ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

PROGRESS REPORT NO. 2

ON

DETONATIVE COMBUSTION

BY

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DAYTON, OHIO

SUMMARY

I. Detonation

The work on detonation during this quarter involved mainly the improvement and calibration of the equipment to measure detonation velocities. Velocities of detonation for acetylene-oxygen mixtures at various pressures were determined. Preliminary runs to determine shock velocities for a combination of hydrogen as a reservoir gas and air as a test gas were carried out.

II. Interferometer

The designs of interferometer and support system were completed. The instrument is partially assembled, awaiting manufacture of a few remaining parts. A descriptive report is being written, including proposals for utilization in combustion studies.

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ON

DETONATIVE COMBUSTION

INSTRUMENTATION

The timer, whose circuit was discussed in Progress Report No. 1, operated sufficiently well to permit accurate readings of time intervals of the order of 150 to 1200 microseconds. There was, however, considerable drift in the meter during the reading interval which was traced to the change in tube characteristics encountered when the "Read" switch was thrown. This situation was remedied by the addition of a potentiometer in the grid circuit which can be adjusted to operate the tube under conditions nearly equal to those present when the "Read" switch is closed (Fig. 1; ref. page 29, Progress Report No. 1).

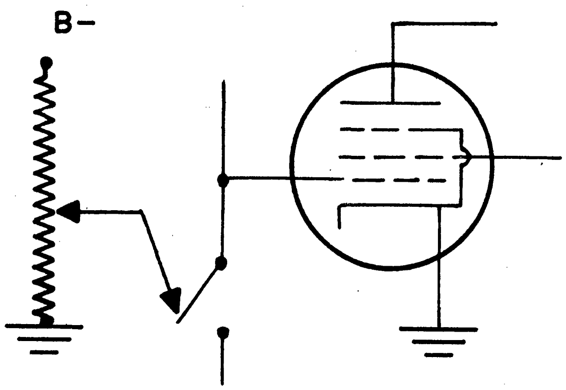


Fig. 1

In order to measure time intervals shorter than those above (ca. 150 microseconds), a 50 Ω resistor was added to the selector switch of

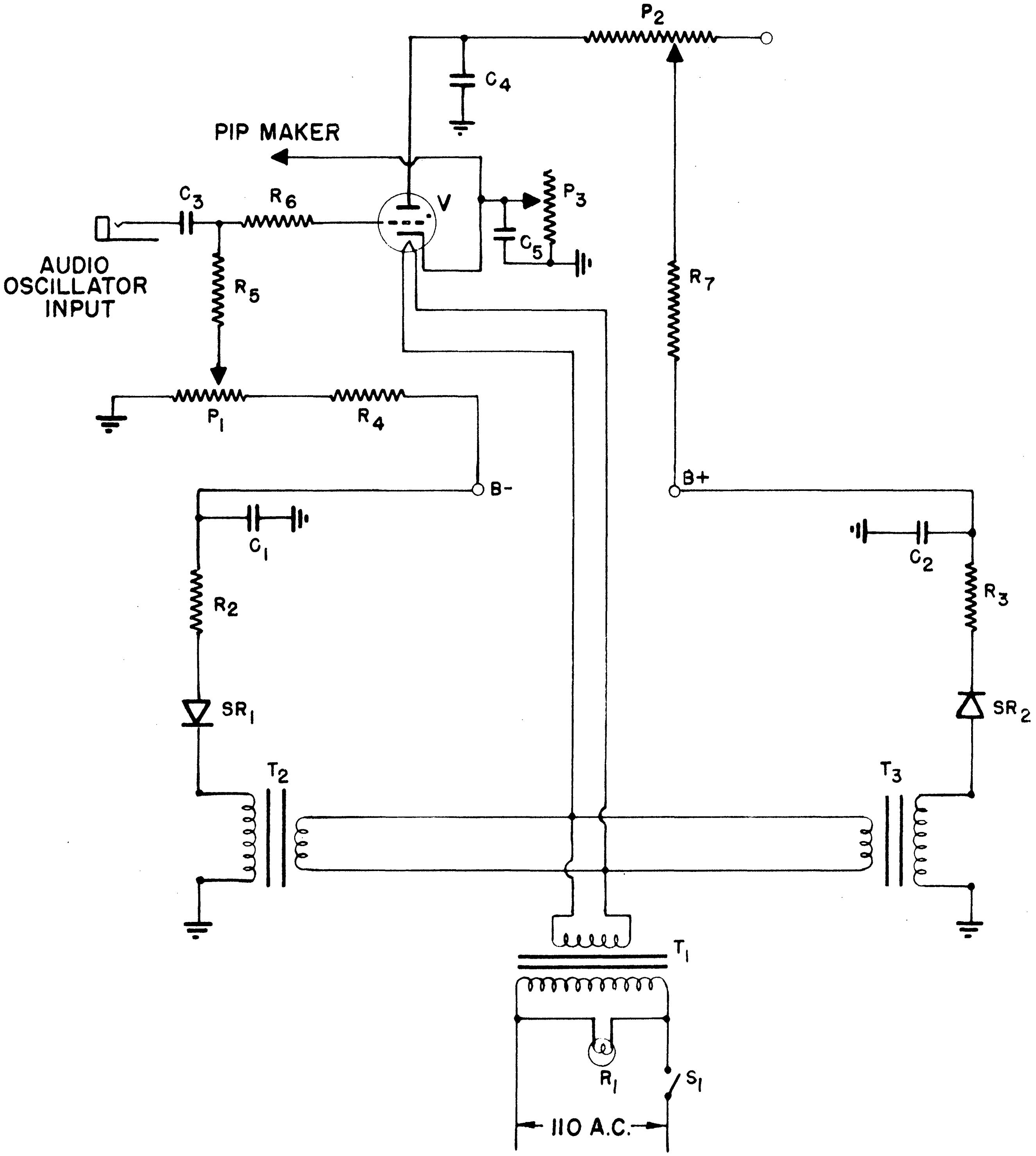
S_5 (page 29, Progress Report No. 1). The time interval that could be measured conveniently was thus extended to approximately 90 microseconds.

