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TECHNICAL REPORT

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DEVELOPMENT REPORT ON
A MEANS OF MONITORING LABORATORY EXPOSURES
TO INTENSE THERMAL RADIATION IN ACCORDANCE
WITH THE GENERALIZED FIELD PULSE

Lab. Project 5046-2, Part 12

FEB 10 1955

Final Report

NS 081-001

Technical Objective AW-7

AFSWP-843

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Final Report

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ADMINISTRATIVE INFORMATION

1. This project has been conducted as part of the program originally proposed by COMNYKNAVSHIPYD (Material Laboratory) confidential letter S99/L5, Ser 960-92 of 14 March 1950 and formally approved by Bureau of Ships speedletter S99-(0)-(348), Ser 348-75 of 6 April 1950. The Naval Material Laboratory's thermal radiation program is under the sponsorship of the Armed Forces Special Weapons Project.
2. This project was planned and executed under the general direction of T. I. Monahan, Supervisor of the Optics Section.

INTRODUCTION

3. Most studies to date at the Naval Material Laboratory on the effects of intense thermal radiation on materials have utilized either stationary exposures, employing rectangular pulses, or dynamic exposures in which the time dependence of irradiance is essentially Gaussian.¹ It is not possible always to predict the behavior of organic materials, when exposed to a nuclear detonation, on the basis of exposures to either of these laboratory sources, because of the evolution of smoke and volatile products which can not be represented mathematically. The Naval Material Laboratory has undertaken the development of a laboratory source in which the irradiance is monitored in accordance with the normalized variation of intensity of irradiation with time for a nuclear detonation. The

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normalized field pulse is characterized by the irradiance rising to maximum value at a time, called t_{max} , and then falling exponentially to a value of 4 per cent of the maximum value at a time equal to $10t_{max}$.

