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MEASUREMENT OF LINEAR BURN RATES OF HEAT PRODUCING SYSTEMS

FLAME, INCENDIARY AND FUEL AIR EXPLOSIVE BRANCH
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13. ABSTRACT

A photocell apparatus has been designed to measure the linear burn rate of heat producing systems. The device consists of an electrical unit and a precision viewing unit containing two photocells. A bar shaped sample is ignited at one end, and as the reaction proceeds down the bar, it is sensed by the photocells. The resulting decreases in resistance at the photocells are recorded as two essentially parallel lines. The distance between the two lines is used to calculate the linear burn rate. The device provides a simple method for obtaining reasonably precise linear burn rates.

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Measurement of Linear Burn Rates of Heat Producing Systems

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FOREWORD

This report documents the results of an in-house study undertaken in support of Project 1082, Task 01, Work Unit 001, Investigation of New and Improved Incendiary Agents. This project is a continuing effort.

This technical report has been reviewed and is approved.

FRANKLIN C. DAVIES, Colonel, USAF
Chief, Flame, Incendiary, and Explosives Division

ABSTRACT

A photocell apparatus has been designed to measure the linear burn rate of heat producing systems. The device consists of an electrical unit and a precision viewing unit containing two photocells. A bar shaped sample is ignited at one end, and as the reaction proceeds down the bar, it is sensed by the photocells. The resulting decreases in resistance at the photocells are recorded as two essentially parallel lines. The distance between the two lines is used to calculate the linear burn rate. The device provides a simple method for obtaining reasonably precise linear burn rates.

SECTION I

INTRODUCTION

The linear burn rate, a macrophenomenon, is a property that generally is of major concern in the design of heat producing systems. The design of systems, such as incendiary, delay train, and first-fire, is optimized to conform to a specified linear burn rate. The reason that a specific rate is selected is generally unique to the job for which the heat source will be used and will not be discussed in this report. The laboratory measurement of linear burn rate can be accomplished by several methods, including high-speed photography, burn-wire, and photocell techniques. The photography method is expensive and time consuming. The burn-wire technique can also be time consuming and may not always give reproducible results for systems that have a high electrical conductivity. This report describes a simplified photocell apparatus that measures the linear burn time of bar shaped heat producing materials.

SECTION II

DESCRIPTION

The photocell apparatus consists of an electrical unit and a precision viewing unit. The viewing unit holds two photocells in alignment and has a passageway for an air flow which prevents plugging of the two precision pin holes that admit light from the reaction. The pin holes also restrict the view of the photocells to a known angle. The assembled apparatus is housed in an aluminum chassis 4 inches deep, 6 inches wide, and 2 inches high. The signal from each photocell is transferred to a separate channel of a Hewlett-Packard, dual channel recorder, Model 3100B, operating at maximum chart speed.

A schematic of the electrical unit and a detailed drawing of the precision viewing unit are shown in Figures 1 and 2, respectively. The precision viewing unit is constructed from an aluminum block, 1 inch deep, 3 inches wide, and 1 inch high. The tube (3/16 inch outside diameter), through which air is introduced into the system, is press-fitted into the precision viewing unit.

