AD-762 149

# HOT PLATE FLAMMABILITY TESTS

Richard C. Strittmater, et al

Ballistic Research Laboratories
Aberdeen Proving Ground, Maryland

May 1973

# BRL



MEMORANDUM REPORT NO. 2292

# HOT PLATE FLAMMABILITY TESTS

by

Richard C. Strittmater
Hughes E. Holmes



May 1973

Approved for public release; distribution unlimited.



USA BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 2292

MAY 1973

# HOT PLATE FLAMMABILITY TESTS

Richard C. Strittmater
Hughes E. Holmes

Interior Ballistics Laboratory



RDT&E Project No. 1J562604A010

ABERDEEN PROVING GROUND, MARYLAND

2

Unclassified

Security Classification

**DOCUMENT CONTROL DATA - R & D**

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

**1. ORIGINATING ACTIVITY (Corporate author)**

USA Ballistic Research Laboratories
Interior Ballistics Laboratory
Aberdeen Proving Ground, Md. 21005

**2a. REPORT SECURITY CLASSIFICATION**

Unclassified

**2b. GROUP**

**3. REPORT TITLE**

HOT PLATE FLAMMABILITY TESTS

**4. DESCRIPTIVE NOTES (Type of report and inclusive dates)**

Memorandum Report

**5. AUTHOR(S) (First name, middle initial, last name)**

Richard C. Strittmater
Hughes E. Holmes

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| MAY 1973 | 25 | 1 |

**8a. CONTRACT OR GRANT NO.**

**b. PROJECT NO.** 1J562604A010

**c.**

**d.**

**9a. ORIGINATOR'S REPORT NUMBER(S)**

BRL MEMORANDUM REPORT NO. 2292

**9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)**

**10. DISTRIBUTION STATEMENT**

Approved for public release; distribution unlimited.

**11. SUPPLEMENTARY NOTES**

**12. SPONSORING MILITARY ACTIVITY**

U.S. Army Materiel Command
5001 Eisenhower Avenue
Alexandria, Virginia 22304

**13. ABSTRACT**

A flammability test apparatus has been constructed which applies the propellant test specimen to a heated copper block for precisely controlled intervals of time. In this way the ignition time can be determined as a function of the copper block temperature. Ignition time is defined as the shortest time interval over which the propellant sample must be applied to the copper block so that sustained burning occurs. Data has been obtained for a double base propellant, X-14, some experimental propellants formulated at Princeton University and two Thiokol/Wasatch propellants.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified

Security Classification

Unclassified

Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Ignition<br>Flammability Test<br>Propellant Vulnerability<br>Caseless Ammunition<br>Self Extinguishing Propellant | | | | | | |



Unclassified

Security Classification

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 2292

RCStrittmater/HEHolmes/jah
Aberdeen Proving Ground, Md.
May 1973

# HOT PLATE FLAMMABILITY TESTS

## ABSTRACT

A flammability tests apparatus has been constructed which applies the propellant test specimen to a heated copper block for precisely controlled intervals of time. In this way the ignition time can be determined as a function of the copper block temperature. Ignition time is defined as the shortest time interval over which the propellant sample must be applied to the copper block so that sustained burning occurs. Data has been obtained for a double base propellant, X-14, some experimental propellants formulated at Princeton University and two Thiokol/Wasatch propellants.

## TABLE OF CONTENTS





Preceding page blank

LIST OF FIGURES



 Preceding page blank

# I. INTRODUCTION

The vulnerability of caseless ammunition to various types of hot objects encountered in the field leads one to try to find a self extinguishing propellant at atmospheric pressure. A self extinguishing propellant is one which will not retain its flame (stop burning) when the hot object is removed.

Ignition and flame retention depend on propellant composition, orientation of propellant sample, size of sample, type of atmosphere around sample, pressure of atmosphere, velocity of atmosphere, not to mention the characteristics of the ignition source such as source type, intensity, and time of application. Since we are concerned with ignition and flame retention in ambient air in this study, the range of conditions to be considered is reduced. The search for self extinguishing propellants then requires the establishment of flammability tests that are severe enough to encompass the worst hazards that are normally encountered in the field.

