

LA-6417-MS

Informal Report

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UC-38

Reporting Date: June 1976

Issued: July 1976

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG. 36

**Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$3.50 Microfiche \$2.25**

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FIELD DISTORTION SWITCH FOR ELECTRICALLY DRIVEN
FLYING PLATE EXPERIMENTS

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ABSTRACT

This paper describes the use of a field distortion switch in electrically driven flying plate research. The switch can be triggered in a range from 1 to 60 kV with a voltage rise time of 15 to 20 ns. The current quarter period of 2 μ s remains the same over this voltage range because the electrode geometry is not changed. Dry air is used to bathe the electrodes when operating in the range from 9 to 60 kV. Argon is used in the 1 to 10 kV range.

I. INTRODUCTION

Plastic discs, which range from 0.4- to 25-mm diam and 10- to 250- μ m thick ($\rho \sim 1.3 \text{ Mg/m}^3$), that have been accelerated by the plasma from an electrically energized exploding metal foil, typically aluminum, are used to generate shocks around 200 GPa for durations of about 1/4 μ s. The pulses can be reasonably planar and offer a convenient way of measuring material properties and detonating explosives. A typical flying plate system¹ is shown in Fig. 1. When the foil bursts, expanding plasma incises the plastic disc (flyer) out of the flyer material (typically Mylar) with a diameter the same as that of the barrel hole.

The flyer accelerates through the barrel (upward in Fig. 1) and impacts an acceptor (not shown) at the far end of the barrel. The velocity and impact pressure can be varied by varying the current, length of barrel, and the properties of the foil and flyer material.

In order to study a wide range of flyer responses, a capacitor discharge unit

(CDU) capable of delivering a range of current densities from 0.01 to 2.0 TA/m^2 with a quarter period of 2 μ s in a variety of metal foils is required. The current densities are determined largely by the size of the foils, which range from 0.4 x 0.4 x 0.01 mm to 25 x 25 x 0.08 mm. In order to vary the current densities over the desired range of a particular size foil, a charging potential range from 1 to 20 kV is required.

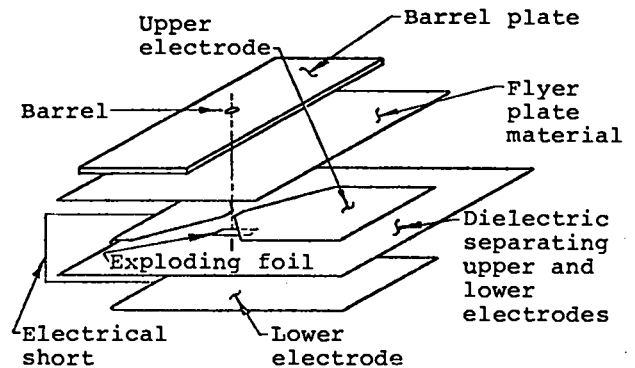


Fig. 1. Exploded view of a flying plate system.

The switching device is the essence of the system. It must switch high currents at the required voltages and be reliable and convenient. It must have short turn-around time and low inductance. Of the many kinds of switches available, four are presently being used in our Laboratory: (1) spark gap [2- and 3-element],² (2) explosive, (3) vacuum, and (4) field distortion.

The various spark gap switches used are limited by the fact that they are difficult to adjust for various voltage levels, and that their inductances vary with gap separation adjustments. The explosive switch introduces an additional safety consideration and has a set-up time of 15 to 30 minutes. Furthermore, it requires a new cable for every experiment, which not only slows the operation but adds significant costs. The fast high-voltage vacuum switch of Ware et al.³ was found to be unsuitable for our purposes when it was moved around to accommodate varying experimental arrangements.

II. FIELD DISTORTION SWITCH

The switch described in this report is an adaptation of the fast high-energy field distortion switch, Fig. 2, described by Carpenter et al.⁴ When this switch is coupled with the capacitor and trigger circuit shown in Fig. 3 and a flat cable 750-mm long x 75-mm wide leading to the flying plate device, the system has an inductance of 100 nH and a quarter period of about 2 μ s. Table I is the parts list.