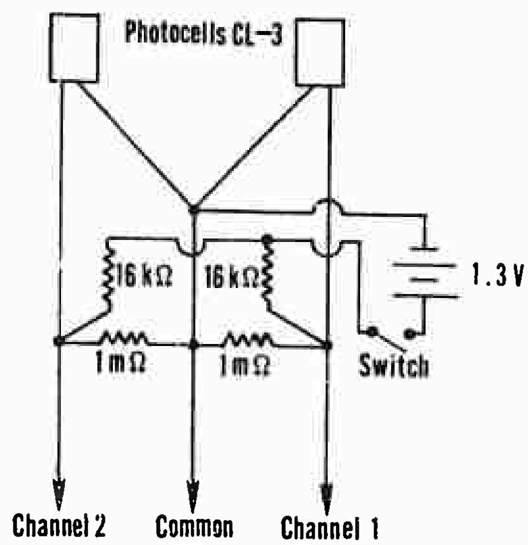

Figure 1. Electrical Unit Schematic for the Linear Burn Rate Apparatus

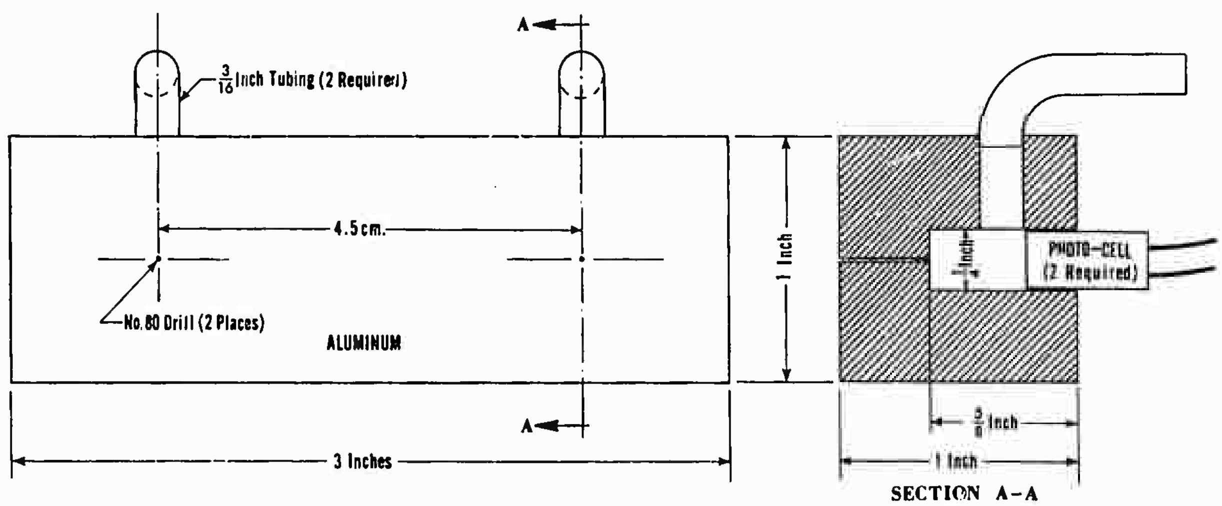

Figure 2. Precision Viewing Unit for the Linear Burn Rate Apparatus

SECTION III

PROCEDURE AND DISCUSSION

Generally, the samples to be tested are pressed into a bar shape at some predetermined pressure. A typical bar for which this apparatus has been used is 0.25 inch by 0.25 inch by 2.5 inches. The bar is placed on an asbestos square approximately 0.5 inch in front of the photocell apparatus, such that it is in alignment with the precision pin holes. The bar is ignited at one end by any convenient means. A typical experimental setup is shown in Figure 3.

As the reaction front proceeds down the length of the bar, it passes in front of the pin-hole openings to the photocells. These openings are spaced 4.5 centimeters apart. The light impinging on the photocell causes its resistance to decrease, thereby resulting in a decrease in voltage to the recorder. The recorder input is set at 2 volts and is operating at a chart speed of 2 inches per second. The event is recorded as two essentially parallel lines on the chart paper. The distance between these lines in the section of the chart where their slopes are similar is used to calculate the linear burn rate. It was demonstrated (Table I) that when the distance measurement is made about midway along the section of parallel slopes, the value obtained is analogous to an average value obtained from three or more measurements along the same section. The data in Table I are compiled for a system composed of 68 percent by weight of titanium (-30 + 100 mesh) and 30.7 percent by weight of amorphous boron (1 micron maximum particle size) with 1 percent by weight of acacia binder. A minimum of three rate determinations should be made for each composition.

TABLE I. LINEAR BURN RATE DETERMINATIONS

Experiment No.	Linear Burn Rates Taken from the Section of Parallel Slope, sec/cm			Average Burn Rate, sec/cm
	Lower	Midway	Upper	
1	0.36	0.34	0.34	0.35
2	0.30	0.30	0.30	0.30
3	0.29	0.27	0.28	0.28
4	0.30	0.29	0.29	0.29
5	0.30	0.30	0.30	0.30
Average Linear Burn Rate		0.30		0.30

The average linear burn rate data obtained by the photocell apparatus are comparable to those obtained by the burn-wire technique (Table II).

TABLE II. COMPARISON OF LINEAR BURN RATE DETERMINATIONS USING THE BURN-WIRE AND THE PHOTOCELL TECHNIQUES

Number of Experiments	Apparatus Used	Average Linear Burn Rate, sec/cm
5	Photocell	0.67 (±0.1)
1	Burn-wire	0.64

The reactive system that provided the data in Table II was composed of 69 percent by weight of titanium (-50 + 100 mesh, 60 micron effective particle size) and 31 percent by weight of amorphou. boron (-325 mesh, 10 micron effective particle size), 90-92% grade. The effective particle sizes of the components were measured by scanning electron microscopy. All samples were pressed into bar shapes at 32 x 10^3 psi. The deviation in the results obtained by the two independent measurements is less than 5 percent.

The photocell burn rate apparatus is simple to construct and has proved to be rugged. Considering all aspects, the data are obtained with less than 15% error in precision. Thus, a quick and easy method is provided for obtaining comparative linear burn rates for exothermic systems with reasonable precision.

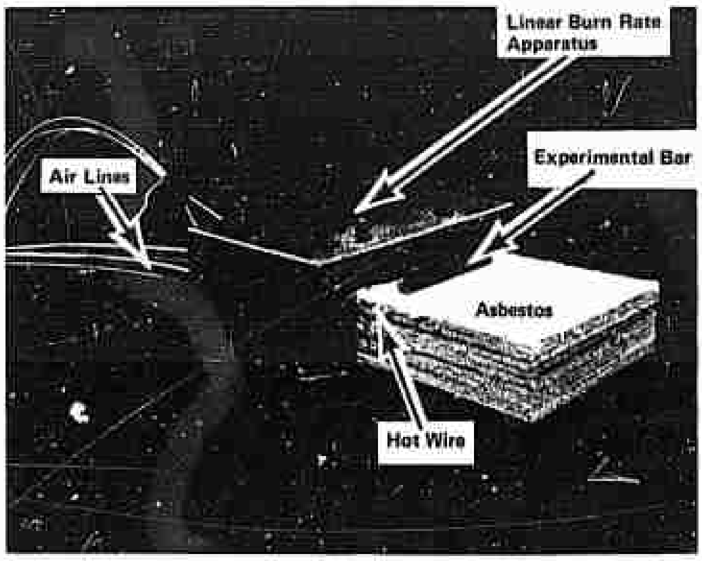

Figure 3. Typical Experimental Set-Up for the Measurement of a Linear Burn Rate