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UR-387

Instrumentation

THE UNIVERSITY OF ROCHESTER  
Atomic Energy Project  
P. O. Box 287, Station 3  
Rochester 20, New York

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Contract W-7401-eng-49 between the U. S. Atomic Energy Commission and the University of Rochester, administered by the Department of Radiation Biology of the School of Medicine and Dentistry.

A METHOD OF SHAPING THERMAL ENERGY PULSES FROM A CARBON ARC SOURCE

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Date Completed: 5/2/55

Date of Issue: 6/6/55

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PULSES FROM A CARBON ARC SOURCE.

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ABSTRACT

A method is presented whereby the constant irradiance of a carbon arc source may be shaped to produce energy pulses of desired characteristics, without otherwise altering the optical or geometrical properties of the beam. This is accomplished by the interposition of a rotating slotted wheel, whose rate of rotation may be accurately controlled. The method in use has proven to be convenient and accurate.

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NOTE: This study was carried out through the facilities of the University of Rochester Atomic Energy Project, under contract with the U. S. Atomic Energy Commission, and a portion of its expenses defrayed under grant from the Quartermaster Corps, U. S. Army.

INTRODUCTION

There are essentially two basic reasons for attempting to produce a pulse of radiant thermal energy whose irradiance can be varied at will as a function of time. The first of these is to obtain a laboratory simulant of the time-irradiance characteristics of field pulses; the second is to produce energy waves of certain geometric forms whose effect on skin or inanimate systems can be predicted by theory and measured in fact. This report is primarily concerned with the latter problem; the former will be separately reported.

Both purposes demand certain requirements of the resultant pulse wave as delivered at the exposure plane. The first of these is that the relative spectral irradiance across the exposure plane be constant, and essentially the same as for the unmodified beam. Previous designs in this laboratory employing a large opaque cam to interrupt the convergent beam of a modified 24" carbon arc (1) were shown to produce asymmetrical patterns at the exposure port. Double counter-rotating cams of the type used by NRDL (2) would also be unsatisfactory when used in the convergent rays of energy.

Other requirements are:

1. That there be no alteration of wave-length distribution during the pulse.
2. That the pulse progress smoothly, without sharp stepwise gradations.
3. That there be little (or, preferably, no) attenuation of the maximum deliverable irradiance of the arc source.
4. That there be no alteration of the angle of incidence of the energy at the exposure plane.

5. The various shapes of pulse can be produced as desired, and
6. That the duration of the pulses can be widely varied.

#### Methods

The basis of the method presented in this paper is the interposition, in the convergent beam of a carbon arc, of the slotted periphery of 53 inch diameter wheel whose rate of rotation can be accurately controlled. At the point of interposition the envelope of convergent rays is approximately 4" in diameter; the radially disposed slots in the periphery of the wheel are 6" in length. For ease in construction, a standard tapered "picket", 0.2" in width at the center, was adopted, and the distance between such pickets varied to transmit whatever percentage of incident energy was desired. It was found that in some instances this width introduced excessive "flicker" at the exposure spot, and in such cases a narrower picket, 0.1" in central width, was used. In order to mount these narrow strips of 20 gauge galvanized iron securely, the central disc of 1/8" aluminum sheet was supplied with a concentric outer ring of light aluminum suspended rigidly at 3 points by 1/4" aluminum braces 0.2" wide. After the pickets were tentatively placed by "Scotch" tape about the periphery, the pulse shape was tested by rotation of the wheel in the arc beam. Minor adjustments of position were then made, and the pickets glued in place at both ends by Duco cement. For very low transmission, pairs of pickets were placed at micrometered distances from each other, and the area up to the next pair blocked off with aluminum foil.