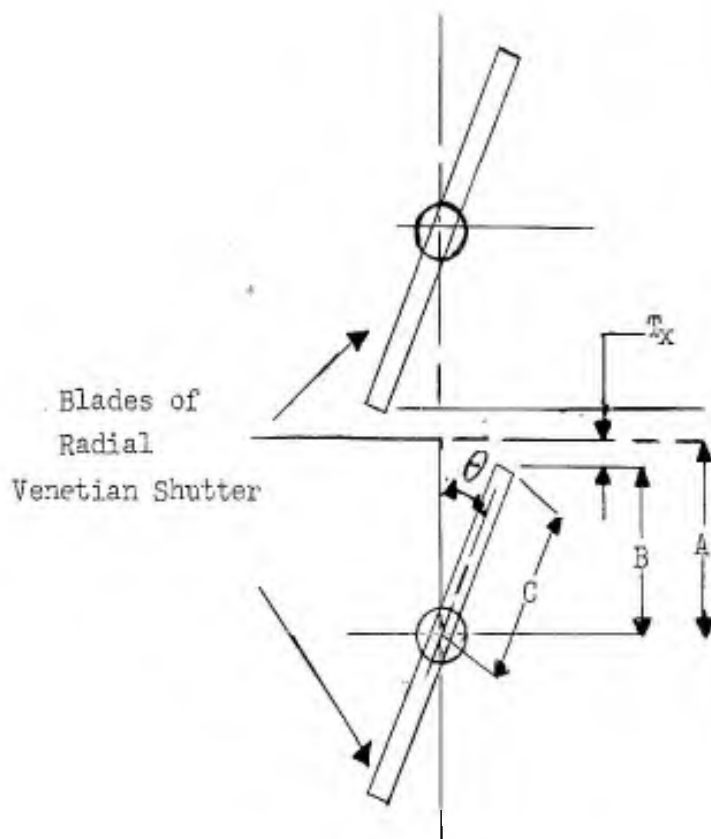
DESCRIPTION OF PULSE MECHANISM

4. The basic exposure mechanism for the laboratory simulated field pulse is a standard 24 inch carbon-arc signalling searchlight, shown as part (a) in Figure (1). The searchlight beam pattern has been altered by substituting a first surface ellipsoidal mirror, part (b) of Figure (1), for the standard paraboloidal reflector, which has a secondary focus at a distance of 55 ± 1 inches in front of the ellipsoidal mirror.
5. The manual signalling lever was replaced with a 30-tooth, $14\frac{1}{2}$ -degree, $1\frac{1}{2}$ -inch pitch diameter steel spur gear, part (c) of Figure (1), which serves as the rotary coupling for driving the signalling shutter or attenuator, part (d) of Figure (1). The attenuator or signalling shutter is a radial venetian-blind-type unit, with long tapered flat blades that normally overlap in the vertical closed shutter plane position.
6. A precision cut cam, part (e) of Figures (1) and (2), which is rigidly coupled to the signalling shutter spur gear by a steel rack, part (f) of Figures (1) and (2), feeds the pulse shape information to the attenuator through a spring loaded cam follower, part (g) of Figures (1) and (2).

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The radii of the pulse shape cam are based on the following calculations:



$$T_x = \frac{A - B}{A} = \frac{A - C(\cos \theta)}{A}$$

where T_x = transmittance or relative irradiance at time "t" from normalized field pulse

A = mean center line distance between blades

B = mean projected width of shutter blades at rotation position " θ "

and θ = angle blades make with vertical or normally closed shutter plane.

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then $\cos \theta = \frac{A(1 - T_x)}{C}$

and $\Delta T = \left(\frac{\pi D}{4}\right) \left(\frac{\pi/2 - \theta}{\pi/2}\right) = \frac{D(\pi/2 - \theta)}{2}$

where ΔT = change in pulse cam radius

and D = pitch diameter of signalling shutter spur gear.

7. The pulse shape cam is driven by a geared down 1/4-H.P. speedranger motor, part (h) of Figures (1) and (2), through a gear system, part (i) of Figures (1) and (2), which gives continuously variable cam speeds of 1.34 through 23.3 RPM. This range of cam speeds is obtained from the speedranger output shaft speeds of 15 to 45 RPM and a 5 to 1 worm gear ratio in conjunction with three gear train-ratios of 70/27, 55/42 and 30/67.
8. A V-blade or knife shutter, operated in conjunction with the signalling shutter and activated by a micro switch working off a timing cam, which is concentric with the pulse shape cam, initiates and terminates the pulsed exposure. The V-blade shutter which is solenoid operated is shown as part (j) in Figure(1).
9. The pulse shape mechanism is operated from a control box, part (a) of Figure (2), which provides for a nearby automatic exposure cycle: depressing the speedranger start button activates one complete exposure cycle and returns the mechanism to its original starting position. The

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speedranger employed has a built-in electric brake which is activated by a cam attached to the pulse shape cam and prevents overshooting of the exposure cycle.

10. A complete wiring diagram for laboratory simulated field pulse mechanism is shown in Figure (3). The control and monitoring panel is shown in Figure (4).

ANALYSIS

11. An evaluation of the performance of the laboratory simulated field pulse mechanism gave the following results: at pulse cam speeds of 1.3 to 23 RPM, the times to pulse peaks, t_{max} , were 0.2 to 3.7 seconds with pulse lengths, τ , of 2.1 to 40 seconds. The irradiance at pulse cutoff is 3 per cent of the peak irradiance value and the total radiant energy in the normalized laboratory simulated field pulse shape 1 per cent greater than the total radiant energy in the generalized field pulse shape.

Successive exposures at any speedranger setting give times to pulse peaks and pulse lengths that are reproducible with an accuracy of greater than 7 per cent.

