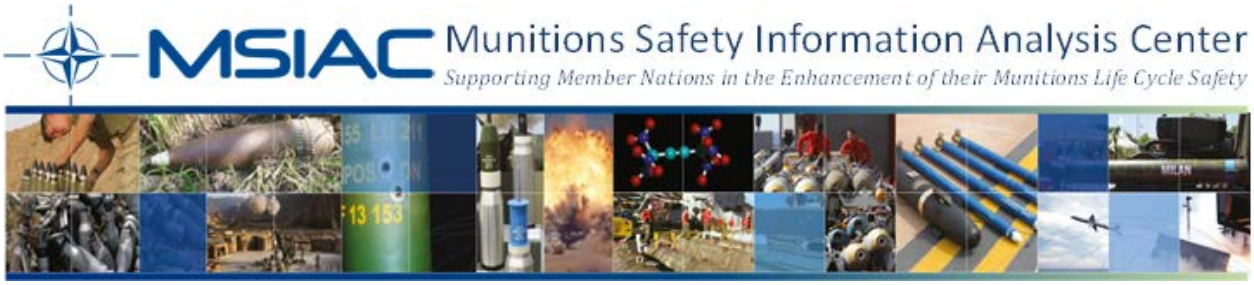

O-160

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MSIAC SHAPED CHARGE JET WORKSHOP: REPORT FOR IMEMTS, ROME 2015

by

Manfred Becker

Abstract MSIAC (Munitions Safety Information Analysis Center) focuses on Supporting Member Nations in the Enhancement of their Munitions Life Cycle Safety. In support of this objective, MSIAC hosted a workshop in May 2014 on SCJ assessment with the underlying theme to improve scientific understanding as well as confidence in the testing and assessment processes across Nations. In addition to the review of the jet characteristics and AUR test considerations, the workshop hosted sessions to discuss and identify small scale testing and modelling capabilities. This was done to consider how these could be used along with all-up-round test results in order to improve confidence in the assessment. The workshop concluded with a list of recommendations. This MSIAC paper informs the greater IM/EM community of the technical outcomes and recommendations from this successful workshop.

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1. INTRODUCTION

MSIAC hosted a Shaped Charge Jet (SCJ) workshop 12 -15 May 2014 at the ENSTA Bretagne campus in Brest, France. This 3 ½ day workshop involved 61 participants from 8 Nations focusing on the threat posed by SCJs on our munitions. The workshop was designed with dual complementary objectives: to increase participants' scientific understanding and to propose improvement to the NATO test standard, STANAG 4526.

This Unclassified workshop was open at no cost to Government, Industry and Academia representatives from all MSIAC member nations as well as South Korea as they had initiated efforts to join MSIAC. A copy of the meeting announcement was widely distributed. During this week, four separate working groups were created to address unique topics in support of the overall objectives. The working group on Detonics and Response mechanisms formed to discuss SCJ threat and response mechanisms; technical viewpoints from the international community on the threat, characterization of jet, its initiation of the energetic materials, and munition system response. The Small Scale Tests (SST) and Predictors group formed to provide a summary of current practices within nations, compare and contrast SST, and develop an understanding of their mechanisms and their relationship to STANAG 4526. The IM Modelling group formed to summarize current approaches, capabilities, limitations, requirements, and potential inter-relationship to the current IM assessment for SCJ. Finally, the Testing and Test Set Up group formed to share best practice in this area, highlight difficulties or deficiencies (in general, or for specific configuration / munitions) and to clarify the STANAG where necessary.

Results and recommendations from each of the break out sessions were then briefed out in the final session. Copies of all presentations during the entire workshop are maintained in the MSIAC database. The comprehensive proceedings of the workshop are included in the MSIAC limited report L-186.

2. BACKGROUND READING

Prior to the workshop, reference and background materials were proposed for the workshop and for each of the break out sessions. Much of this documentation was posted on the MSIAC web forum for participants to review before the workshop, and then was also provided to the attendees on CDs as part of their welcome package. Of particular interest for this workshop, MSIAC had already prepared a review of the existing STANAG shortfalls and is summarized in MSIAC Report O-151 by Peron, P-F. "Shaped Charge Jet Review: Recommendations for the Review of STANAG 4526 Ed 2". Further information regarding the shortfalls and gaps had been previously presented by IMEMG and discussed and highlighted during a prior MSIAC workshop, The 2011 IM Technology Gap Workshop. An outcome from that workshop, and as documented in O-151, is that the threats described within the current STANAG 4526 are no longer representative and require revision. The proposed outcomes for this workshop were therefore based on this and many of the other referenced materials.

