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Guidance on Test Item Configurations for Sympathetic Reaction Testing in Accordance with AOP- 4396

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Abstract

The Sympathetic Reaction test is used for Hazard Classification of munitions and Insensitive Munitions assessments. The results determine the munition's storage and handling procedures and are used in allotting investment funds for improving munition safety. The North Atlantic Treaty Organization (NATO) Insensitive Munitions (IM) Sympathetic Reaction Custodian Working Group (SRCWG) met in Utrecht, Netherlands on Sept 17-18, 2018 to review and revise STANAG/AOP 4396 'Sympathetic Reaction, Munition Test Procedures'. The focus of this review was to update the test requirements, assess the technical metrics within the document for validity and applicability, ensure conformity with other NATO documents, and discuss national implementation procedures to ensure consistency of munition assessments. During discussions, it became apparent that there were discrepancies amongst the nations in selecting the quantity of munitions for the test, the test configuration, and the donor parameters. Additionally, while the volumetric requirement of 0.15 m^3 (5.3 ft^3) was undoubtedly adopted from the HC community (e.g. Orange Book / CFR-49), the technical rationale for this specific metric could not be ascertained.

Per STANAG 4396 Ed 2

- Section 8a states: *"The test items should be in their storage/transport configuration, but in the smallest configuration (smallest individual package) offered. The test requires sufficient packages or articles to give a minimum total volume of 0.15 m^3, with a minimum of one donor and two acceptor packages"*.
- Section 9b(1) states: "*The volume of the stack must be at least 0.15 m^3 minimum. If the volume of the donor and one acceptor package exceeds 0.15 m^3, two acceptors are required, but three are desirable"*.
- Section 9b(2) states: *"Two tests shall be performed – one with confinement and one without"*.

The discrepancies were not only between the NATO member nations, but between the Hazard Classification (HC) community and the IM community as well. In general, each NATO member nation described their test set-up differently, such as: not applying the minimum volumetric requirement, utilizing inerts to meet the volumetric requirement, only using one acceptor, etc. The HC community noted that for HC assessment two tests are required, one in the Confined Configuration and one in the Unconfined Configuration; while the IM community noted that for IM assessment two tests are required, both in the Unconfined Configuration. These discrepancies could be an impediment to harmonization efforts between these communities.

The authors have investigated typical logistical configurations for munitions and found that the current volumetric requirement is appropriate as it applies to test item configurations. The technical justification is presented, along with a proposed guidance section to be incorporated into the STANAG/AOP, at the following SRCWG meeting in Brussels, BE in April, 2019. This paper discusses the technical justification for the volumetric requirement and the proposed guidance section.

Successfully implemented IM technology saves soldier lives' and their assets, and properly tested weapon systems improves safety at the at home in the load plants, as well as overseas in the battlefield.

Objective

To provide a review and guidance for properly selecting and constructing the appropriate configuration(s) for conducting the Sympathetic Reaction (SR) test per AOP-4396. This paper discusses the analyses conducted that identify the potential technical reasoning for the origins of the volumetric requirements found in STANAG-4396, which will be incorporated in AOP-4396 and can affect how the Sympathetic Reaction test is conducted when performing harmonized Insensitive Munitions and Hazard Classification testing.

The intention of this paper is to communicate, to the various Safety and Hazard Identification communities, the importance of the Sympathetic Reaction (Detonation) test, and the proposed origins of the requirements that bound the experimental test. The proposed origins of the requirements are discussed in this paper, and are theorized based on mathematical analyses that were conducted in reference to Standard NATO shipping and storage processes and materiel. The reader should better understand how to properly design the configuration, and set up the test item, for a Sympathetic (Reaction) Detonation test for Insensitive Munitions, Safety, and/or Hazard Classification/Division purposes. This test is an extremely valuable test to perform to understand / characterize the worst reaction a munition can produce when another adjacent munition detonates accidently. Performing and evaluating this test properly enables engineers to design IM Technology that provides a safer environment for Ammunition Load, Assemble, Package (LAP) Plant employees and the Warfighter.

Background

The 2nd Sympathetic Reaction Custodian Working Group (SRWG) in Utrecht, Netherlands took place Sept 17-18, 2018, to review/revise STANAG/AOP 4396. During discussions regarding the appropriate configurations in which to test, it became apparent that there were discrepancies between the countries with respect to how to properly select and set up the test item appropriately. Additionally, there were discussions regarding the differences between how the Hazard Classification Community and the Insensitive Munitions community do so. This paper discusses the guidance instructional being proposed to the SRCWG for incorporation into the Standards Related Document (SRD) for reference when preparing to conduct a SR test for Insensitive Munitions and Hazard Classification purposes.