12. The peak irradiance obtained with this exposure system is 12 cal/cm² sec over an area 9mm in diameter, and 10 cal/cm² sec over an area 17mm in diameter without the searchlight doorglass. Employing the doorglass, part (K) of Figure (1), the peak irradiance is attenuated by 10 to 15 per cent, but this procedure has the advantage of stabilizing the arc

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during long exposures. The peak irradiance of successive exposures is reproducible within the range of the arc fluctuations, which is + 6 per cent.

13. An analysis of laboratory pulse traces derived from exposures of various copper disc calorimeters and radiometers to the pulse cam source gave the following empirical expressions for the total radiant energy in the laboratory simulated field pulse and the times to peak irradiance as follows:

$$Q = 0.216 H_0 \tau,$$

where Q = radiant energy (cal/cm²),

H_0 = peak irradiance (cal/cm²sec),

τ = pulse length (sec),

and $t_{\max} = 0.094 \tau,$

where t_{\max} = time to peak irradiance of laboratory pulse (sec).

14. A graphical comparison of the normalized laboratory pulse shape with the normalized field pulse shape is shown in Figure (5).

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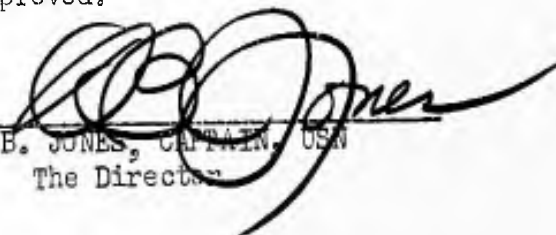
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CONCLUSIONS

15. The laboratory simulated field pulse mechanism has performed more than satisfactorily during its numerous test runs and has also shown that it is quite versatile and rugged in construction. The infrequent adjustments to the mechanism are very simple to make and are of the order of magnitude that if left unadjusted do not materially affect the operation of the mechanism or the empirical expressions derived for the pulse.

16. Exposures of materials to the laboratory simulated field pulse have shown the need of additional units that will generate times to peak irradiances somewhat less than now obtainable and also peak irradiances somewhat greater than presently obtained. With these factors the basis, the Naval Material Laboratory is presently constructing an additional unit identical to the existing mechanism but with faster cam speeds to cover a range of t_{max} from 0.15 to 2.3 seconds. The Material Laboratory is also modifying the pulse generating mechanism for adoption to the 36 inch parabolic carbon-arc source for obtaining higher peak irradiances at the t_{max} range of 0.15 to 2.3 seconds.

Approved:


