



**Committee of Experts on the Transport of Dangerous Goods
and on the Globally Harmonized System of Classification
and Labelling of Chemicals****Sub-Committee of Experts on the Transport of Dangerous Goods****Forty-third session**

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Explosives and related matters: review of test series 6**Amendments to Test Series 6(c)****Transmitted by the Sporting Arms & Ammunition Manufacturers'
Institute (SAAMI)¹****Introduction**

1. The programme of work for the current biennium includes a comprehensive review of Test Series 6 of the Manual of Tests and Criteria. Experience indicates a need to clarify appropriate application of the manual. This document would clarify important existing practices of a majority of experts in the conduct of Test Series 6(c) and provides some additional ideas.

2. As explained in a companion paper by SAAMI on the introductory text of the Manual (ST/SG/AC.10/C.3/2013/17), these proposals are believed to be compatible with a survey on Test Series 6 that is currently being undertaken by the Institute of Makers of Explosives (IME). Discussions on the Manual will also take place amongst the International Group of Experts on the Explosion Risks of Unstable Substances (IGUS) in April. SAAMI will participate in these discussions and may submit additional information as it develops. The proposals in this document are made independently of each other.

¹ In accordance with the programme of work of the Sub-Committee for 2013-2014 approved by the Committee at its sixth session (refer to ST/SG/AC.10/C.3/84, para. 86 and ST/SG/AC.10/40, para. 14).

Discussion

3. Section 16.6.1.2(g)

Non-availability of test materials has been a developing subject of discussion by explosives experts for several years. It is known that the type of aluminium specified for the witness stands is not available in many parts of the world, being too soft to have broad application in industry. Research is beginning to show that the consistency of response of this aluminium to projections is subject to an array of variables. These may include heat as determined, for example, by the distance from the fire and thermal output; support structure design; and fragment shape and orientation. The requirement in 16.6.1.2(g) for aluminium sheets should be amended to clarify the specification and type of equivalents allowed. The results of research should be incorporated into the method and interpretation of projection results.

4. Section 16.6.1.2(h)

This section specifies one or more cameras to record the test: "Cine or video cameras, preferably high speed and normal speed, to record events in colour." The types and number of cameras were discussed by the Working Group on Explosives during the forty-first session of the Sub-Committee as described by the report of the working group, (informal document INF.67). There is no longer a need to specify colour versus black and white video. High speed cameras are only desirable on certain tests, when appropriate to some special need, for example to measure the velocity of high speed projections. The use of a high speed camera should be at the discretion of the person performing the test. The pluralisation of the word "cameras" in the text has been interpreted as requiring more than one normal speed camera, whereas it applies to the possibility of using a high speed camera in addition to a normal speed camera. While it is true that some authorities like to use multiple cameras, for example for normal and magnified zooms when testing is performed remotely, this is not a requirement of the test procedure as concluded by the working group in the last session. Thus this section should be clarified to state actual requirements and eliminate extraneous text.

5. Section 16.6.1.3.1

Changes to 16.6.1.3.1 are proposed as a new paragraph in the proposal section of this paper. Specific sentences are discussed below.

The second sentence states "Packages should be oriented in such a way that a maximum probability for projections hitting the witness screens is obtained." This sentence is intended to address articles which have intentionally directional projection effects. While some competent authorities address it in practice, the similar hazard of intentionally directional flame jets is not addressed in the text. Vertical flame heights are not limited, as flame heights of other dangerous goods meet or exceed Class 1 products, as was discussed in the 41st Session. Therefore articles which direct either flame jets or projectiles should not be placed in a manner so as to pass the test because the effects are pointed up or projectiles intentionally pass between witness stands. The INF 67 report of the last Working Group on Explosives states: "The United Kingdom explained that it is the responsibility of the person undertaking the test to design the test to provide the evidence required, and for that reason, would not want the test to be overly prescriptive. France observed that before performing the test good knowledge of the product should be developed. With that knowledge, the lab can better anticipate the reactions that may occur during the test and better design the setup to capture those reactions." SAAMI agrees with both these comments. Industry has experienced situations where minor or unanticipated effects may be used to reject tests regardless if they are of substantive magnitude or importance.

