Gap tests : comparison between UN gap test and card gap test

Ruddy Branka, Christian Michot

GAP TESTS: COMPARISON BETWEEN UN GAP TEST AND CARD GAP TEST

by R. BRANKA and C. MICHOT

INSTITUT NATIONAL DE L'ENVIRONNEMENT INDUSTRIEL
ET DES RISQUES (INERIS)
BP n° 2, VERNEUIL EN HALATTE, FRANCE
(tel.: 33 3 44 55 65 19, fax: 33 3 44 55 65 10)

ABSTRACT:
UN gap test, type 1(a) or 2(a), is the recommended test in the acceptance procedure for transport of explosives in class 1. Up to the revision of the UN Manual of Tests ans Criteria, four tests were applicable, including the French Card Gap Test (CGT), type 1(a)(iv) or 2(a)(iv). Th French CGT is nevertheless always in force in the explosive safety at work French regulation. This leads to the necessary performance cf both tests in some occasions. In order to allow the performance of only one test, a comparison between UN gap test and French CGT has been made.
Five different explosives or reactive substances have been selected for a large scaling of results. The output of the comparison is such that any result in one test allows now to derive the result in the second test.

I – INTRODUCTION

The UN test 1 (a) /2 (a) known as the "UN gap test" is now, in revision 2 of the UN Manual of tests and criteria [1] in force since 1 January 1997, the only detonation test for inclusion in class 1 explosive materials in the meaning of the regulations governing the transport of dangerous goods.

In revision 1 of the UN Manual, 4 detonation tests previously existed together:
- UN 1 (a) (i) / 2 (a) (i): BAM test in 50/60 steel tube
- UN 1 (a) (ii) / 2 (a) (ii): TNO test in 50/70 steel tube
- UN 1 (a) (iii) / 2 (a) (iii): "gap test": detonation initiation test
- UN 1 (a) (iv) / 2 (a) (iv): "gap test": detonation initiation test through a barrier.

The final test, of French origin, is also used for the risk classification of pyrotechnic establishments for the application of the regulations governing safety at work (protection of workers). In practice this means that in France, for the classification of transport and pyrotechnic establishments, two tests must be carried out (the "UN gap test" and the "detonation initiation test through a barrier"), instead of only one (the detonation initiation test through a barrier).

Twenty-Fourth International Pyrotechnics Seminar, Monterey, 27-31 juillet 1998, p. 85-92.

The fact that 2 tests coexist can lead to significant additional costs for users and a lack of coherence in the classifications.

Accordingly the study performed consisted in defining the procedures for UN test 1 (a) / 2 (a) - the "UN gap test" - that render it suitable for meeting the needs of the classification of pyrotechnic establishments in France. Since the two tests are of the same nature, it was in fact a question of defining the thicknesses of the methyl polymethacrylate (PMMA) barriers in the "UN gap test" equivalent to the limiting numbers N of 340, 320, 300 and 240 cellulose acetate cards in the test on initiating detonation through a barrier.

II – STUDY PROGRAMME

The study programme involved, first, the detonation initiation test through a barrier (known as "P5" at INERIS), starting the test at a selected value of the number of cards of cellulose acetate in order to limit the number of tests and, secondly, tests using the conditions of UN tests 1 (a) and 2 (a) but with a search for the limiting block (thickness of the PMMA barrier) that gives, as in test P5, three negative results in three tests, with at least one positive result using the next smaller block.

In order to approach the conditions of test P5, we decided to conduct the "UN gap test" with blocks of PMMA of thickness varying in 5 millimetre steps.

II.1 –EXPLOSIVE MATERIALS USED

To permit comparison of the two tests, we chose materials giving limiting number of N cards in the P5 test covering a wide range of barrier thicknesses. These were the following explosive materials:

- Crushed tolite T/D (TNT) of particle size 0-1400 µm,
- Hexogen B (RDX) with particle size 0-800 µm,
- Ammonium perchlorate with mean particle size 200 µm,
- Dried musk-xylene (moisture content below 0.1%) the particle size of which was measured between 0 and 100 µm,
- Humidified musk-xylene containing about 8% water.