The calibration of the timing circuit was carried out in the following manner. An audio-oscillator was calibrated against radio station WWV as a standard. The audio-oscillator was then used to lock in a thyratron sawtooth oscillator (Fig. 2), which produces a series of sharp pips from a cathode follower. These pips are fed continuously into the calibration sequence pulser (see Fig. 3). The sequence pulser receives these pips on the grids of two thyratrons which are adjusted to sufficient grid bias to keep them from firing. When switch S_2, which is initially closed, is opened, the grid-bias voltage is quickly reduced to a state wherein the next pip will fire it. The firing of the first thyratron simultaneously sends a pip to the timer and reduces the grid bias of the second thyratron. The next succeeding pip fires the second thyratron which sends a second pulse to the timer. An example of these calibrations is shown in Fig. 4.

Under operating conditions in the shock tube it was found that the timer worked best when one side of the ionization probes was grounded and the other side fed to the grid of the thyratrons. Several probes were experimented with until one was found which worked satisfactorily. (See Fig. 5.) It is felt that the convergent section of the probe serves to intensify the strength of a wave and thereby increases the ionization in the region of the wave. These probes have been adjusted to sufficient sensitivity to respond to shock waves of moderate intensity. In the case of detonation waves the response has been very satisfactory.

Fig. 2

PIP MAKER



R_1 - Indicator Light	C_1 - 40 μf, 450 v	S_1 - SPST Switch
R_2 - 500 Ω	C_2 - 40 μf, 450 v	SR_1 - Selenium Rectifier 7.5 ma
R_3 - 500 Ω	C_3 - .005 μf	SR_2 - Selenium Rectifier 7.5 ma
R_4 - 170,000 Ω	C_4 - .005 μf	V - Thyratron - 884
R_5 - 170,000 Ω	C_5 - .005 μf	P_1 - Potentiometer 100,000 Ω
R_6 - 100,000 Ω	T_1 - Filament Transformer 6.3 v	P_2 - Potentiometer 250,000 Ω
R_7 - 120,000 Ω	T_2 - Filament Transformer 6.3 v	P_3 - Potentiometer 20,000 Ω
	T_3 - Filament Transformer 6.3 v	

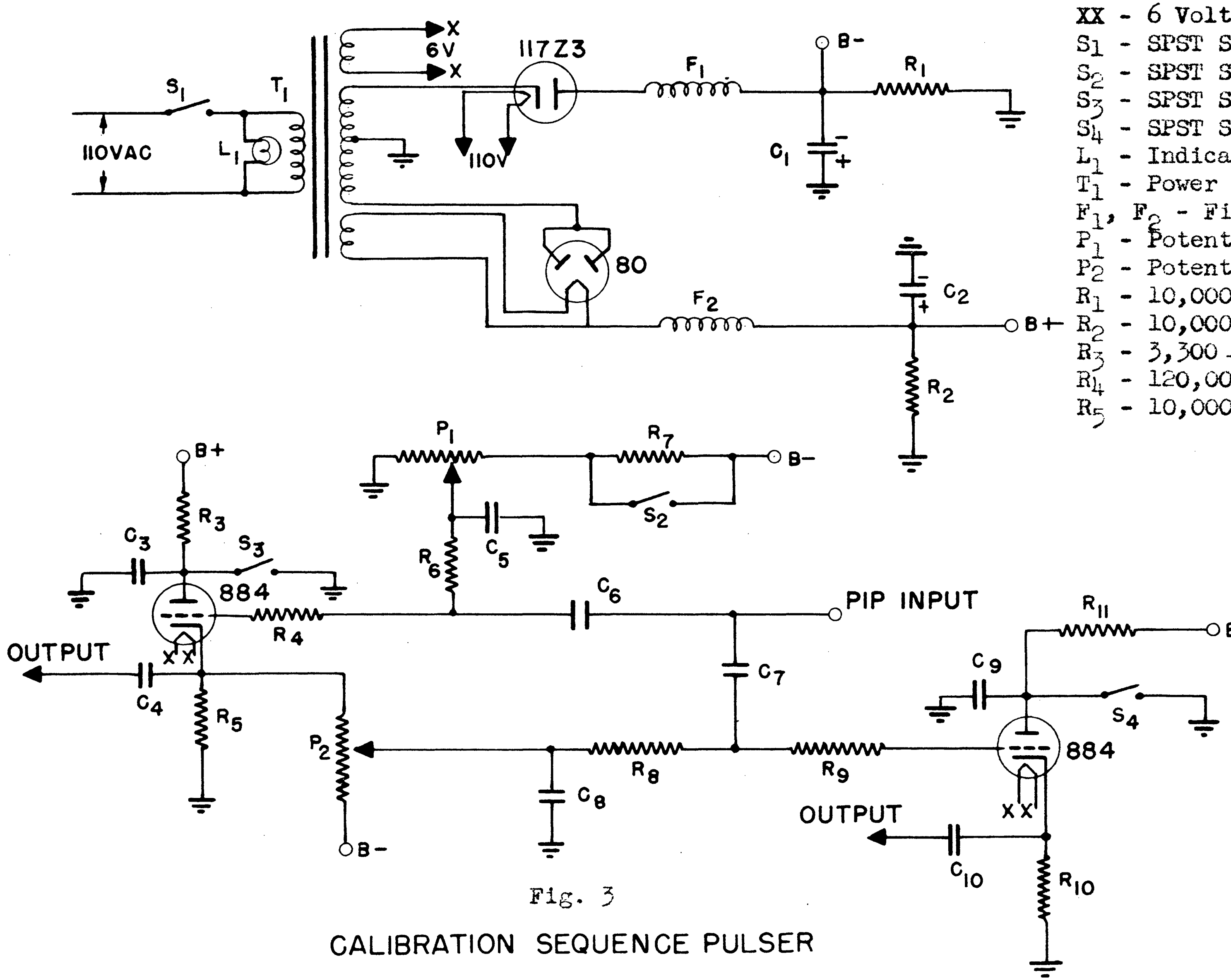
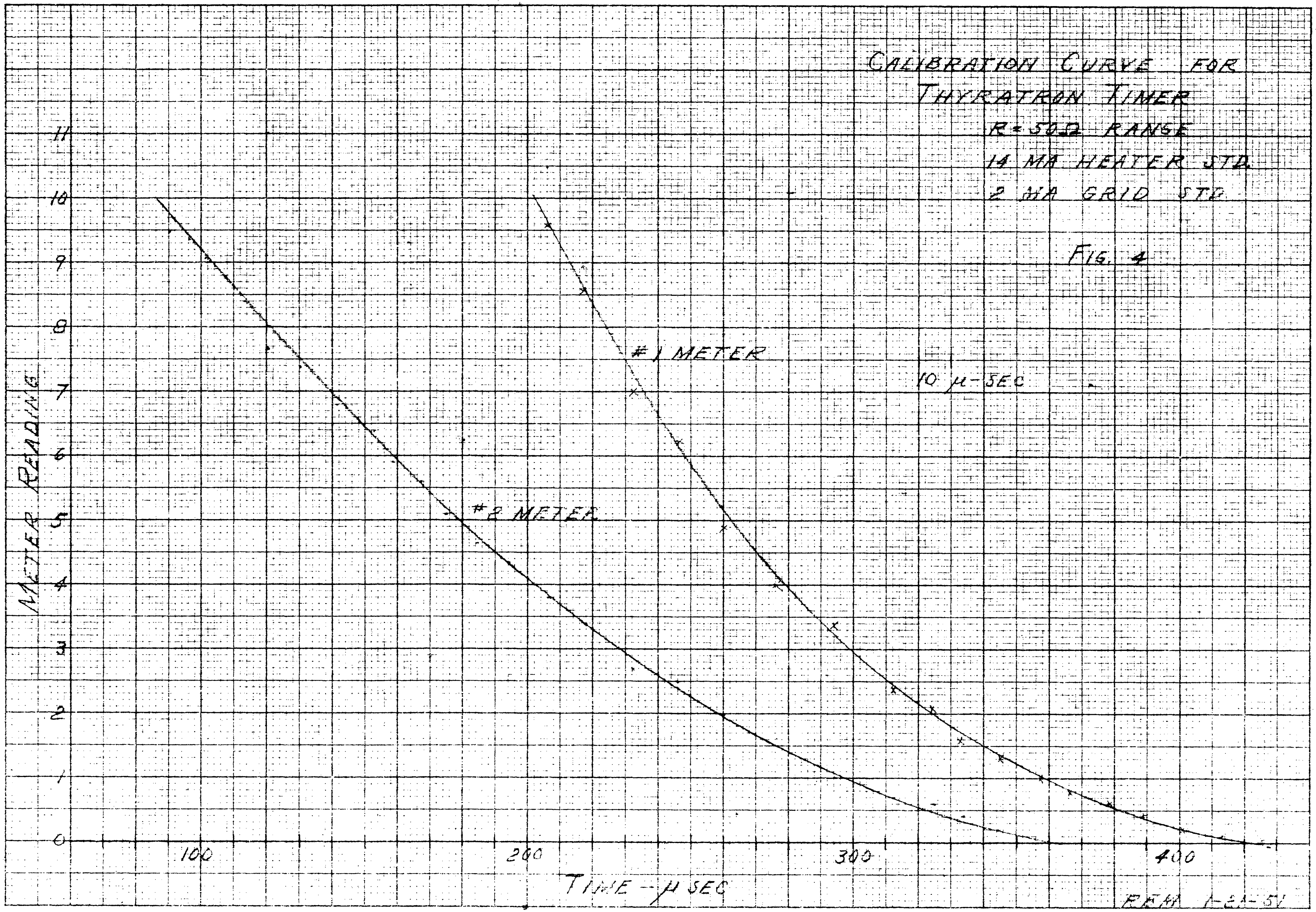


