].

Subsequently, a small group of people who worked on the Chief of Naval Operations Executive Board briefing on Insensitive Munitions wrestled with the definition of an "Insensitive Munition" and finally after many modifications, LCdr. John Kelly of OP-354, Dr. Lloyd Smith of the Naval Air Warfare Center, Weapons Division, China Lake, CA, Mr. Jack Turner of JJH, Incorporated (then with NKF Engineering, Inc.), and Mr. Ray Beauguard proposed the following definition [3]:

"Insensitive Munitions are those that reliably fulfill their performance, readiness, and operational requirements on demand, but are designed to minimize the violence of a reaction and subsequent collateral damage when subjected to unplanned heat, shock, fragment or bullet impact, electromagnetic pulse (EMP), or other unplanned stimuli."

As a result of Adm. Bulkeley's recommendation to make insensitive ordnance available to the Fleet, and some follow-on actions taken by other Naval officers, what began as the U.S. Navy initiative to improve ship survivability evolved. This initiative has now grown into an internationally recognized goal applicable to all weapon platforms used by the land, air, and sea forces. This background is an excerpt taken from Mr. Ray Beauguard's "History of the US Navy IM Program" [4].

Current IM Criteria

In 1985, NAVSEAINST 8010.5 was introduced to establish technical requirements for Insensitive Munitions (IM). This instruction and its successor, NAVSEAINST 8010.5A (DoN 1986), described the Fast Cook Off (FCO), Slow Cook Off (SCO), and Bullet Impact (BI) tests from the WR-50, and added the Fragment Impact (FI) and Sympathetic Detonation (SD) tests, with pass/fail "goals to strive for achievement by 1995".

MIL-STD-2105A was issued in 1991 and described the basic tests required for the assessment of explosive safety and IM characteristics. Test requirements as well as pass/fail criteria were detailed for FCO, SCO, BI, FI, SD, as well as the addition of Shaped Charge Jet Impact (SCJI) test and the spall impact test. MIL-STD-2105B superseded MIL-STD-2105A in 1994, and was approved as the IM safety test standard for all DoD Departments and Agencies. MIL-STD-2105B noted that the standard was “revised to add additional IM tests as called out by the Joint Service Requirement for Insensitive Munitions (JSRIM)”; MIL-STD-2105B makes a distinction between explosive safety tests and the IM tests. Regarding passing criteria, MIL-STD-2105B noted that “failure to meet all predetermined test criteria is not necessarily grounds for automatic rejection of that weapon system for service use”.

In 2003, MIL-STD-2105C superseded MIL-STD-2105B by referencing the individual NATO STANAGs for the assessment of munition safety and Insensitive Munitions (IM) characteristics of non-nuclear munitions, the pass/fail criteria in STANAG 4439 (NATO 2006), and AOP-39 for guidance on the development, assessment and testing of IM. Efforts were undertaken during Calendar Year 2000 in NATO AC/310 and AC/258 (later to merge into AC/326) to harmonize Insensitive Munitions and Hazard Classification large-scale testing. This work has resulted in a more cost effective test and analysis program for program managers and technology development programs, although there is still room for improvement. With the approval of AOP-39 Edition 2 in 2006, STANAG 4439 and AOP-39 became the controlling documents for assessment and testing of IM.

In conjunction with the approval of AOP-39 Edition 2, the November 6, 2006, Joint Requirements Oversight Council (JROC) memorandum recommended a standardized, single set of Insensitive Munitions (IM) tests and passing criteria for use by all Components for assessing IM compliance. These standard protocols, which are shown below, endorsed the JROC's activities in validating any unique variations thereto within the Joint Capabilities Integration Development System (JCIDS). Although the IM standard tests and passing criteria have been implemented for all programs since their recommendation by the JROC, and this process has been overseen by the Office of the Under Secretary of Defense through the Joint Services IM Technical Panel, they had not been officially issued until February of 2010 [5].