A.B. JONES, CAPTAIN, USN
The Director

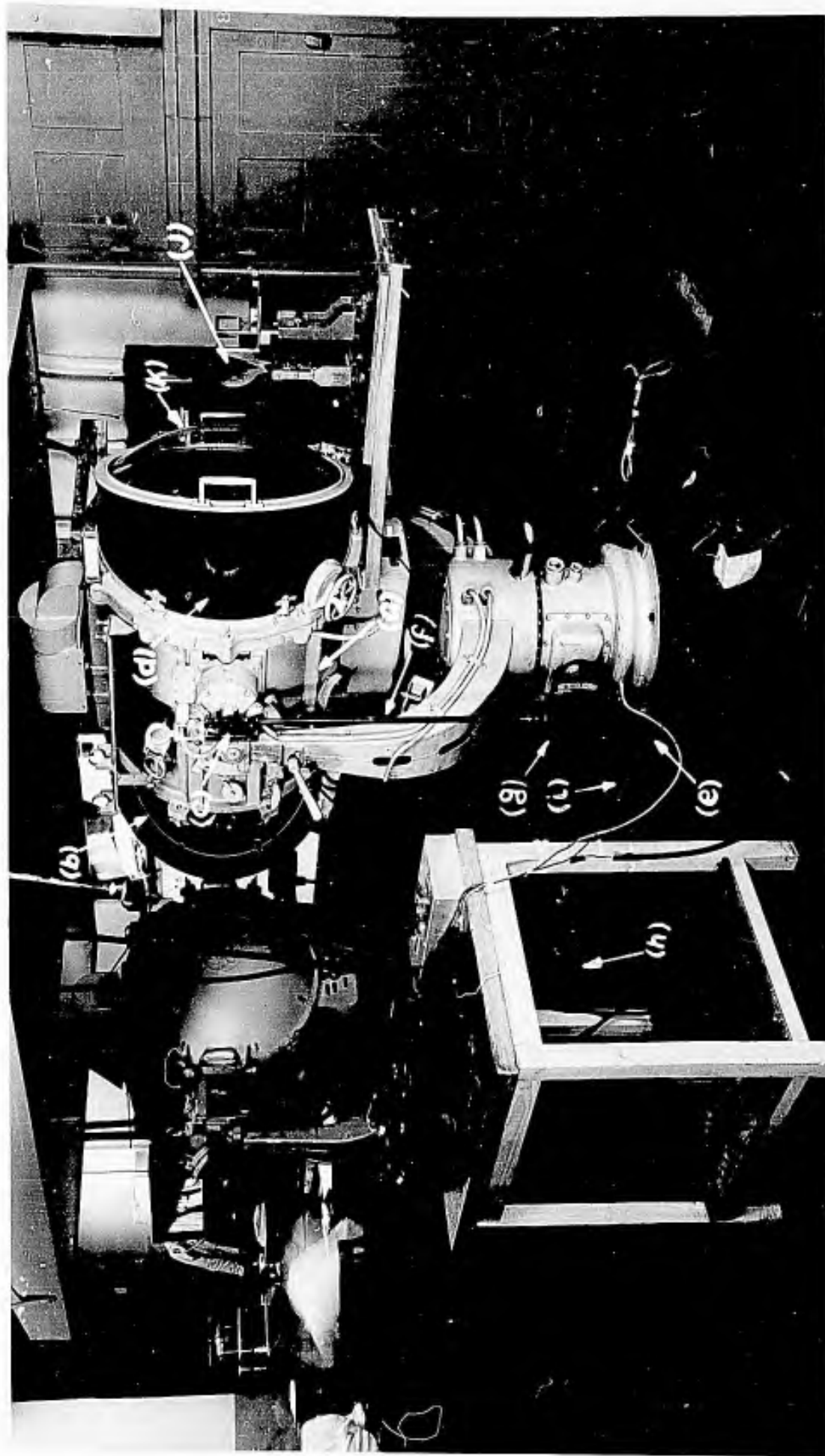


FIGURE 1 - LABORATORY SIMULATED FIELD