Discussion

The aim of STANAG 4396 (Edition 2), ratified 12 December 2001, is to provide a standard test procedure to assess the potential for a munition to sympathetically react to the initiation of an adjacent munition. The STANAG is currently under review to update the test requirements, assess the technical metrics within the document for validity and applicability, ensure conformity with other NATO documents, and discuss national implementation procedures to ensure consistency of munition assessments. Additionally, the new AOP-4396 is under development for the purpose of providing guidance on conducting a SR test per the updated STANAG-4396.

STANAG 4396 (Ed 2), Section 8a. 'Sample Section' states that: 'The test requires sufficient packages or articles to give a minimum total volume of $0.15m^3$, with a minimum of one donor and two acceptor packages'. Section 9b. 'Number and Layout of Munitions' further clarifies that: 'The volume of the stack must be at least $0.15m^3$ minimum. If the volume of the donor and one acceptor package exceeds $0.15m^3$, two acceptors are required, but three are desirable. While reviewing the current requirements for this test at the SRCWG II meeting, the technical reasoning for the metric of $0.15m^3$ was questioned. Of the ~19 SMEs participating in this CWG, no one was able to identify the historical reason for this metric. Since this metric defines the quantity of energetic test items (called packages and/or articles in the Ed. 2 terminology), it is an important requirement that must be evaluated, understood, and either accepted or changed. Representatives from US Army CCDC-AC took initiative to investigate potential sources for this specific metric. The following is the outcome of the analysis performed by US Army CCDC-AC.

Since the SR test is addressing packaged / logistical configurations of munitions, initial thoughts were that the metric is tied to the packaging and palletization of munitions. After reviewing several 'Unitization' (Pallet) drawings used for shipping and storing common (high production, cross-service use) munitions, it was found that 40in x 48in is a typical aerial dimension of an ammunition pallet. In fact, the standard NATO pallet (Figure 1) is 40in x 48in ≈ (1.0m x 1.2m). Depending on the munitions being stacked, and other load requirements (e.g. weight, ammo quantity, etc.), the pallet is typically stacked ~38in-52in high.

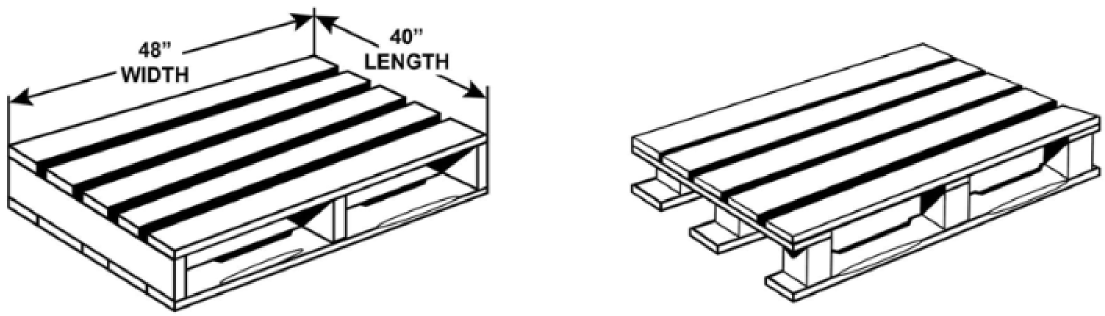


Figure 1 — Standard NATO Pallet

So, for simplicity, 40in(L) x 48(W)in x 40in(H) will be used to calculate the volume of a common pallet load.

- 40inx 48in x 40in = $44.44ft^3 \approx 1.25m^3$

Using a sample of 1/8 of this Pallet Load Volume,

- $44.44ft^3 / 8 = 5.55ft^3 \approx 5.3ft^3 \approx 0.15m^3$

*Note the similarity of 1/8 of a pallet load, which is $5.55ft^3$, to the SR test volumetric requirement of $5.3ft^3 \approx 0.15m^3$. It is apparent that this is where the volumetric requirement of $0.15m^3$ ($5.3ft^3$) originates, and it is accepted that this is the technical reasoning supporting this legacy metric.

To evaluate this similarity to common munitions, the analysis was performed with three different common munitions that are typically packaged in three common families of ammunition containers. Typically medium caliber ammunition (20cal, 30cal, 40cal, 50cal, grenades, mines, demo etc.) are packaged in rectangular ammo boxes, as illustrated in Figure 2.