II.2 – DESCRIPTION OF THE INERIS P5 TEST

The principle of this test is to position the test piece of material between two explosive relays. The initiating relay is separated from the test piece by an inert barrier, consisting of a stack of cellulose acetate cards. The second relay is in contact with the test piece. The assembly consisting of the relays, the tube containing the material to be tested, and the cards is 40 mm in diameter (tube OD).

Detonation of the ignition relay induces a fairly intense explosive wave in the material being tested depending on the thickness of the inert barrier. The limiting thickness of the barrier for which detonation of the second relay or controlled relay is not initiated is determined.

The thickness of the barrier is varied in steps of 5 acetate cards each of which is 0.19 mm in thickness. The density of the material is always measured prior to the tests.

The result is expressed as the minimum number of cards (equivalent to a given thickness) that gives three negative results out of three tests while giving at least one positive result for the thickness of cards immediately below. The positive or negative result of a test is given by the penetration of a steel plate 10 mm in thickness placed in contact with the standard relay.

II.3 – DESCRIPTION OF THE UN GAP TEST

The procedure is given in the UN Manual of tests and criteria [1].

II.4 – CHANGES MADE TO THE UN TEST PROCEDURE

We made the following adaptations to the test described in the UN Manual:

- the steel tube was closed at both ends (and not only at the bottom) by a food-grade plastic film (thickness 7 ± 1 µm) held in place by adhesive tape;

- a wooden support (of square cross-section measuring 100 x 100 mm, and 150 mm in length, having a recess 90 mm deep and 50 mm in diameter to accommodate the initiating relay and the block of PMMA, an axial hole 10 mm in diameter for the detonator, and a groove at the bottom for the electric detonator leads to pass is placed at the bottom so as to hold in place the assembly consisting of the detonator, relay, block of PMMA, and steel tube;

- a cardboard tube of inside diameter 50 mm (outside diameter 56 mm, 300 mm in length) was used to hold the steel tube and block of PMMA when the length of the block of PMMA was such that the steel tube could not be held in the wooden support (i.e., for PMMA block lengths of 45 mm or greater).

The other items used were:

- seamless steel tubes type TU37b (NFA 49-210) of OD 40 ± 2 mm, wall thickness 4.0 ± 0.1 mm and length 400 ± 5 mm. Each tube was measured internally prior to the test so that the charge densities of the materials being tested were known,
- blocks of PMMA 50 ± 1 mm in diameter and lengths varying from 5 to 90 mm (± 0.1 mm) in steps of 5 mm,
- steel washers (shims) 1.6 ± 0.2 mm in thickness, ID 40 mm and OD 50 mm,
- mild steel standard plates measuring 150 x 150 mm and 3.2 ± 0.2 mm thick,
- UN standard detonators charged with 0.6 g of penthrite (PETN),
- hexogen wax relays 95/5/0.5 CH, diameter 50 ± 1 mm, length about 50 mm, mass 160 g and density 1600 ± 50 kg/cm^3.

A diagram of the set-up is attached.

II.5 – STUDY PROGRAMME

The test programme consisted in:

- performing the P5 test on the 5 materials,
- performing the UN gap test on the same 5 materials, using the same procedure to make the results comparable.

The objective is to be able to define the thicknesses of PMMA barriers in the UN test equivalent to the limiting numbers N of 340, 320, 300 and 240 cards in the P5 test.

III – TEST RESULTS

The results are summarised in the following table:

materials	charge density	P5 test (number of cards)	UN gap test (mm of PMMA)
hexogen B 0-800 µm (RDX)	1.15	380	95
tolite T/D 0-1400 µm (TNT)	1.10	315	80
ammonium perchlorate 200 µm	1.15	160	45
dried musk-xylene	0.75	125	35
musk-xylene containing 8% of water	0.75	75	15