The fifth sentence states: “Precautions against side winds may be required to avoid dissipation of the heat.” However wind speed is limited in 16.6.1.3.6 to 6 m/s. In practice the direction of the wind is often variable. Furthermore, such precautions may shield or block the witness screens thus negatively affecting the classification criteria. This sentence overstates the importance of high heat, and in fact high heat is degrading consistency in the performance of witness stands. The absence of this sentence would not inhibit those conducting a test from using precautions against side winds. The sentence is superfluous and should be deleted.

The last sentence states: “Suitable methods of heating include a wood fire using a lattice of wooden laths, a liquid or gas fuel fire, that produces a flame temperature of at least 800 °C.” It should be stressed that the three different fuels are examples, while the main intent is a fire that engulfs the test items. However, this text has in practice been used to prohibit the use of wood other than laths, and to specify wood from certain trees. Pallets are commonly available, have a good fuel air ratio and are acceptable for this test. The specification of shape and type of wood is illogical considering that wood does not have to be used at all. The temperature of a fire does not have to be 800 °C to have a dependable test, as flame engulfment already specified is adequate and appropriate. A broad range of products are tested which are not conducive to only one procedural approach. Some easily ignite after 90 seconds of a normal wood fire, burn at temperatures far exceeding 800 °C, and are consumed after 3 minutes. The 800 °C fire is irrelevant to these products. Furthermore, the possibilities to change the temperature of a fuel fire are limited. The most important parameter is the type of fuel, the lay-out of the fire and ample access of oxygen. For those reasons, many authorities do not measure the temperature of the bonfire at all. Meanwhile this criterion has been used to reject tests where the fire temperature momentarily dipped below 800 °C. The high flame temperature is detrimental because it must often be obtained with over-size fires which degrade the witness stand performance which is susceptible to softening when the product itself would not generate that much heat. It is common to use more than one type of fuel simultaneously in a fire.

6. Sections 16.6.1.3.2-4

These particular examples all specify an extension of the fire to 1.0 m beyond the test items. This brings the fire closer to the aluminium witness stands and can contribute to their degradation. Also, the wood fire example has been interpreted that the fire must burn for thirty minutes, whereas for some products it is certain that they have all been consumed in three minutes.

The examples are often enforced by competent authorities as the only allowable method. SAAMI has proposed text in a separate working paper to amend the introduction of the Manual to explain about the enforcement of examples. If more than one example was provided then any method between them could be allowed. SAAMI’s approach is to change the example into a test specification reduced to commonality for all fires. We propose a change to the wood fire example as it seems to cause the most problems of interpretation and use.

7. Section 16.6.1.3.5

The requirement to place soft aluminium witness stands 4 meters from an 800 °C fire must be technically assessed, as it may reveal regardless of wind direction that this degrades the measurement of witness stands for dents and perforations because the witness stand criteria in this regard were only tested at ambient temperatures. The witness stands were originally designed to evaluate effects in the immediate vicinity, which was defined in Section 44.4.6 of the 2nd edition of the Manual of Tests and Criteria (ST/SG/AC.10/11/Rev.1) as 5 meters from the product. The statement not to put a witness stand in the downwind quadrant to control heat impact is an option but is often in contradiction of the common practice to keep

this quadrant with no witness stand open for the camera and free from smoke. The problem of heat impact to the stands is addressed elsewhere in this paper, and is best controlled by limiting the size of the fire, which may degrade witness stand dent or perforation results regardless of wind effects. Wind speed is already controlled by section 16.6.1.3.6. The height placement of the witness stands should be measured from the ground, and should not be over specified. While designs vary, due to their size and lack of air vents witness stands are subject to blowing over, and in general they derive their physical stability by being firmly affixed to the ground.

8. Section 16.6.1.3.6

The last sentence states “A safe waiting period, prescribed by the test agency, should be observed after the fire has extinguished.” This sentence is intended to protect people conducting the test. While expertise and caution are necessary, there are a number of issues with the inclusion of this restriction in the Manual. First, only competent operators should conduct a test, and there are many other safety precautions which should be taken which are not mentioned and have no place in a Manual of this type. Next, depending on the type of the explosive and the test results it is easy to assess that all material has been burned or no explosive hazard remains so that an approach for extinguishment may be made. These fires may last a long time after the explosive is consumed, and often a full day of testing may involve many tests one after another with no time to let a fire burn out by itself unless a specific situation merits this. Therefore the fires must often be extinguished with water by people approaching the fire. The risk is typically greater before extinguishment than after, whereas the waiting period is specified to be after extinguishment. After extinguishment there is no reason to wait in many scenarios, whereas those scenarios where further waiting is advisable would not be appropriate to differentiate into a written requirement in the UNMTC. Furthermore, if the test is done at the facility of the competent authority then their own standard operational procedures will apply. Conversely, if the test is done by industry, the test agency will usually not be in a position to specify this parameter or any other procedural safety precaution, which otherwise could result in assumption of liability for the authority. Per section 1.1.2 expert competence is a prerequisite for using the Manual, and this must be relied upon for safety as well as accurate classification. Therefore this sentence is ultimately not helpful and should be deleted so that it does not complicate the test procedure or impede judgment decisions by experts.

9. Section 16.6.1.3.7

This section adds no value where it is and could be deleted. Alternatively, some might find it useful as a new 16.6.1.4.1. SAAMI proposes to delete this text, but depending on the advice of the Secretariat perhaps the second option might be desirable.

10. Section 16.6.1.4.2.

This section specifies the criterion for assignment to Division 1.1 based on mass explosion. The text varies from the definition in the Model Regulations and should be aligned with Section 2.1.1.4(a) of the UNMR.

11. Section 16.6.1.4.3.

This section specifies two criteria for assignment to Division 1.2 based on perforations or metallic projections. Competent authorities are trending towards more rigid enforcement of these criteria. For example, the 2nd edition of the Manual did not allow any dent for a material to be 1.4S, whereas many 1.4S products make some sort of dent.

Dents are common for metallic articles thrown by hand, and perforations may occur depending on their shape. Similar dents and perforations may occur if non-explosives, even non-dangerous goods, were evaluated in the bonfire. The measurement of perforations is meant to address serious hazards due to explosively propelled and potentially supersonic

projections. This criterion may be trivialized by inclusion of results in the realm of hand-thrown objects or non-explosives. Therefore it could be beneficial to be more specific in the intent since the use of judgment is expected.

The perforation criterion may be modified by using the text from the 6(d) test criterion for the measurement of projections and apply it to perforation of the witness stands, therefore a complete perforation. If a small perforation is made, it may be a manageable hazard, whereas if a projection passes clear through the aluminium then it is obviously in the realm of an explosively propelled projectile.

Regarding the mass-distance criterion, a metallic projection with a kinetic energy exceeding 20 J is also a criterion for assignment to Division 1.2. Similarly to the concerns presented for perforations, this energy can easily be attained by hand thrown objects. With the advancements in measurements of projectile dangers to people (e.g. standards for protective vests and other equipment) industry is conducting research to evaluate the energy levels used as thresholds for classification. The 20J value is placed in square brackets pending the completion of research.

12. Section 16.6.1.4.4. This section specifies the criterion for assignment to Division 1.3 based on threshold limits for fireballs, jets of flame, fiery projections, and heat output.

The bonfire can be quite large with a force and energy of its own. In paragraph (a) the term “fireball” is meant to describe a flame effect generally with impetus in all directions. This is thought of as roughly spherical, as opposed to a vagary of the flames of the fire as directed by a light wind. The term “jet of flame” is intend to describe an intentionally directional control of flame by an article, not an unrelated effect. These concepts are generally agreed upon and would be helpful to state.

The prohibition in paragraph (b) against fiery projections should be clarified as not applying to packaging such as plastic or fibreboard wafting up out of the fire on the heat column or being gently expelled in a parabolic fashion obviously differentiable from a primarily linear projection.

Recent mathematical computations have been made to explain the procedure of how to scale time measurements for thermal flux based on heat of combustion of a test product. These will be made available, and the current reference has been placed in square brackets in case further clarification is deemed helpful.

13. Section 16.6.1.4.5. This section specifies the criterion for assignment to Division 1.4 other than compatibility group S based on threshold limits for fireballs, jets of flame, fiery projections, witness screen indentations, energy of metallic projections and heat output. The same discussion of fiery projections, fire balls and flame jets for Section 16.6.1.4.4 applies to this section. This is also true of heat flux scaling calculations which are again placed in square brackets. The threshold values for witness screen indentation and mass distance have been placed in square brackets pending the completion of research for presentation in an informal paper.