The switch described is a symmetrical field distortion switch. Initially the trigger electrode is biased at half of the charge voltage. The diagram (Fig. 3) shows that when the circuit through the thyatron, U-1, is closed, a trigger pulse is applied of amplitude and polarity such as to cause breakdown from the trigger electrode to one of the main electrodes. The full voltage is now applied to the remainder of the gap, causing it to break down if the voltage is sufficient. Since the switch is symmetrical either side can be broken down first.

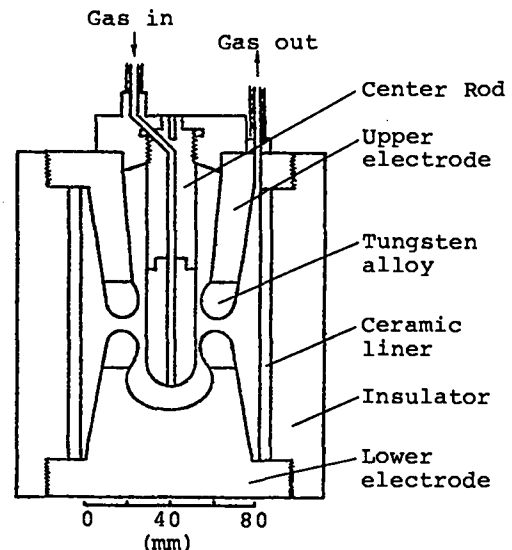


Fig. 2. 60-kV, 20-kJ field distortion pressure switch.

In the previous paper,⁴ it was not reported that the switch would operate below 20 kV (Fig. 4). We found that the lower limit is about 9 kV. The range of 9 to 60 kV can be chosen by selecting a dry air* pressure from 3.5 to 400 kPa without varying the electrode separations. Air is used instead of a gas not containing oxygen because the oxygen seems to replace the oxide coating of the electrode surface, which is momentarily denuded by a discharge. The measured operating range is shown in Fig. 5.

The range was extended even further to as low as 1 kV (Fig. 6) by replacing the dry air with argon. The switch is thus capable of functioning over a range of potentials from 1 to 60 kV at constant inductance. Experiments have been run using a mixture of 80% argon and 20% oxygen. The oxygen is included to replace the oxide coatings that may be removed by the discharge. However, since argon is used mainly at low potentials (1 to 10 kV) the presence of oxygen does not

*Dry air used in the Laboratory is 80% N₂ and 20% O₂ made from converting liquid nitrogen and liquid oxygen to gases and then mixing. This mixture contains only a few ppm of impurities such as argon.