Fig. 3

CALIBRATION SEQUENCE PULSER

XX	-	6 Volt Heater Circuit
S_1	-	SPST Switch
S_2	-	SPST Switch
S_3	-	SPST Switch
S_4	-	SPST Switch
L_1	-	Indicator Light
T_1	-	Power Transformer
F_1, F_2	-	Filter Choke
P_1	-	Potentiometer 250,000 Ω
P_2	-	Potentiometer 500,000 Ω
R_1	-	10,000 Ω
R_2	-	10,000 Ω
R_3	-	3,300 Ω
R_4	-	120,000 Ω
R_5	-	10,000 Ω
R_6	-	120,000 Ω
R_7	-	500,000 Ω
R_8	-	100,000 Ω
R_9	-	100,000 Ω
R_{10}	-	10,000 Ω
R_{11}	-	2,700 Ω
C_1	-	40 µf
C_2	-	16 µf
C_3	-	6 µf
C_4	-	2 µµf
C_5	-	0.1 µf
C_6	-	50 µµf
C_7	-	50 µµf
C_8	-	200 µµf
C_9	-	700 µf
C_{10}	-	2 µµf


CALIBRATION CURVE FOR
THYRATRON TIMER
R = 50Ω RANGE
14 MA HEATER STD.
2 MA GRID STD.
FIG. 4
#1 METER
#2 METER
10 μ-SEC
METER READING
0
1
2
3
4
5
6
7
8
9
10
11
100
200
300
400
TIME — μ SEC
REM 1-31-51

