UCID - 16748

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.

LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

HIVELITE PROPELLANT CHARACTERIZATION

Unclassified

Milton Finger

Bernard Hayes

March 14, 1975

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

"Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Administration to the exclusion of others that may be suitable."

Prepared for U.S. Atomic Energy Commission under contract no. W-7405-Eng-48

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

leg

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

HIVELITE Propellant Characterization

I. SUMMARY

A Teledyne McCormick Selph (TMc/S) new class of very fast burning solid propellants called HIVELITE has been tested to ascertain its dynamic characteristics. The tests conducted were burn rate measurements, handling properties, impact sensitivity (drop hammer), differential thermal analysis, and chromatographic gas analysis.

The original claim by TMc/S that the material does not detonate was substantiated for the nominal sample sizes used in this investigation. Section II details the burn rate measurements technique and data analysis. The main problem was to obtain unambiguous shot records. Diagnostic ambiguities can arise because intense sound waves generate precursor signals obscuring the subsonic reaction front.

The longitudinal sound speed in HIVELITE is approximately 2,190 m/s. The reaction front burn rate appears to have two components: (1) an initial value of 230 m/s measured over a distance of 20 mm including any induction time associated with initiation, and (2) a terminal velocity of about 1200 m/s. There is insufficient data to be certain that the burn rate is constant since the data can be construed as showing acceleration.

In the limited sample sizes examined and fired (all 12 mm diameter of various lengths up to 120 mm) the HIVELITE propellant samples were fast burning, and did not detonate with light confinement. The material was safe to handle - in appearance it resembles dense blackboard chalk - being easily sawed, sanded and trimmed. However, it is spark sensitive, and this is the preferred method of initiation from a diagnostic instrumentation point of view.

II. DIAGNOSTIC PROCEDURES

II.1 Burn Rate Measurements

The initial idea of measuring the burn rate of HIVELITE with conventional pin foils between segments of material had to be discarded because the method was unreliable. It now appears that while the combustion products are electrically conducting the rate of increase in conductivity at the flame front is low, causing

the pin circuit capacitor to bleed off without generating a fast switch action. Small capacitors gave no response on raster oscilloscopes while large capacitors produced only a slow small oscilloscope trace deflection not suitable for reading purposes. Also, the original initiation scheme employed an electric match butted against one end of a HIVEHITE pellet. Electronic synchronization of oscilloscopes and raster scopes was severely hampered by this method of initiation because trigger signals were as unreliable as pin signals.

Switching to painted gap spark initiation and a barium titanate (BaTi) pressure transducer pin solved the synchronization and reliability problems. The final evolution of the burn rate measurement setup is shown in Figure 1.

Figure 1: Exploded and makeup views of a typical HIVEHITE (white pellet) burn rate test setup. The upper right component is a painted gap spark initiator. The long slender cylindrical pin is the BaTi transducer. Assembled, the HIVEHITE is wrapped in cloth tape with epoxy holding the pin and initiator in place.

The HIVELITE pellets, similar in appearance to ordinary white blackboard chalk, were wrapped with several layers of cloth tape before firing to prevent pre-ignition up the side of the cylinder. The initiator was a regular Bendix bridgewire header with the bridge, sanded off, replaced by a stripe of conducting paint. A conventional detonator capacitor discharge unit supplied the energy to vaporize the paint and provide the spark to initiate the HIVELITE.

This initiation method was completely reliable (not one failure occurred) and allowed the convenience of utilizing existing trigger delay circuitry. There was some question whether preshock from the spark might cause some damage to the HIVELITE, but suspicions were removed when a piece of chalk substituting for the active material survived with no apparent damage, not even pitting.

Although Figure 1 shows the BaTi pin held in place by a clear plastic, less precursor noise was obtained when the hold down material was brass. For the final tests 20 mm long, 16 mm diameter brass cylinders were employed. The transducer pin was epoxied into a snug hole on the axis of the much more massive brass cylinder, and the whole assembly was epoxied to one end of the HIVELITE. A thin cushion of epoxy between the HIVELITE and the brass provided good sound and shock wave transmission to the flush BaTi pin.

The final instrumentation used to record the transducer signals was a pair of Tektronix oscilloscopes: (1) a type 7904 single beam wide band oscilloscope, and (2) a dual beam nominal band pass type 556. The type 7904 oscilloscope has a 50 ohm input impedance; the type 556 has a megohm. To accommodate the disparity a matched signal splitter was used.

II.2 Experimental Results

Figure 2 shows a pair of typical BaTi transducer records taken from a shot having sample lengths of 82.5 mm (record a) and 20.5 mm (record b). Consider the top record from the single beam oscilloscope first. The sweep speed for this record was 50 μ s/cm, and the effective vertical sensitivity (corrected for the matching network) was 0.5 v/cm. The trace starts with a slight delay to allow for some runup time. The first bump in the trace represents the spark gap signal, or the start of initiation. This signal was created by connecting the firing cable braid to the ground side of the pin; the discharge current ground

a. Type 7904 Oscilloscope Record

b. Type 556 Oscilloscope Record

Figure 2: Typical BaTi transducer records. See text for a complete explanation

loop signal. This fiducial lasts for a short time and is then followed by another bump on the signal trace. This second signal represents the leading sound wave propagating through the unreacted HIVELITE material. From the length of the sample and the time for propagation the average sound speed turns out to be 2190 m/s.