Joint Insensitive Munitions Test Standards and Passing Criteria

1. Introduction

a. The standardized Insensitive Munitions (IM) testing protocols, test article configurations, and passing criteria are described below.

b. The IM scores generated using the standardized tests and passing criteria are the basis for reporting the IM compliance status of munitions in the submission of a Program Executive Officer’s (PEO) or Program Manager’s (PM) IM Strategic Plan.

c. The standardized IM testing protocols are the default procedures to be used for all munitions. Munitions and packaging design features intended to improve IM (and hazard classification) performance are to be in place during testing, as appropriate. Knowledge, analysis, or experience may lead to an assessment of pass or fail of a particular IM test by a munition, in lieu of actual testing.

d. In addition to standardized IM testing, each munitions program should continue to evaluate their cradle-to-grave lifecycle and develop a Threat Hazard Assessment (THA) to identify hazards and risks from threats more severe than those addressed by standardized testing, which DoD component acquisition organizations should incorporate into the existing risk identification, mitigation, and acceptance process. Engineering testing of such other extreme conditions is encouraged, as appropriate, for assessing incremental improvements in performance such as vulnerability and survivability. The THA may also provide information relevant during Joint Capabilities Integration Development System (JCIDS) activities addressing proposed unique variations from the established standardized IM protocols.

2. Standardized IM Test Parameters and Passing Criteria – Background

a. The standardized IM test parameters and passing criteria are based on MIL-STD-2105, which currently implements NATO Standardization Agreement (STANAG) 4439, Policy for Introduction and Assessment of Insensitive Munitions, and individual test STANAGs 4240 (Liquid Fuel/External Fire, Munition Test Procedures), 4382 (Slow Heating, Munitions Test Procedures), 4241 (Bullet Impact, Munition Test Procedures), 4496 (Fragment Impact, Munitions Test Procedures), 4526 (Shaped Charge Jet, Munitions Test Procedure), and 4396 (Sympathetic Reaction, Munition Test Procedures).

b. The passing criteria for each test are described below and are drawn from STANAG 4439. These passing criteria represent attainable goals that push IM technology and are based on warfighter, fire-fighting, and survivability needs.

c. The response type definitions used in the determination of IM test scores are also drawn from STANAG 4439.

3. Joint IM Test Standards and Passing Criteria

a. This section describes the approved standardized IM tests and passing criteria which were recommended by JROCM 235-06 [6]. Each paragraph below identifies the common name for the test, the standard procedure, the standard test article configuration(s), passing criteria, and whether the test may be integral to achieving a favorable hazard classification.

b. The following is intended to serve as the baseline definition for test article configurations:

> i) **Logistical Configuration (Storage, Shipping, or Transportation):** The logistical configuration is intended to be synonymous with the packaged configuration in which the munition is stored, shipped, or transported. In the event that a munition has different storage, shipping, or transportation configurations, multiple configurations or at least the configuration expected to result in the reaction providing the maximum credible event will be tested.
>
> ii) **Operational Configuration:** The operational configuration is intended to be synonymous with the tactical configuration in which a munition is ready to be employed as in an All-Up-Round (AUR) in a bare state. In the case where a munition is not removed from its packaging and shipping container prior to employment, the logistical configuration testing should be replicated where standardized testing specifies any operational configuration tests.

c. Liquid Fuel/External Fire – The standard test protocol is described in STANAG 4240, excluding Annex B. Two tests will be conducted – one each in a logistical and operational configuration. The passing reaction for this test is not more severe than burning (Type V). This test is core for hazard classification.

d. Slow Heating – The standard test protocol is described in STANAG 4382, Procedure 1. Two tests will be conducted in the logistical configuration. The passing reaction for this test is not more severe than burning (Type V). If no reaction has occurred when a temperature of 365°C is attained, the munition is assessed as passing the test. Slow heating testing may be relevant to achieving a favorable hazard classification.

e. Bullet Impact – The standard test protocol is described in STANAG 4241, Procedure 1. Two tests will be conducted – one each in a logistical and operational configuration. The passing reaction for this test is not more severe than burning (Type V). A third test, typically with the munition's booster as the target, is required to achieve a favorable hazard classification.

f. Fragment Impact – The standard test protocol is described in STANAG 4496, Standard Procedure. Two tests will be conducted – one each in a logistical and operational configuration. The passing reaction for this test is not more severe than burning (Type V). This is currently the only test that has no possible relevancy for hazard classification; however, a United Nations (UN) Intercessional Working Group is now considering the inclusion of a fragment impact hazard classification test within UN Test Series 7.