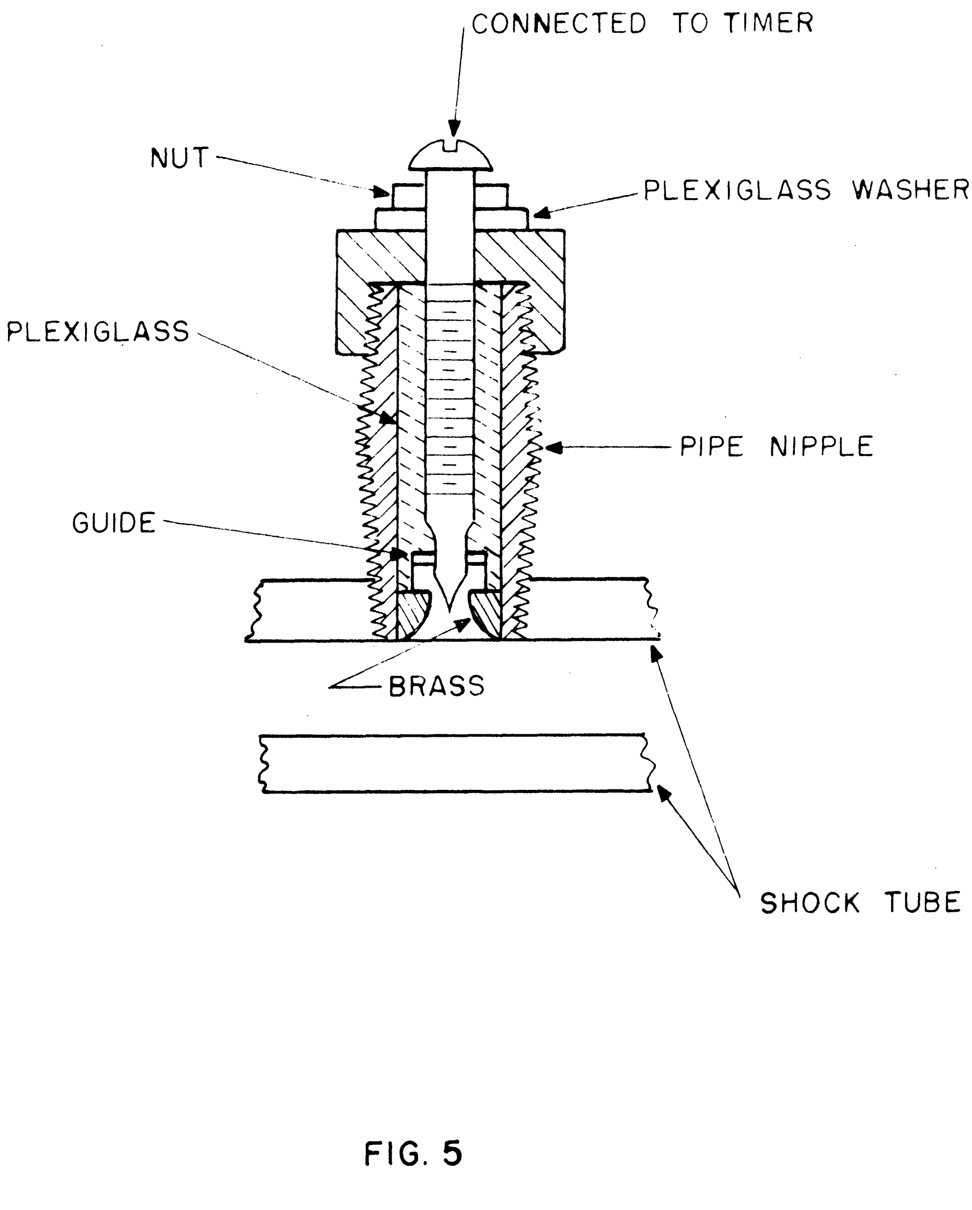

CONNECTED TO TIMER
NUT
PLEXIGLASS WASHER
PLEXIGLASS
PIPE NIPPLE
GUIDE
BRASS
SHOCK TUBE

FIG. 5

EXPERIMENTAL PROCEDURE

Acetylene-oxygen mixtures were selected for the initial experimentation with detonation inasmuch as it detonates readily and some data on its detonation velocities are easily obtainable. The tube in which the experiments were performed was a 15-ft length of schedule 160 pipe connected to a 6-1/2-ft length of similar pipe by means of a pipe union which was machined to receive diaphragms (see Fig. 6).

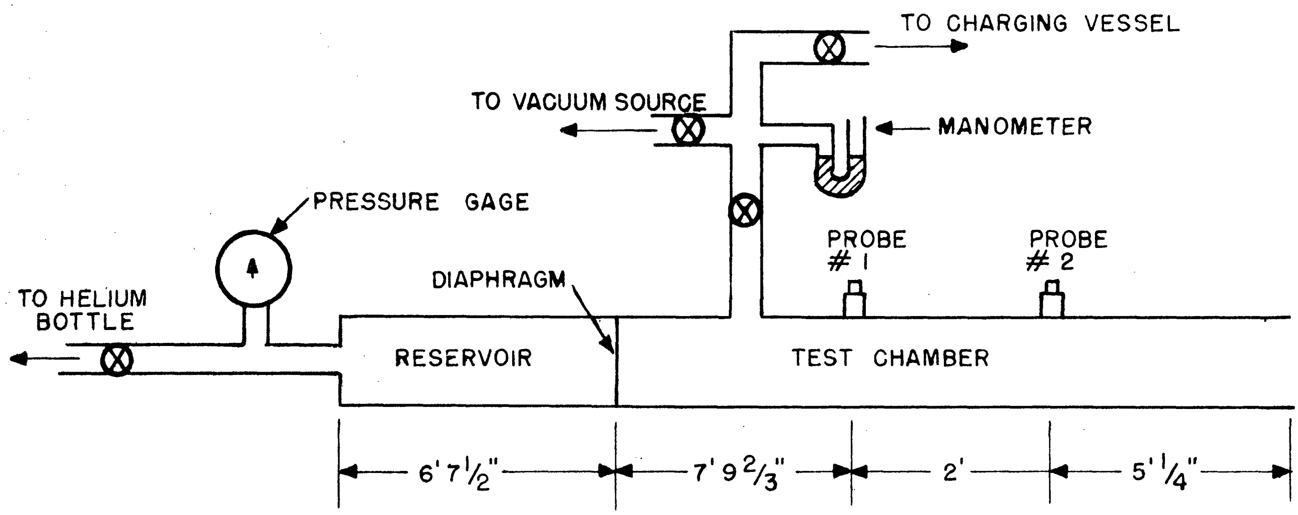


Fig. 6

The probes were located about 8 ft downstream from the diaphragm. At this location it was felt that the detonation wave would be fully developed. A few runs were made with the probes 2 ft further downstream with no change in results.

The acetylene and oxygen were premixed in a charging vessel of approximately a cu-ft volume, the fuel-oxygen ratio being determined by the

partial pressures to which the vessel was charged with each gas. Preliminary to charging the test chamber, a diaphragm was put in place and a piece of rubber tape was stuck over the open end of the tube. The test chamber was evacuated by the vacuum source and the tube filled with a fuel-oxygen mixture. The test chamber was re-evacuated in order to purge it and then filled to the desired pressure. Helium was then let into the reservoir until its pressure broke the diaphragm.

Data obtained in this manner for acetylene-oxygen mixtures are shown in Fig. 7. Shock velocities obtained in this manner are shown in Fig. 8.

DEVELOPMENT OF THE 8-INCH MACH-ZEHNDER INTERFEROMETER

The manufacture and construction of the interferometer is in the final stages. Design work has already been completed for some time and only the manufacturing of some parts remains. There has been a considerable delay in the shop; apparently due to priority. However, it is anticipated that all parts will be finished in the next three or four weeks. Partial assembly of already completed parts has been made.

Considerable time has been spent also on the design, manufacture, and assembly of a suitable support system for the interferometer. An overhead crane system is now available in the laboratory for convenient transporting of the approximately 1800-lb instrument. Its operating position may be conveniently fixed at any desirable angle. This support system will lend itself very readily to bringing the interferometer to the various test setups, increasing its versatility.