Following the initial sound wave are additional sound signals of lower amplitude but higher frequency. Finally, the main reaction front impinges on the pin. The signal experiences a discontinuity relaxing back to zero output when the pin is destroyed. The overall event time against overall sample length is then plotted to obtain incremental changes of velocity with length of run. The composite results are shown in Figure 3.

Figure 2b is a dual beam oscilloscope record of a HIVELITE pellet 20.5 mm in length. The signals were from the same source but the amplification and sweep speeds for each beam were different: scope settings are shown in the photograph margin. For this short pellet length there was considerably less acoustic attenuation and the details of the sound waves are more pronounced. The spark gap fiducial, leading sound wave and main wave discontinuity retain the diagnostic features of interest.

Figure 3 presents a plot of the accumulated burn rate data; total transit time vs total pellet length of HIVELITE (Reference No. B277-6738205). The function of this type of data presentation is to show incremental velocity changes with the assumption that all the samples have similar initiation characteristics. Also shown on the graph is the material longitudinal sound speed.

The burn rate data appear to break into two slopes: (1) an initiation phase and (2) a final phase. The initiation portion of the graph indicates the average velocity is approximately 230 m/s while a regression fit for the final phase indicates the average velocity is about 1200 m/s.

Since there is a fair degree of scatter among the data points, which may be non-uniformities in the material as a consequence of the incremental pressing technique used to manufacture the longer pellets, conclusive evidence is not available to reach a concrete judgement. Thus, the data can also be interpreted as showing a continuous build-up. A final judgement on this point would require more extensive tests not only of burn rate as a function of length but also diameter.

In any event the burn rate of HIVELITE is substantial when compared to other propellants and it does not detonate in the diameter and lengths tested thus far.

II.3 Drop Hammer

Impact sensitivity tests were carried out on 35 mg samples to observe material reactions from a 2.5 Kg steel weight falling from different heights. The samples were loose powder on sandpaper over a steel plate.

No explosions were observed from a maximum drop height of 1.77 m, but some burning was observed at 0.5 m.

It should also be noted that the material has been cut with a razor blade and sawed with a coping saw during the course of shot makeup with no difficulty or any apparent reactions.

After a normal firing the product gases form a dense white cloud having no apparent odor. The health and safety aspects of the product gases has not been addressed.

II.4 Thermal Analysis

A differential thermal analysis was made on 4.6 mg of HIVELITE loose powder to observe thermal events as a function of temperature. The analysis graph is shown in Figure 4. There are six events worth noting, and they are listed in Table I.

The first event is the possible volatilization of residual butyl acetate. The second event at 130°C could be either the volatilization of residual butyl acetate (boiling point = 126.5°C) or a possible phase change of KNO_3 . There are literature reports citing rhombic to trigonal phase changes at 128°C. The last event may be the melting point of KNO_3 since the shape of the curve has the characteristics of melting, and the literature reports the melting point as 332°C.

Table I
Thermal Analysis Events

Thermal Event	Type of Event	Onset of Event	Peak of Event	Endo, Exo
1	Endotherm	57°C	75°C	+
2	Small Endotherm	130	139	+
3	Exotherm	~215	242	-
4	Small Endotherm	281	288	+
5	Decomposition?	320	397	-
6	Sharp Endotherm	337	340	-

RUN N^o: 1336 SAMPLE: HIVILITE, 300435, B-277

DATE: 1-22-75 REF: Al_2O_3

RATE: $10^\circ\text{C}/\text{MIN}$ ATM: STATIC AIR

DTA THERMOGRAM OF HIVILITE

II.5 Gas Analysis

A chromatographic gas analysis on some HIVELITE powder (TMC/S Material B-277 300435 lot 105) was made to measure the evolution of N_2+O_2 and N_2O gas. The run lasted 22 hours at a temperature of $120^{\circ}C$ using initially 0.2128 g of material. The total volume of evolved gas was 0.096 cc. Of this total 0.011 cc was N_2+O_2 . This result is only a little more than might be expected from HMX explosive material.

Distribution:

Internal:

H. Cheung - L-402
G. Dorough - L-82
M. Finger - L-402 (3 copies)
B. Hayes - L-402 (3 copies)
H. Hornig - L-402
J. Kury - L-401
E. Lee - L-402
H. Rizzo - L-402
R. Varosh - L-406
F. Walker - L-402
TID (5 copies)

External:

A. L. Korr
Frankfort Arsenal
Bridge & Tacony Street
Philadelphia, Pennsylvania 19137

Don Thatcher
McCormick Selph
P. O. Box 6
3601 Union Road
Hollister, California 95023

R. Allen
McCormick Selph
P. O. Box 6
3601 Union Road
Hollister, California 95023

E. Harris Walker
Ballistics Research Laboratory
Aberdeen Proving Ground
Aberdeen, Maryland

O. H. Borum, Attn: AMCOL
U.S. Army Material Command
5001 Eisenhower Avenue
Alexandria, Virginia 22333

R. Dillaway
U.S. Army Material Command
Attn. AMCOL
5001 Eisenhower Avenue
Alexandria, Virginia 22333

R. Nelson
U.S. Army Armament Command
General Thomas Rodman Laboratory
Rock Island, Illinois 61201

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights."