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NATIONAL BUREAU OF STANDARDS REPORT

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THE OBSERVED NATURE OF IGNITION AND BURNING

OF

TWO SOLID PROPELLANTS AT PRESSURES BELOW ONE ATMOSPHERE

by

T. G. Lee

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Experimental observations are reported on the burning characteristics of a double base and a composite propellant under low ambient pressure conditions.

INTRODUCTION

The theory of the influence of pressure on burning rate of solid propellants has been given considerable attention (1). Generally, however, data are available only for pressures normally found inside rocket motors and ballistic chambers. If one extrapolates these pressure-burning rate data to zero pressure, a finite burning rate is found, although propellants cease to burn at higher pressures. Thus, it was shown by Huggett (1) that such extrapolation is not valid. Very little unclassified data are available on propellant burning rates at reduced pressure. The present work was undertaken to determine experimentally a pressure below which self-sustaining combustion of a small sample of a given propellant would not be maintained in an ambient atmosphere at 75°F. We shall call that pressure the "maximum quenching pressure." Two types of propellant, supplied by the Navy, were investigated, Double Base Navy Mark-32 and a composite propellant containing 82 percent $KClO_4$, NH_4ClO_4, and 18 percent Polyurethane. The pressure region investigated was between 10 mm and 760 mm Hg absolute. Some information on the combustion behavior of the propellants near the region of maximum quenching pressure and its dependence on propellant composition was also obtained.

Ignition and combustion of propellants are governed by energy balance relations (2). Ignition occurs when a small volume of the propellant is raised to a temperature at which the rate of heat generation by exothermic reaction exceeds the rate of heat loss by conduction, convection, and radiation. Quenching or extinction of a burning propellant will occur if the reverse of the above case is true. At reduced pressure (generally below atmospheric) high heat loss is caused by diffusion of hot gaseous reaction products and reacting vapor away from the fizz zone. This reduces the rate of decomposition or melting in the subsurface zone and finally results in quenching.

The maximum quenching pressure appears to be influenced by propellant composition, including stabilizer and coolant, as well as by specimen configuration. For composite propellants, the type of matrix (binder) and the particle size of the filler are also important factors (3).

EXPERIMENTAL PROCEDURES

The experiment was designed to observe the nature of ignition, combustion, and quenching at reduced pressures ranging from 10 mm to 760 mm Hg absolute and a ambient temperature of 75°F for a Double Base Propellant-Navy Mark-32 and a composite propellant consisting mainly of potassium and ammonium perchlorate filler and polyurethane matrix.

Electrically heated 26 gauge Nichrome resistance wire, 3 cm long, was used as the ignition source. The wire was inserted through a hole in the center along the short axis of a specimen 2 mm thick, in the shape of an equilateral triangle 7 mm on a side. To prevent subsequent sliding, the wire was slightly bent downward at the middle where the specimen rested. The ends of the wire were connected to two electrode clips suspended in a 7 liter vacuum jar. The jar could be evacuated to any desired pressure down to about 10 mm Hg absolute. The power supplied to the ignition wire, about 4 watts, was sufficient to make the wire red hot.

Depending on the pressure condition, the hot wire would cause melting, decomposition, slow combustion or ignition of the propellant at the surface of contact with the wire. In the non-ignition cases, slow decomposition or melting next to the hot wire would gradually increase the diameter of the hole in the propellant. As a result of the weight of the specimen, a slot would be formed in the specimen by the hot wire, allowing it to drop from the wire. Then all activity would cease. If the pressure in the jar were slightly higher than the maximum quenching pressure, the specimen would continue its slow combustion or decomposition after the drop, as evidenced by fuming or generation of white or brown smoke. At a still higher pressure, with double base propellant there was spark burning but no visible flame. In this case small glowing particles were ejected from the burning propellant.

Table 1 is a summary of the results obtained. It is based on a limited number of runs, 30 runs were made for the two types of propellant. The indicated pressure ranges are only approximate, since only gradual transition from one mechanism to the other was observed. For the double base propellant, the pressure rise was less than 5 percent above the initial absolute pressure. The composite propellant produced somewhat higher pressures.

CONCLUSIONS

For the two propellants tested, there exist maximum quenching pressures below which all specimens were quenched. Such quenching pressures probably depend primarily on the composition of the propellant, but experimental conditions such as specimen configuration, size, ignition-wire temperature and contact area may influence the quenching pressure observed.

The quenching pressure range for the Double Base, Mark-32 propellant was between 300 and 400 mm Hg absolute. For the composite propellant of $KClO_4$-NH_4ClO_4-polyurathane, it was between 40 and 50 mm Hg absolute.

Additional work should be done to determine the maximum quenching pressure for other propellants and the effect of specimen size and configuration on quenching pressure before any general conclusions can be drawn.

Table 1. Observed Nature of Ignition and Burning of Two Propellants at Reduced Pressures

Double Base Mark-32		Composite - $KClO_4$-NH_4ClO_4Polyurethane	
Pressure mm Hg abs		Pressure mm Hg abs	
10 to 200	No ignition. Fuming at contact surfaces. Immediate quenching after specimen dropped from wire.	10 to 50	No ignition. Fuming at contact surface. Immediate quenching after specimen dropped from wire.
200 to 300	Same as above, except larger slot produced in specimen.	50 to 120	Ignited slowly. Continued slow burning after drop. specimen consumed.
300 to 400	Spark burning at contact surface. Quenching after drop.	120 to 300	Ignited more readily. Continued burning after drop. Specimen consumed.
400 to 500	Spark burning at contact surface. Momentarily burning after drop.	300 to 760	Immediate ignition, bright flame, fast burning. Specimen consumed.
500 to 600	Slow flame-type burning before and after drop. Specimen consumed.		
600 to 760	Immediate ignition, bright flame, fast burning. Specimen consumed.		

REFERENCES

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(3) Crawford, B. L., et al. Study on Propellants, Office of Scientific Research and Development Report 6374, 1945.

U. S. DEPARTMENT OF COMMERCE
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THE NATIONAL BUREAU OF STANDARDS

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