3. PARTICIPANTS

The list of the 61 participants and their contact details is included in MSIAC report L-186. From a National perspective, the workshop had participation from 8 of the MSIAC nations, including Australia, France (including 4 professors from ENSTA), Germany, The Netherlands, Norway, Sweden, the United Kingdom and the United States. Presumably due to the location, approximately ½ of the workshop participants were from France and Great Britain - and the other significant nation represented was Germany. Overall, MSIAC was very pleased with this

multinational participation. In addition to the diverse backgrounds, it was the groups' experiences, talents and expertise that combined throughout the week and fundamentally supported the multiple successes of the workshop.

Of the 12 technical presentations given on Tuesday, the USA presented four, three from the United Kingdom, three from France, one from Germany and one from MSIAC. Considering the US only sent 5 participants, they were active presenters. A second paper could also be attributed to MSIAC as it was an overview of the MSIAC report O-151 but presented by its French author.
The main extracts from these documents dealing with the fragment impact test are reported in Appendix 2.

4. AGENDA, WORKSHOP STRUCTURE AND ACTIVITIES

The workshop structure is shown in Figure 1. A welcome letter was provided to all attendees when they registered. This letter included the final planning for the break out sessions. Registration and workshop administration was done via the MSIAC website which allowed tracking of diagnostics for workshop effectiveness.

The majority of participants arrived Monday afternoon the ENSTA Campus, at 2 Rue François Verny in Brest, France to register, receive their welcome package and partake in a welcome reception. The bright orange bag, of course selected to indicate a Type III IM reaction for SCJ testing, contained amongst other pertinent items, a CD with copies of the presentations and a variety of reference materials. The reception facilitated an informal exchange of information and discussions that would be continued over the following days of the formal workshop.

Session I on Tuesday was for plenary sessions. The presentations were designed to welcome the participants, provide an overview of the workshop and then cover four primary areas of background and interest:

- Existing STANAG shortfalls and recommendations
- SCJ characteristics and Response Mechanisms
- National Priorities, Design aspects and Modelling
- STANAG structure : AOP / TTCP Protocols

This session provided the participants an overview of the workshop topics and highlighted the issues raised by the MSIAC Gaps Workshop, Nations accomplishments and areas of interest, and other pertinent technical background, reports and studies. All lunches and breaks were provided on work site in order to facilitate discussion and maximize the workshop time for the participants.

The following day was structured with four Break out sessions: SCJ Mechanisms & Detonics chaired by Dr Baker, Small Scale Tests (SST) & Predictors chaired by Dr Proud, Modelling chaired by Mr. Scholtes, and Testing & Test Set up chaired by Mr. Bénard. Each of these break out sessions provided their participants an agenda. Due to the number of specialists participating in the SST and Modelling session, and the technical overlap of the two groups being predictors for AUR testing, these two groups combined during certain times of workshop Session II and III. Day 2 of the workshop concluded with a group dinner and short presentation by the MSIAC Project Manager, Dr Sharp.
The workshop final day was on Thursday with Session III as the workshop reconvened in a plenary session wherein the Working Group chairmen presented their group findings and recommendations to all participants.

The workshop structure shown for Thursday in Figure 1 was modified during the workshop to allow additional worktime for the break out sessions. Therefore, the presentations on National priorities as well as the "Review of SOTA systems that pass STANAG 4526" were eliminated

from the workshop agenda. However, an opportunity was provided to a representative from each Nation with a representative on the Custodial Working Group (CWG) to discuss their priorities and outcomes from the workshop. The day ended with a synopsis of findings from the US perspective. This was of interest to the workshop attendees as the US is the custodian for STANAG 4526 and they would be immediately taking workshop output into the SCJ CWG the following day.

SCJ Workshop Agenda

	Monday	Tuesday	Wednesday				Thursday
			Break-Out Workgroups				
		Welcome and Plenary Sessions	(A) SCJ Mechanisms & Detonics	(B) Small Scale Tests / Predictors	(C) Modelling	(D) Testing & Test Setup	Break out Reports & Plenary
			Baker Becker	Proud Andrews	Scholtes Sharp	Benard Schultz	
07:30		Registration	Arrive and form into 4 separate break out sessions				
08:00							
08:30		Welcome: MSIAC, ENSTA, DGA	Welcome/ Introductions	Welcome/ Introductions		Welcome/ Introductions	Reporting out from Break out sessions A and D (E Baker, H Benard)
08:40		Admin & Workshop Overview M Becker	Discussion per Agenda outline	Presentation: SCJ Model		MSIAC Introduction	
09:00		"MSIAC SCJ Review – Elements for STANAG 4526 Revision" Dr P-F Péron		Presentation: Energy Fluence		Presentations Bofors Test Center, KC W&M, DGA/EM, Bayern-Chemie	
09:30		"SCJ STANAG: IMEMG Propositions for an Updated Edition" Y Guengant		National Viewpoint & Shortfalls Identification			
10:00		BREAK	BREAK				Group Picture / BREAK
10:20		"SCJ-Initiation Phenomena related to STANAG 4526" Dr T Hartmann	Discussion continue	SST Discussion	Modeling Discussion	Discussion per Agenda outline	Reporting out from Break out sessions B and C (G Scholtes, B Proud)
11:00		"Shaped Charge Initiation Test Configurations for IM Threat Testing" Dr. E Baker					
11:30		"French Reference Shaped Charge Characterization" Dr G Baudry					
noon		LUNCH	LUNCH				LUNCH
13:30		"Effects of SCJ on EMs at Extended Range" P Pitcher	Discussion continue	SST Discussion	Modeling Discussion	Discussion per Agenda outline	Discussion toward common outputs, conclusions and recommendations (Becker)
14:00		"JIMTP Efforts for Characterization and Modeling of SCJ Initiation" Dr C Michienzi					
14:30		"Modelling of SCJ Initiation of Munitions" M Cook					
15:00	Registration	"AOP & TTCP Protocols" Dr M Sharp					
15:30		BREAK	BREAK				BREAK
16:00	Welcome reception	STANAG 4526 Shaped Charge Initiation Test Updated Considerations US Army IM Board Dr B Fuchs	Preparation of output presentation	SST & Modelling Précis Preparation of output presentation		Preparation of output presentation	Review of SOTA - Systems that Pass STANAG 4526
16:30		"UK Position on the SCJ Threat" P Cheese					National Priorities / Key Points on Path Toward SCJ Standard Revision (CWG reps)
16:45		"STANAG / AOP Format Structure" K Tomasello					
17:00		Plenary Session Wrap up and Closing Comments	***Break before Group Dinner***				Closing Remarks (Becker, Sharp) Adjourn
17:30							
19:00			Dinner				

Figure 1: Workshop Structure

5. PRESENTATIONS

5.1 SESSION I: TUESDAY PLENARY

Tuesday was organized with presentations in a plenary format. The day began with three welcomes; first from the MSIAC Project Manager, Dr Michael Sharp, next by our French representative, Dr Pierre-Francois Peron representing DGA and Patrick Lamy, and finally from our ENSTA host, represented by Ms Foncesa, giving a short overview on ENSTA Bretagne, the Graduate and Post-graduate Engineering School and Research Institute.

Dr Sharp welcomed the participants and encouraged their active participation. Dr Peron welcomed the participants and expressed appreciation for their support to this important workshop from the French government. In his address, he focused on the connection between ENSTA, MSIAC and the SCJ community. He also noted that ENSTA will soon develop a full course on Energetic Materials – which could be of interest to this community. Ms Foncesa offered a short overview of the campus, highlighting aspects that related to our interest areas. She noted that 18% of the students there are military engineers and their research labs provide laboratories in Mechanics of materials and assemblies, Dynamics of Fluids, Materials and Structures as well as Energy and Electromechanical. She offered a tour of the campus to any interested participants.

Following the Welcomes, the workshop organizer Manfred Becker provided the necessary administrative comments, an overview of the workshop, encouraged participants involvement and stressed the two primary objectives matched to the intended deliverables from the workshop.