IV – DISCUSSION

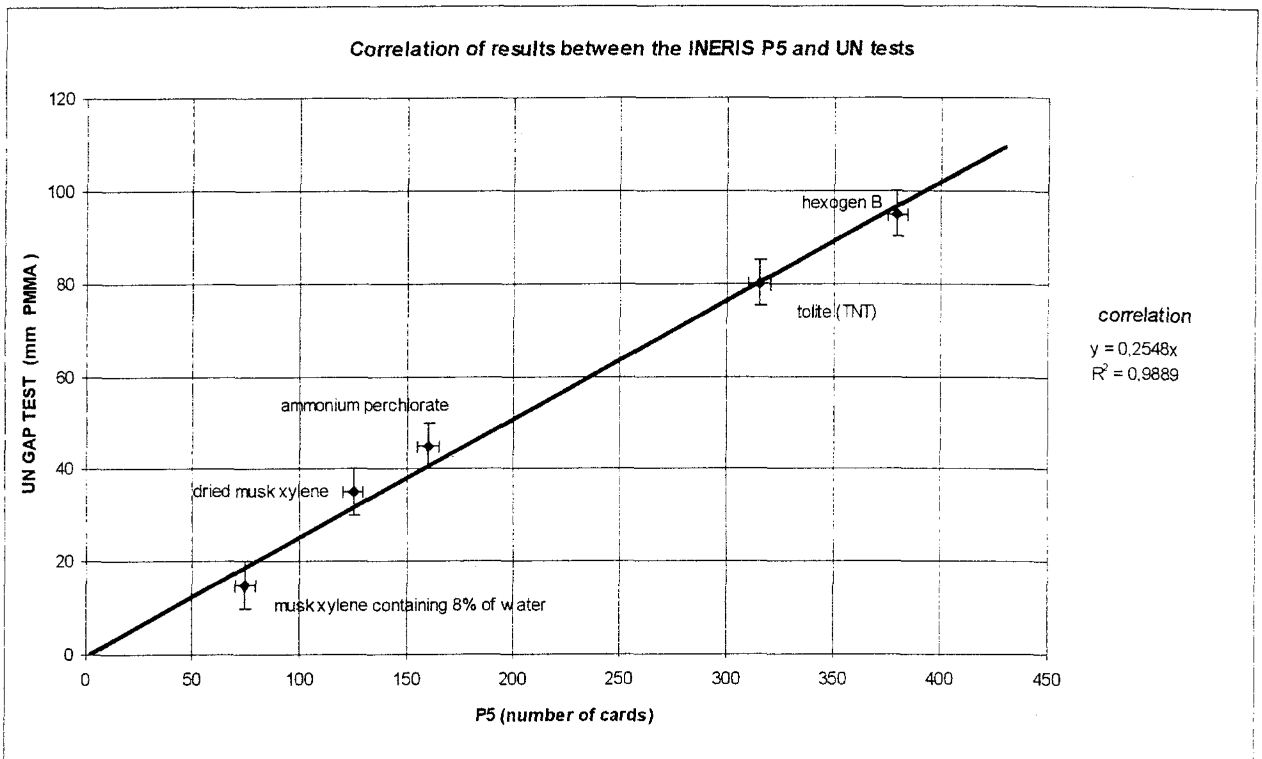
IV.1 – REMARKS CONCERNING THE UN GAP TEST PROCEDURE

It became clear during the tests that the procedure could be improved:

- the height of the wooden support block can be increased still further in order to cover all possible sizes of the PMMA barrier, which would make it possible to eliminate the cardboard guide tube and make the assembly more stable,
- the standard steel plates are very thin and are often ejected or shredded. This makes it difficult to compare the tests since the perforation diameters are difficult to measure,
- the interpretation of the test results should be better defined. In fact, it is not sufficient to say – as in the UN gap test – that a test is positive when the standard plate is perforated or when the steel tube containing the explosive material is completely fragmented. It is essential to define the state of the tube that determines whether a test is positive or negative. We propose to define a positive test in the following manner:
  - reference plate perforated or
  - steel tube: tube fragmented into at least 5 pieces. If the tube is fully opened up, flattened and/or in between 1 to 4 pieces, the test is negative.