g. Shaped Charge Jet Impact – The standard test protocol is described in STANAG 4526, Procedure 2, and uses an PG-7V surrogate. This standardized stimuli is defined as an 81mm BRL precision shaped charge loaded with LX-14 explosive with four inches of conditioning aluminum (Surrogate configuration is identified by ARDEC Picatinny Arsenal DWG 7GP20078. Two tests will be conducted – one each in a logistical and operational configuration. The passing reaction for this test is not more severe than an explosion (Type III). This test may be relevant for hazard classification because during sympathetic reaction testing the 81mm SCJ stimuli may be the means of initiation of a donor rocket motor, propelling charge, or similar item where the propellant poses the predominant hazard.

h. Sympathetic Reaction – The standard test protocol is described in STANAG 4396. Two tests will be conducted in a logistical configuration – one confined and one unconfined. A minimum of one donor and two acceptor packages are required per test. This test is core for hazard classification. A passing reaction for this test that qualifies for a hazard classification assignment of Hazard Division (HD) 1.2.3 is no detonation (Type I) or partial detonation (Type II) of any acceptor rounds in a package surrounding the donor package; for hazard classification assignment to HD 1.6, no detonation (Type I) or partial detonation (Type II) of any acceptor rounds, to include within the donor package, must be exhibited during testing. The means of donor initiation for rocket motors, propelling charges, or similar items where propellant poses the predominant hazard, should consider both the items' own means of initiation and other initiation sources (e.g., detonators or shaped charges) capable of stimulating the donor in excess of its own means, yet not overwhelmingly masking the reaction effects of the munitions being tested.

Since 1984, the Navy's Insensitive Munitions Office (IMO) has worked to uphold the changing standards and criteria by tracking the Navy Program POA&Ms for all Navy weapons to follow their progress toward meeting the IM Policy goals, providing support to the Insensitive Munitions Coordinating Group (IMCG) and providing support to the OPNAV Insensitive Munitions Council. The IMO also directs the Insensitive Munitions Advanced Development (IMAD) Program, coordinating the application of new IM technology to weapon systems, maintains a liaison with the NAVAIR IM Technology Transition Program Manager, reviews, comments and recommends concurrence for IM Test Plans and Interfaces the Navy's position within the Joint Service IM Technical Panel (JSIMTP).

Hazard Classification (HC) Background

Hazard classification identifies the damage potential of hazardous materials during transportation and storage. For the Department of Defense (DoD), the classification of a munition is a critical element in the overall explosive safety program. With the munition's classification, the appropriate transportation mode and conveyance and the proper storage location can be determined. A DoD final hazard classification is assigned once the munition' s design has been established and prior to release for operational service. Historically once the final hazard classification is assigned, it is as its name implies final. It lasts for the life of the munition.

Hazard classification has been part of the explosive safety program for decades. Within the DoD, the earliest tri-service instruction for hazard classification that can be identified is dated 31 July 1962; however, test reports for assigning classifications date back to the 1950s. Through the years various classification systems have been utilized. In the 1960s, a munition would be assigned numerous hazard classifications for different applications. This included an Interstate Commerce Classification, a Coast Guard Classification, an Army classification, and a Navy classification. As time and regulations passed, these different types of classifications have been consolidated into one (1990 time frame), or close to one, classification system that can be used for transportation and storage.

Current HC Criteria

The current instruction is the Department of Defense Ammunition and Explosives Hazard Classification Procedures are shown below.

1. TB 700-2 (DoD 2005)

2. UN Orange Book (UN 2007)

3. DoD Ammunition and Explosive Hazard Classification Procedures NAVSEAINST 8020.8B

4. DoD Transportation and Storage Data for Ammunition, Explosives and Related Hazardous Materials NAVSEA SW020-AC-SAF-010

5. TO 11A-1-47, DLAR 8220.1 of 5 Jan 98

6. Department of Transportation Title 49, Transportation (CFR 1991)

7. Code of Federal Regulations and the North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) No. 4123 "Methods to Determine and Classify the Hazards of Military Ammunition and Explosives".

To assign the hazard classification, the US Navy evaluates the munitions behavior to a variety of stimuli. There are two questions to be answered as a result of this evaluation. They include: (1) is the munition too dangerous to transport, and (2) which division within Class 1 does this munition belong. The first question is answered through thermal and sensitivity testing (drop testing on articles, impact, friction and small scale burn testing on substances). Tests are conducted to answer the question "Which Hazard Division (HD) (1.1, 1.2, 1.3 and 1.4) corresponds most closely to the behavior of the product?" The test series includes internal ignition or initiation, propagation of burning or explosion, and fire tests of products. The geometrical arrangement of the products should be realistic in regard to the packing method and the conditions of transport and storage should be such as to produce the most disadvantageous test results. Details of the test criteria are shown below [7].