The large wheel, bolted to a brass hub, was mounted on a 1/2" steel shaft in self-aligning pillow blocks above the arc drum and parallel to the optical axis. An eccentric cam and microswitch allowed synchronization of wheel rotation with the sliding shutter control. Three chain sprocket wheels,

Figure 1

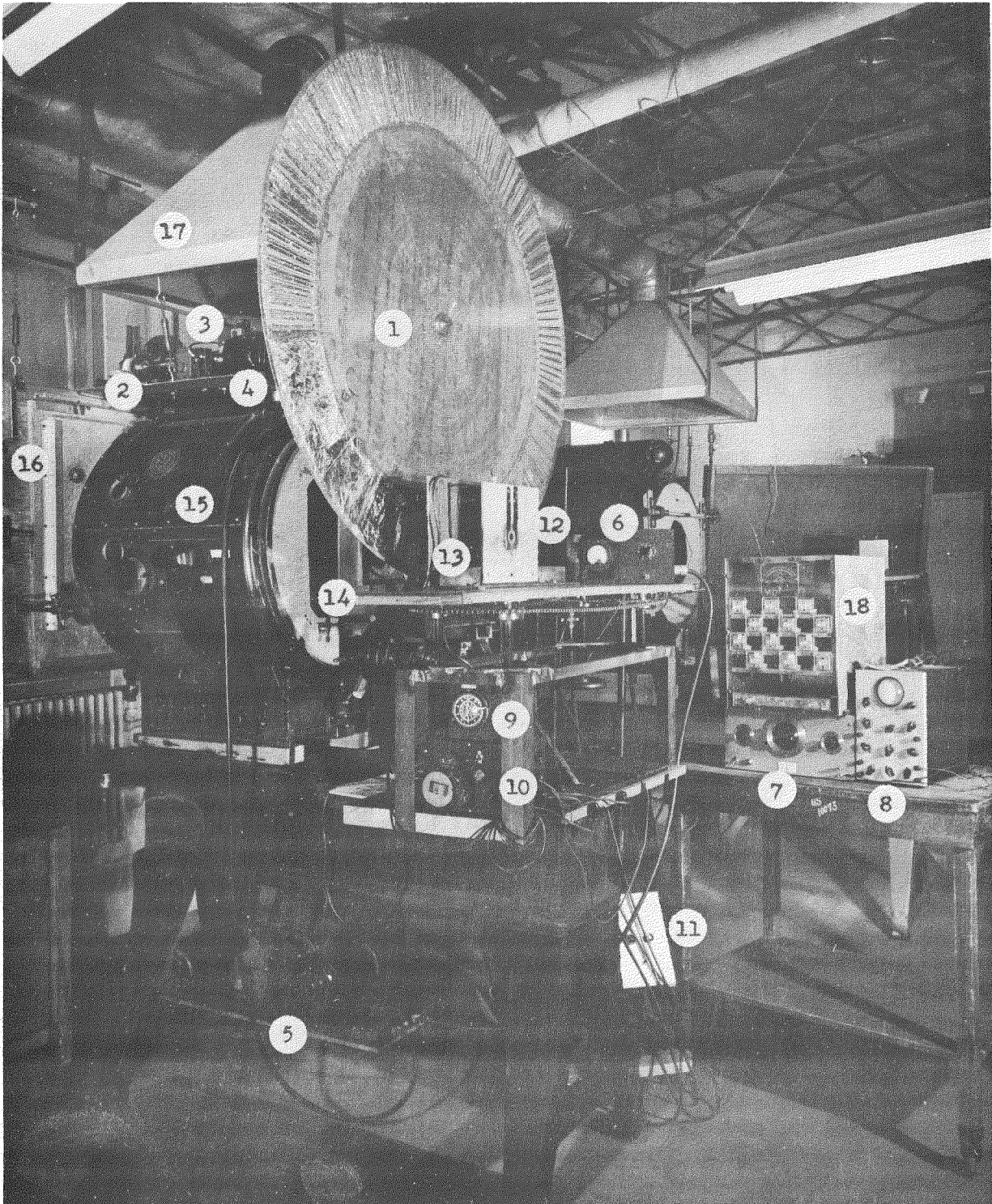


Figure 1

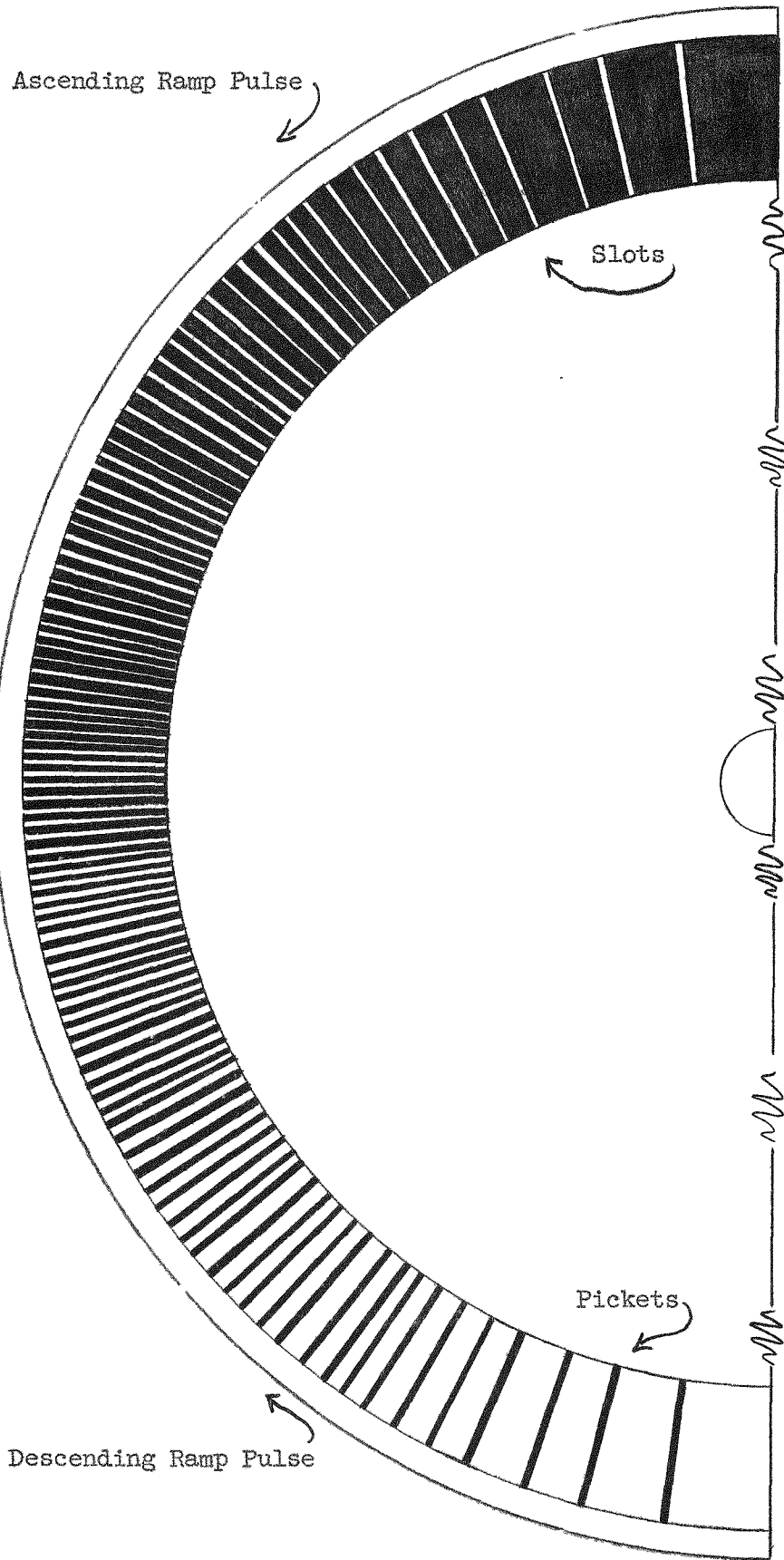
1. Slotted Wheel
2. Reduction Drive
3. Magnatic Pick-up
4. Drive Motor
5. Ward-Leonard Generator
6. Control Rheostat and Excitation Voltmeter
7. Variable Audio Oscillator
8. Cathode Ray Oscilloscope
9. Timing Clock
10. Shutter Control Box
11. Thermostat Control Panel
12. Water-cooled Exposure Port
13. Sliding Shutter
14. Movable Diaphragm
15. 24" Arc Drum
16. Mounting Plate for Ellipsoidal Mirror
17. Exhaust Hood
18. Fabric Chest with Controlled Humidity

mounted on the back end of the shaft, gave three alternative ratios of speed to a jack-shaft, which was itself chain-driven by two alternative sprocket wheels through a constant-speed reduction gear box from a 1/20 H.P. DC motor. Thus six reduction ratios were readily available: 1:1, 1:2, 1:3, 1:4, 1:6 and 1:8.