IV.2 – CORRELATION BETWEEN RESULTS

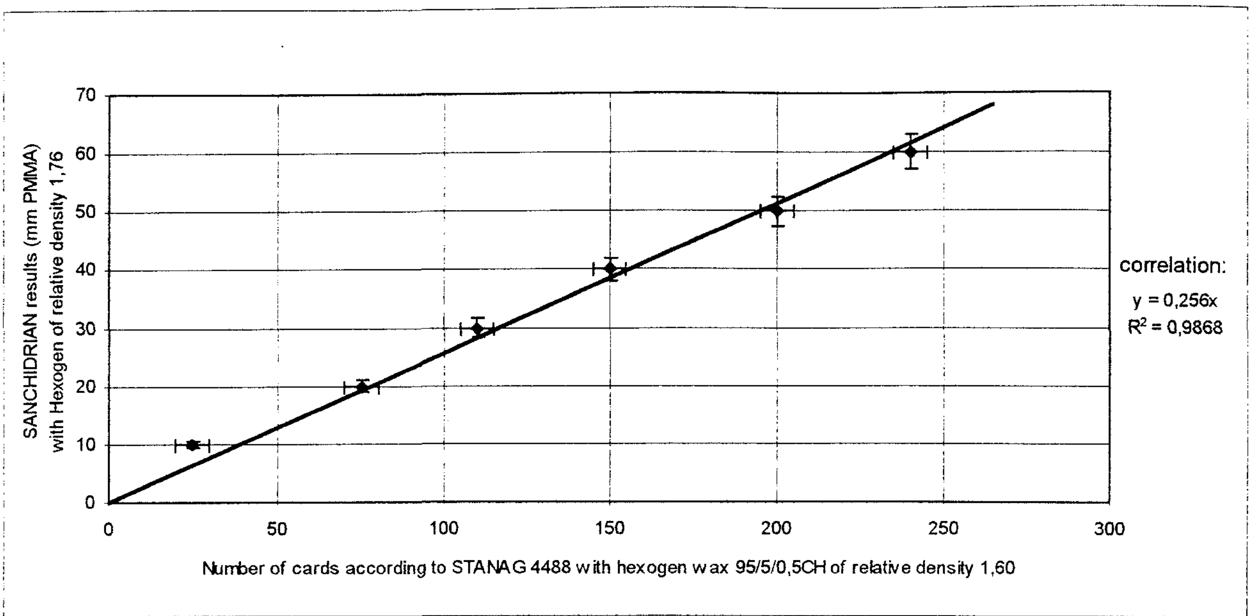
To make it possible to correlate the results obtained in the two tests, we have plotted, on the following graph, the results of the UN gap test as a function of the results of the INERIS/P5 test.



It was also possible to compare the two tests by inspecting two documents:

- document STANAG 4488 appendix B [2] which gives the shock pressure leaving a barrier as a function of the number of cellulose acetate cards for a test identical with the P5 test,
- an article by J. A. SANCHIDRIAN [3] which gives the shock pressure leaving a barrier consisting of cellulose acetate cards or blocks of PMMA for different types of explosive.

We give below the thickness of PMMA (SANCHIDRIAN's article) as a function of the number of cards (STANAG 4488) in the same conditions as the UN gap test and the INERIS/P5 test, and using the shock pressures given in each document (the explosives used were hexogen for SANCHIDRIAN's results and hexogen wax 95/5/0.5 CH in STANAG 4488. The two types of explosive have similar detonation velocities: 8750 m/s for hexogen of relative density 1.76 [5] and 8350 m/s for hexogen wax of relative density 1.60 [6], which results in fairly similar detonation pressures.



It can be seen that practically the same curve is obtained in both cases (see the coefficients of the equations of the lines given on the curves). It can be concluded from these correlations that there is equivalence between the two methods, and the following correspondence can be deduced:

Limiting number of cards in the P5 test	Equivalent thickness of PMMA in the UN gap test (mm)
340	86.7 rounded to 85
320	81.6 rounded to 80
300	76.5 rounded to 75
240	61.2 rounded to 60

It therefore seems possible to define a more straightforward UN gap test similar to the simplified INERIS/P5 test [4]

V - CONCLUSIONS

It is possible to show equivalence between the two tests so as ultimately to replace the test currently used for classifying risk in pyrotechnic establishments in France by the UN gap test.

The procedure of the UN gap test should be modified in order better to define the criteria governing the results of each test (see paragraph 4.1).

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[3] J. A. SANCHIDRIÁN, « Analytical and numerical study of the shock pressures in the gap test », Propellants, explosives and pyrotechnics, 18, pp 325-331, 1993

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[5] J. KÖHLER, R. MEYER, « Explosives », VCH, 1993, p.71

[6] J. CALZIA, « Les substances explosives et leurs nuisances », DUNOD, 1969, p124

Appendix : UN GAP TEST
Schematic diagram