<u>Thermal Testing</u>: UN Test Series 3C for Substances and UN Test Series 4A for Articles

<u>Sensitivity Testing</u>:

- Drop Testing on Articles: UN Test Series 4B
- Impact: UN Test Series 3A
- Friction: UN Test Series 3B
- Small Scale Burn Testing for Substances: UN Test Series 3D

The second question of which HD to assign is typically more complicated and utilizes at a minimum sympathetic reaction (SR) and liquid fuel/external fire testing (LF/EF) and can include slow heating (SH) and bullet impact tests (BI) as well as testing of the energetic within the munition. To determine which of these tests are needed depends on the classification being assigned. The table below provides the tests needed to support the specific hazard division.

<u>Sympathetic Reaction</u>: UN Test Series 6B Stack Testing (most similar testing to IM SD criteria)

<u>Liquid Fuel / External Fire Testing</u>: UN Test Series 6C (most similar testing to IM Fast Cook Off criteria)

<u>Slow Heating</u>: UN Test Series 7H (most similar testing to IM Slow Cook Off criteria)

<u>Bullet Impact Test</u>: UN Test Series 7H (most similar testing to IM Bullet Impact criteria)

Hazard Division/Subdivision	Tests required to determine division
1.1, 1.2.2, 1.2.2, 1.3, and 1.4	SR and LF/EF
1.2.3	SR, LF/EF, SH, and BI
1.6	SR, LF/EF, SH, BI, and Series 7 substance tests

<u>Thermal Testing: UN Test Series 3C for Substances and UN Test Series 4A for Articles</u>

This test is designed to measure the stability of the substance when subjected to elevated thermal conditions to determine if the substance or article is too hazardous to transport in the state in which it was tested.

Criteria and method of assessing Substance results:
(a) Thermal instability. A test result is considered failing (positive (+)) if ignition or explosion occurs and passing (negative (-)) if no decomposition has occurred. Any decomposition other than minor surface discoloration from oxidation requires the second part of the test to be conducted.

(b) Severity of instability. The sample is considered thermally unstable (positive (+) response (-) failing) if a temperature difference (i.e., self-heating) of +3°C of the sample (for a minimum time of ten seconds) is

recorded. If no ignition or explosion of self heating of 3°C or greater is recorded in the test, but self-heating of less than 3°C is noted, additional tests and/or evaluation may be required to determine thermal stability.

Criteria and method of assessing Article results:
A test result is considered positive (+) if any of the following occurs:
1. It explodes.
2. It ignites.
3. It generates colored fumes or odor.
4. It experiences a temperature rise exceeding 3°C.
5. The outside casing of the article or the outside packaging is damaged.
An article or packaged article(s) which gives a positive (+) test result is judged to be too hazardous for transport.

<u>Sensitivity Testing</u>:

- Drop Testing on Articles: UN Test Series 4B

This test determines whether a test unit (packaged substance or article) can withstand a free-fall impact without producing any fire or explosion hazard. It is not intended as a test to evaluate whether the package will withstand the impact. Criteria and method of assessing results:
A test is considered positive (+) if a fire or explosion resulted from impact. Rupture of the package is not considered a positive result.

- Impact: UN Test Series 3A

This test is designed to measure the sensitivity of the substance to mechanical stimuli involving normal impact to determine if the substance is too hazardous to transport. It is applicable to solid and liquid substances by using two different sample assemblies. Criteria and method of assessing results:
(a) Solids. The criteria used in the interpretation of this test for solids are that a measurement is considered positive if either an audible report or flame is observed. A sample is considered impact sensitive at a specific drop height if a flame or report is observed in at least 50% of the test trials. A sample which shows impact sensitiveness at a drop height of 10.16 cm (4.0 inches) or less (a positive (+) response) is considered too sensitive for transport.

(b) Liquids. The criterion used in the interpretation of this test for liquids is that a measurement is considered positive if either an audible report or smoke is observed in one of 10 test trials. Any liquid explosive which fails this test at a drop height of 25.4 cm (10.0 inches) or less (a positive (+) response) is considered too sensitive for transport.