A separate report is currently being written describing in detail the interferometer. This report will also include an operation manual.

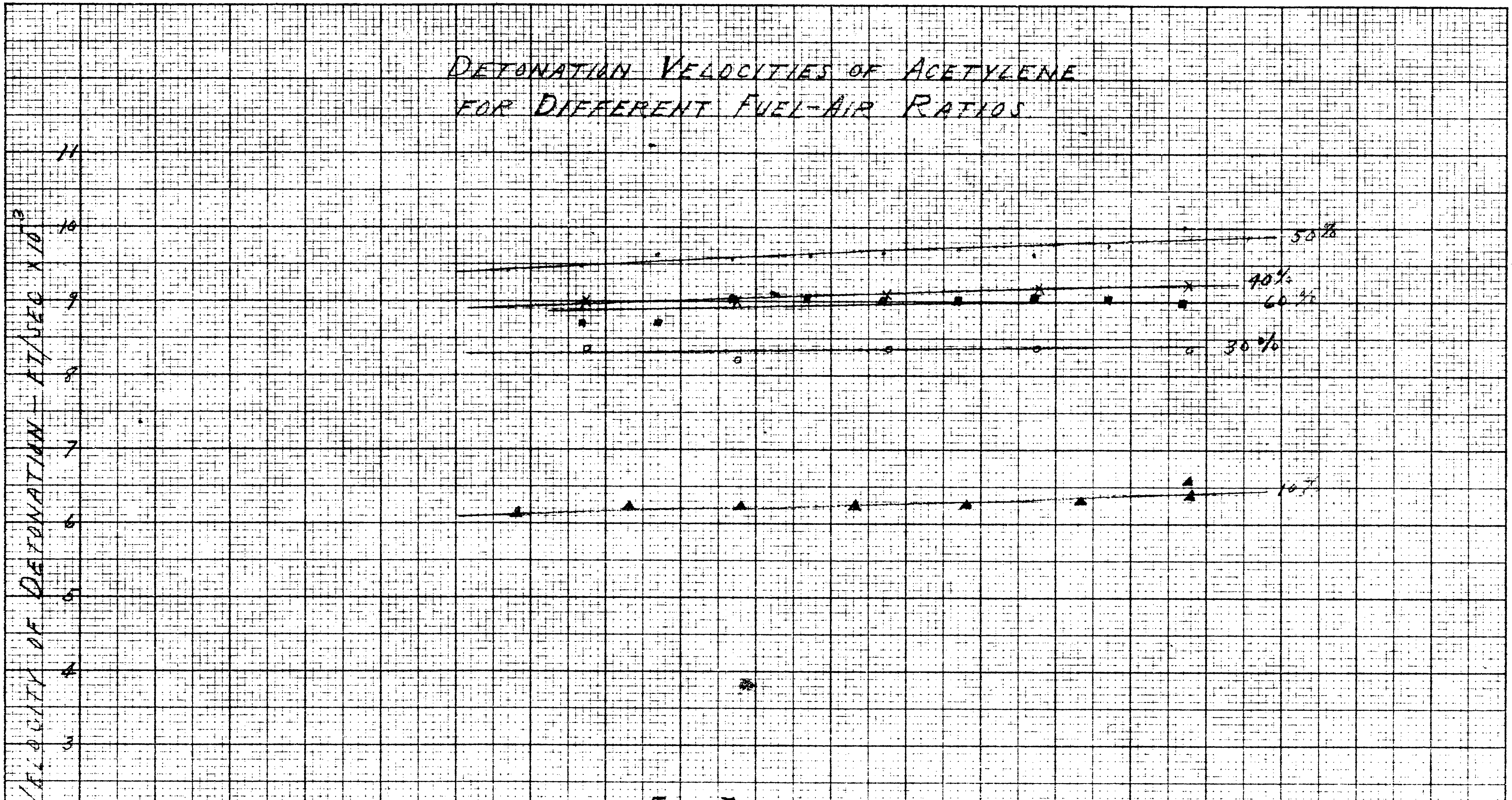

DETONATION VELOCITIES OF ACETYLENE
FOR DIFFERENT FUEL-AIR RATIOS
VELOCITY OF DETONATION - FT/SEC X 10^{-3}
PRESSURE - INCHES Hg ABSOLUTE
50%
40%
60%
30%
10%
0
1
2
3
4
5
6
7
8
9
10
11
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

