Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals

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Explosives and related matters: test series 8

Recommendation on the use of 50/50 pentolite donor in the Ammonium Nitrate Emulsions, Suspensions and Gels: Series 8 Test (b)

Transmitted by the Institute of Makers of Explosives

I. Introduction

1. Section 18.5.1.2.1 (b) of the United Nations Committee of Experts Recommendations on the Transport of Dangerous Goods Manual of Tests and Criteria 5th Revised Edition (ST/SG/AC.10/11/Rev.5 - referred to subsequently in this note as MTC5), specifies as a donor charge, a "95 mm diameter by 95 mm long pressed 50/50 pentolite or 95/5 RDX/Wax pellet with a density of 1 600 kg/m^3 ± 50 kg/m^3".

2. Neither of the specified donors in MTC5 can be sourced locally in Australia as pressed pellets, since pressing is a military technology which is seldom if ever utilised by the suppliers of explosives to the mining industry. It is however possible to obtain cast 50/50 pentolite of the correct dimensions and with a compliant density (namely a nominal density of 1 640 kg/m^3). The aim of this report is to recommend the use of *95 mm diameter by 95 mm long 50/50 pentolite or 95/5 RDX/Wax pellet with a density of 1 600 kg/m^3 ± 50 kg/m^3*. This material has been found to be more readily available.

II. Discussion

3. The TS8(b) in MCT5 appears to have evolved almost directly[1] from MTC's TS7(b), which was developed with only minor modifications from the Naval Surface Warfare Center Expanded Large Scale Gap Test (NSWC ELSGT)[2], which in turn grew from the original standardised Naval Ordinance Laboratory Large Scale Gap Test (NOL LSGT). In all Gap Tests, the role of the donor is to generate a shock pressure that after partial attenuation by the gap material, delivers a specified shock pressure to the confined test material. In TS8(b) the test material is an Ammonium Nitrate Emulsion, Suspension, or Gel sample.

[1] Michael M. Swisdak, Jr., "Hazard Class/Division 1.6: Articles Containing Extremely Insensitive Detonating Substances (EIDS)", *NSWC TR 89-356*, Naval Surface Warfare Center, 1 December 1989.
[2] T.P. Liddiard and D. Price, "The Expanded Large Scale Gap Test", NSWC TR 86-32, Naval Surface Warfare Center, March 1987.

4. Gap test shock pressure has been measured in a number of studies. In the NOL LSGT, Tasker and Baker[3] calibrated the shock pressure in the PMMA attenuator against distance. Their donor comprised of two half-length pressed 50/50 Pentolite pellets of density = 1.56 g/cm^3. Both their raw data and their derived calibration curve are plotted (in blue) in Figure 1. Their estimated mean error of the pressure calibration was between 1.6 and 4.1 percent between 9 mm and 100 mm of PMMA attenuator distance, with the raw data collected at 0.25 mm intervals and the final smoothed calibration provided at 1.0 mm intervals.

5. An associated NATO version of the Gap Test, the STANAG-4488 (developed with only minor changes from the NSWC ELSGT), allowed the choice of either pressed 50/50 Pentolite at 1.56 ± 0.01 g/cm^3 or pressed 95/5/0.5 RDX/Wax/Graphite at 1.60 ± 0.02 g/cm^3 as donor pellets, though still specifying that two pellets each of 47.6 mm length should be used. The published results from the defining testing program[4] for STANAG-4488 appeared to employ only the RDX/Wax/Graphite donor, providing experimental PMMA shock pressure versus distance calibration for that donor, though experimental data were collected at only four distances (namely 10 mm, 50 mm, 100 mm and 150 mm). These data points are also plotted in red in Figure 1, together with the tabulated calibration curve included in the STANAG-4488 document. It appears that the calibration may have been performed using additional experimental data from some other unidentified source, as the curve is a poor representation of the higher pressure data points.