The most relevant ignition source for a given problem out of those commonly used (e.g. gas torch, hot plate, radiation) is the one which best simulates the most probable exposure occurring in the field situation. In instances of hot spall fragments or ruptured brass cases touching propellant, it is apparent that the most relevant test would be the hot plate test. Following along this line of thinking, the hot plate flammability test apparatus, described in the next section, was designed and constructed.

# II. APPARATUS AND TEST PROCEDURE

In order to specify the precise time interval that the ignition source is applied to the propellant, it is necessary to have an action time, as the source is applied or withdrawn from the propellant, which is short compared to nominal ignition times. For this reason a fast acting solenoid is employed to move the small, propellant sample onto the source (heated copper block). A schematic diagram of the apparatus used to do this is shown in Figure 1. A test starting switch energizes a relay which applies 110 volts to the solenoid. As the solenoid is energized the shutter is withdrawn and the propellant is pressed against the copper block. At the instant after the propellant contacts the block a sequence timer starting switch is closed by the interrupted motion of the propellant holder.

A schematic diagram of the operating circuit is shown in Figure 2.

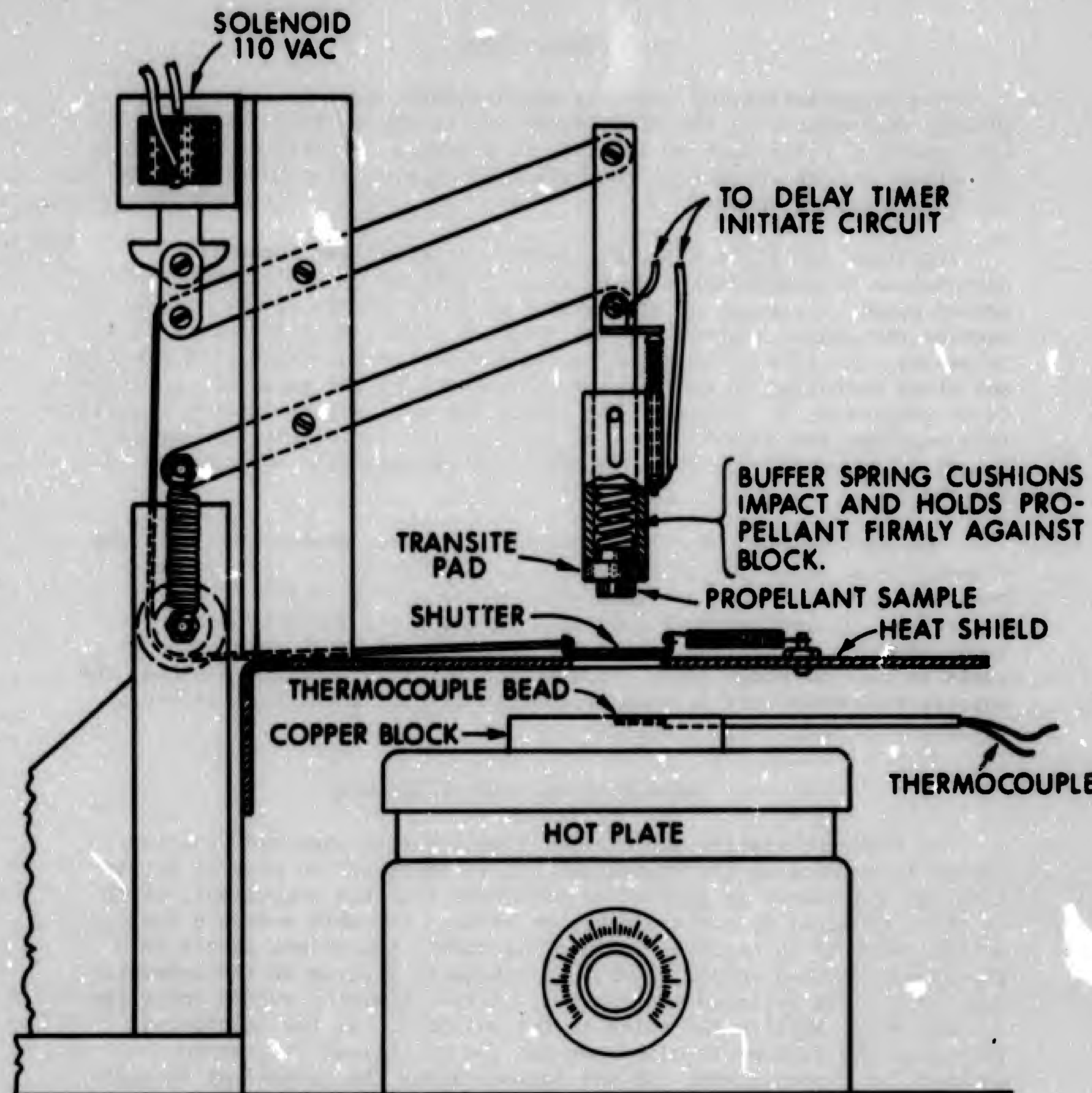


Figure 1. Diagram of Hot Plate Ignition Test Apparatus

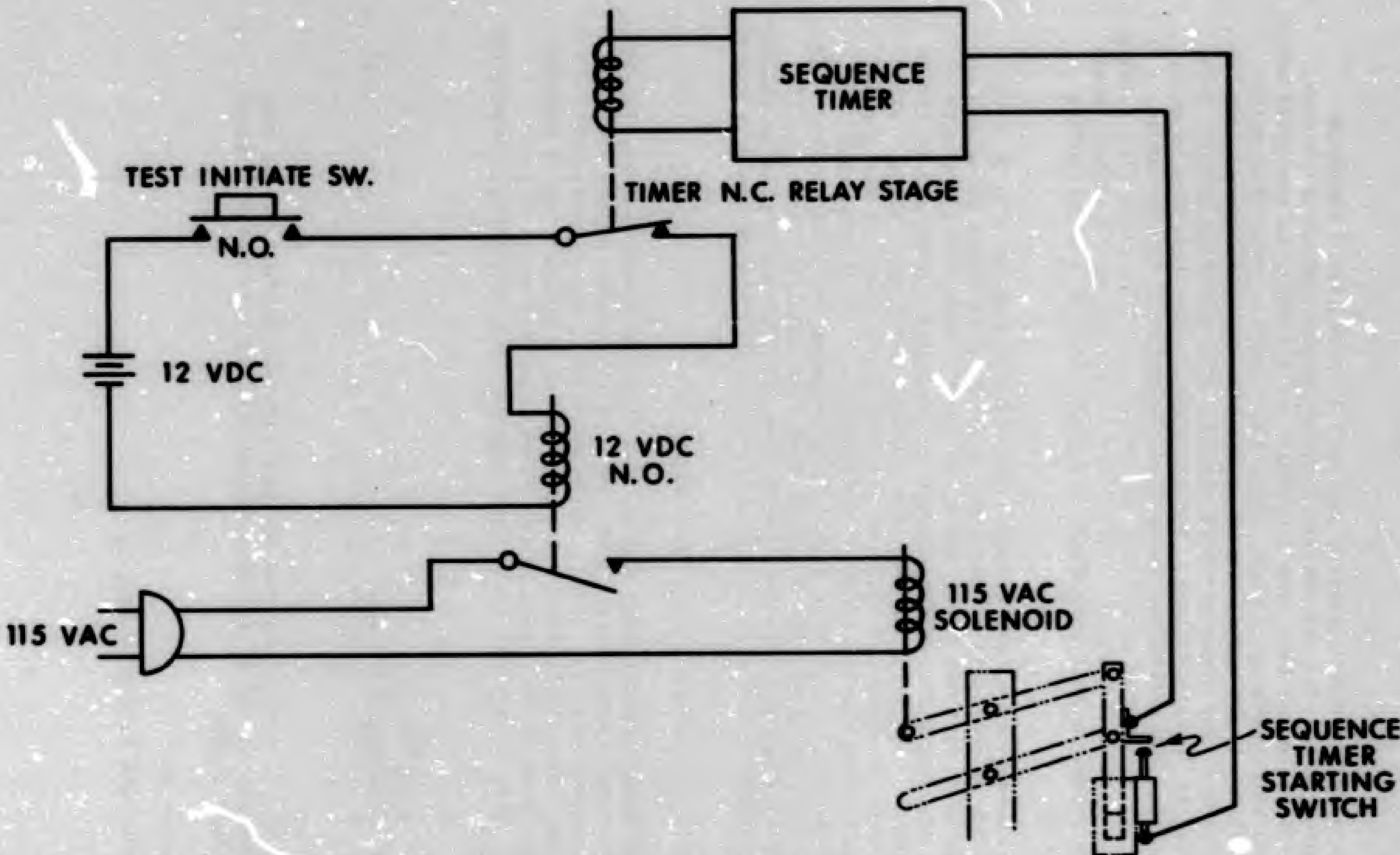


Figure 2. Electrical Schematic-Hot Plate Propellant Ignition Test Apparatus

