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G05-05

Determination of Potential Effects for Explosives

Explosives Regulatory Division
Explosives Safety and Security Branch

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Table of Contents **Page**

1. INTRODUCTION

This guideline is published in accordance with Part 3 of the *Explosives Regulations, 2013* (ER, 2013). It is written in conjunction with the Explosives Regulatory Division (ERD) document titled *General Standard for the Authorization and Classification of Explosives* and specifies the methodology for the determination of the potential effects (PE) of an explosive.

The possible potential effects are:

- PE1 - mass explosion hazard, i.e., the entire body of explosives explodes as one;
- PE2 - serious projectile hazard, but not a mass explosion hazard;
- PE3 – fire hazard and either a minor blast or minor projection hazard, or both, but not a mass explosion hazard;
- PE4 - fire hazard or slight explosion hazard, or both, with only local effect.

1.1 Background

In the past, the transport classification has been used as the basis for the application of the Quantity Distance Principles (QD) in agreement with the *Explosives-Quantity Distance Standard.*

The transport classification does not adequately cover situations encountered in process or storage conditions since it is based on testing limited quantities of explosives as covered by the United Nations (UN) Manual of Tests and Criteria methodology for packaged explosives substances or articles that are safe to transport. When explosives are being stored or kept in large quantities or under confinement, packaged or unpackaged, there is a need for a more detailed hazard assessment to determine explosives hazards throughout the course of their manufacture and storage, for determining minimum safety distances at licensed magazines or factories.

1.2 Scope

This guideline is intended to specify the explosive's potential effect categories and to assist in determining what QD principles must be applied in agreement with the *Explosives-Quantity Distance Standard*. This applies to all explosives that are subject to the *Explosives Act* and *Regulations*.

2. NET EXPLOSIVES QUANTITY (NEQ) AND NET EFFECTIVE EXPLOISIVE QUANTITY (NEEQ)

The NEQ is the mass of an explosive excluding the mass of any packaging or container and, in the case of an explosive article, excluding any component that is not an explosive substance.

The NEEQ is a concept used when a test is shown that the effective quantity of explosive is significantly different from NEQ. There are two broad categories for using NEEQ:

i) When the inherent properties of the explosives in question are PE1 but the method in which they are packaged or arranged precludes the whole quantity from undergoing a mass explosion (examples are shaped charges used in perforating guns, detonators or detonating cord so packaged). UN Test Series 6 would have provided information on how many articles do participate in the reaction. Calculate the percentage and use that number as NEEQ. For example, if a maximum of 25% of the articles participate in 6a or b (all three series 6 must be done, i.e., 6a, 6b, 6c) and there is a NEQ of 80 kg, use 20 kg as NEEQ. Note that the NEEQ assessment may only be done when series 6c (external

fire test) show no mass explosion and series 6a and 6b shows a percentage function. If there is a mass explosion in 6c, then NEEQ is not allowed and NEQ must be used; and

ii) When the explosive does undergo a mass explosion but the power of the explosive is other than what is implied in the QD tables, i.e., TNT. The actual TNT equivalency can be measured by testing. If the TNT equivalency is within ±20%, then no correction is needed. If it is outside ±20%, then the NEEQ should correct for the lesser or higher power. For example, if the TNT EQ is 140% and the NEQ is 100 kg, use 140 kg as NEEQ.

3. DETERMINATION OF THE DEFAULT POTENTIAL EFFECTS

When explosives are authorized, as per Part 3 of ER 2013, they are assigned:

- a type;
- a hazard (i.e., PE); and,
- a UN number (i.e., transport classification).

In many cases, the information available will be sufficient for determining which PE is to be used. However, in some cases, the PE may be variable since the effect will differ based on circumstances or conditions

In order to determine the potential effects of an explosive, the methodology takes into account items such as:

- the inherent properties of the explosive;
- the method of packaging;
- the process conditions; and,
- the storage conditions.

Guidelines are provided in this section to indicate what PE shall be used in the absence of test results. This preliminary assessment assumes that the substance, in-process component or article has explosives properties and that the question to be answered is whether the process or storage conditions may be more hazardous than the transport classification. Examples of conditions that may lead to a more significant hazard are:

- increased confinement;
- processing at elevated pressure and/or temperature;
- critical diameter or height being exceeded; and,
- articles handled in a mass propagating format.

If the TDG classification is determined as 1.1 or as 1.2 the Potential Effect would be PE1 or PE2 respectively. If the TDG classification is determined as 1.3, 1.4 or 1.4S, the PE may depend on processing and storage conditions.