Continuous fine adjustment of rotation rate was obtained by driving the 1/20 H.P. DC motor by a Ward-Leonard system, whose interbelted motor and two generators were mounted below the arc drum. A variable resistor and voltmeter allowed accurate control of armature voltage delivered to the DC motor, thus giving control of rotation speed to very close tolerances. In practice, it has been possible to obtain accurate wheel rotation times from 1.0 to 60 sec. duration by the use of a specially devised tachometer to monitor the drive motor speed. An "Electro" Model 3010-A magnetic pick-up was mounted in close apposition to the six-jawed coupler between the drive motor and the 25:1 reduction box. A single rotation of the motor shaft now gave six electrical impulses; this signal was impressed upon the vertical deflection plates of a cathode ray oscilloscope. The output of a variable frequency audio oscillator was impressed upon the horizontal deflection plates of the oscilloscope.

At a given setting of the audio oscillator, the motor speed could be adjusted until a stationary Lissajou pattern was obtained on the oscilloscope screen. Appropriate frequencies for such settings were computed to yield any desired time of rotation from 1 to 60 sec. In practice, this tachometer allows continuous correction of rotation speed, and greatly accelerates the establishment of desired pulse durations.

Figure 2



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SEMI DIAGRAMMATIC SKETCH OF THE ARRANGEMENT  
OF PICKETS AND SLOTS USED TO PRODUCE THE RAMP  
HALF OF THE PULSE WHEEL DESCRIBED IN TEXT.

Fig. 1 shows a general view of the apparatus mounted and ready for operation. In routine studies thus far it has been possible for two operators to place 200 to 400 individual burns on the skin of anesthetized pigs per day. One operator controls the arc irradiance, while the other adjusts wheel speed and positions the animal.

The first pulse shape desired was one which ascended in a linear fashion from 0 to 100% transmission; this was easily constructed on 180° of the wheel's circumference (Fig. 2). The other half of the wheel was then picketed to give 50% transmission over the full 180°. Three pulses were now available: by blocking off the even half, an ascending pulse; by reversing the wheel, a descending pulse; and by covering the "ramp half", a constant energy pulse. Each pulse would deliver the same total energy for a given incident irradiance and wheel speed.

## RESULTS

### 1. Relative intensity across the exposure plane.

This laboratory has previously published curves of relative energy distribution across the exposure plane (1). Using the same methods, the exposure plane was explored during rotation of the wheel, and no significant difference was found between the two distributions.

### 2. Spectral energy distribution.

It was assumed that, since energy incident on the wheel periphery was either passed unaltered or totally blocked by the pickets, there could be no alteration of relative spectral energy distribution from that previously described (3).

### 3. Flicker

Fig. 3 shows reproductions of actual records of time-intensity curves obtained during rotation of the wheel. These measurements were made using a