The sequence timer starting switch then energizes a sequence timer which is set for the desired time of application of the source. At the expiration of this time a normally closed relay is energized which opens the test starting circuit, which then opens a relay that opens the solenoid circuit and allows the spring to remove the propellant from the source and close the heat shield. The operating circuit relay delay time is 30 milliseconds. A photograph of the apparatus is shown in Figure 3. The propellant is held on the end of a spring loaded plunger that holds the propellant in contact with the block with a force between 6.8 and 8.7 Newtons. This force is low enough to soften impact and high enough to hold propellant and plate in firm contact during application.

The dimensions of the copper block are 7 1/2 cm by 7 cm by 1 cm thick. The thermocouple is located 1.5 mm from the top edge of the copper block. With the block heated to 200°C, 300°C and 400°C only one per cent variation in temperature was detected across the thickness of the block. To perform a test the sequence timer was set to a value shorter than the expected ignition time and the propellant was given this exposure to the hot block. If ignition was not accomplished the sample and copper block were cleaned and prepared for another test. The exposure time was increased in large time intervals, at first, until ignition occurred and then this large time interval was probed in smaller time increments (10 milliseconds) until the ignition time was determined.

## III. THEORY

When semi-infinite body number one, at uniform temperature, $T_1$, is suddenly brought into contact with semi-infinite body number two, at uniform temperature, $T_2$, along a plane interface, the interfacial temperature immediately takes on and maintains a constant value between $T_1$ and $T_2$ which is dependent on the thermal properties of the two bodies. If $T_2$ is assumed to be zero degrees, the interfacial temperature is given by[1]*

$$v = \frac{K_1 k_1^{-1/2} T_1}{K_1 k_1^{-1/2} + K_2 k_2^{-1/2}} \tag{1}$$

where $K_1$ and $k_1$ are the thermal conductivity and diffusivity of body number one and $K_2$ and $k_2$ are the thermal conductivity and diffusivity of body number two.

---

*References are listed on page 18

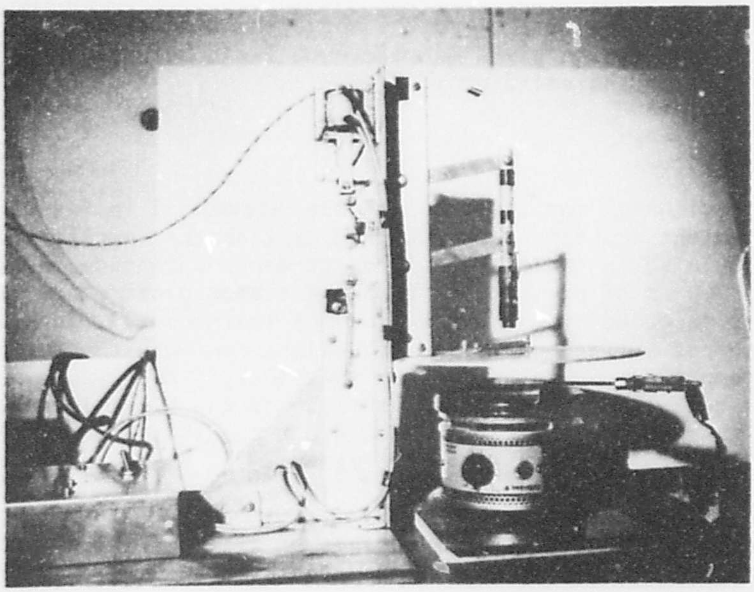

Figure 3. Photograph of Hot Ignition Test Apparatus

Using $K_1 = 22 \frac{\text{Watts}}{\text{M °K}}$ and $k_1 = 1.14 \times 10^{-4} \frac{M^2}{\text{sec}}$ for copper and 0.012 $\frac{\text{Watts}}{\text{M °K}}$ and $10^{-7} \frac{M^2}{\text{sec}}$ as nominal values for double base propellant it can be determined from equation (1) that the propellant surface is raised to 98 per cent of the hot plate temperature. This equation will describe conditions at the interface at the instant of contact and shortly there after until boundary effects become important. Characteristic times for heat flow in the solid propellant sample are long compared to nominal ignition times (1 sec) so the above equation along with the space dependent solution given in reference 1 can be used for estimates of temperatures in the solid propellant.

## IV. RESULTS

The experimental results obtained are summarized in Figure 4. The data from the ignition time runs and next shorter application time runs are tabulated in Table I. All measurements were made in still air at 22°C and 760 mm of pressure. The temperatures plotted are the temperatures recorded by the chromel alumel thermocouple, located 1.5 mm below the copper surface where the propellant contacts the surface. Since the temperature gradient across the block is negligible, and also because the temperature drop at the surface of the block is small (~2%) when the propellant contacts the block the thermocouple temperature is proportional to and just slightly higher (~2%) than the surface temperature of the propellant.

Because the heat flux at the surface of the propellant is directly proportional to $T_1$, the ignition time data shown in Figure 4 are plotted vs. temperature ($T_1$). Graphing data in this way makes comparison with arc image furnace data easy, since this data is graphed similarly.

The results of this type of testing are most useful for comparing the flammability of one propellant with another. To use the data in any quantitative way to determine ignition times would require that the hot metallic source be very large compared to the propellant it contacts. In many types of exposure occurring in the field this would not be the case and the ignition time would be longer than given in Figure 4.

Future work on this task will extend the data to higher temperatures of the copper block and also include the effect of air velocity on ignition time.

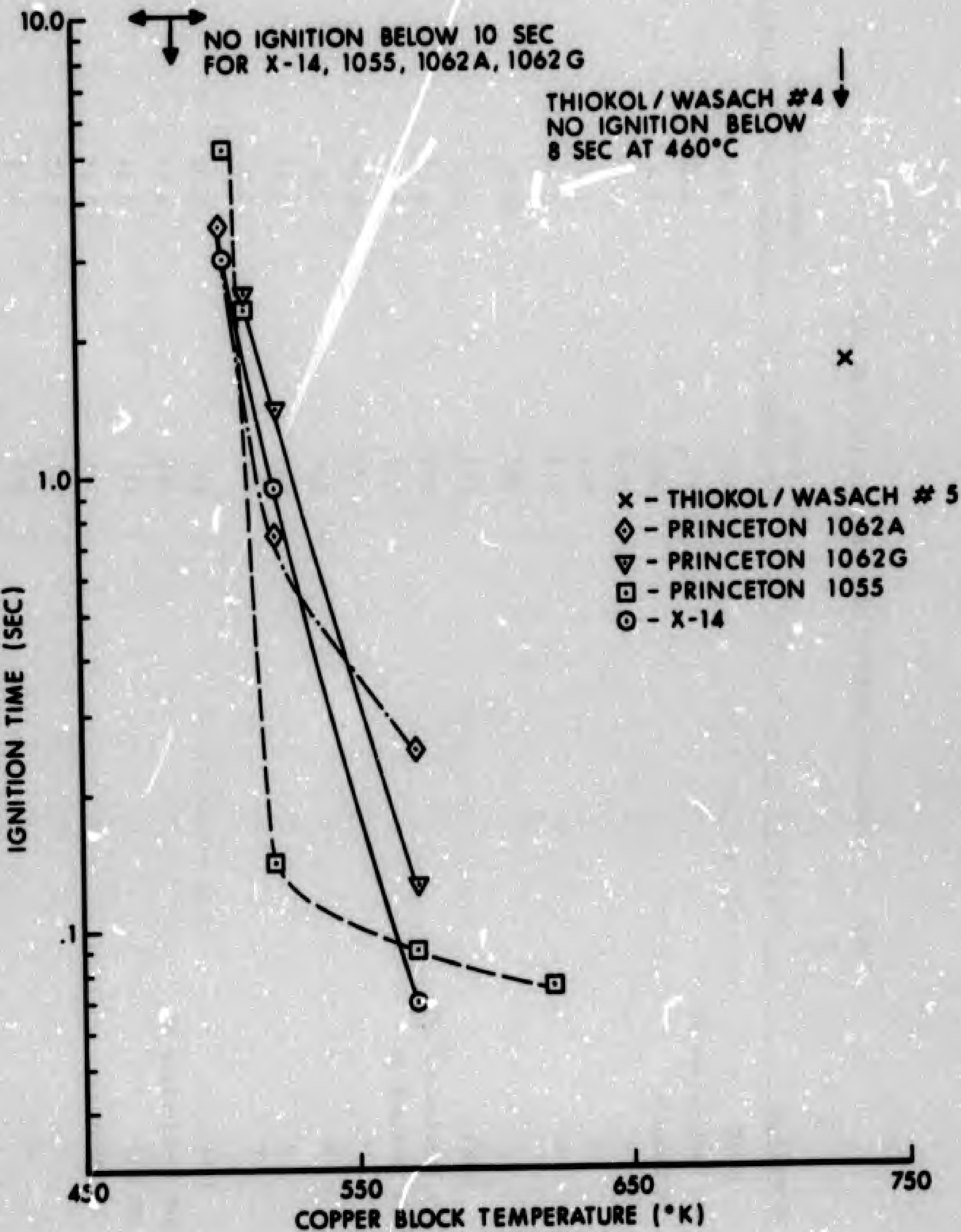


Figure 4. Graph Showing Ignition Time vs Hot Plate Temperature for Six Propellants

TABLE I. PROPELLANT DESCRIPTIONS AND IGNITION TIME DATA

| Propellant | Propellant Dimensions (cm) | Hot Plate Temperature (°K) | Ignition Source Application Time (sec) |
|---|---|---|---|
| 1062G | 0.60 x 0.60 x 0.30 | 573 | 0.1 |
| 95% Particulate NC | " | 573 | 0.15* |
| 5% Oxamide | " | 523 | 1.3 |
| " | " | 523 | 1.4* |
| " | " | 513 | 2.4 |
| " | " | 513 | 2.5* |
| " | " | 503 | 10.0 |
| 1062A | 0.60 x 0.60 x 0.30 | 573 | 0.2 |
| 97% Particulate NC | " | 573 | 0.25* |
| 3% Phoschek 30 | " | 523 | 0.7 |
| " | " | 523 | 0.8* |
| " | " | 503 | 3.4 |
| " | " | 503 | 3.5* |
| " | " | 473 | 10.0 |
| 1055 | 0.60 x 0.60 x 0.30 | 623 | 0.05 |
| 54% Particulate NC | " | 623 | 0.1* |
| 39% MTN | " | 573 | 0.08 |
| 7% TEGON | " | 573 | 0.1* |
| " | " | 523 | 0.13 |
| " | " | 523 | 0.14* |

TABLE I. PROPELLANT DESCRIPTIONS AND IGNITION TIME DATA (Cont'd)

| Propellant | Propellant Dimensions (cm) | Hot Plate Temperature (°K) | Ignition Source Application Time (sec) |
|---|---|---|---|
| 1055 | 0.60 x 0.60 x 0.30 | 513 | 2.2 |
| " | " | 513 | 2.3* |
| " | " | 503 | 5.1 |
| " | " | 503 | 5.2* |
| " | " | 493 | 10.0 |
| X-14 | 1.25 Diameter 0.60 Thick | 573 | 0.05 |
| Double Base | " | 573 | 0.08* |
| | " | 523 | 0.9 |
| " | " | 523 | 0.95* |
| " | " | 503 | 2.9 |
| " | " | 503 | 3.0* |
| " | " | 473 | 10.0 |
| Thiokol#4 oxamide 10% Binder 15% HMX 75% | 1.25 Diameter 0.60 Thick | 733 | 8.0 |
| Thiokol$5 Binder 16.7% HMX 83.3% | 1.25 Diameter 0.60 Thick | 733 | 2.0* |

*Ignition Time

## REFERENCES

1. Carslaw, H. S. and Jaeger, J. C. Conduction of Heat in Solids, Second Edition, Oxford University Press, p. 86 (1959).