The PE and QD do not apply to articles that are classified for transport as 1.4S and for which this classification is not package-dependent.

For PE that may depend on process or storage conditions, the PE may be arrived at from historical data or from testing previously done. An example of historical data is a history of incidents with accidental initiation.

Less stringent PE than the default PE indicated must be supported by testing. This testing shall be consistent with the test methodology indicated in Section 5.

4. DETERMINATION OF POTENTIAL EFFECTS FOR SPECIFIC TYPES

4.1 Type P – Propellants

Propellants are explosive substances with a burn rate that is highly pressure sensitive and with numerous geometries designed for the intended purpose. Their basic ingredients, for example nitrocellulose, nitroglycerin or fine ammonium perchlorate, are explosives with a mass explosion hazard. Consequently, propellants with a high level of porosity or small web, or a high content of NG for example, are expected to present a mass explosion hazard depending on the processing or storage conditions.

Therefore, the PE must be determined with care based on test results consistent with the methodology of Section 5. Some of the test results that may be considered are critical height; a more rigorous 6b test with double or triple the amount, or a full-scale test as intended to process or store, are possibilities. The basic guidance is as follows:

Manufacture of Propellant
Propellants classified for transport as UN 1.3 have PE3. However, if the following conditions are present they are classified as PE1:

- confined in metal, such as closed blending barrels (unless provided with blow out panels)
- above their critical height in bulk (unless provided with venting and demonstrated by testing [section 5])

Storage
Propellants classified for transport as UN 1.3 have PE3. However, the following conditions are met and in the absence of testing (see Section 5) the default is PE1:

- propellants are stored more than two drum high; and,
- propellants are stored in an aggregate of more than 2000 kg.

4.2 Type I - Initiation Systems (Detonators)

Detonators are articles that contain both a secondary and a primary explosive. As a consequence, an accidental initiation may propagate rapidly from detonator to detonator, generating a shock wave and multiple small metallic shrapnel to exposed personnel. The hazards are significant in a manufacturing environment when partially assembled detonators are handled in a mass propagating format (boxes or plates). The hazards diminish significantly when assembled units are handled due to the separation imposed by the presence of lead wires or shock tubing between detonator tubes, which diminishes the likelihood of propagation between units.

Manufacture
PE1 unless placed into non-propagating blocks or cassettes, in which case PE4.
Note that the non-propagation must be demonstrated by testing (Section 5).

Storage
Detonators classified for transport as 1.1 are stored as PE1.
Detonators classified for transport as 1.4 are stored as PE4 when kept in their original transport packaging, otherwise they become PE1.

Default NEQ
The default NEQ of detonators is one (1) gram per detonator.

4.3 Type F – Fireworks

4.3.1 F.1 - Consumer Fireworks

Manufacture
Consumer fireworks compositions have:

- PE3 for unconfined stars and effects other than flash
- PE1 for flash powder, black powder or whistle composition

Finished consumer fireworks have PE4.

Storage
Consumer fireworks have PE4 up to 25 000 kg (NEQ).
Above 25 000 kg (NEQ) PE4 applies only if the storage is sprinkled; otherwise, PE3.

4.3.2 F.2 – Display Fireworks

Display fireworks are large articles with the potential hazards of mass detonations and generation of shock waves. Caution should be exercised when fireworks contain compositions with a metallic fuel and oxidizers such as perchlorates, or when the storage building adds to confinement. The worst cases are to be expected with large quantities of loose compositions with these ingredients and when under confinement, such as in ISO containers.

Manufacture
Display fireworks compositions have:

- PE3 for unconfined stars and effects other than flash
- PE1 for composition of flash or used as a burst charge, black powder, whistle, or when confined in metal

Storage
Display Fireworks have PE3 if:

- less than 50 000 kg NEQ
- more than 40% free space in the magazine
- magazine is unconfined
- otherwise PE1
-

4.3.3 F. 3 – Special Effect Pyrotechnics

Manufacture
Special effect pyrotechnics composition has:

- PE3 for unconfined stars and effects other than flash
- PE1 for composition of flash or used as a burst charge, Black powder, whistle, or when confined in metal

Some two component powders will have PE3.

4.3.4 NEQ and NEEQ for Fireworks

If the NEQ is unknown, a default NEQ can be used based on the type of firework. NEEQ must be used for display fireworks classified for transport as 1.1G.

F.1 - Consumer Fireworks
The default NEQ of consumer fireworks is 25% of gross weight.

