LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-461913

Addendum to High Pressure Burn Rate Measurements on an Ammonium Perchlorate Propellant

E. A. Glascoe, N. Tan

November 10, 2010

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Addendum to High Pressure Burn Rate Measurements on an Ammonium Perchlorate Propellant

Addendum
11/5/2010

Dr. Elizabeth Glascoe and Noel Tan

Lawrence Livermore National Laboratory
Energetic Materials Center
7000 East Ave., Livermore, CA 94550

Introduction

As part of a small follow-on study, the burn rate of the ammonium perchlorate (AP) based material TAL-1503 was studied at a relatively mild pressure. The goal of this final experiment was to burn TAL-1503 at the lowest pressures possible using the LLNL High Pressure Strand Burner (LLNL-HPSB). The following is a description of the experiment and the results with a brief discussion of data and a comparison to the higher pressure data. This is not meant to be a stand-alone report and readers should refer to the main report for experimental details and discussion.

Method

Instrument

The LLNL-HPSB is designed for very high pressures (i.e. 10 – 600 MPa), therefore, doing an ambient and near ambient pressure burns is difficult. In particular, the load cell on the LLNL-HPSB, which provides the initial pressure reading prior to burn-initiation, is not reliable below ca. 200 psi. In addition, the mechanism for sealing the HPSB requires a minimum amount of Argon in the system and safety regulations for the operation of the HPSB require that the system is only operated when sealed. For these reasons, it was necessary to pressurize the vessel with Argon, however, argon pressurization was kept to a minimum.

Results and Discussion

Figure A1 shows the pressure and flame front time-of-arrival data for the near-ambient-pressure burn (identified as burn number 10023. For the most part, the burn is considered a good burn because the burn wires report in order (except for burn wire #4) and are well correlated with the pressure rise. Burn wire #4 reported prematurely, between burn wires 2 and 3, and the most likely reason is either flying debris that broke the wire or some form of misfiring or cross-talk of the electronic/wires. Burn wire #4 was omitted from the analysis of the pressure dependent burn rate.

The pressure dependent burn rates for experiment 10023 are listed in Table A1 and are plotted in Figure A2. Figure A2 is a reproduction of Figure F9 in the original report, with the lowest pressure burn included. It is clear in Figure A2 that the results of burn 10023 do not overlap well with the burn-law-fit to the higher pressure data; therefore this low-pressure data was fit to its own burn-law fit. Many materials display breaks in the burn rate at various pressures and this change in the burn-law-fit is not surprising. In fact, our collaborators at Nammo-Talley were expecting a change in slope at this pressure compared with the higher pressure burns. Figure A3 shows all of the TAL-1503 data collected at LLNL with high pressure burn rate measurements of two other AP-based propellants. The HPP data in figure A3 also has a slope break at ca. 10-20 MPa.

Conclusion

High pressure deflagration rate measurements of a unique AP/HTPB based material (TAL-1503) were performed using the LLNL high pressure strand burner apparatus. The material burns in a well behaved, laminar fashion between 20 and 300 MPa with a burn law of

$$B = (0.6 \pm 0.1) \times P^{(1.05 \pm 0.02)}$$

that was calculated based on the best data available from the experiments. In the pressure range of 2 and 10 MPa the material burned laminarly with a burn law of

$$B = (2.0 \pm 0.2) \times P^{(0.66 \pm 0.05)}$$

In these results, *B* is the burn rate in mm/s and *P* is the pressure in units of MPa. Comparison of the TAL-1503 results with similar propellants that contain micrometer sized aluminum indicate that the burn rates are relatively unaffected by the aluminum. However, the pressure change is significantly larger when aluminum is present, most likely due to the high temperatures achieved from burning aluminum.

