NATIONAL BUREAU OF STANDARDS REPORT

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SELF-HEATING CHARACTERISTICS OF A SOLID PROPELLANT

by

JOSEPH LOFTUS

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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SELF-HEATING CHARACTERISTICS OF A SOLID PROPELLANT

ABSTRACT

A brief study was made of the self-heating characteristics of a solid double-base propellant. The method of determination and the behavior of the propellant as compared with several common materials are described.

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1. INTRODUCTION

A current extensive research investigation, designed to assist in the solution of fire hazard problems associated with the military use of a variety of fuels and oxidizing agents, includes a study of the ignition properties of solid propellants. In connection with this program, particularly as concerned with possible hazards in the storage of propellant materials, a study of the self-heating characteristics of a representative double-base solid propellant has been made.

2. MATERIAL

The propellant furnished by the Navy was designated as AFN 3336, and was cast into wafers 2 inches in diameter and ½ inch thick.

3. TESTS AND RESULTS

The material was tested in a small automatic furnace designed for study of the self-heating characteristics of poorly conducting materials. The furnace and its controls were constructed to maintain a furnace temperature closely following, at all times, that of the center of the specimen. Thus, loss of heat from the specimen became negligible, and the whole specimen was

allowed to heat at the same rate. The conditions established approach, therefore, those which exist in an infinitely large sample of the material, and permit a study of the behavior which may be expected in large quantity or highly insulated storage.

The test specimen with thermocouples mounted at the center and near the surface was mounted within the furnace chamber. The air temperature within the furnace was indicated by a thermocouple mounted below the specimen, and during the initial warm up period a constant selected furnace temperature was maintained by a thermostatic controller. After the interior of the specimen had attained the temperature of the air in the furnace chamber, any further increase in the specimen temperature automatically disconnected the thermostatic controller and initiated operation of a servo-controller which supplies heat as needed to maintain the smallest possible temperature difference between the interior of the specimen and the gases in the furnace. A continuous chart of the temperatures within the specimen and in the furnace was obtained by means of an automatic recorder and the specimen temperature was plotted against time to give a time-temperature curve characteristic of the material. A more convenient expression of the data may be developed in the form

$$\ln \frac{dT}{d\theta} = \ln \frac{A}{\rho c} - \frac{Q}{T}$$

where T = absolute temperature
θ = time
A = a constant
ρ = density of the specimen
c = specific heat
Q = an activation constant divided by the gas constant,

from which it is evident that $\ln \frac{dT}{d\theta}$ plotted against $\frac{1}{T}$ gives a straight line having a slope of $-Q$ and intercepting the $\ln \frac{dT}{d\theta}$ axis at $\ln \frac{A}{\rho c}$.

The propellant test specimens were made up into cylinders of 2 inch length and 2 inch diameter by stacking four wafers, one upon the other. The weight of the test specimen assembly was 163 grams. The furnace was set at approximately 104°C and increased above that temperature only when heating within the specimen actuated the automatic follow-up controls. Under those conditions the propellant materials required about 10 hours to self-heat to ignition.