FIG. 7

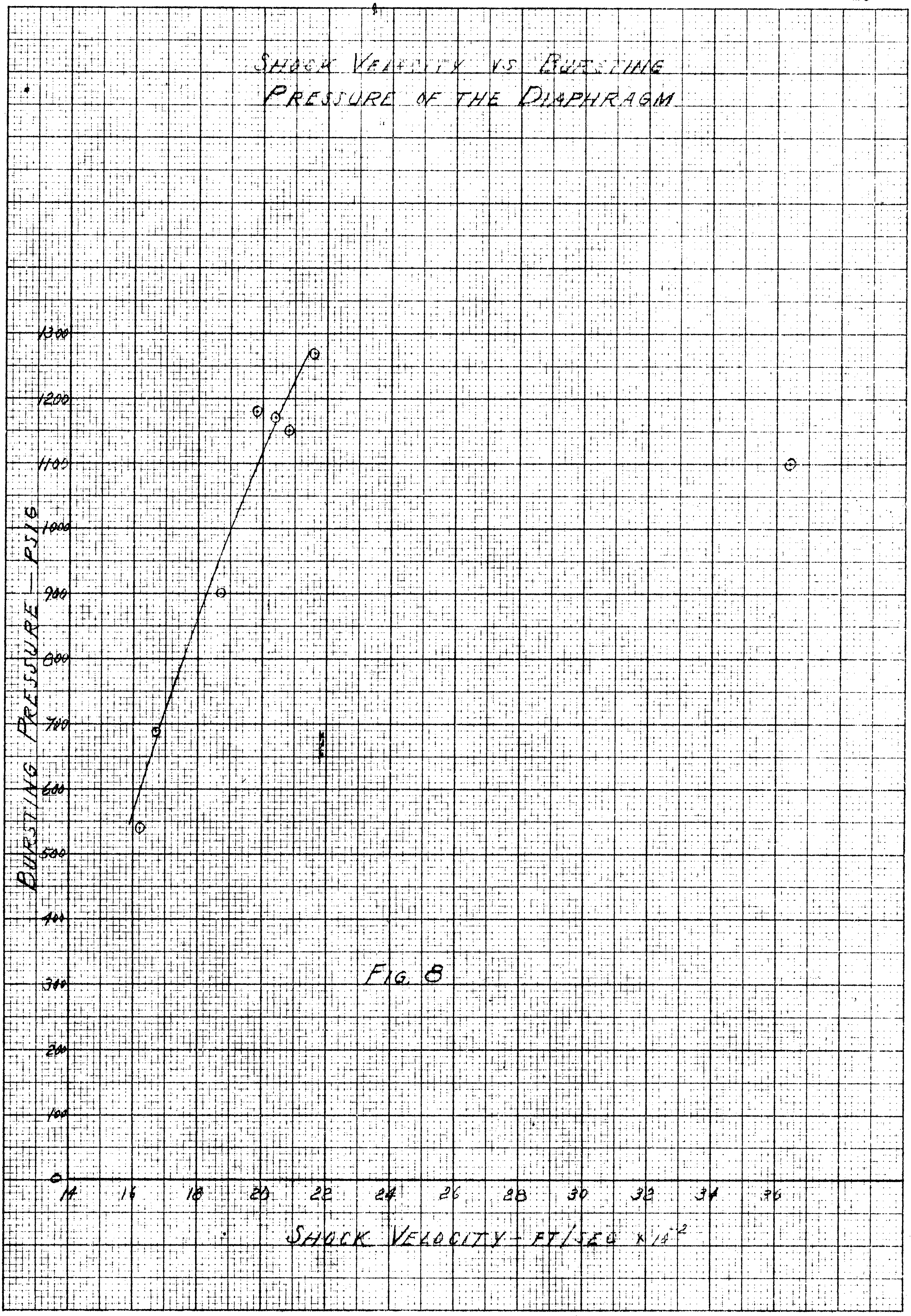

SHOCK VELOCITY VS BURSTING
PRESSURE OF THE DIAPHRAGM
BURSTING PRESSURE — PSIG
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
14
16
18
20
22
24
26
28
30
32
34
36
SHOCK VELOCITY — FT/SEC x 10^-2

FIG. 8

Proposals for the use of the interferometer in combustion and propulsion studies have been partially completed. These should be available for discussion as soon as the instrument is assembled.

The light-source system will use a B-H6 mercury-vapor lamp as the prime source of monochromatic light (with suitable filters). The control unit for this lamp has been completed and is shown in Figs. 9 and 10. Continuous or flash operation is possible. The flash unit is shown on top of the main control box. Fig. 11 shows a schematic diagram of the electrical and air-cooling setup for continuous operation. The lamp operating only in a horizontal position must be air-cooled with about 7 cfm of air at about 40 lbs of pressure. The time-delay relay keeps the air on for about 10 seconds after the current has been shut off. This lengthens the life of the lamp.

Other characteristics of the B-H6 mercury lamp are:

Rated lamp watts	900
Lumens	65,000
Candle	$300/mm^2$
Pressure	110 atm
Operating voltage	840 v
Operating current	1.4 amp
Starting time	4 sec to full output
Source size	2 x 20 mm approximately

The flash duration of the lamp is about 4 to 5 microseconds. It is flashed by discharging a 2-μf capacitor at 2200 volts and triggered by a thyratron circuit. Fig. 12 shows the circuit diagram of the flash unit.