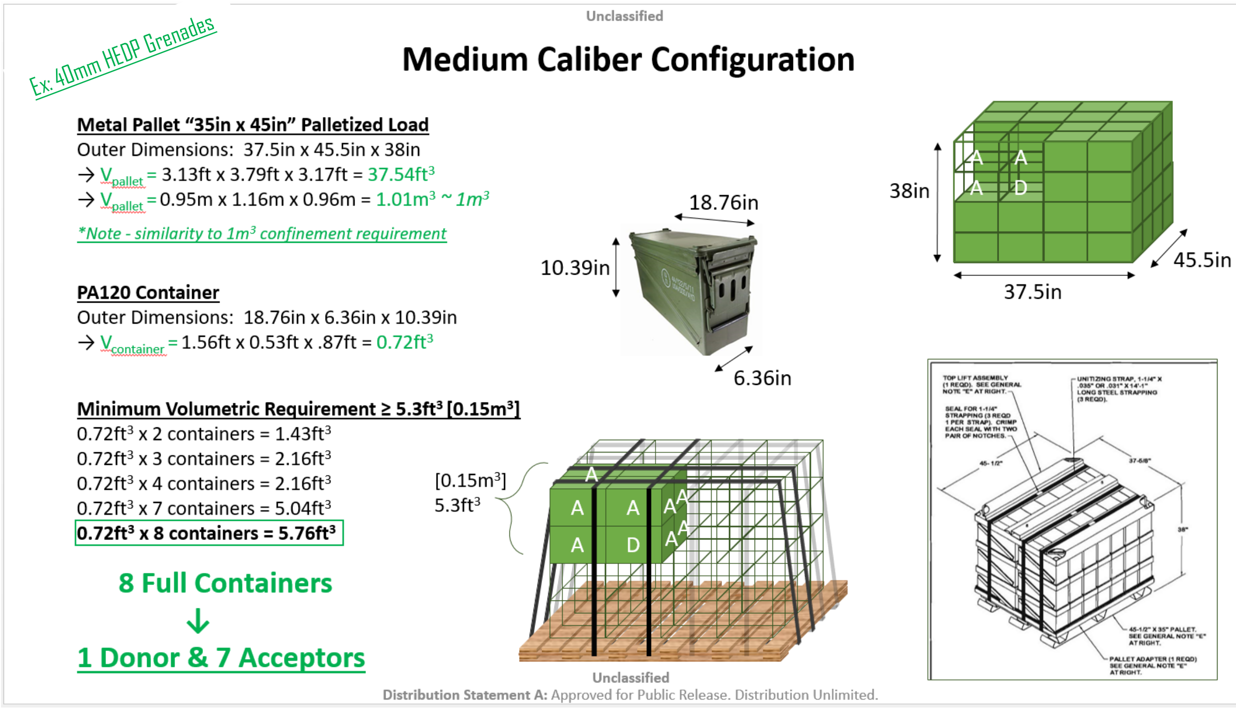
Figure 2 — Typical Palletized Load for Medium Caliber Ammunition

Large caliber ammunition (mortars, tank, propelling charges, etc.) are typically packaged in either tall rectangular containers, stored vertically in only one layer (illustrated in Figure 3, right), or in long cylindrical containers, stored horizontally in several layers (illustrated in Figure 3, left.

Figure 3 — Long, Horizontal (left); Tall, Vertical (right)

The following are three examples encompassing the typical range of common (highly produced, cross-service use) palletized munitions.

Example 1: Palletized load of 40mm Grenades packaged in small ammo boxes.