14. Section 16.6.1.4.6. This section specifies that if all five Division 1.4 criteria in section 16.6.1.4.5 are passed then a product is assigned a classification of 1.4S. The current text has an incomplete reference to the definition of 1.4S which leads to misinterpretation:

“If none of the events occur which would require the product to be assigned to Division 1.1, 1.2, 1.3 or 1.4 other than Compatibility Group S, the thermal, blast, or projection effects would not significantly hinder fire-fighting or other emergency response efforts in the immediate vicinity, and if hazardous effects are confined within the package, then the product is assigned to Division 1.4 Compatibility Group S.”

While this is a close approximation of the definition of 1.4S, it leaves out the text “unless the package has been degraded by fire” leading to a misinterpretation that no effects are allowed outside the package in the bonfire test, despite the contradiction that metallic projections are allowed to the prescribed threshold per 16.6.1.4.5(d) and Figure 16.6.1.4.8. It is not clear to all authorities that 1.4S has a two part definition, one part for a fire and another part for accidental ignition.

Other authorities have interpreted this section to mean “and the thermal, blast, or projection effects would not significantly hinder fire-fighting or other emergency response efforts in the immediate vicinity...”, i.e. that a subjective judgment about the safety of fire fighters and emergency responders is an additional criterion. This is not a valid interpretation in the English language edition, however it can be confusing since the text is superfluous. This was discussed by the Working Group on Explosives at the 39th session of the Sub-Committee with the following text in their report: “The group noted that the existing test criteria fully implement the 1.4S definition, particularly as it relates to emergency responders, and any additional criteria used at the discretion of a competent authority should be objective and not subjective.” Emergency responders were specifically called out because they may not be wearing personal protective equipment, as opposed to fire fighters who wear protective gear.

This wording is causing mis-classifications. Since its deletion would not change the application of the UNMTC, SAAMI proposes to delete the superfluous text.

Proposals

Individual proposals modify the Manual of Tests and Criteria as shown below. [Square brackets] indicate a subject of discussion.

1. Amend 16.6.1.2(g):

Three 2 000 mm x 2 000 mm x 2 mm [1100-0 aluminium sheets (Brinell Hardness 23, tensile strength 90 MPa)], or equivalent, to act as witness screens together with suitable supports to hold them vertically. The witness screens shall be mounted rigidly to their frames. When more than one panel is used to make a witness screen, each panel shall be supported at all joints;

2. Amend 16.6.1.2.(h):

~~Cine or video cameras, preferably high speed and normal speed, to record events in colour.~~ Video equipment capable of recording the events necessary for classification. In most cases one normal speed video camera will be sufficient. In some cases more video cameras might be useful, e.g. wide angle and zoomed in on the fire or looking at the fire from different directions. A high speed camera might be employed to record the speed and direction of projectiles where these are anticipated based on product knowledge.

3. Replace 16.6.1.3.1 with the following:

~~16.6.1.3.1 The required number of packages or unpackaged articles, in the condition and form in which they are offered for transport, are arranged as close as possible to one another on the metal grid. Packages should be oriented in such a way that a maximum probability for projections hitting the witness screens is obtained. If necessary, the packages or unpackaged articles may be encircled with a steel strip to support them during the test. Fuel is placed beneath the grid so that the fire will engulf the packages or unpackaged articles. Precautions against side winds may be required to avoid dissipation of the heat. Suitable methods of heating include a wood~~

~~fire using a lattice of wooden laths, a liquid or gas fuel fire, that produces a flame temperature of at least 800 °C.~~

The required number of packages or unpackaged articles, in the condition and form in which they are offered for transport, are arranged as close as possible to one another on the metal grid. If directional effects are anticipated, typically caused by articles designed to channel energetic effects, packages should be oriented in such a way to maximize probability for projections to hit witness screens and for discreet flame jets to be pointed horizontally. If necessary, the packages or unpackaged articles may be encircled with a steel strip to support them during the test. Fuel is placed beneath the grid so that the fire will engulf the packages or unpackaged articles. Suitable methods of heating include a wood, liquid or gas fuel fire or a combination thereof.