PULSE MECHANISM

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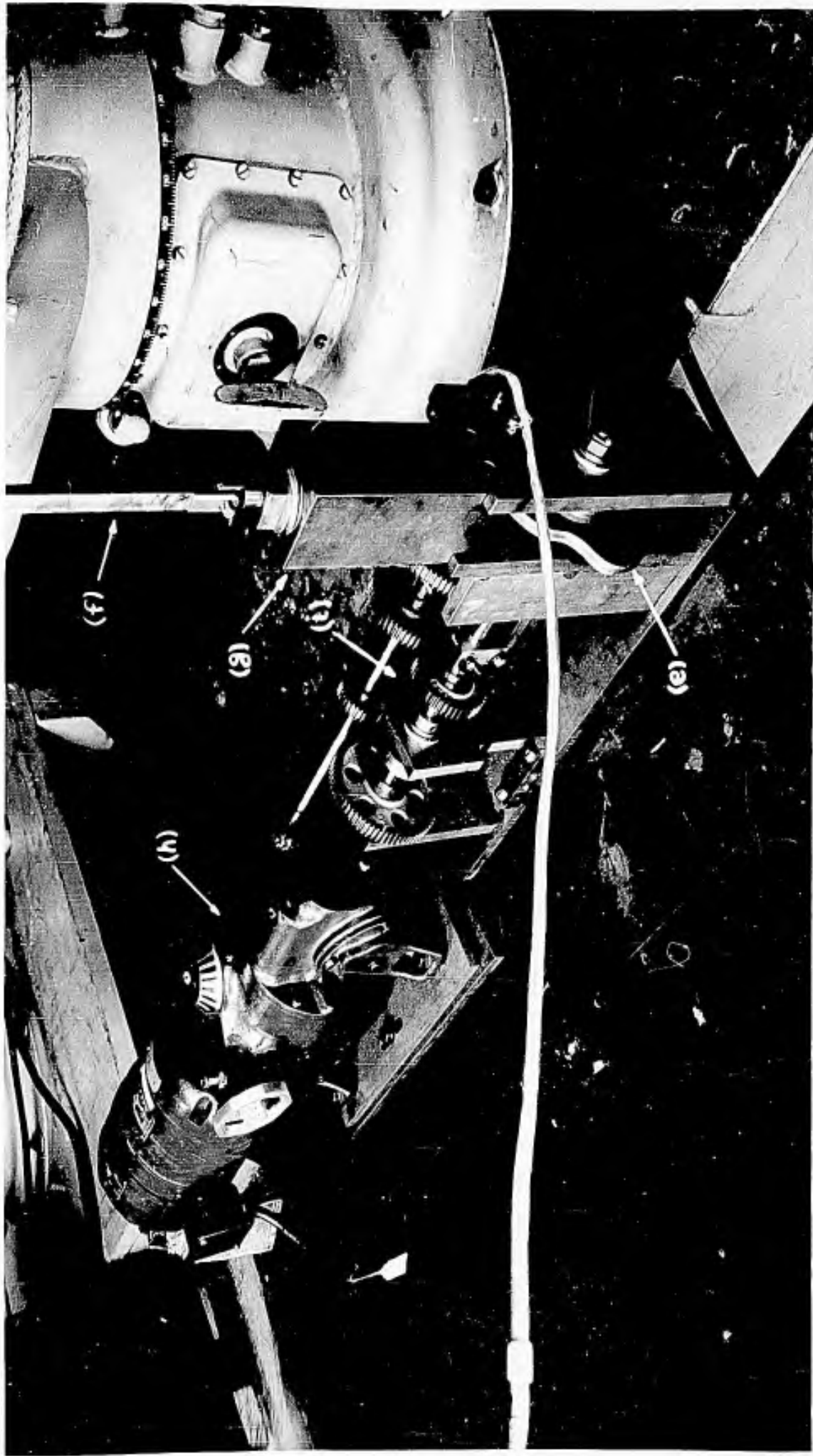