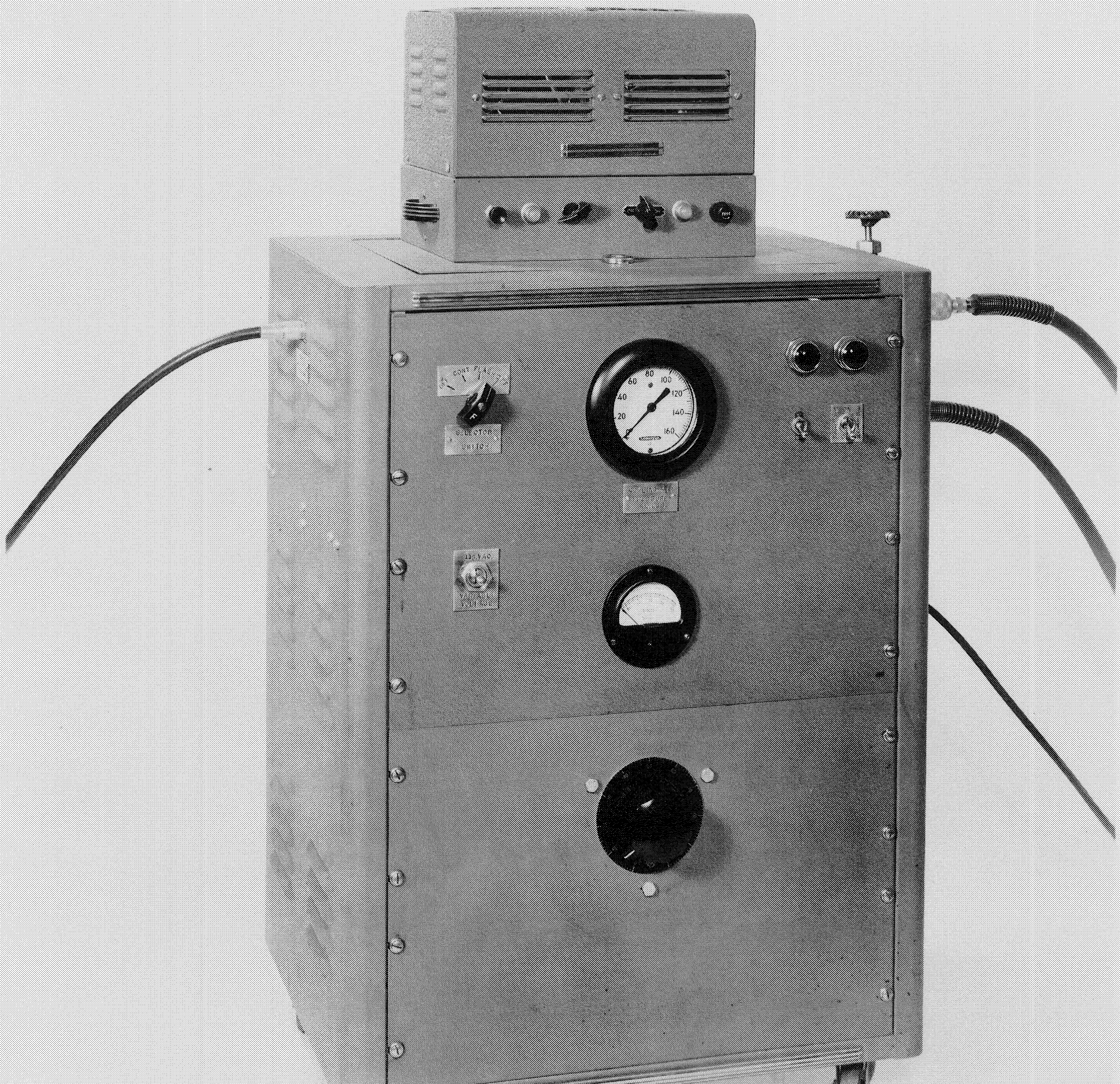


Fig. 9

Front View Control Unit

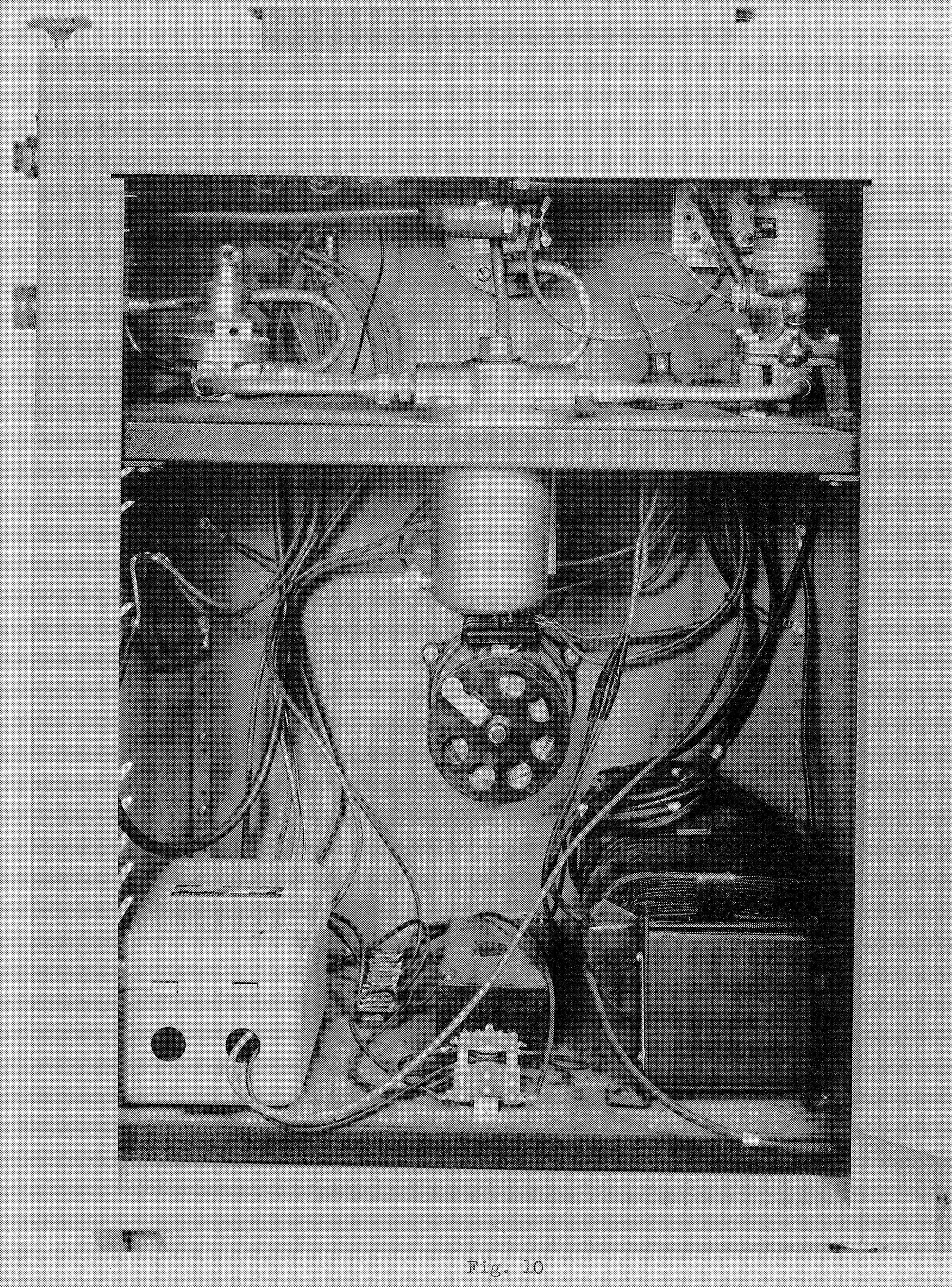


Fig. 10

Rear View Control Unit

CONTROL UNIT B-H6 LAMP