Dr.Pierre-François Péron then began the technical presentations with a review of MSIAC report (O-151). This oft referenced report identified shortfalls of the existing STANAG and made some initial recommendations for improvement. The report highlights the threats in the standard are no longer representative nor are the V^2D levels realistic. As known in the community, while few tests are actually conducted in accordance with the specifics of the STANAG, tests are being reported as compliant to it by use of Procedure 2 that allows a tailored test. Therefore, there is no current standardized test. Dr Péron provided an overview of SCJ characteristics, jet formation, response mechanisms, and shortfalls of the existing STANAG. He noted the discrepancies in V^2D values could partly be explained by the shaped charge impact probe and where measurements are taken.

However, while STANAG 4526 only imposes V^2D levels, it is a simple empirical model mostly valid for bare explosives and does not reflect the complex phenomena for encapsulated (covered) explosives. Therefore, additional parameters are required to fully standardize the test charges.

The specifics of the O-151 report were mentioned and identified by multiple presenters throughout the workshop. Dr Péron concluded his presentation with a summary of questions to be addressed by the workshop: what is the correct number of aggression levels, should the aggression family (e.g. bomblet) name be indicated, is V^2D an appropriate criterion for the standard and does it need to be more precisely defined, and finally how shall we define the relevant value(s) for the aggression level?

Following this, Yves Guengant provided a review and recommendations as compiled by IMEMG, an European Organisation representing twenty one armament industry groups working with Insensitive Munitions technologies to express the armament industry's viewpoint with regards to relevant transnational regulations and requirements. He began with an overview of the requirement as found in STANAG 4526 and AOP 39 and then identified a number of

shortfalls as well as recommendations. IMEMG also proposed for a given V^2D, munitions responses can be different. To address this, they propose some kind of qualification procedure to be organized under NATO or MSIAC authority, in order to compare the shaped charges against the same target & explosive arrangement. They also propose an alternate V^2D value as a V^2D stimulus of 141 $mm^3/\mu s^2$ would cause detonation in most charges (including insensitive PBX) and only a few EIS would survive (Extremely Insensitive Substance in accordance with UN HD 1.6). Therefore, it is proposed the STANAG define different stimuli according to Life Cycle and Threat Hazard Assessment. If the standard procedure is defined with the stimulus V^2D around 141 $mm^3/\mu s^2$ then an alternative procedure could consider stimulus around 60 to 70 $mm^3/\mu s^2$.

These first two technical presentations provided a foundation of the existing STANAG shortfalls and recommendations, based on extensive work already completed by MSIAC and by the industry partners, for the workshop to build upon.

After a break, Dr Hartmann provided a synopsis of SCJ Initiation Phenomena work he and Dr. Arnold have completed. The presentation was enlightening and also highlighted through test results and analysis presented there remains much science left to be understood. He presented some V^2D vs. P Calibration Curves as well as a number of plots of Explosive Reaction Level (ERL) vs. V^2D that showed different SCs (Calibers) deliver different ERL Results. He also discussed some Software-Tools for Calibration Curves and hydrocodes for SCJ Simulation and penetration modelling. As such, he was able to compare modelling to a prior calibration curve which well supported a presentation conclusion that preparing a V^2D vs. P Calibration-Curve is not an easy task. However, their recommendation is that for all SCs identified for inclusion in the revised STANAG, and it should be a limited number of them, Calibration-Curves should be provided.

Drs Baker and Baudry provided overviews of the US and French test configurations, respectively. Dr Baker began by providing reasoning behind the US test configuration, including images of the inconsistent jets possible from actual threat munitions. It was clear to see these jets are not straight and the velocities, mass, length, break-up, diameters vary widely. This is indicative of why poor quality inconsistent warheads should not be used for a standardized test.

Dr Baker's presentation then provided information on the US developed charge and test set up. He noted that while the RPG-7V was considered as the main current threat, it wasn't the highest performance threat. He also went on to document a rising threat of smaller shaped charges.

Dr Baudry provided a status on the French reference shaped charge characterization of the CCEB 62. While this charge is already used for many years and some characteristics are available, it is necessary to complete the characterization. He described the experimental program and the preliminary conclusions, along with a series of radiographs at differing conditioning plate thicknesses. The quality of the charge was highlighted by the straightness of the jet at long stand-off and small variations of jet tip velocity and the jet diameter behind the conditioning plates. He was also able to show the effect of the distance between the back of the conditioning plate and the tested item. While the jet has a reproducible shape at short distance, shape modification at longer distances become evident due to the collapse on the jet front of the penetration residues. Distance between the conditioning plate and the tested item must be defined precisely since the jet diameter decreases as it elongates. This was further supported by an OURANOS hydrocode simulation. France typically uses a mild steel conditioning plate with an HDPE layer on the back of it. The effect of the HDPE layer at the back of the conditioning plate reduces the spall effect from the steel plate and may contribute to a "cleaner" and more reproducible jet shape.