- Friction: UN Test Series 3B

This test determines the sensitivity of substances to friction. The test substance is subjected to vertical compression force under a non-rotating wheel, while the substance is moved in a horizontal direction on a sliding anvil. It is intended for both liquid and solid substances. Criteria and method of assessing results:
(a) A trial is considered positive (+) if any one of the following results is obtained:
1. Visible sparks.
2. Visible flame.
3. Audible explosion.
4. Loud crackling noise.
5. Detection of reaction products by a gas analyzer.

(b) Discoloration of the sample holder, crepitation (i.e., subdued cracking due to crumbling of the sample), or slight odor in the absence of additional indicators is not considered positive (+) results.

(c) A substance with friction sensitivity equal to or greater than dry PETN, i.e., lower compressive force, is considered a positive (+) result and is too sensitive for transport. PETN has a TIL of 184 N (41.4 lb) at 0.9 m/sec (3 ft/sec).

- Small Scale Burn Testing for Substances: UN Test Series 3D

A Small-Scale Burning Test is used to determine if small quantities of substances transition from deflagration to detonation when unconfined. Criteria and method of assessing results:
A test result is considered positive (+) if explosion or detonation occurs. The substance is judged to be too hazardous for transport (in the form in which it is tested) if any results are positive (+).

<u>Sympathetic Reaction: UN Test Series 6B Stack Testing</u>
This test is conducted three times with stacks of packages of an explosive product or stacks of non-packaged articles (if that is how they are transported/stored) for the purpose of determining: (*1*) Whether burning or explosion in the stack is propagated from one package to another or from one non-packaged article to another; and *(2)* in what way the surroundings could be endangered by this event. Criteria and method of assessing results:
If in Test 6B explosion of virtually the entire contents occurs practically instantaneously, then the product is assigned to Hazard Division 1.1. Evidence of such an occurrence includes:
(a) A crater at the test site appreciably larger than that given by a single package.

(b) Damage to the witness plate beneath the stack which is appreciably greater than that from a single package.

(c) Measurement of blast which significantly exceeds that from a single package.

(d) Violent disruption and scattering of most of the confining material. If the product is accepted as Hazard Division 1.1 and the fragment hazard range does not exceed the default value of 381 m (1250 ft),
Note. If two or less acceptor packages detonate in a confined stack test with four acceptor packages, then the packaged article can be hazard classified as Hazard Division 1.2; otherwise, it is hazard classified as Hazard Division 1.1.

<u>Liquid Fuel / External Fire Testing: UN Test Series 6C</u>

This is a test on a stack of packages of an explosive product or a stack of articles (as configured for transport and storage) for the purpose of determining:

(a) How the packages or non-packaged articles in the stack behave when involved in an external fire.

(b) Whether and in what way the surroundings are endangered by blast waves, thermal effects and/or fragment projection.

Criteria and method of assessing results:
The methodology used to determine the assignment of a Hazard Division based upon the results of Test Series 6. The following sections describe the assignment process.

(a) The article is classified as Hazard Division 1.1 if explosion of the total contents appears to occur instantaneously.

(b) The articles are classified as Hazard Division 1.2 if an explosion reaction results
Note. If two or less acceptor packages detonate in a confined stack test with four acceptor packages or more, then the packaged article can be hazard classified as Hazard Division 1.2; otherwise, it is hazard classified as Hazard Division 1.1.

<u>Slow Heating: UN Test Series 7H</u>
The 1.6 Article Slow Cook Off is a test on a possible Hazard Division 1.6 article. It is used to determine reaction to a gradually increasing thermal environment and the temperature at which such reaction occurs. Criteria and method of assessing results:
If there is a reaction more severe than burning, the result is noted as positive (+) and the item is not classified as Hazard Division 1.6. The energetic material may ignite and burn and the case may melt or weaken sufficiently to allow mild release of the combustion gases. Burning should be such that case debris and package elements stay in the area of test except for case closures which may be dislodged by the internal pressure and thrown not more than 15 meters (50 ft).

<u>Bullet Impact Test: UN Test Series 7J</u>

The response of a possible Hazard Division 1.6 article to the kinetic energy transfer associated with the impact and penetration by a given energy source. Criteria and method of assessing results:
For an item to be considered as a Hazard Division 1.6 article, there should have been no detonation (or explosion) resulting from any of the tests. Reactions of the article identified as no reaction, burning, or deflagration are considered as negative (-) test results.