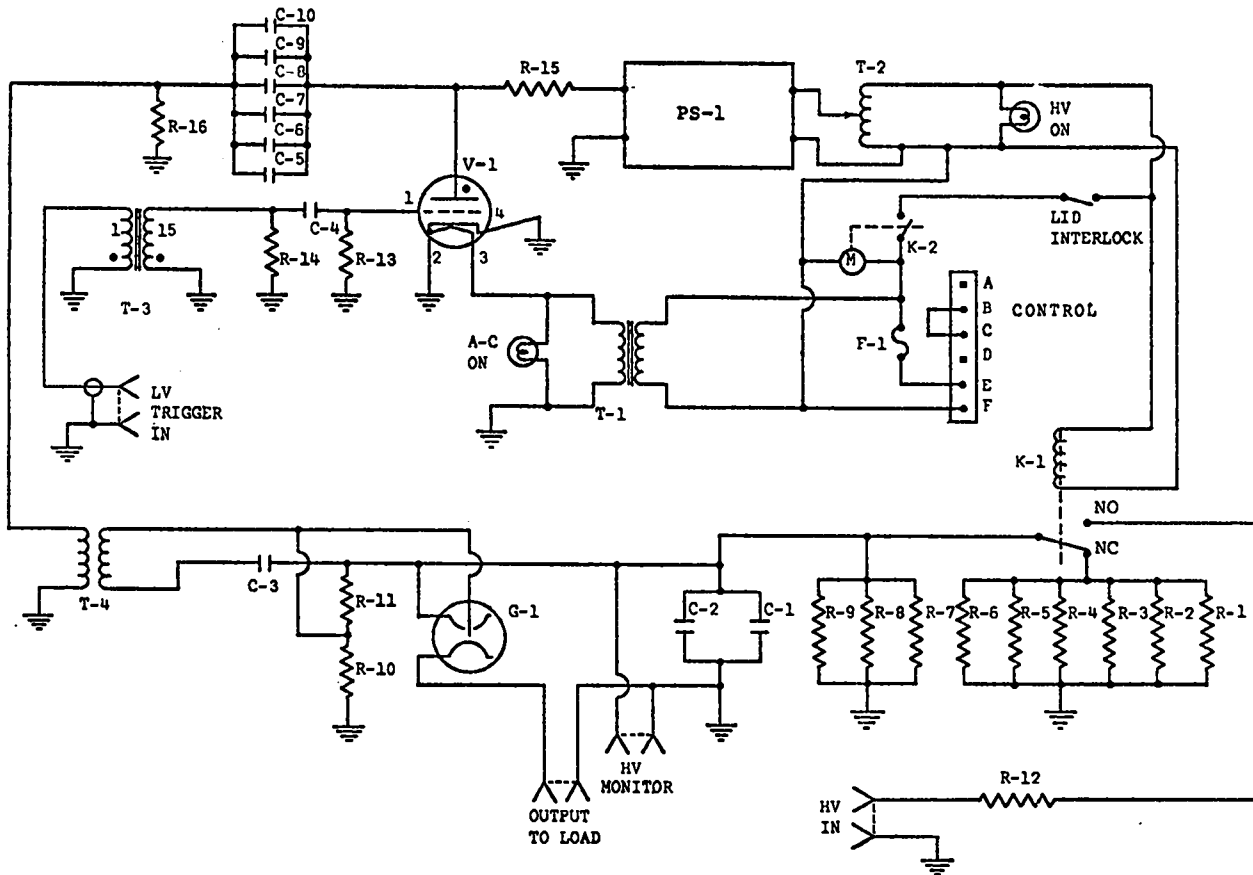


Fig. 3. Circuit diagram of field distortion switch.

TABLE I
PARTS LIST

Reference	Specifications
R-1 - R-6	Resistor, 500 Ω , 100 W
R-7 - R-11	Resistor, HV, 20 M Ω , 30 W, 50 kV
R-12	Resistor, 10 k Ω , 200 W
R-13	Resistor, Carbon, 1.1 k Ω , 1 W
R-14	Resistor, Carbon, 110 k Ω , 1 W
R-15	Resistor, HV, 500 k Ω , 10 W, 15 kV
R-16	Resistor, HV, 100 k Ω , 10 W, 15 kV
C-1 - C-2	Capacitor, 15 μ F, 20 kV Tobe Deutschmann Type XN 273
C-3	Capacitor, 500 pF, 20 kV
C-4	Capacitor, Ceramic Disc, 0.05 μ F
C-5 - C-10	Capacitor, "Glassmike," 0.001 μ F, 20 kV
T-1	Transformer, Filament, 6.3 VAC @ 10 A, Stancor P-6308
T-2	Transformer, Variac, Model 10 B, Powerstat
T-3	Transformer, Pulse, 15:1, Sandia #152800-00
T-4	Transformer, Pulse, made from coaxial cable
V-1	Thyratron, 5C22 (6279)
PS-1	Power Supply, 20 kV, 5 mA
G-1	Switch, Field Distortion, LASL Drawing #2Y-57873
K-1	Relay, HV, Price Electronics Model 6225-15
K-2	Relay, Time Delay, Tenor Co. #650-5-H
F-1	Fuse, 2 A, 250 V