F.2 - Display Fireworks
The default NEQ of display fireworks that have been classified 1.3G for transportation is 75% of gross mass.

For display fireworks containing flash powder* that have been classified 1.1G for transportation (i.e. salute aerial shells), the NEEQ (TNT equivalency) must be used. The NEEQ in this situation is 70% of NEQ. The NEQ would be 75% of gross mass.

Otherwise, the NEEQ (TNT equivalency) for all other display fireworks classified 1.1G for transportation (i.e. shells with diameter size > 155mm) is 50% of NEQ. Again, the NEQ would be 75% of gross mass.

Note: Articles containing flash powder (i.e. salutes shells) are now generally classified for transport as 1.3 (package dependent). If they are not in their original means of containment while being stored, their NEEQ would be calculated at 70% of NEQ.

F.3 - Special Effect Pyrotechnics
The default NEQ of special effect pyrotechnics is 50% of gross weight.

4.3.5 Summary

Table 1: General guideline for determining the PE classification for fireworks

Name and Description	Class	Type	PE	NEQ
CONSUMER FIREWORKS	1.4G	F.1	4	25% of gross weight
CONSUMER FIREWORKS	1.4G	F.1	3	75 % gross weight
DISPLAY FIREWORKS	1.3 G Arial shell ≤ 155 mm	F.2	3	75 % gross weight
DISPLAY FIREWORKS	1.3 G Arial shell ≤ 155 mm	F.2	1	> 50 000 kg NEQ, less than 40% free space in the magazine or the magazine is confined
DISPLAY FIREWORKS	1.2G Roman Candles ≥ 50mm	F.2	2	
DISPLAY FIREWORKS	1.1G Arial Shell > 155mm Salute Shells-all sizes	F.2	1	Use the NEEQ to determine QD: Fireworks containing flash – NEEQ is 70% of NEQ. Fireworks not containing flash but classified as 1.1-NEEQ is 50% of NEQ
SPECIAL EFFECTS PYROTECHNICS	1.4G	F.3	4	50% of gross weight
FIREWORKS ACCESSORIES	1.3G Quickmatch, blackmatch	F.4	3	75% of gross weight

4.4 Type E.2 - Shaped Charges

Shaped charges are prepared with high explosives such as RDX or HMX. They are often packaged in such a way that it is possible to classify them for transport as 1.4D based on the UN methodology. Testing was conducted at the Canadian Explosives Research Laboratory (CERL) which further described the potential hazards from the accidental initiation where significant energetic shrapnel were generated, creating more hazards than the jet itself.

Consequently, shaped charges are classified as PE1.

Default NEEQ
The default NEEQ is 25% under the following provisions:

- can only be used for a NEQ of 200 kg or less;
- shaped charges are as packaged for transport; and
- shaped charges are stored by themselves and without any mass detonating explosive such as detonating cord.

4.5 Type S.1 or S.2 - Cartridges, Oil Wells and Cartridges, Power Devices

Cartridges, oil wells with UN numbers 0277 (1.3C) or 0278 (1.4C) and cartridges, and power devices with UN numbers 0275 (1.3C), 0276 (1.4C) or 0323 (1.4S) may be used by the perforating industry and are sometimes prepared with formulations that have a very high oxidizer content or with formulations more similar to propellants.

Manufacture
Compositions have PE3 when unconfined.
Compositions will be PE3 when confined in metal, but compositions similar to fireworks "flash powder" (i.e., with metallic fuel and oxidizers) will be PE1.

Storage
For quantities below 50 kg, PE4.
For quantities equal and above 50 kg, PE3.

4.6 Type E - Ammonium Nitrate Explosives

Ammonium nitrate explosives classified for transport as 1.1 or 1.5 are PE1.

5. TESTING METHODOLOGY FOR DETERMINING POTENTIAL EFFECTS

Testing may be needed to establish the PE if no analogous situation may be used as a reference. The recommended test protocols are as follows:

- For in-process substances, the methodology must be consistent with the protocol described in Figure 1 or otherwise assessed as per the process conditions with possible sources of ignition;

- For in-process articles, the methodology must be consistent with the protocol described in Figure 2 or otherwise assessed as per the process condition with possible sources of ignition;

- For the storage of substances or explosive components, **to obtain a PE other than the default PE,** the testing conducted shall represent the proposed storage condition at the appropriate scale.

This testing methodology may be simplified in cases where information is already available. For example, where articles with low output and non-detonable explosives are used, it would be appropriate to conduct Series 6 testing only or alternatively to test as per the process conditions.