<u>Synchronization of IM and HC</u>
Historically, it has been the SR and LF/EF tests that have been the cornerstone for determination of the hazard division. As the previous table shows, Hazard Division 1.2.3 and Hazard Division 1.6 utilize more than just these two tests. These divisions were created to provide storage quantity distance (QD) benefits as compared to the QD of hazard division 1.1, 1.2.1, or 1.2.2. The concept is that munitions should get QD benefits as they improve their insensitivity. This solidified a link with IM testing.

Through the use of new energetics, munitions casing, and transportation/storage packaging, the IM and HC programs have had numerous success stories in reducing a munition's sensitivity. The benefit of this reduced sensitivity may be shown in the hazard classification assigned or the longevity of the munition's insensitivity. It's no coincidence that the SH and BI testing required for HD 1.2.3 and 1.6 are also IM tests. A passing reaction for SR qualifies for a hazard classification assignment of Hazard Division (HD) 1.2.3 is no detonation (Type I) or partial detonation (Type II) of any acceptor rounds in a package surrounding the donor package; for hazard classification assignment to HD 1.6, no detonation (Type I) or partial detonation (Type II) of any acceptor rounds, to include within the donor package, must be exhibited during testing. This is the same for the IM testing. The result is a synchronized test with synchronized results.

In fact, the harmonization of hazard classification and Insensitive Munitions has been an ongoing effort within DoD for many years. With the very large costs to the Joint Services to test and evaluate ammunition and explosive ordnance, conducting separate hazard classification and Insensitive Munition tests is not practical when evaluating similar stimuli. One objective of a harmonized IM and HC plan is to accomplish all testing criteria by expending a minimum number of assets.

<u>Details of the Synchronization of the HC and IM Test Criteria</u>
In MIL-STD-2105C, for the FCO test, which is performed in accordance with STANAG 4240, the minimum flame temperature requirement was changed to 800°C (1472°F). This represents a lowering of the minimum flame temperature from that of MIL-STD-2105B. This was done to maintain a consistent flame temperature when wind is a factor [8, 9, 10] and to harmonize with the hazard classification (HC) External Fire Test of TB 700-2 and the UN Orange Book, which is implemented by 49 CFR. This harmonization was also pursued for SCO, BI, and SD/SR (nomenclature moving to SR).

There were no changes to the 6°F/hr or 3.3°C/hr heating rate requirement throughout the different versions of the specifications for SCO. For MIL-STD-2105A and subsequent controlling standards, the passing criterion was that there be no reaction more severe than burning (Type V) at a heating rate of 6°F/hr. The SCO requirements in MIL-STD-2105C provided harmonization with the HC Slow Heating Test of TB 700-2 and the UN Orange Book [11].

In MIL-STD-2105C for BI, a three-round burst was specified with a firing interval equivalent to 600±50 rounds/min, and the velocity tolerance was tightened slightly to 850±20 m/s. The change from a single 20 mm bullet impact to the three-round burst of 0.50 cal projectiles resulted in a defacto synchronization of the IM tests with the hazard classification (HC) BI test of TB 700-2. The second and third bullets impact damaged or shock-sensitized explosive, which represents a more severe or worst case threat.

When MIL-STD-2105C was released, it called for the FI test to be performed in accordance with STANAG 4496, for which the requirement was for an 18.6 g conical-ended cylindrical fragment to have an impact velocity of 2530 ± 90 m/s (8300 ± 300 ft/s). STANAG 4496 also included alternate procedure to provide an alternate test with a lower stimulus level 1830 ± 60 m/s (6000 ± 200 ft/s). There were no further changes for STANAG 4439 and AOP-39. This is not a harmonized test with HC, not required for HC.

The passing criterion for the SD test in MIL-STD-2105A and MIL-STD-2105B was no detonation (Type I) of any acceptor (munition test item). For MIL-STD-2105C and subsequent controlling standards, the passing criterion

was no response more severe than Type III (explosion). The SR requirements in MIL-STD-2105C provided harmonization with the HC Sympathetic Reaction Test of TB 700-2 and the UN Orange Book.
The passing criterion for the SCJI test in MIL-STD-2105A and MIL-STD-2105B was no detonation (Type I) of any acceptor (munition). For MIL-STD-2105C and subsequent controlling standards, the passing criterion was no response more severe than Type III (explosion). This is not a harmonized test with HC, not required for HC.