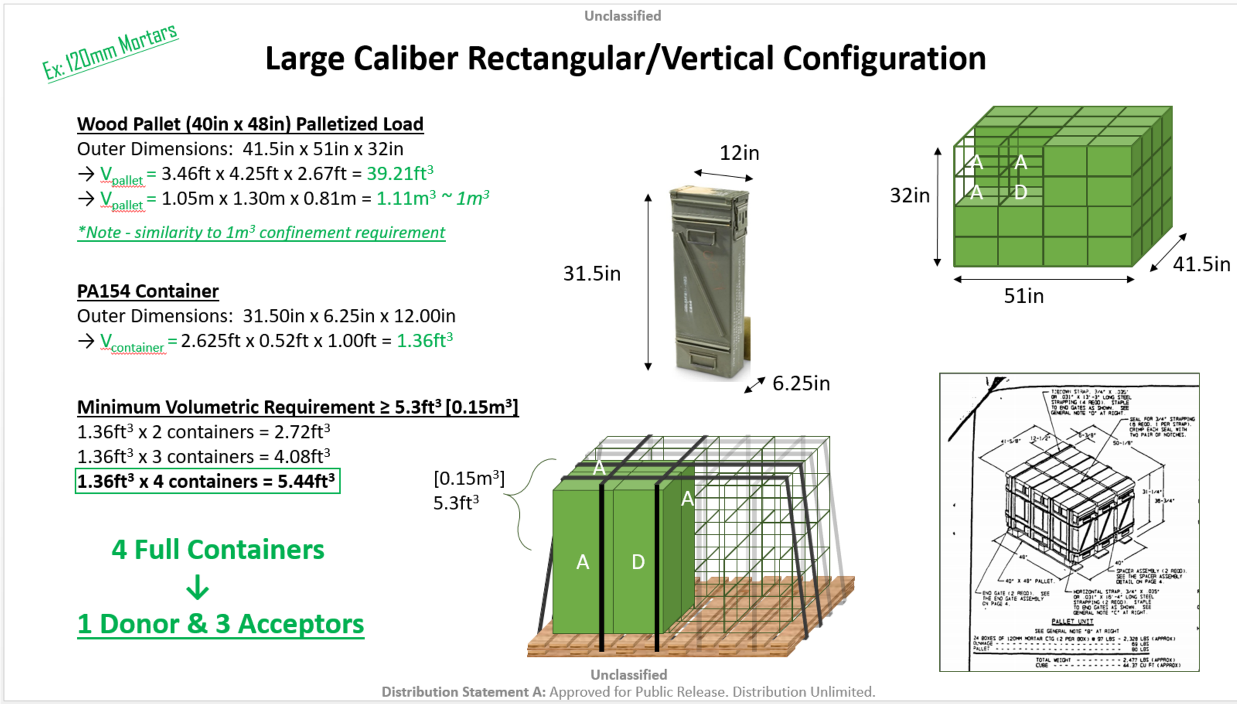


Note that the palletized load for this particular medium caliber round is slightly different / smaller than the standard 40in x 48in x 40in pallet dimensions used earlier. This is why it is important that the specific test item under evaluation be addressed individually. The Threat Hazard Assessment (THA) will include, or call out, the palletization / unitization drawing as illustrated above. Using the dimensions provided from this drawing, as well as the container drawings, the sampling size can be calculated for each unique test item.

For this particular analysis, 8 containers are needed to achieve the 0.15m^3 (5.3ft^3) requirement. This would result in a test including 1 donor and 7 acceptors.

Note – quite often it is realized, through up-front experimental engineering testing / computational analysis that the reaction of the item does not propagate beyond the container. In this case, a single package test can be conducted for official scoring.

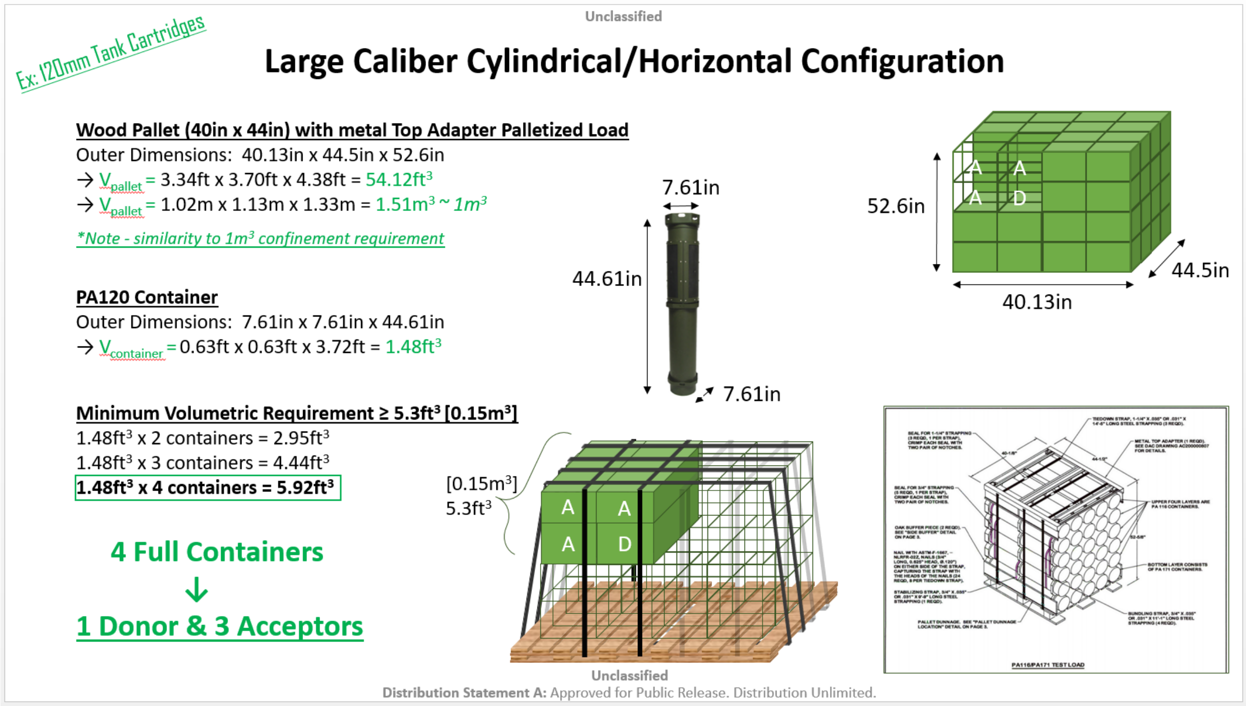
Example 2: Palletized load of 120mm Mortars packaged in tall rectangular containers, vertically.