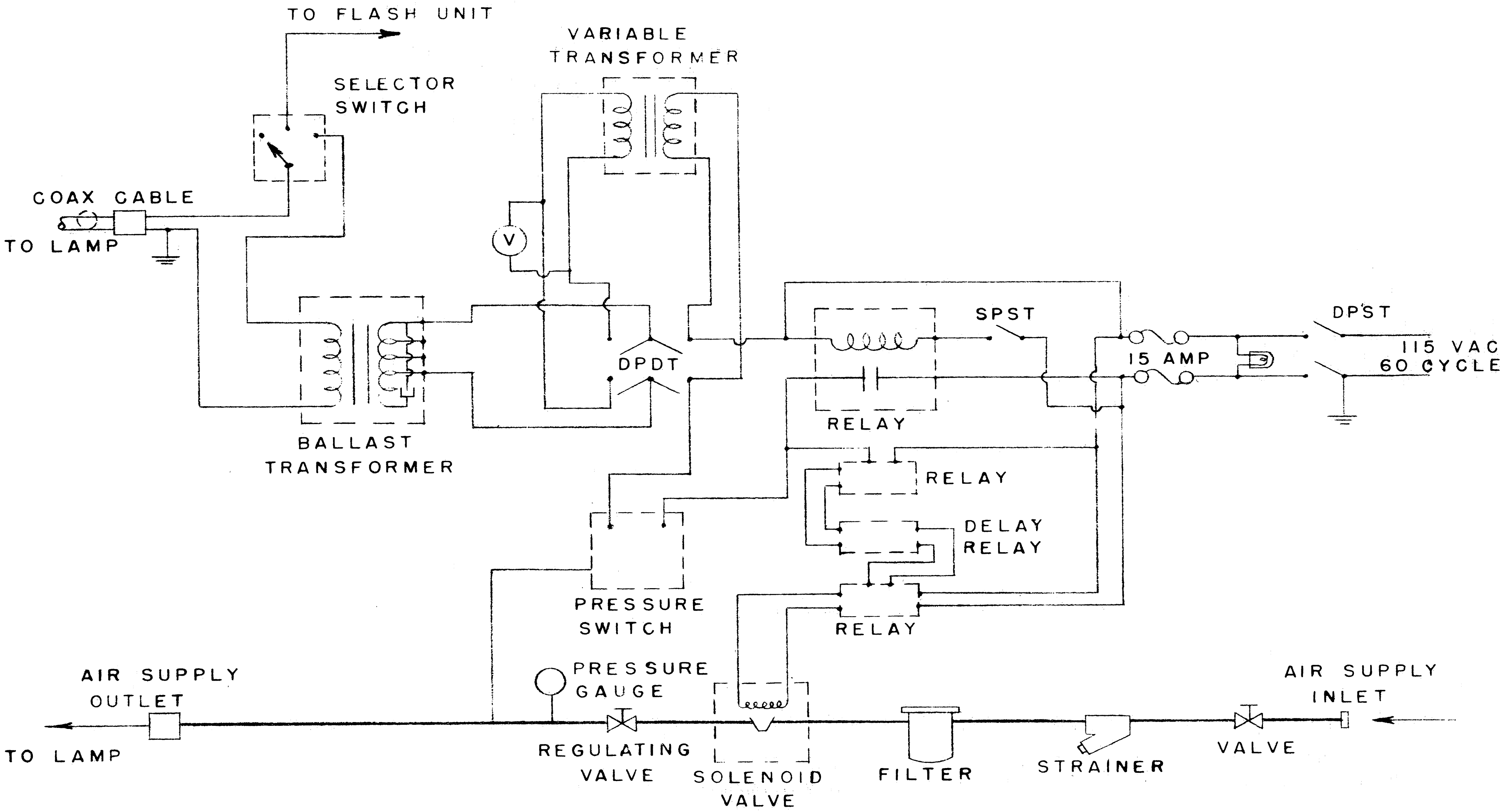
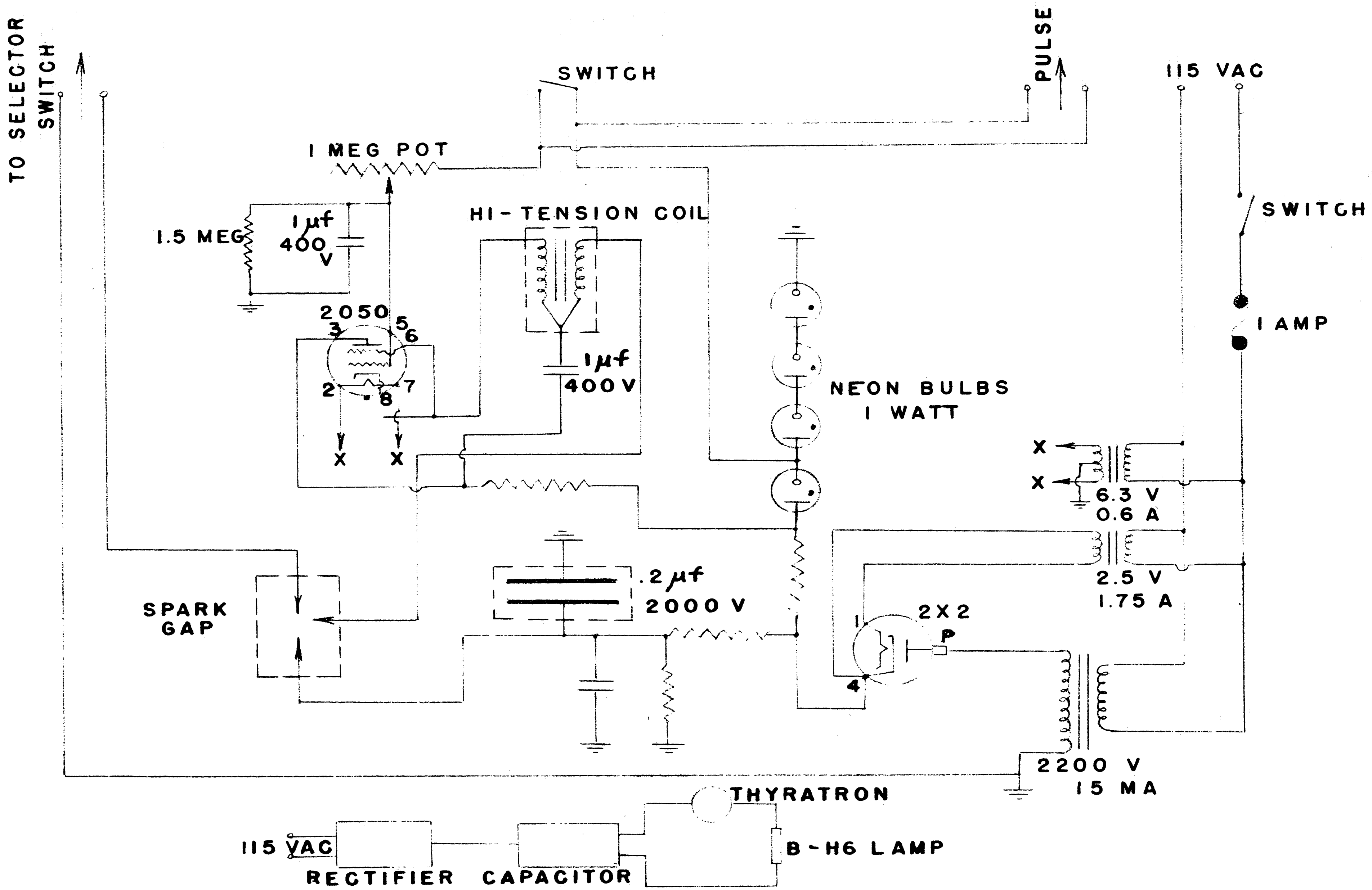


FIG. 11



FLASH UNIT B-H6 LAMP

FIG. 12

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