4. Revise Section 16.6.1.3.2 as follows:

~~16.6.1.3.2 One method is to use a wood fire which has a balanced air/fuel ratio, thereby avoiding too much smoke which would obscure the events, and which burns with sufficient intensity and duration to bring many kinds of packaged explosives to reaction in 10 to 30 minutes. A suitable method involves using air dried pieces of wood (approximately 50 mm square section), stacked to form a lattice beneath the grid (1 m off the ground), and up to the base of the grid supporting the packages or unpackaged articles. The wooden laths should extend beyond the packages or unpackaged articles to a distance of at least 1.0 m in every horizontal direction and the lateral distance between the laths should be about 100 mm.~~

16.6.1.3.2 A wood fire should burn the packages or unpackaged articles with sufficient intensity and duration to completely react packaged explosives. Dry pallets, boards or laths alone or in combination may be stacked to form a lattice beneath the grid (1 m off the ground), and up to the base of the grid supporting the packages or unpackaged articles. The wood should extend beyond the packages or unpackaged articles sufficiently for the fire to engulf the product.

5. Amend section 16.6.1.3.5:

~~16.6.1.3.5 The vertical witness screens are erected vertically in each of three quadrants at a distance of [4] m from the edge of the packages or unpackaged articles. ~~The downwind quadrant is not used for screens because prolonged exposure to flames may change the resistance of the aluminium sheets to projections.~~ The sheets should be placed so that the centres are level with the centre of the packages or unpackaged articles or, if this is less than 1.0 m above the ground, in contact with the ground. If there are any perforations or indentations in the witness screens before the test, they should be marked so that they can be clearly distinguished from those created during the test.~~

6. Amend section 16.6.1.3.6:

~~The ignition system should be put into place and the fuel ignited on two sides, one the upwind side, simultaneously. The test should not be performed under conditions where the wind speed exceeds 6 m/s. A safe waiting period, prescribed by the test agency, should be observed after the fire has extinguished.~~

7. Delete section 16.6.1.3.7

8. Modify section 16.6.1.4.2:

If mass explosion occurs then the product is assigned to Division 1.1. A mass explosion is one which affects almost the entire sample virtually instantaneously.

9. Modify section 16.6.1.4.3:
- (a) A projection passes completely through ~~A perforation of~~ any of the witness screens (see 16.6.1.3.5);
 - (b) A metallic projection with a kinetic energy exceeding [20 J] as assessed by the distance- mass relation given in Figure 16.6.1.1;
- A possible modification of paragraph (b) may be proposed by a separate informal paper based on ongoing research.
10. Modify section 16.6.1.4.4:
- 16.6.1.4.4 If none of the events occur which would require the product to be assigned to Division 1.1 or 1.2 but any one of the following events occurs:
- (a) A spherical fireball or article's jet of flame which extends horizontally beyond any of the witness screens;
 - (b) A fiery projection emanating from the product is ~~thrown~~ linearly projected more than 15 m from the edge of the packages or unpackaged articles;
 - (c) A burning time of the product measured to be less than 35 seconds for 100 kg net explosive mass [(see 16.6.1.4.8 Notes for scaling time measurements in evaluating thermal flux effects).] Alternatively, in the case of articles and low energy substances, the irradiance of the burning product exceeds that of the fire by more than 4 kW/m² at a distance of 15 m from the edge of the packages or unpackaged articles. The irradiance is measured over 5 seconds, during the period of maximum output;
- then the product is assigned to Division 1.3.
11. Modify section 16.6.1.4.5:
- 16.6.1.4.5 If none of the events occur which would require the product to be assigned to Division 1.1, 1.2 or 1.3, but any one of the following events occurs:
- (a) A spherical fireball or article's jet of flame which extends horizontally more than 1 m from the flames of the fire;
 - (b) A fiery projection emanating from the product is ~~thrown~~ linearly projected more than 5 m from the edge of the packages or unpackaged articles;
 - (c) An indentation in any of the witness screens of more than [4 mm];
 - (d) A metallic projection with a kinetic energy exceeding [8 J] as assessed by the distance - mass relation given in Figure 16.6.1.1;
 - (e) A burning time of the product measured to be less than 330 seconds for 100 kg net explosive mass [(see 16.6.1.4.8: Notes for scaling time measurements in evaluating thermal flux effects)];
- then the product is assigned to Division 1.4 and to a compatibility group other than Compatibility Group S.
12. Modify section 16.6.1.4.6:
- ~~“If none of the events occur which would require the product to be assigned to Division 1.1, 1.2, 1.3 or 1.4 other than Compatibility Group S, the thermal, blast, or projection effects would not significantly hinder fire fighting or other emergency response efforts in the immediate vicinity, and if hazardous effects are confined within the package, then the product is assigned to Division 1.4 Compatibility Group S.”~~