Note that the aerial (LxW) dimensions (40in x 48in) of the palletized load for this particular large caliber round is the same as the common pallet example used earlier. However, due to system requirements, as well as several palletization/unitization requirements, these containers are stacked vertically, and only one layer high. Therefore, the height of this load is slightly different / smaller than the 40in height used earlier. Also note that the width dimensions (41.5in) of the unitized load (containers) is smaller than that of the aerial dimensions of the pallet. This is due to the palletization/unitization materials configured to brace/secure the load on the pallet. Therefore, it is important to identify the actual dimensions/configuration of the unitized load, and not just use the pallet dimensions, when configuring the sampling size for the SR test.

For this particular analysis, 4 containers are needed to achieve the 0.15m^3 (5.3ft^3) requirement. This would result in a test including 1 donor and 3 acceptors. Note that a there is potential for an identical pallet of identical munitions to be stacked above or below this pallet, whether in s warehouse or on a ship/truck, etc. If the THA identifies that this munition produces a worst case threat vertically, rather than horizontally (i.e. end to end, rather than side to side), the THA should identify this as the worst case (or most credible) threat. Since this case would involve munitions from a second (or potentially third) pallet, this case/configuration would have to be presented to the technical authority for consideration and approval.

Example 3: Palletized load of 120mm Tank Cartridges packaged in long cylindrical containers, horizontally.



Note that the unitization height dimension is larger than the container stack by a few inches. This is due to the bracing and strapping system used to secure the load on the pallet. If/when testing a configuration of this munition, and representing the outer surfaces/corners of the pallet, these unitization/palletization materials (braces, straps, etc.) should be taken into account when calculating the sampling size.

For this particular analysis, 4 containers are needed to achieve the $0.15m^3$ ($5.3ft^3$) requirement. This would result in a test including 1 donor and 3 acceptors.
Note that this particular large caliber munition is packaged in a cylindrical container, horizontally on the pallet. Same caveats as the vertical configuration apply here. If the THA indicates that a worst case scenario can result from end-to-end placement, a technical justification must be presented to, and approved by, the technical authorities.

Based on the sampling sizes calculated using these common pallets, it is evident that the $0.15m^3$ ($5.3ft^3$) requirement is a sampling size of a fraction of a pallet. In general, $0.15m^3$ ($5.3ft^3$) is approximately 1/8 of the common palletized load. For the large caliber munitions, 4 containers were required to meet the $0.15m^3$ ($5.3ft^3$), which also satisfies the minimum of 2 (or preferably 3) acceptors requirement. For the medium caliber munition, 8 containers were required to meet the $0.15m^3$ ($5.3ft^3$) requirement, which has been common practice, and does provide a better sampling size of the pallet than just 2 or 3 acceptors.

Note that for extra-large munitions (e.g. rockets, missiles, etc.) the $0.15m^3$ ($5.3ft^3$) requirement does not typically meet the 2 or 3 acceptors requirement. This is understood, as the quantity of the larger, more expensive munition systems are merely a fraction of the common medium and large caliber munitions of interest with respect to Insensitive Munitions.

Configuring Acceptors and Donors

Using a similar scenario as the medium caliber example above, this section will describe how to configure the acceptors and donors for IM & HC purposes.