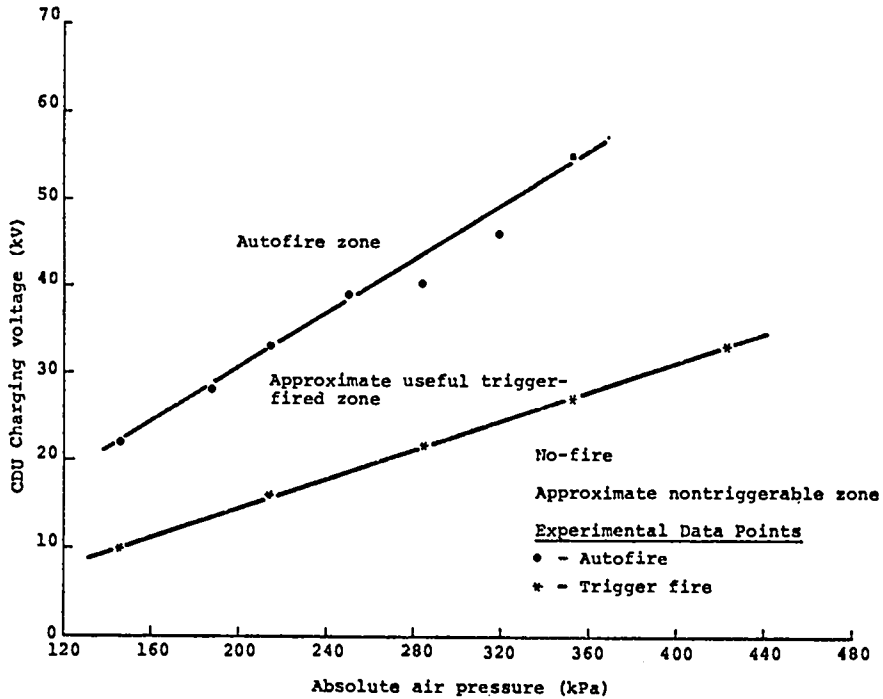


Fig. 4. Field distortion (pressure) switch calibration curve showing approximate autofire, useful and nontriggerable zones using dry air.⁴