Test Series 6 – tests 6a and 6b are conducted to determine if a mass explosion occurs from an ignition with the intended means of initiation and if the result is not a mass explosion, a test 6c bonfire is conducted. The 6c test results assist in determining what type of hazard may be expected and, therefore, what transport classification is to be applied, i.e., 1.1, 1.2, 1.3, 1.4 or 1.4S.

Figure 1. Determination of the PE for In-Process Energetic Materials (PE1, PE3, PE4)

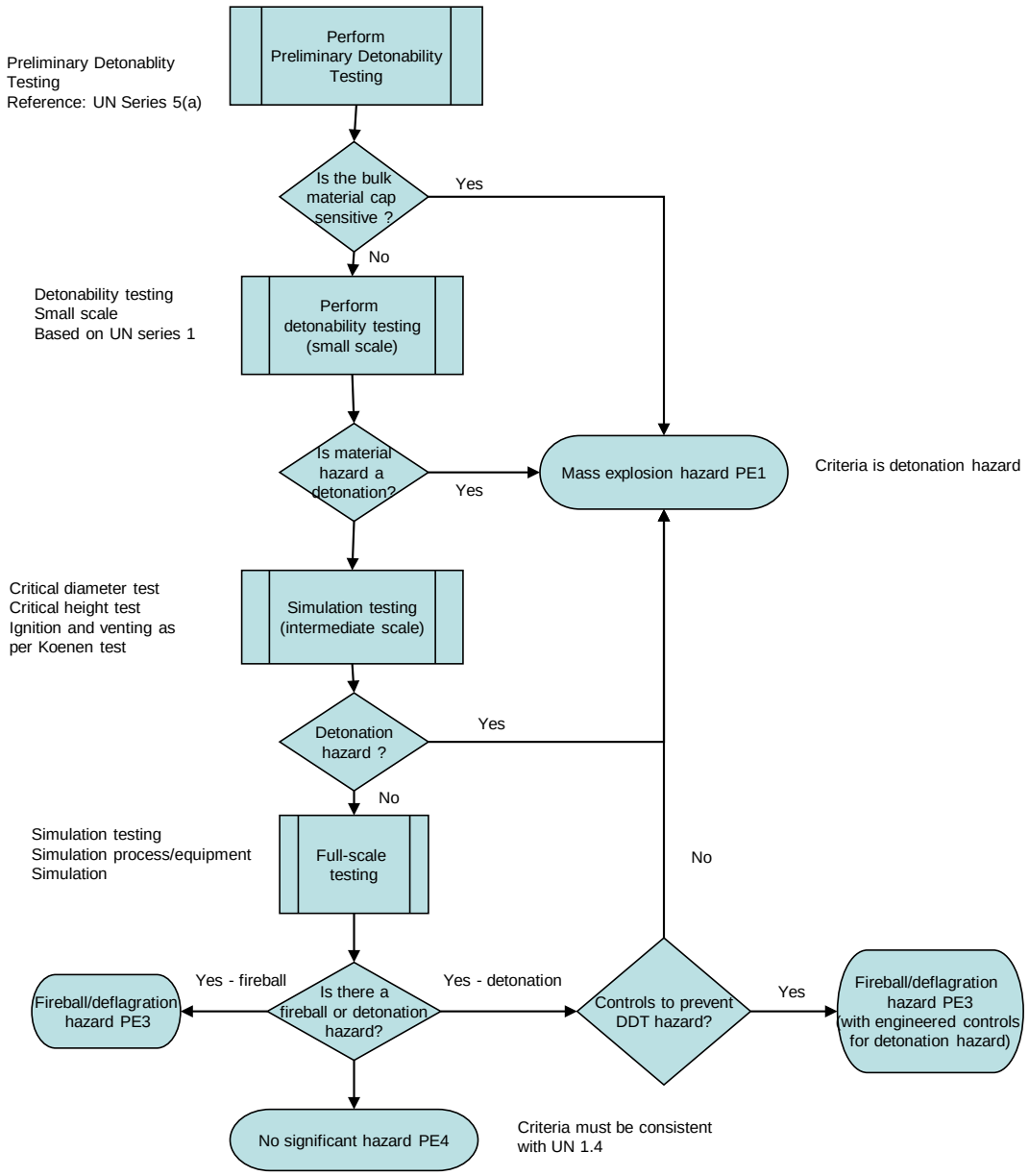

Figure 2. Determination of the PE for In-Process Articles