Phil Pitcher provided the workshop with a presentation on the effects of SCJs at extended ranges based on a series of trials conducted, and reminded us that our workshop topic directly relates to the threats our troops are facing with an opening video. There was strong justification

provided on the need for conducting a realistic Threat Hazard Analysis, and then conducting tests appropriately. This may support conducting realistic tests even if the SCJ particulates. As shown in the presentation, increased SC jet range can introduce additional threat difficulties due to dispersion of the jet.

Dr Michienzi provided a technical overview of the efforts being done in the US to characterize and model SCJ initiation. Current high rate continuum shock initiation modelling uses long duration shock data for parameterization. This is using Wedge test data for models such as Forest fire, Ignition and Growth, History Variable Reactive Burn (HVRB). Within the US there are ongoing efforts to obtain experimental data on long and short duration shocks and shock initiation model parameterization. This is intended to support SCJ initiation threshold data for a range of critical diameters (prompt and bow wave initiation). The presentation covered two ongoing projects currently in process to investigate this topic area that should improve predictions for IM designs resistive to SCJ threats.

Malcom Cook followed with a presentation on modelling efforts for SC initiation. The premise of this work is that in order to mitigate against SCJ initiation, a given mitigant will act to disrupt the jet in some manner. The project askes if it is possible to predict (through modelling) the circumstances under which the resulting disrupted jet will initiate a munition? The presentation provided a quick overview of modelling options; Engineering models, Fully parameterised Phenomenological models, and Partially parameterised Physics based models. This presentation summarized that while SCJ initiation via SDT mechanism should be predictable by existing methods, initiation via DDT is more challenging. It will require joint experimental / modelling approach to develop, parameterise and validate models.

The presentations on modelling showed a level of interest by multiple nations toward modelling of SCJ phenomena. It should also be noted for modelling there are areas of exceptionally good exchange of information between theory and the practitioners working in SST, energetic development and AUR testing. It indicated the level of maturity for the current state of the art, as well as reasonably good promises of improved capability, predictability and confidence in the near term.

Dr Michael Sharp concluded this part of Session I with a review of the AOP-39 and TTCP protocols. This presentation was to provide an overview of the information and guidance currently available on SCJ Assessment (other than in STANAG 4526) and to remind the audience of some of the critical linkages we need to consider as we move forward in making recommendations for improvement.AOP-39 contains guidance on IM assessment methodology, Threats and Configurations, assessing the response of munitions to threats, guidance on conduct and reporting of IM tests, IM Signature & Response Descriptors, IM assessment report and IM Design techniques. The aim of Annex H, AOP-39 is to provide guidance on the best practices for designing, conducting and reporting full-scale IM tests and is included to mostly compliment the STANAG test procedures and identify best practice.

The first day was anchored by presentations on the US and UK perspectives, presented by Dr Brian Fuchs and Phil Cheese, respectively. These presentations both highlighted the interest and need for improvement along with relevant questions that need to be addressed by our workshop recommendations.

Dr Fuchs discussed a number of papers and prior work on the shortfalls of STANAG 4526 and questioned as we move forward if there should be more than one scale of threat identified:- small (<50mm), medium (75 - 84mm), large (>100mm), and possibly even for an EFP?

He proposed two possibly complimentary approaches whereby standardization and cross acceptance of testing can be achieved by either specifying the shaped charge and firing conditions or the characteristics of the jet. Standardization of the shaped charge eliminates computations and verification. Specifying the jet eliminates problems of standard hardware availability across nations, but it introduces verification issues. Based on their considerations, he proposed as a starting point to define the standard SCJ with some or all of the following parameters: Jet diameter, Tip velocity (with or without probe), V^2D (and how measured), Standoff, Accumulated mass profile and Jet ductility/break-up time. Once all parameters are identified, we must still determine what critical parameters should be included in the STANAG/AOP. These should then have quantitative measurement and tolerances along with measurement methods for each parameter. The test set up is proposed to have both standard and non standard examples of test arrangement provided.