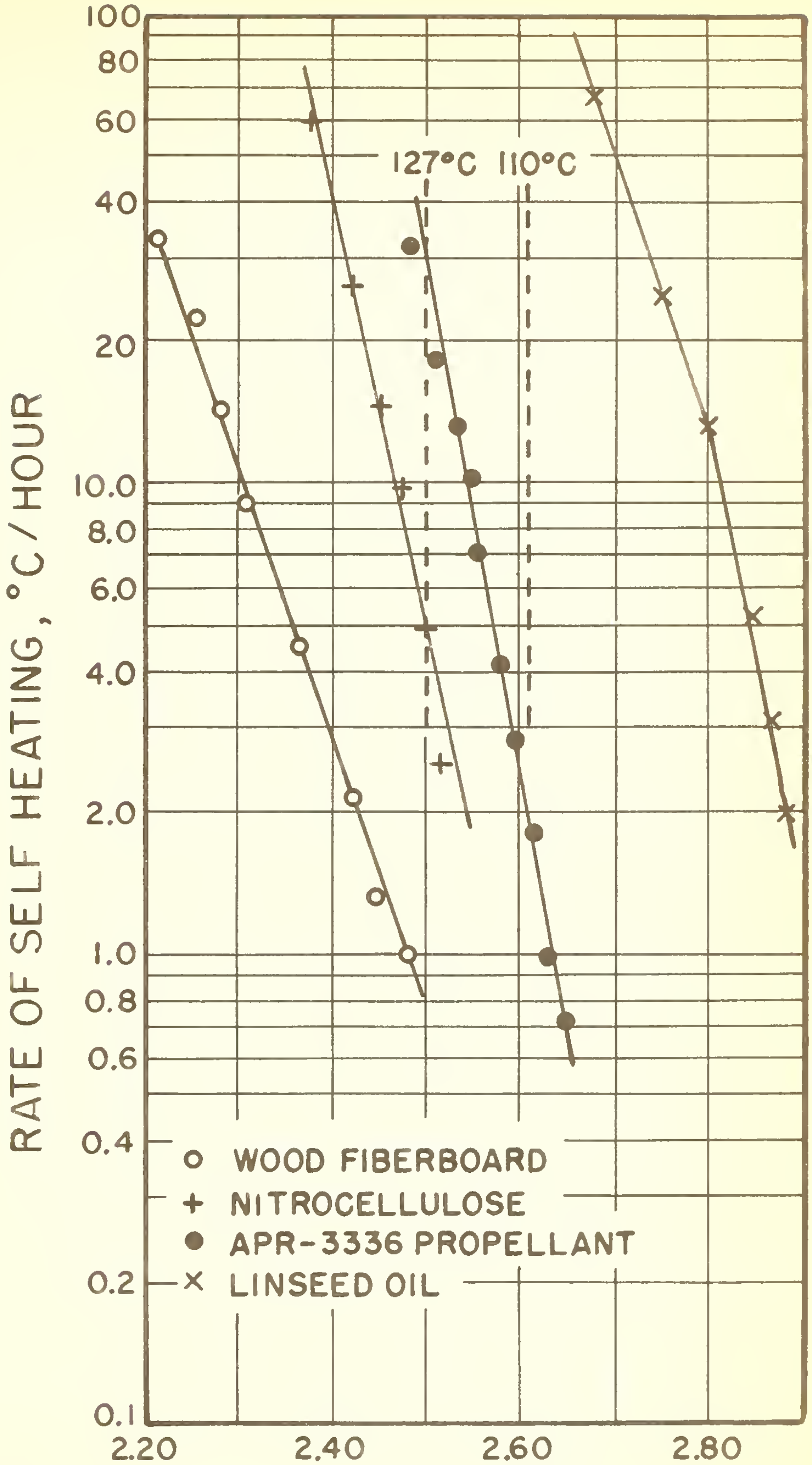
The results of the propellant tests are given in Figure 1, together with those of similar tests on nitrocellulose, wood fiberboard and linseed oil. The curves show the rate of temperature rise in the specimen after self-heating had started and the automatic follow-up regulation of the furnace had become operative. Curves at higher values of reciprocal temperature indicate self-heating at relatively lower temperatures. Comparative rates of self-heating may be read directly from the graph, as illustrated at the following temperatures.

Material	Rate of Self Heating		
	110°	127°	140°
	°C/hr	°C/hr	°C/hr
APR-3336 Propellant	1.75	28	-
Nitrocellulose	—	5	25
Wood Fiberboard	—	0.8	2.2
Linseed Oil	118		

The propellant material showed self-heating at a rate approximately 6 times that of nitrocellulose and 35 times that of wood fiberboard, which commonly does not give trouble at storage temperatures up to 60°C (140°F), but has been known to ignite spontaneously when stacked hot from manufacture, without proper cooling.

4. CONCLUSION

From an initial temperature of 104°C the APL-3336 propellant material when tested as described, self-heated within 10 hours to a temperature of 159°C. At thistemperature very rapid combustion set in and the sample was consumed.



$\frac{1}{T°K} \times 10^3$

FIG. I SELF HEATING CHARACTERISTICS OF MATERIALS TESTED

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BOULDER, COLORADO

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