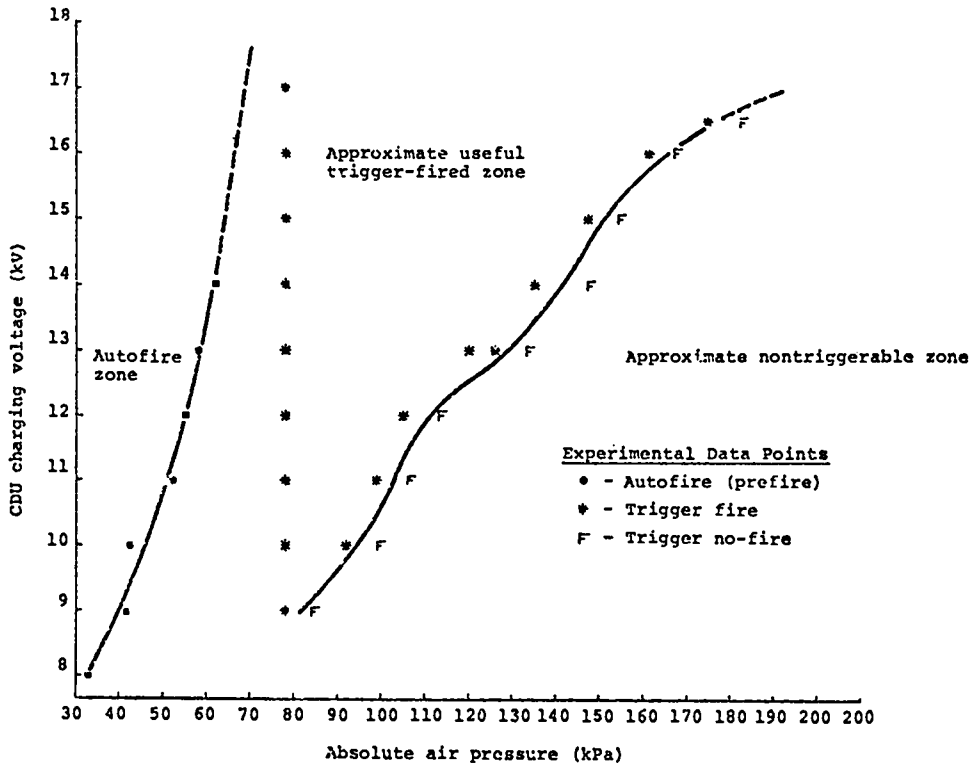


Fig. 5. Field distortion (pressure) switch with 30- μ F CDU (SUPERPATT) calibration curves showing approximate autofire, useful, and nontriggerable zones using dry air.

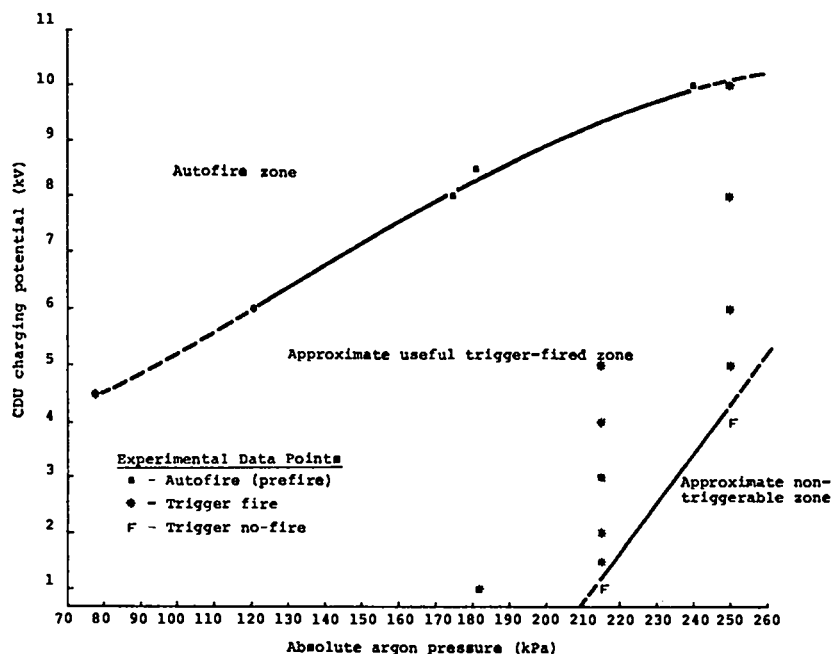


Fig. 6. Field distortion (pressure) switch with 30- μ F CDU (SUPERPATT) calibration curves showing approximate autofire, useful, and nontriggerable zones using argon.

seem important. The useful triggering range is 6 to 10 kV using this argon-oxygen mixture.

Experiments were done to test the performance with sulfur hexafluoride (SF_6) as the gas bathing the electrodes. For pressures of 77.8 kPa (Los Alamos average atmospheric pressure) or above and potentials of 20 kV or below, the switch would not trigger or autofire. It did trigger fire erratically between 56 and 70 kPa at potentials between 14 and 18 kV. It autofired at 38 kPa and 18 kV. These sketchy data suggest SF_6 could extend the useful range of the switch above the 60-kV limitation found for air. In the 14- to 20-kV range, the voltage stand-off can be maintained with pressures of SF_6 well below those needed for air.

III. CONCLUSIONS

The field distortion switch provides a convenient, safe, inexpensive method of triggering high voltages (1 to 60 kV) and high-current electrical pulses with short rise times and constant inductance.

IV. ACKNOWLEDGEMENTS

The authors are indebted to I. A. Garcia for his expertise in the operation of the apparatus and to C. W. Wilson for construction of the CDU.

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