Phil Cheese began by reminding the audience that at present, UK does not identify SCJ during IM certification. In fact, as it is generally ignored by THA and is not a requirement from IMAP, the UK does not test for SCJI and has little current experience. Yet the UK position is that SCJ is a real threat to current and projected operations, and throughout the logistic chain. It further illuminated that SCJ is qualitatively and quantitatively different to Fragment Impact and the other threats. The mechanisms induced by SCJ impact are not all exercised by the other IM threat stimuli (e.g. BSDT) and therefore, design solutions are likely to be specific to SCJ.

Mr Cheese further pointed out that STANAG 4526 as it stands is clearly unsatisfactory, as the MSIAC review and earlier presentations demonstrated unambiguously. To have a standard test, it must have well defined stimulus and diagnostics. The IM standard must set the stimulus at a sensibly high level, and there has to be a chance of developing solutions that meet or exceed the Standard. He expressed concerns with the cost of the test and challenged the international scientific community to develop a charge scale test that reproduces the behavior induced by SCJs, but faster and at lower cost than by using SCJs. In consideration of materials, a number of energetics have been shown to survive SCJ impact, but as performance exceeds that of Comp B, these materials then generally fail. The purpose of IM policy for the UK is to encourage making and buying safer weapons. Therefore, in order to be successful, there have to be solutions in sight to justify effort. He stated a stretch goal would be LX-14 performance and a critical diameter of 20mm or greater.

Ken Tomasello closed out the session and the first day of the workshop with an overview of the STANAG format as is now directed by AAP-03(J). AAP-03(J) principles for standardization of AC 326 document structure is that the covering document will be STANAG. The custodian is responsible to ensure that each STANAG contains a section on implementation of the agreement which defines the minimum implementation guidance and criteria (see AAP-52) to achieve the interoperability requirement. This pointed the audience ahead that as STANAG 4526 is updated, it will in its new format only include the minimum implementation guidance to agree to conduct a Shaped Charge Jet test, while a new accompanying AOP – to be written at the same time - will now contain the pertinent technical details.

5.2 SESSION II: BREAK OUT SESSIONS

As stated earlier, Wednesday and part of Thursday was for breakout sessions to delve into 4 topic areas of interest. Dr Ernie Baker led a group on Detonics and Response Mechanisms, Gert Scholtes chaired the Modelling group, Dr William “Bill” Proud chaired the Small Scale Testing group and Mr Hervé Bénard led the group on AUR Test Set up. These groups were facilitated by an MSIAC representative: Mr Manfred Becker, Dr Matt Andrews, Dr Michael Sharp and Mr Emmanuel Schultz, respectively. Each of these groups addressed their topic areas as was planned before the workshop by the Chair and his MSIAC facilitator.

5.3 SESSION III: PLENARY

On Thursday, each of the Break out session chairs briefed their accomplishments. Dr Baker in his out brief on Detonics and Response Mechanisms, began by reviewing the shortfalls of the existing STANAG and then stating that the RPG-7 was considered the dominant threat based on prior work and the reference materials. Therefore they worked to identify and document how this threat would be accurately described for the standard. It was proposed other threats could be identified by a THA and then considered as a secondary option. The group reviewed initiation mechanisms primarily associated with SDT, BSDT and XDT. It was agreed the reflected shock phenomena associated with the bow wave jet impacting against exiting surfaces cannot be ignored as an initiation mechanism. It was also again recognized that XDT may become more dominant mechanism as we address shock mitigation through the use of non-ideal energetics, such as those with extremely large critical diameters.

The group reviewed threat test shaped charge characteristics and recommended there should be a reproducible well defined test configuration and it should be consistent with actual threat RPGs. For the jet itself, the Held Criteria, V^2D of the jet tip is not enough to fully characterize the threat characteristics associated with the identified reaction mechanisms. Yet it is an important characteristic and the group recommended that V^2D shall be a 120-140 $mm^3/\mu s^2$ and the jet diameter at the target interaction position should be 2.5 – 3.5mm.

It was proposed that test centers use a reference scale in x-rays to aid in consistency of measurement of the jet characterization. In best practices it is suggested that a ~3mm diameter rod (similar to jet diameter) be used to assist in measurement precision.

