Chemical Propulsion Information Agency (CPIA)

CPIA Story 1 Story 2

Hazard Classification of Large Solid Rocket Motors Based on Shock Sensitivity

In practice, solid rocket motors have been hazard classified in many cases using a simple test procedure based on an assessment of propellant formulation and shock sensitivity characteristics, as determined from the Naval Ordnance Laboratory (NOL) Large Scale Gap Test (LSGT), and other pertinent design features. The NOL LSGT shock sensitivity threshold criterion of 70 cards (or 70 kbar input shock pressure) has been used as a primary discriminator between Hazard Division (H/D) 1.1 (mass explosion) and H/D 1.3 (mass fire) propellants/motors. The selection of 70 cards as a dividing point had no particular technical basis but was a comfortable criterion for compositions known to be in use or under development in the early 1960s.

Continued on Story 1

NATO Research and Technology Organization (RTO), Advanced Vehicle Technology AVT Working Group (WG)

The final report of a four-year NATO effort to evaluate solid propellant burning rates has recently been completed under the direction of a senior CPIA Rocket Scientist. A senior CPIA technical staff member chaired The NATO Research and Technology Organization (RTO), Advanced Vehicle Technology (AVT), Working Group (WG) 016 (formerly AGARD/PEP Working Group #27 multi-year effort to evaluate methods used within the NATO propulsion community to measure burning rate in solid propellant rocket systems. The purpose was to identify similarities and differences among the member nations. The WG 016 sought to contribute to improvements in the burning rate tools by addressing issues that have remained unresolved in the solid propulsion industry for over 40 years:

1. Better understanding of burning rate, rb(p,To), data from various facilities to ease the comparison of propellants from various manufacturers and to improve international exchanges and cooperation.

2. Improved measurement accuracy and reliability to allow a decrease in the number of tests (and associated time and cost) and improved control of manufacturing and quality assurance and the assessment of aging.

Continued on Story 2

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CPIA Story 1 Story 2

Hazard Classification of Large Solid Rocket Motors Based on Shock Sensitivity (continued)

The most recently published revisions to Department of Defense regulations (5 Jan 1998) governing hazard classification of ammunition and explosives eliminated the use the NOL LSGT (with a 70 card discriminating criterion) as the sole hazard classification criterion, and provided a new alternate method specifically for the hazard classification of larger solid rocket motors. This alternate protocol involves performing a series of detonation sensitivity tests (Figure 1) with propellant samples of increasing diameter, from the conventional NOL LSGT (1.44 inch diameter) or the analogous United Nations card gap test, up to the 8-inch diameter Super Large Scale Gap Test (depending on propellant grain and/or overall motor geometry and dimensions). The associated pass/fail criterion direct that these tests be performed at zero cards (the high explosive donor directly in contact with the propellant sample), essentially implementing the tests under heavily confined conditions using a very strong explosive donor (approximately 200 kbars input shock pressure).

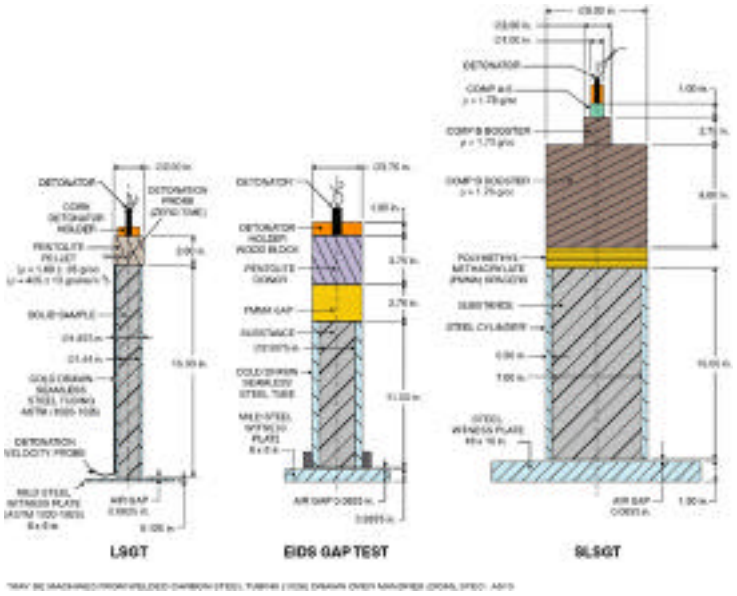

Figure 1. Alternate Card Gap Detonation Test Series. All tests are run without spacers between the explosive donor and sample (although not shown in the test schematics).

CPIA recently coordinated a JANNAF study (at request of the Department of Defense Explosives Safety Board) of alternatives to this test procedure for application to the hazard classification of large solid rocket motors. The study concluded that the test series should be modified to apply a consistent shock criterion in each of the three Gap Tests, as the dividing line between assignment of H/D 1.1 and H/D 1.3 for solid propellants. Two possible approaches were identified. Ultimately, the one recommended was to select a constant shock pressure and tailor the gap in each test to provide that pressure. The 70 kilobar criterion of the LSGT was recommended.

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NATO Research and Technology Organization (RTO), Advanced Vehicle Technology AVT Working Group (WG) (continued)

AVT WG 016 was formed in 1996 with a senior engineer from CPIA as chairman of the working group. The Working Group membership consisted of active representatives from 6 of the 15 member nations of NATO, which included France, Germany, Italy, The Netherlands, United Kingdom, and the United States. Six meetings were held at various sites from October 1996 through October 1999 and 30 facilities from 12 countries were surveyed for the characteristics of solid propellant burning rate test and analysis methods employed. The list of facilities includes Canada (1), France (2), Germany (3), Italy (2), The Netherlands (1), Norway (1), Portugal (1), Spain (1), Turkey (1), United Kingdom (1), and the United States (16). Over 75 individuals from these facilities contributed to this compendium of international burning rate measurement methods.

The recently completed final report represents a complete survey of all major international facilities involved in burning rate measurement and a thorough presentation of the fundamental methods used in the solid propulsion community today. Peer review of the results and conclusions was sought outside the WG throughout this effort. This report provides the final results of this study, including the objectives, approach, detailed findings, and recommendations of this working group based on activity from October 1997 to August 2001.

Burning rate fundamentals are reviewed and industrial test and analysis practices currently in use by the facilities surveyed are thoroughly documented. Detailed recommendations are provided on direct and non-intrusive burning rate measurement test hardware and test methods, data analysis methods, and performance scaling to support improved prediction of internal ballistics of full-scale solid propellant motors. AVT WG 016 activities have identified that manufacturer burning rate data may not easily be compared without accounting for industry-wide differences in subscale devices, test methods and scaling analysis methods. The WG recommended the NATO propulsion community review these findings as a means of advancing their own burning rate measurement and analysis methods.

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