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 Extruded PMMA Rod as an alternative to Cast PPMA 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 (e) 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 a "*cast* polymethyl methacrylate (PMMA) rod, of 95 mm diameter by 70 mm long". This material has proven difficult to source locally in Australia. The aim of this report is to recommend the alternative use of *extruded* polymethyl methacrylate (PMMA) rod, of 95 mm diameter by 70 mm long. This material has been found to be readily available.

II. Discussion

2. The TS8(b) in MCT5 appears to have evolved almost directly[1] from MTC5's TS7(b), which was developed with only minor modifications from the Naval Surface Warfare Center Expanded Large Scale Gap Test (NSWC ELSGT), which in turn grew from the original standardised NOL Large Scale Gap Test (LSGT). For that transition, most test dimensions were doubled, with the major exception being the donor pellet diameter whose size increase was limited to a factor of only 1.875 due to limitations in the size of available larger pressing moulds. The witness plate thickness was doubled, but its area was not "because of handling problems" associated with the greater mass to be manhandled. This doubling enabled the test to be applied to test materials with confined critical diameters up to 73 mm, which was deemed suitable for the vast majority of IHE of interest to military applications.

[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

3. The only known reference[2] to the use of a *cast* PMMA rod in reports of the NOL LSGT clearly shows that selection was based on its superior optical quality. Indeed Erkman et al.[2] state that:

> "*The cylinders were machined and polished in the Optics Shop of the National Bureau of Standards starting with 63 mm (2.5 inch) diameter cast rod. They were free from the optical distortion reported on cylinders used in earlier work*".

4. The optical properties facilitated streak camera experiments to record the location versus time of the shock front along the axis of the transparent PMMA attenuator. Elsewhere in the test literature, the source of the PMMA was left unspecified, and indeed, NOL recognised no difference in shock attenuation when **cellulose acetate playing cards** were used as a spacer alternative to **PMMA**, with the outcome of the gap tests depending only upon the total thickness of the attenuator. The NSWC ELSGT report[3] also mentions the selection of cast PPMA for its optical clarity during the calibration procedure.

5. Some mechanical properties[4] of relevance during shock wave loading are compared in Table 1. Evidently, even moderate differences in the mechanical properties of the attenuator do not materially affect the outcome of these gap tests.

Table 1. Mechanical properties of attenuator materials.

Mechanical property	PMMA	Cellulose acetate
Density (g/cm^3)	1.186	1.261
Hugoniot intercept (mm/µs)	2.598	2.266
Hugoniot slope	1.523	1.585
Longitudinal sound velocity (mm/µs)	2.72	2.45
Shear sound velocity (mm/µs)	1.36	1.15
Bulk modulus (GPa)	5.85	5.34
Shear modulus (GPa)	2.19	1.67

6. It may be noted that Table 1 does not specify if the properties relate to cast or extruded PMMA. This is because that information was not recorded in the source document[4]. Indeed, a search of manufacturers' web sites has failed to locate any data sheets that provided separate mechanical properties for the cast form and the extruded form of PMMA. Instead, the quoted material properties seem to apply to "generic" PMMA, rather to any particular manufacturing method.

[2] Erkman, J.O., Edwards, D.J., Clairmont, A.R. Jr. and Price, D., (1973) "Calibration of the NOL Large Scale Gap Test; Hugoniot Data for Polymethyl Methacrylate", NOLTR 73-15, Naval Ordnance Laboratory, 4 April 1973.

[3] T.P. Liddiard and D. Price, "The Expanded Large Scale Gap Test", *NSWC TR 86-32*, Naval Surface Warfare Center, March 1987.

[4] Stanley P. Marsh, editor, *LASL Shock Hugoniot Data*, University of California Press, 1980.

7. Hence, while it cannot be demonstrated conclusively that extruded PMMA would attenuate shock similarly to cast PMMA, there is no indication in the published literature that the two manufacturing routes to PMMA would lead to any measurable differences in mechanical properties, and certainly none greater than those between PMMA and cellulose acetate demonstrated to bear no measurable influence on test outcomes.

8. The gap test TS2(a) in MTC5 does not distinguish between cast and extruded PMMA spacer.

III. Recommendations for Test Changes

9. It is recommended that the reference to “cast” in Section 18.5.1.2.1 (e) be removed, and the text modified to read:

> “Polymethyl methacrylate (PMMA) rod, of 95 mm diameter by 70 mm long. A gap length of 70 mm results in an incident shock pressure at the ANE interface somewhere between 3.5 and 4 GPa, depending on the type of donor used (see Table 18.5.1.1 and Figure 18.5.1.2);”

10. This modification would allow either cast or extruded PMMA to be used. A search of the literature has failed to find any reason to suspect that the mechanical properties are altered significantly by the manufacturing technique, especially as the developers of the NOL LSGT and the NSWC ELSGT recognised no functional differences between PMMA and cellulose acetate, which do indeed have different mechanical properties.