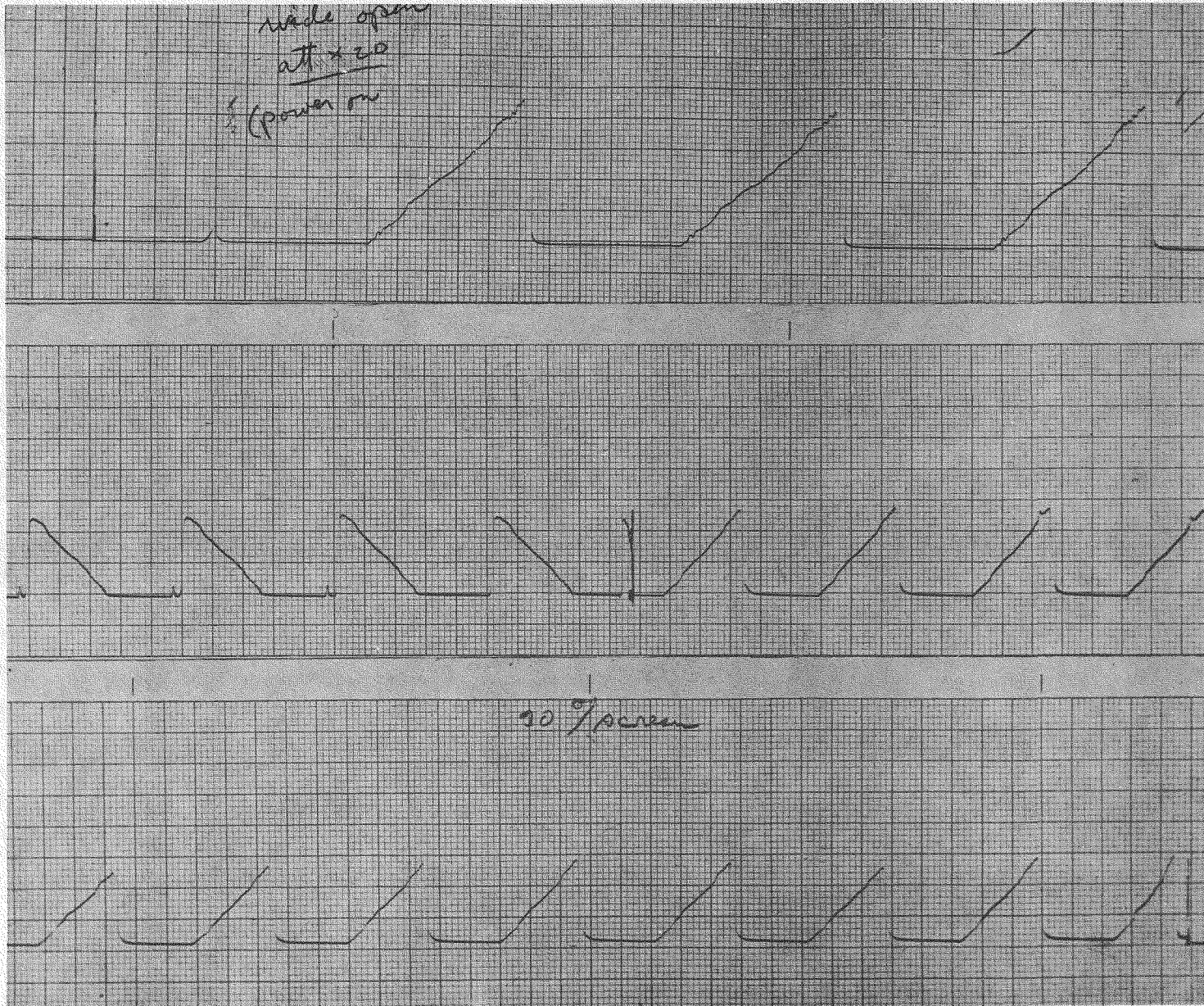


Figure 3

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FIGURE 3

Photographs of actual records taken from integrating sphere.

Upper Curve: Ascending ramp, full arc output ( $34 \text{ cal/cm}^2/\text{sec}$ ).

Middle Curve: Descending and ascending ramps, arc output at  
half full ( $16 \text{ cal/cm}^2/\text{sec}$ ).

Lower Curve: Ascending ramp, arc output  $1/5$  of maximum  
( $7 \text{ cal/cm}^2/\text{sec}$ ).

10" diameter integrating sphere (4) with a  $1.0 \text{ cm}^2$  circular aperture, and employing a 917 vacuum phototube as the photometer. Recordings were made on a Sanborn Model 128-T recorder, which has a frequency response of 0 to approximately 80 cps.

4. Peak irradiance.

Calorimetry of the beam through segments of the wheel designed to transmit 100% of arc output show no evidence of attenuation by the wheel.

5. Pulse duration.

The duration of single rotations of the wheel was accurately measured by attaching a Springfield electric timer to a microswitch riding on the cam of the main shaft. At 48 r.p.m. the variation of rotation time is limited to  $\pm 1\%$ ; at 1.5 r.p.m. the variation is within  $\pm 0.2\%$ .

6. Constancy of pulse shape for various peak irradiances.

The optical paths of convergent energy from our arc are modified somewhat by the movable diaphragms employed to obtain irradiances less than the maximum available (1). In effect, the lower the irradiance, the narrower the beam at its point of interruption by the pulse wheel. A series of time-irradiance curves was obtained with the integrating sphere over the full range of available irradiances and mean curves constructed for five such individual runs at three irradiances. No significant difference could be noted between the three curves.

### DISCUSSION

It seems evident from the information presented above, that the criteria for a satisfactory pulse shaper enumerated in the introduction are fulfilled by the present design. A considerable amount of experimental work has been done with the "ramp pulses", which will be reported separately. This experience has been sufficient to demonstrate that the use of pulses shaped by this device is simple, convenient and practical.

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