FIGURE 2 - DRIVING MECHANISM FOR LABORATORY
SIMULATED FIELD PULSE ASSEMBLY

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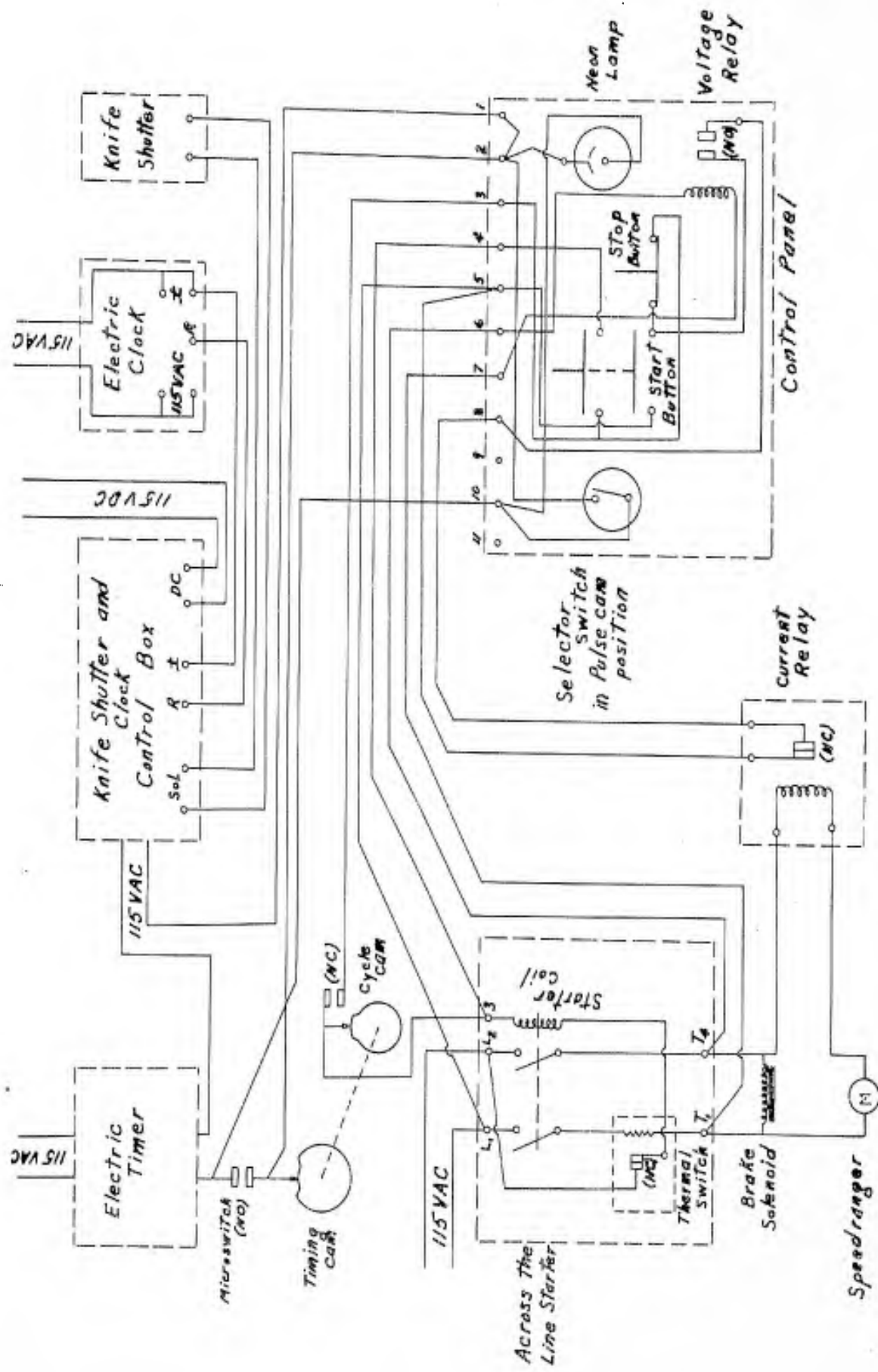