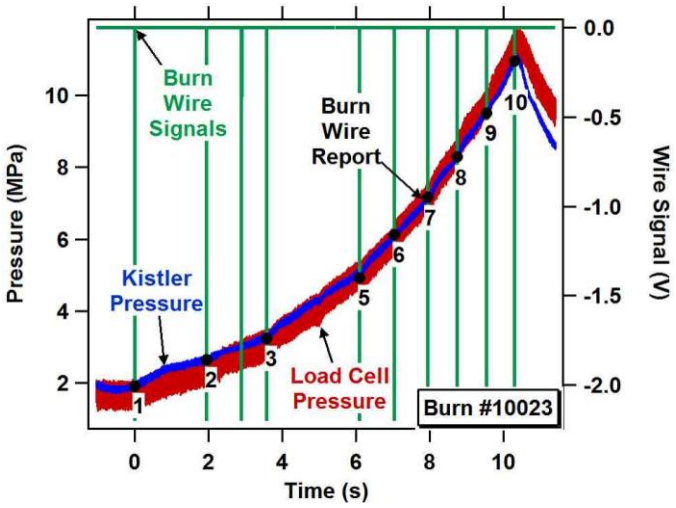

Figure A1. Pressure and burn wires data for burn number 10023.

Pressure (MPa) #10023	Burn Rt. (mm/s) #10023
2.27847	3.35318
2.93993	4.00114
4.08576	5.15113
5.52847	6.79588
6.64306	7.0766
7.72639	8.27467
8.90347	8.07687
10.2368	8.66574

Table 1. Burn rate results for TAL-1503 from experiment 10023.

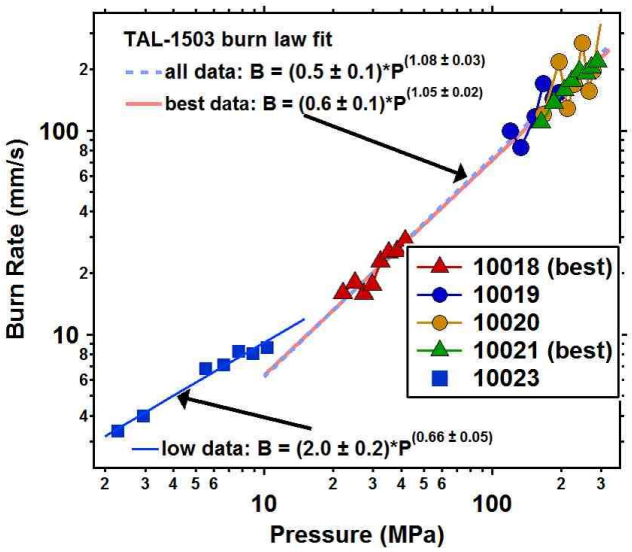

Figure A2. Results of TAL-1503 LLNL high pressure strand burner experiments. Each color represents a different strand and therefore an individual experiment. The two experiments depicted with the triangles (#10018 and 10021) appear to be the most stable and least erratic and a burn rate fit to just these two experiments is reported. A burn rate fit to all the data is also included. The blue squares are derived from burn #10023 and were fit separate from the higher pressure data.

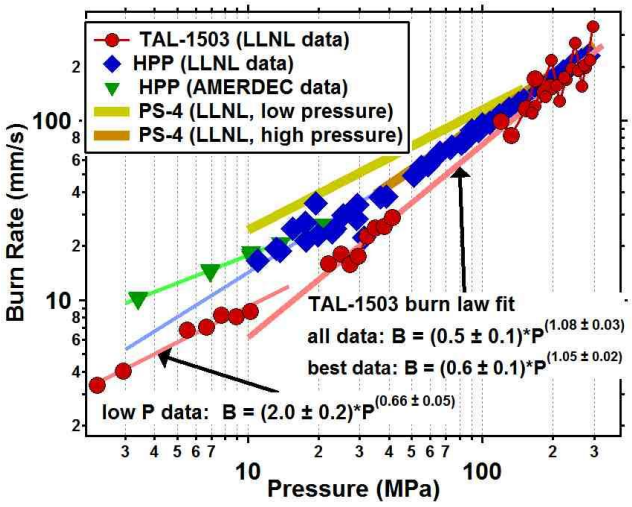

Figure A3. Results of TAL-1503 (an AP/binder formulation) pressure dependent deflagration rate measurements (in red). Also included are results for HPP (an AP/Al/binder formulation) and PS-4 (an AP/Al/binder formulation).

Acknowledgements

We gratefully Nammo Talley (specifically Mark Harris) for supplying the TAL-1503 parts. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.