Dr Proud provided the out brief of workgroup B on Small Scale Tests (SST) and Predictors. In their session, they reviewed the definition of the SST, the drivers, diagnostics, test vehicle, materials of interest and material properties. The group considered anything other than a All-up-Round (AUR) test used to rank threats or aimed to probe the physical process, quantitative limits, materials or structural properties could be considered a SST. This investigation should be part of the whole body of evidence considered when assessing vulnerability to SCJ attack and can take on any number of parameters, including time, pressure, temperature, length or mass. It was proposed that material properties and applicable SST procedures could also reside within a best practices guide.

Hervé Bénard provided the out brief from the Test Set up workgroup. Their objectives were to review the AUR test procedure and related documents (STANAG 4526 and AOP-39), share best / current practice in performing the SCJ test, identify issues related to this test and then make recommendations to update the STANAG. The group documented a number of shortfalls in the current standard wherein the test is not sufficiently defined and each nation uses their own charges for conducting the test. These are some of the primary factors causing interoperability issues for this standard that require resolution.

The test set up considerations were presented. Main parameters that should be defined include the stand-off, the distance between the SC and the test item, and the thickness and material of the conditioning plate. The group reviewed and presented diagnostic measurement and reaction level assessment. It was noted that the response descriptors in AOP-39 give no concern specific to this test.

Gert Scholtes presented the output from the Modeling group. It was presented that while some codes are mature, they should not be a black box. Users must understand their capabilities and limitations. Some codes lack routines to cover all aspects of response to SCJ, such as IG and reactive burn models, ignition mechanisms, pore collapse, shear, pressure and temperature

dependent models. For initiation mechanisms, SDT is rather well understood, while other mechanisms are generally understood but difficult to model. There is a shortfall in good constitutive models for damage. Some of the engineering models can be very simple and be used to give a rough idea if the munition will fail. Analytical models and hydrocodes can be used to model the jet formation.

A consistent shortfall identified by the group was in order to know the mechanisms and model them, a comprehensive list of properties is required. Further, the group felt more and better instrumentation was needed in tests, to collect data on pressure, temperatures, shock waves, case expansion, timing, ignition site location and mechanical deformation. The group summarized the modeling desires for data were generally hampered by the gaps of data, mechanisms, funding and occasionally cooperation difficulties. There were no specific recommendations of changes toward the SCJ standard from this group.

6. DISCUSSIONS

In unclassified terms, threat levels were presented and discussed. It was noted that the levels identified for the standard should reflect the threat but also be achievable by the munition designers to “pass” the test in order to provide an improvement to the troops. There was a discussion on the inclusion of defined lesser and greater threats (40mm and ATGMs). It was generally agreed such tests would provide additional information and confidence, and for lesser threat potentially would show incremental improvement. There was concern on how such tests could be documented or required and what the results would imply toward passing or failing the test. There was no clear indication or recommendation this be pursued.

There was discussion if V^2D requires both a maximum and minimum parameter, or if a minimum is sufficient. Initial conclusions presented from group A was there should be no upper limit in order to allow the standard to evolve with future threats, however there was strong opinion otherwise from Group D. There was concern expressed if an upper bound is not identified a test center could conduct a test and achieve a passing reaction. A secondary test center could then test with a compliant but significantly higher V^2D and fail the test with a prompt shock reaction. Due to this discussion it was generally recommended to reasonably bound the characterization of the jet to be used in the test standard. The tolerance of 120 -140 $mm^3/\mu s^2$ was considered sufficient for the variety of charges that may be considered for the standard, and also sufficiently stringent for a high quality test specimen. The jet diameters of 2.5 – 3.5 mm was considered similarly reasonable. The description of the shaped charge liners was also discussed at length.

There was discussion on firing at a reference target, both of an inert as well as energetically loaded reference target. The topic of cost and validity/capability of data to be potentially captured during such a test was repeatedly highlighted during these discussions. Yet some form of an inert test was discussed in three of the break out sessions and generally recommended in order to better understand the null reaction scenario. For the energetically loaded test, the use of two test configurations that would provide both a detonation and non-detonative response was considered. Yet due to cost and certainty of what such tests would reveal, the live test was not generally recommended.