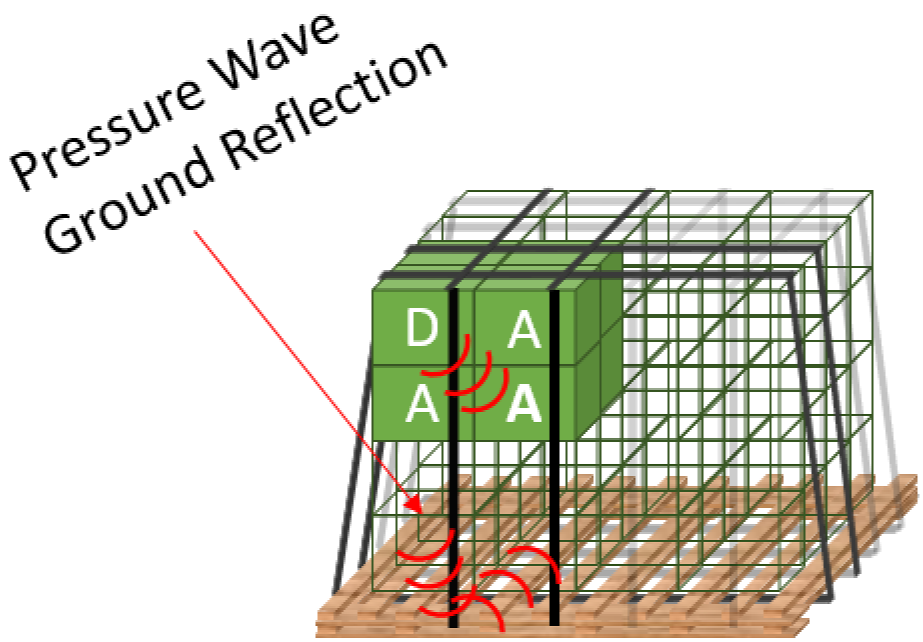


Figure 4 — Example of Unconfined Configuration

One manner of configuring the 8 containers would be to place the acceptors in as many adjacent positions to the donor as possible. As seen in Figure 4 above, the sampling size was configured in a way to represent the donor on the outside of the pallet load, where it would be susceptible to threats outside of the pallet (fire, heat, bullet/fragment/shaped-charge, impacts, etc). The acceptors were arranged in a manner that represents the corner of a pallet. This test would help in evaluating how the acceptors on the corner of a pallet react due to a donor reacting from the outer surface of the pallet. It can also help in evaluating how the acceptors at the corner of a pallet react to a donor reacting from an adjacent pallet initiating and setting off the donor. For Insensitive Munitions purposes, this is the preferred configuration, as there is little to no confinement, which allows the fragment debris and overpressures from the acceptors to project about the test arena, providing the evidence needed to evaluate the overall reaction violence of the acceptor munitions. This configuration would suffice for the 'Unconfined' test

For Hazard Classification purposes, it is preferred to represent the $0.15m^3$ ($5.3ft^3$) in the center of the pallet(s), or a manner in which the donor and acceptors are surrounded by other containers/pallets. This would provide the confinement around the donor and acceptors needed to allow the Hazard Classifiers to evaluate the reaction of the acceptors when subject to a confined donor initiating. Since the requirement is 1m of confinement in all directions of the $0.15m^3$ ($5.3ft^3$) sample, typically a full pallet of containers (with inert rounds) will be required to conduct this test. For smaller pallets, adjacent pallets will have to be incorporated to meet the 1m thickness requirement. Note that the adjacent unitization/palletization materials (braces, straps, etc.) must be taken into account for this type of configuration.