6. Due to the described difficulties in obtaining appropriate pressed Pentolite donors, experimental comparison of *pressed* versus *cast* Pentolite donors has not been possible. However the likely consequences of the substitution of the cast for pressed donors have been examined via a series of numerical simulations using the hydrocode AUTODYN[5], with the results included in Figure 1. These simulations were performed from first principles, using the thermodynamic equilibrium code CHEETAH[6] to predict the details of the CJ detonation state and the attached principal expansion isentropes of 50/50 Pentolite at 1.56 g/cm^3 and 1.64 g/cm^3, and using the Johnson and Cook constitutive model[7] to describe the shock wave response of PMMA[8] and of steel[7] taking large strains, high strain rates and thermal softening into account.

7. It can be seen in Figure 1 that the predicted calibration curve from the simulation assuming 50/50 Pentolite at 1.56 g/cm^3 is in excellent agreement with Tasker and Baker's[3] experimental data, in particular at the gap length of 70 mm specified in the TS 7(b) and 8(b) gap tests. It can also be seen that the predicted shock pressure at 70 mm gap from the simulation assuming 50/50 Pentolite at its higher cast density of 1.64 g/cm^3 is coincidentally very similar to that published for the RDX/Wax/Graphite donor.

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[3] Douglas G. Tasker and Robert N. Baker, Jr., "Experimental Calibration of the NSWC Expanded Large Scale Gap Test", *NSWCDD/TR-92/54*, Naval Surface Warfare Center, January 1992.

[4] J. Isler, "Classification Tests For Assignment to Hazard Class/Division 1.6: SNPE Two Years Experience", *25th US Department of Defence Explosive Safety Board Seminar*, Anaheim CA, August 1992, pp. 419-441.

[5] Century Dynamics, "AUTODYN Theory Manual", Revision 4.3, 2005.

[6] L.E. Fried, W.M. Howard and P.C. Souers, "CHEETAH 2.0 User's Manual", *Lawrence Livermore National Laboratory report UCRL-MA-11751 Rev. 5*, 20 August 1998.

[7] G.R. Johnson and W.H. Cook, "A Constitutive Model and Data for Metals subjected to Large Strains, High Strain Rates and High Temperatures", *7th International Symposium on Ballistics*, April 1983, pp. 541-547.

[8] David L. Kennedy, "High Strain Rate Deformation and Initiation of EXEL Shock Tube", *Orica Explosives Report B58392*, 23 August 2001.

8. Two conclusions can be drawn from the information shown in Figure 1.

(a) Substituting ***cast*** 50/50 Pentolite at 1.64 g/cm^3 for ***pressed*** 50/50 Pentolite at 1.56 g/cm^3 leads to a higher initial shock pressure delivered to the test sample, and hence to a more severe test.

(b) Substituting ***cast*** 50/50 Pentolite at 1.64 g/cm^3 for ***pressed*** 50/50 Pentolite at 1.56 g/cm^3 leads to an initial shock pressure that falls within the allowable pressure range specified in Table 18.5.1.1 of MTC5 for a gap length of 70 mm.

III. Recommendations for Test Changes

9. It is recommended that Section 18.5.1.2.1 (b) of MTC5 be modified to read:

"95 mm diameter by 95 mm long 50/50 pentolite or pressed 95/5 RDX/Wax pellet with a density of 1 600 kg/m^3 ± 50 kg/m^3;"

10. With this modification in TS8(b), the peak shock pressure at the end of the 70 mm PMMA gap would still fall within the current allowable range if a cast 50/50 Pentolite pellet were used. This modification would allow the pentolite pellets to be cast using the most common manufacturing technique adopted by suppliers of boosters to the mining explosives industry, while still permitting the use of pressed pellets if available from suppliers of military explosives. The modification also brings the TS8(b) donor into better alignment with the TS1(a) and 2(a) gap tests, which actually require their Pentolite donor to be cast.