FIGURE 3 - WIRING DIAGRAM OF LABORATORY
SIMULATED FIELD PULSE MECHANISM

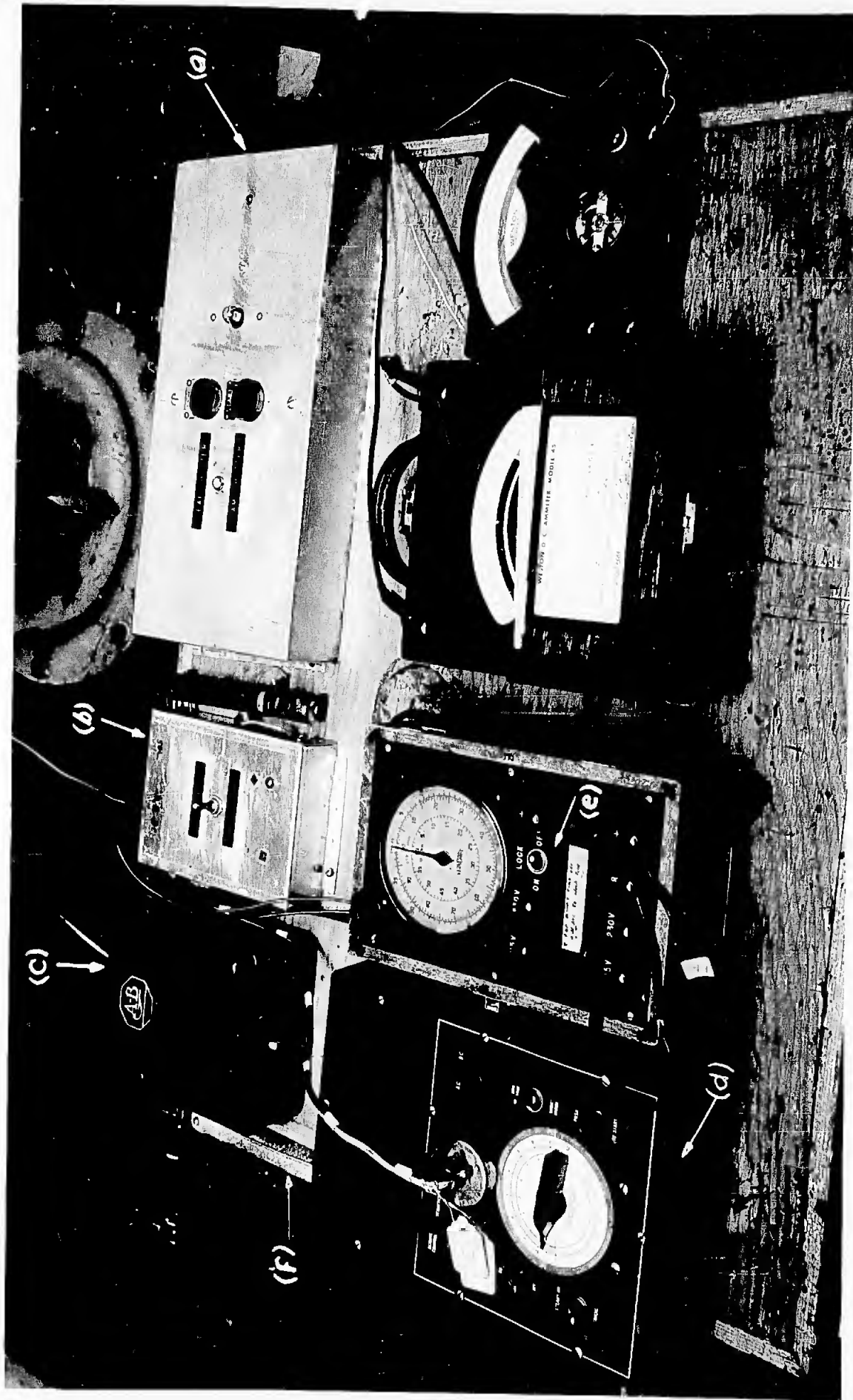
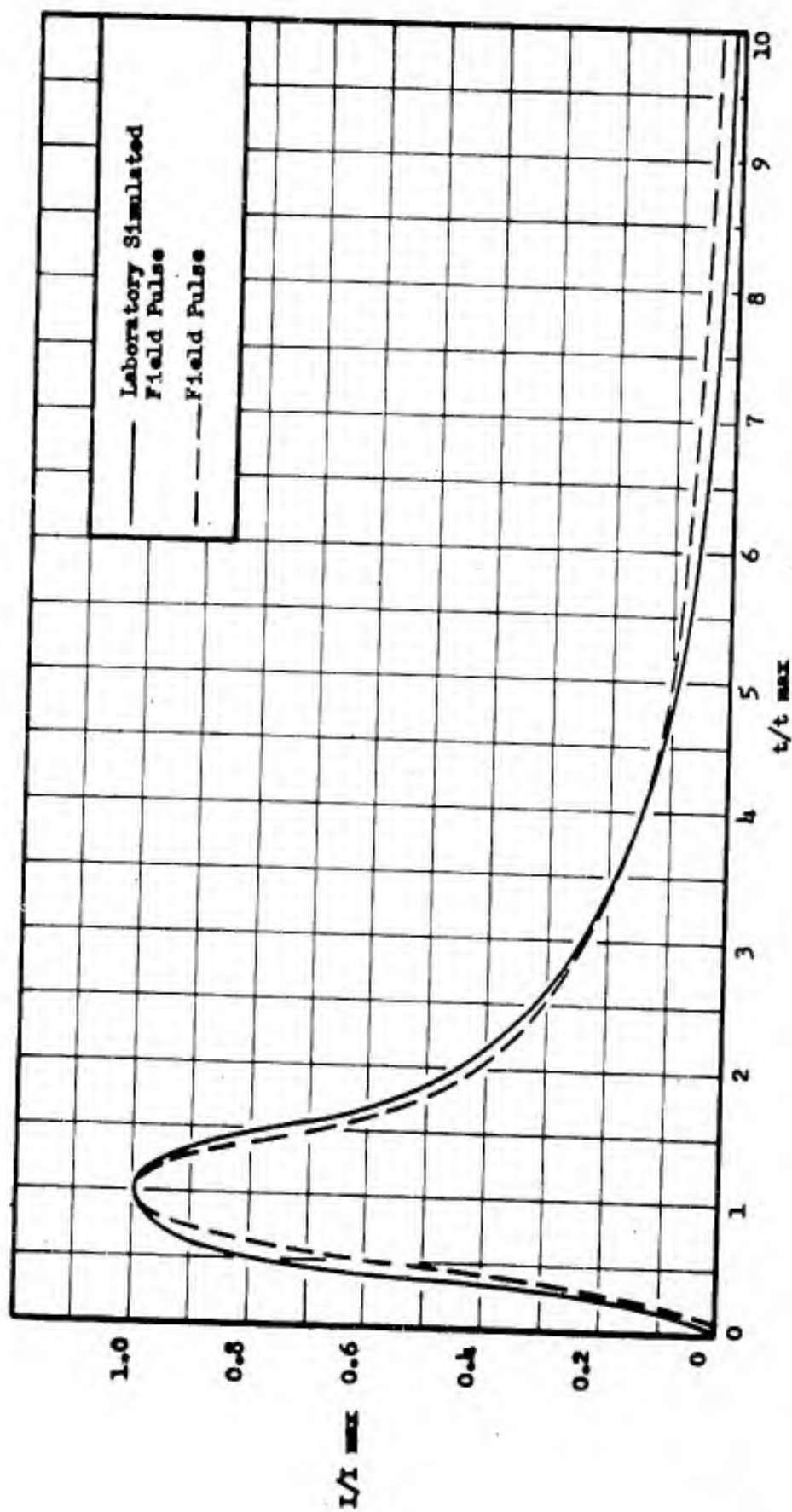


FIGURE 4 - CONTROL AND MONITORING PANEL FOR
LABORATORY SIMULATED FIELD PULSE
MECHANISM

- PART (a) CONTROL PANEL
 (b) KNIFE SHUTTER AND CLOCK CONTROL BOX
 (c) ACROSS THE LINE STARTER
 (d) ELECTRIC TIMER
 (e) ELECTRIC CLOCK



NORMALIZED LABORATORY AND FIELD PULSE SHAPES

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Figure (5)

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1. Thermal radiation sources
 2. Atomic detonation simulator
- I. Carter, J. A.
 - II. NS 081-001
 - III. AFSWP-843

Naval Material Laboratory, New York Naval Shipyard
5046-2, Part 12

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A mechanism is described for monitoring laboratory exposures to intense thermal radiation in accordance with the variation of irradiance with time as given in the generalized field pulse. The unit is particularly applicable to sources utilizing carbon-arc searchlights. The method of operation of the "pulse shaper" is outlined and the reliability of its performance is discussed.

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