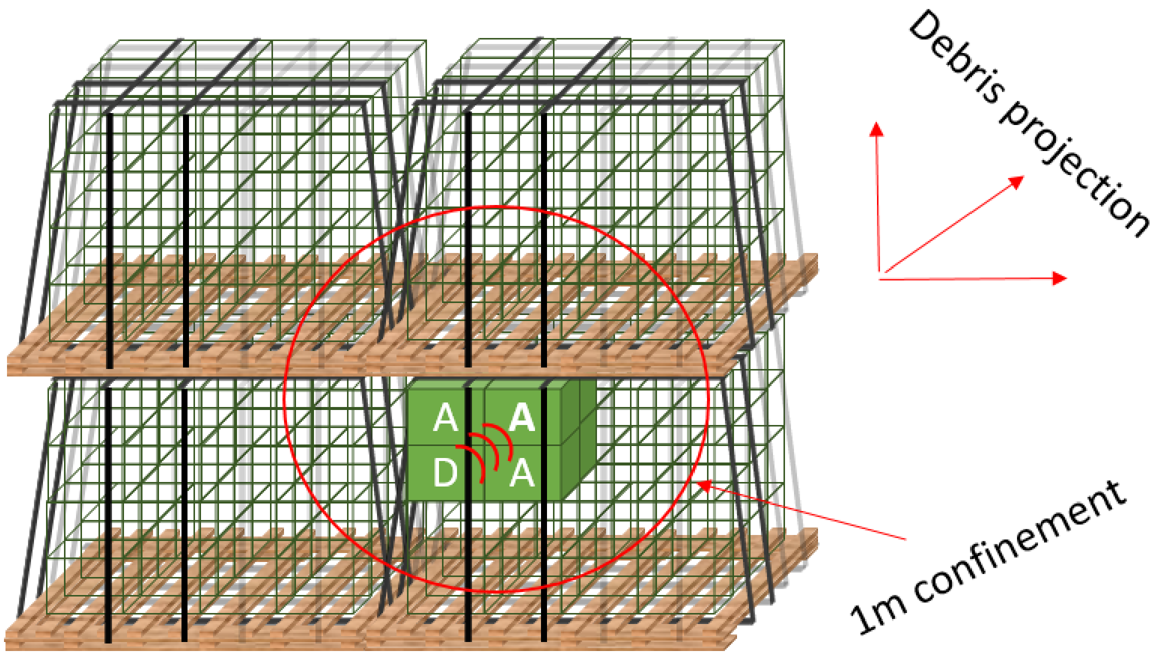


Figure 5. Example of Confined Configuration

When testing in the confined configuration for Hazard classification purposes, it is preferred to place the donor in a manner that projects downward to the acceptors, which typically results in a worst case by exacerbating the confinement. Figure 5 illustrates a cross-section of the confinement for a Confined Configuration.

<u>External Confinement</u>

Section 9e. 'External Confinement' states that: 'Any confinement should represent that of a typical storage confinement. Confinement may be simulated with sandbags or sand/earth-filled containers stacked around the test stack at least 1m thick in all directions'. When performing the Confined Test in a Harmonized manner, as one of the two required tests, the configurations must meet Hazard Classification requirements. That notwithstanding, it is preferred by the Insensitive Munitions community to represent the munition's defined palletized/unitized load as possible. Therefore, the test should be conducted with containers, not sand bags, and the containers should be filled with the best replication of the true rounds as possible. For example, aluminum rods, steel spheres, etc. of same mass and inert dunnage (foam packaging, etc.) will suffice if true inerts are not achievable to attain. Sand-filled containers are a last resort option as they can extremely hinder the fragment debris and overpressure projection that would normally propagate outward. A technical justification can be presented to the technical authorities to approve the use of sand-filled containers, however it is noted that this is not the preferred method.

The '1m thick in all directions' was another requirement that was questioned, and again resulted in no known historical / technical reasoning for the specific metric.
Once again, using the Standard NATO Pallet as a common pallet load, the following analysis was performed:

Common pallet load dimensions: 40in(L) x 48in(W) x 40in(H)

- 40in(L) = 1.016m
- 48in(W) = 1.219m
- 40in(H) = 1.016m
- Avg. thickness = 1.084m

*Note the similarity of the average thickness of a pallet (1.084m) to the external thickness requirement of 1m. It is apparent that the technical reasoning for this is to evaluate the response of the acceptors centralized in a confinement of pallet loads 1m thick in all directions.

Figure 6 illustrates the propagation of the donor to the acceptors, as well as the confinement around them.