In 2009, the Navy took the step to consolidate the IM and HC offices into one. This combined office has the responsibility to uphold the rigorous criteria of both IM and HC testing. The Insensitive Munitions Hazard Classification Office (IMHCO) interfaces with the Joint Service IM Technical Panel (JSIMTP) and Joint Service Hazard Classifiers (JSHC) to communicate a substance or article munition round test plan that will satisfy both the IM and HC criteria. Because the IMHCO works so closely with the JSHC and JSIMTP, test plan concurrences take a significantly shorter amount of time. The Navy's IMHCO is in a unique position among the other Services. This office has within its construct, personnel, the Branch Manger and two Team Leaders, which participate in both the JSHC meetings as well as the JSIMTP meetings. The result is that both the IM and HC facets are cognizant of the Navy Programs coming before each panel. The Navy's IMHCO staff members are also well versed with other Service programs.

The IMHCO also liaises with the Munition Reaction Evaluation Board (MREB) to ensure their concurrence with synchronized IM and HC test plans for upcoming official reaction scoring. Comments and recommendation are given as once Navy voice to the JSHC and JSIMTP from the Navy IMHCO office,

Conclusion
The chart shown below indicates the current IM criteria with the relationship to HC.

					STANAG
FCO		Liquid Fuel Fire (e.g., truck or an aircraft on a flight deck)	Burning	HC Relation : Required for hazard classification Stimulus : Rapid heating response Comments : None	4240
SCO		Slow Heating 3.3 °C/Hr (e.g., fire in adjacent magazine, store or vehicle)	Burning	HC Relation : Required for reduced hazard classification Stimulus : Slow heating response Comments : Additional technical studies appropriate	4382
BI		.50 Cal M2AP 3 round burst (e.g., small arms from terrorists or combat)	Burning	HC Relation : Required for reduced hazard classification Stimulus : Low level kinetic impact Comments : Relevant small arms threat More severe threats exist Additional studies appropriate	4241
FI		18.6 gram fragment 8300 +/- 300 fps (e.g., bombs, artillery, or IEDs)	Burning	HC Relation : Not required for hazard classification Stimulus : Combine shock, mechanical, thermal Comments : Artillery fragments slower Some KE and EFP threats more severe	4496
SD		Detonation of a single donor (detonation of adjacent stores)	Explosion	HC Relation : Required for hazard classification Stimulus : Output of a like munition Comments : Does not address mixed storage Does not address multiple donor	4396
SCJ		81-mm Precision shaped charge (e.g., RPG, Bomblets, ATGMs: Combat or terrorists)	Explosion	HC Relation : Not required for hazard classification Stimulus : Shock Comments : More severe threats exist Pragmatic threat considering technology potential	4526

The test procedures of SR, LF/EF, SH and BI have all been synchronized with IM and updated STANAGS released. The next version of the DoD Hazard Classification instruction incorporates these harmonized procedures. Though the standardized tests fall within the test parameters of the STANAGs, the specificity of the test parameters and test conditions has generated a continuing need for an updated version of MIL-STD-2105. An update to MIL-STD-2105C (MIL-STD-2105D) is being planned. This update will be coordinated through the IMHCO. This update will ensure the IM tests, policy, procedures and response descriptors are appropriately aligned with IM and HC to achieve full international test coordination with the STANAGs.

References:

[1] Bulkeley, John D. VAdm. USN(Ret.), President, Navy Board and Inspection and Survey Confidential letter to Admiral R.L.J. Long, Vice Chief of Naval Operations dated 27 February 1979.

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Biography:

Dr. Kerry Clark is the Technical Authority of the Navy's Insensitive Munitions (IM) and Hazard Classification (HC) programs to include explosives and propulsives, qualification and type qualification programs and interim and final hazard classifications. She manages the Navy's IM Advanced Development (IMAD) program and leads and participates in Joint Services and international groups to guide IM and HC policy from a Navy perspective. Dr. Clark is a supporting member of the OSD IM IPT, JSIMPT, JSHC panel and collaborates with NATO and allied nations DEAs/IEAs and NATO Action Committee 326 Subgroups.