The number of test items was discussed briefly, primarily due to cost considerations but also in reference to stochastic predictions drawn from the results. There was no clear conclusion or recommendation from this other than to continue with the recommendation in the standard there remain circumstances where the SCJ Impact test should not be done, such as where considering the critical diameter of the explosive fill would clearly predict failure of such a test. Improved understanding of materials, modelling and SST could also preclude unnecessary testing or improved confidence in the results obtained when testing.Acknowledgement

MSIAC would like to acknowledge the custodian of the STANAG, France, and particularly Dr. Pierre-François Péron for his review and amendment of the survey.
MSIAC also acknowledge the individuals from all the test centers who have contributed to the survey by providing an answer to the questionnaire or information related to this test.

7. FUTURE WORK

The technical output from the workshop for inclusion in the STANAG and AOP will be developed by the CWG formed under AC/326 SG/B. They intend to develop the draft documentation and circulate this through the community prior to submitting for promulgation.

A number of technical topics were collected during the workshop. These included:

- The small scale testing and modelling workgroups identified the need for material properties. Such properties may be needed across strain rate and damage in order to properly account and support SCJ impact requirements. It was considered that determination of material properties at high strain rates was an under-researched area of physics/materials science. Another separate action proposed was to identify the minimum requirements for properties of interest, similar to or in addition to the list of properties found in AOP-39.

- Another possible output and work directed towards MSIAC was the collation of a report on diagnostic techniques used in energetics testing.

- Information on practices, procedures and reference documentation on materials could be assembled into a best practices guide. This information is not normally included in the standard but would be immensely useful to practitioners in this subject field.

- As the STANAG 4526 and it associated AOP is drafted, the effect on other standardization documents must be evaluated. Specifically AOP 39 and STANAG 4439 must be reviewed for consistency with the new documentation.

8. CONCLUSIONS AND RECOMMENDATIONS

Primary conclusions to be proposed for STANAG consideration came from workgroups A and D (Detonics and AUR Testing, respectively), while workgroups B and C provided improved confidence in the assessment results.

A summary of the recommendations for the STANAG:

- The RPG 7 type should be the primary threat defined in the STANAG update.
- A Procedure II –alternate threat – may be conducted as dictated by THA
- Do NOT include a defined larger or smaller threat in this standard
- Examples of acceptable surrogate charges are to be included in the appendix of the AOP. Recommended charges from Germany, France, and US, and possibly UK and Australia.
- Nations are to verify the details proposed for inclusion in the standard do not violate security or confidentiality considerations.
- V^2D of the jet tip is insufficient to adequately identify the SCJ.
- V^2D shall be a minimum of 120 $mm^3/\mu s^2$ and a maximum of 140 $mm^3/\mu s^2$
- Jet diameter at the target impact position should be: 2.5 - 3.5mm.

- Jet measurements should be taken at the target impact point, and after the conditioning plate. A diagram will be included to clarify the location.
- The V^2D and jet diameter values should be reviewed for accuracy by each of the Nations to determine if they are reasonable and realistic.
- The explosive charge diameter should be larger than 60mm and less than 95mm.
- The explosive charge should be at least the performance of COMP B or above (equivalent or higher Gurney energy).
- Oxygen free Copper liners with a purity of at least 99.99% shall be required
- Accumulated mass profile was determined not necessary for inclusion in the standard; but can be provided in the characterization documentation as useful information.
- Maintain limitation recommendation in the standard that the test is not appropriate if the failure diameter is not significantly larger than the jet diameter predicted to impact the energetic material.
- It was generally agreed the test could be conducted with an actual RPG-7, but it would need to have been characterized and meet the required parameters.
- A conditioning plate (or nose probe) shall be used to clean the jet. Effort should be made to limit or eliminate spall generated by whatever process is chosen.

Based on feedback reports collected at the workshop, the workshop was considered successful by the participants. Across all feedback collected, the scores averages 4.5 out of a possible 5.0. There was general consensus the workshop achieved the two primary objectives. Further, the output was immediately used to effect change to the existing standard.

Finally, MSIAC was encouraged to continue hosting such technical workshops on an annual basis. It was agreed to plan workshops within the acceptable limits of resources, both of MSIAC and of the participants potentially participating in such conferences.

Manfred Becker concluded the workshop stating appreciation for the attendance and contributions of the attendees, encouraged their continued support to continue and finish the efforts proposed during the week and then closed the workshop.


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