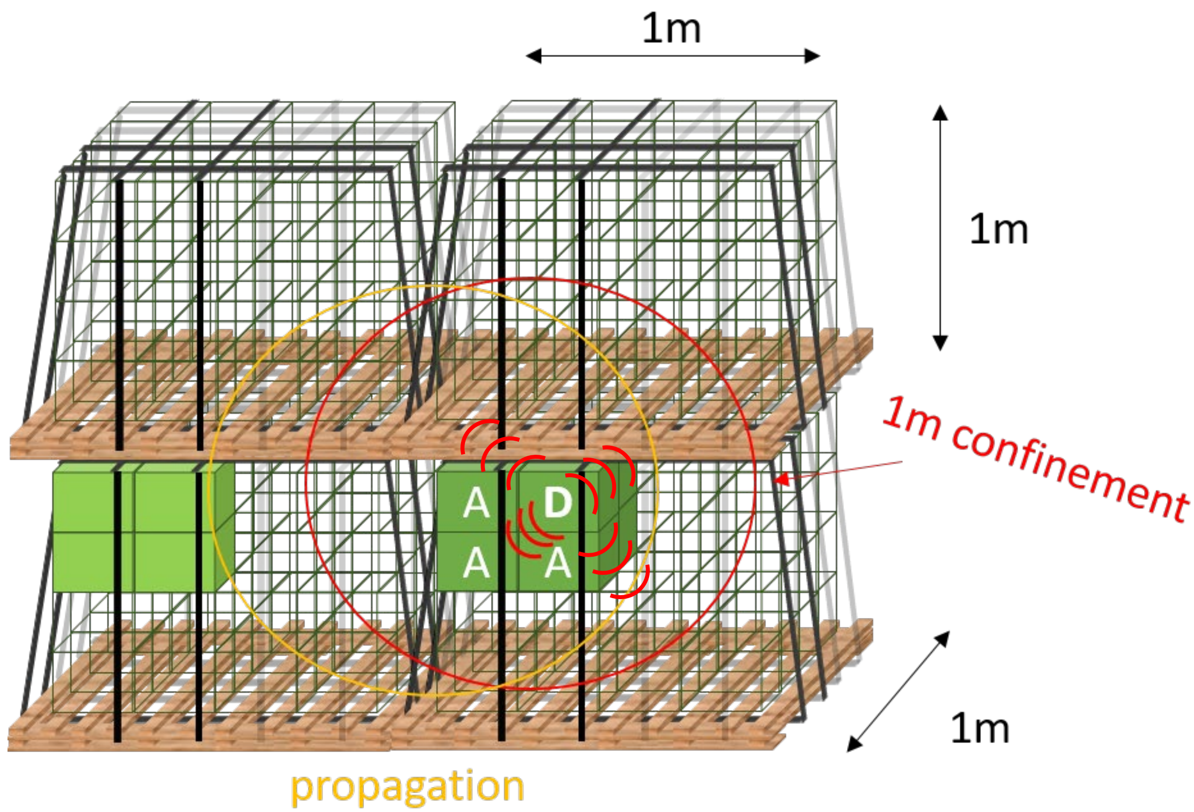


Figure 6. Example of propagation through Confined Load

CONCLUSIONS

Several factors delineate test item configurations for the SR test (e.g. container geometry, pallet dimensions, unitization, palletization). Requirements in STANAG 4396 call for the test items (donor and acceptors) to meet a minimum volume of 0.15m^3 (5.3ft^3). Based on the analysis provided above, 0.15m^3 (5.3ft^3) is a fraction (approximately 1/8) of the common munition pallet load volume. The standard NATO pallet of 40in x 48in x 40in (1.0m x 1.2m x 1.0m) was initially used to prove this theory. Then the three most common palletized configurations for medium and large caliber munitions were used to further support this as the technical reasoning for this metric.

The External Confinement Analysis provided above also used the Standard NATO pallet to support the technical reasoning for the '1m thick in all directions' requirement called out in STANAG 4396. The average thickness of the pallet load is approximately 1m thick. As the HC community is interested in evaluating the confined configuration, pallet loads are to be used to replicate the confinement around the acceptors in order to evaluate their response under confinement. It was noted earlier that it is preferred to place the donor in a manner that it projects pressure/debris downward, exacerbating the confinement. Container filled with inerts, or simulants, should be used to replicate the confinement. Sand, or sand-filled containers, is not preferred as they may hinder the outward propagation of the donor's pressure and debris projection.

For the Unconfined configuration, it is preferred to place the donor in a manner in which the donor projects upward towards the acceptors and outward from the configured load. Unitization / palletization materials (e.g. Banding, dividers, etc.) should be used appropriately to represent the configured load, without introducing any additional confinement beyond the designated configured load per the unitization / palletization drawings.

FUTURE WORK

This proposed technical justification will be presented to the SRCWG for concurrence, and will be recorded as the reasoning for the $0.15m^3$ ($5.3ft^3$) volumetric requirement, as well as the 1m thick requirement starting with the new AOP-4396. A survey will be conducted to obtain responses from each country to come to an agreement regarding confined vs. unconfined configurations and how they relate to IM/HC, as well as their respective donor locations. A follow-up paper will be written to capture the SR-CWG conclusions. Final schematics and verbiage will be provided for inclusion into the AOP-4396 / SRD for guidance and clarity.

REFERENCES

[1] North Atlantic Council, STANAG 4396 - Sympathetic Reaction, Munitions Test Procedures, 2001, Ed 2.

[2] 49 CFR HAZMAT Transportation Regulations, Oct 1, 2018.