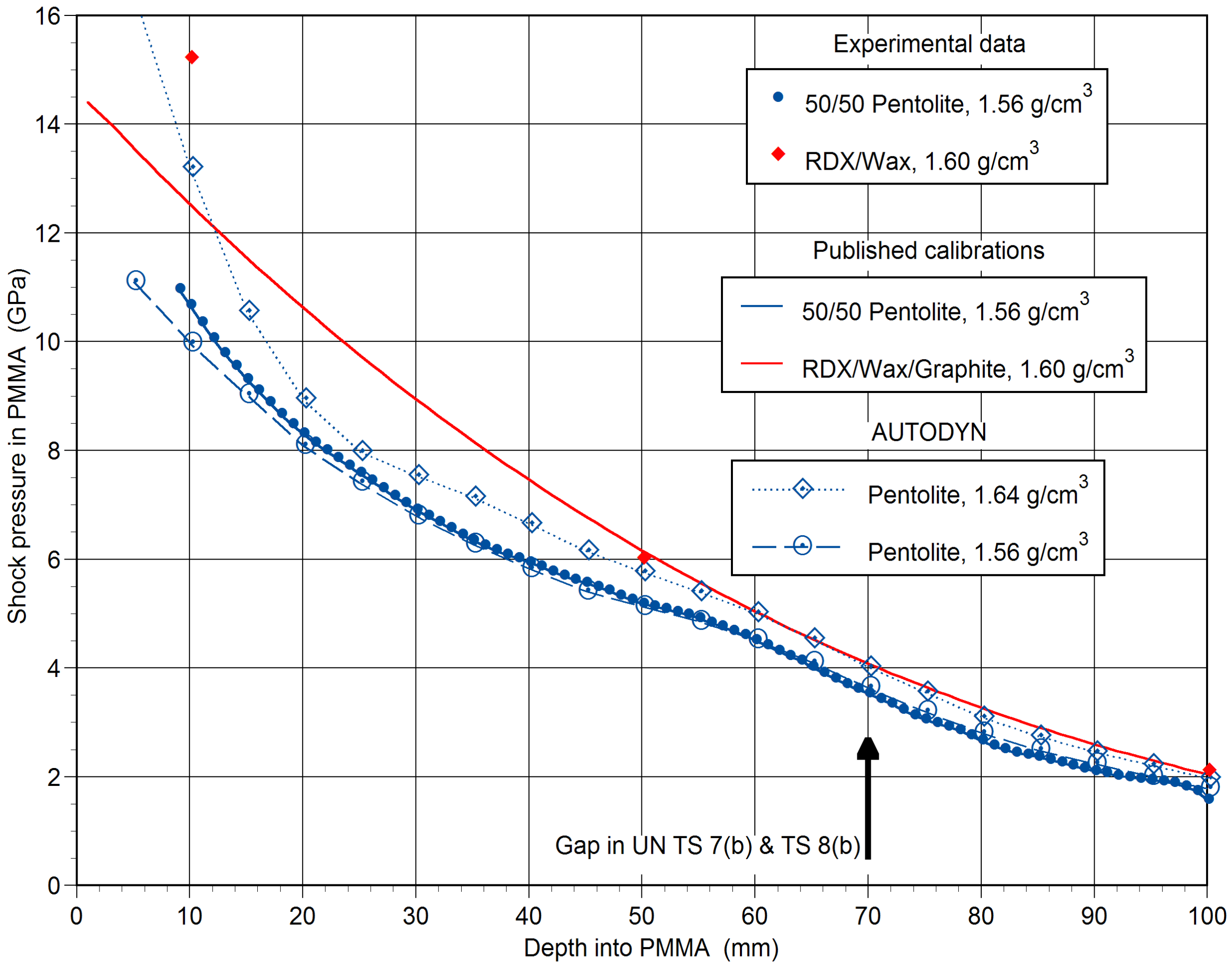

Figure 1.. Calibration curves for NSWC ELSGT, STANAG-4488 and UN TS 7(b) and TS 8(b) gap tests.

Both the experimental data and the calibration curve for 50/50 Pentolite are from Tasker and Baker[3]. The data for RDX/Wax are from Isler[4] while its calibration curve is from Erikson[9]. The AUTODYN curves are calculated for the purposes of this recommendation note.

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[9] J. H. Erikson, "Explosives, Shock Sensitivity Tests", *NATO Standardization Agency Agreement STANAG 4488,* Edition 1, 12 September 2002.