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JULY 16th NUCLEAR EXPLOSION: FAST ELECTRONIC TIMING SEQUENCE

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Abstract

The present report discusses the design and performance of the electronic equipment which was used at Trinity on July 16th to provide time signals during the last 100 milliseconds to an accuracy of $\pm 1/2$ ms, to fire the gadget and to provide certain signals related to the firing signal with an accuracy better than 0.1 microseconds.

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Problem

In order to coordinate the functions of the cameras, spectroscopes, electronic measuring gear, etc., set up in the countryside around the test bomb at Trinity a master timing system was required. Since observers were not allowed to be nearer to the gadget than the 6-mile shelters S10[4], W10[4] and N10[4] (Fig.1) remote control of most field equipment was necessary and timing signals between the 3 main shelters were essential.

The functions required of a master timing system fall into 3 main categories.

1) Switching required in the period up to 60seconds before the event. For example, turning on heaters of electronic equipment in the field, etc.
Such functions can be carried out satisfactorily by manual switching at the control station.

2) Switching required in the last 60 seconds which does not require time accuracy better than ± 50 milliseconds. Examples are application of B+ to field equipment, camera shutter excitation, etc.
Such switching can be readily achieved mechanically by means of a rotating drum system.

3) Operations required in the last 100 milliseconds with accuracies of ± 1/2 milliseconds or better. The equipment requiring such service will be described fully later and the present report discusses the design and performance of the electronic circuits built to meet the requirements.

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The equipment for 1 and 2 above was designed and built by E. Marlowe and J. L. McKibben and is described elsewhere. The equipment under 3 is the subject of this report.

Electronic Method Used for Timing in the Interval (t_o - 0.1) sec to t_o

The block diagram of Fig. 2 indicates the elements of the method.

A long sawtooth, initiated by a relay closure at (t_o - .1) sec from McKibben's Drum System, rising linearly to 200 volts in 100 milliseconds, together with a second sawtooth of five times the slope started at (t_o - 20) m secs and rising linearly to 200 volts by t_o are the essentials.

A system of discriminators arranged to fire at preselected points on either the fast or slow sawtooth then allow pulses to be generated at any time within the given 100 m sec interval. The signals derived from the discriminator pulses were shaped and could be made to put either positive or negative signals onto the lines by means of the Mixer Line Driver.

A code of positive and negative signals could thus be transmitted over the lines to N10,000 or W10,000. The band-pass characteristics of these lines in order to give rise times at the receiving end of 1/2 ms or so will be seen to be about 2-3 KC. Standard Army-Navy twisted pair telephone line fulfil the requirement and was used to convey the signals a little over 12 miles to N10,000 (a big loop around the gadget was necessary) and some 8 miles to W10,000 (Fig. 1).

The local t_o signal required accurately for equipment in the S10,000 shelter was tied in with the firing pulse to better than ± 1/2 microseconds. To carry the fast firing signal from S10,000 to the gadget a line of much greater band-pass was essential and 5 miles of RG54AU coaxial cable were laid.

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Even then experiment showed that the rise time at the receiving end was greater than 5 microseconds and to eliminate difficulties from the slow wave front, this pulse was sharpened at the gadget and the high-accuracy timing required for the Wilson and Rossi experiments was made with respect to this exceedingly steep wave-front.

Measurement of Time Intervals

In order to calibrate the saw-tooth generators and the over-all equipment a time measuring system was required. A scale of 2^{10} (1024) was provided for this purpose. Normally it was set up to "count" the cycles of a 16KC sine wave derived from a Hewlitt-Packard RC oscillator type. 200C. This oscillator was found to be very stable after a warm-up period but was adjusted to the exact frequency whenever necessary by scaling the 16KC down to 2KC and using this 2KC wave to form a Lissajou figure with a standard 1KC frequency from an electrically maintained tuning fork. A stationary pattern on the CRO indicated exact tuning to 16KC.

In order to measure time intervals the scaler unit was converted to a Counter Chronograph by the addition of a "gate" circuit. That is, the 16KC sine wave was applied to the scaler through an electronic circuit which, normally, prevented its passage. However, on receipt of a positive signal (the beginning of the interval of be timed) the circuit is "opened" and the scaler commences to count the cycles of the 16KC sine wave.

A second signal applied to the circuit, at the end of the interval to be timed, "closes" the gate and prevents the sine wave from reaching the scaler. The scaler, therefore, counts the number of cycles bracketed by the two signals and hence provides a measurement of the interval between them to 1 cycle or 1/16 millisecond.

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Thus measurements of all signals including the (t_o - 0.1) sec with respect to the t_o signal could be accomplished.

Statement of Requirements

a) Slow timing, i.e. accuracy ± 1/2 milliseconds
May 6th requirements 100-ton test

MACK

Place	Instrument	Time and Tolerance Milliseconds
N 10^4 W 10^4	B L Spectroscope	-97 ± 1
N 10^4 W 10^4	Hilger Spectroscope	-16.8 ± 1

HOUGHTON + COON

		Time Required
N 10^4 S 10^4	Geophone Recorders	t_o ± 1 millisecond

WALKER

N 10^4 S 10^4	Piezo Gauges	Signal related to t_o ± 1 millisecond

BARSCHALL

N 10^4 S 10^4	Sound Velocity Measurement	Signal related to t_o ± 1 millisecond

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These requirements reduce essentially to 3 signals

- 97 $\pm$ 1 milliseconds

- 16.8 $\pm$ 1 milliseconds

t_o $\pm$ 1 milliseconds

and for the 100-ton test were coded onto the lines as indicated in Fig.

For the July 16th test Mack's requested requirements changed to: -

Place	Instrument	Milliseconds
N 10^4 W 10^4	B + L Spectroscope	$t_o \pm 1$
N 10^4 N 10^4 W 10^4	Hilger Spectroscope	- 16.8 $\pm$ 1/2
N 800 W 800	Marley Camera	- 40 $\pm$ 1
W 10^4	Photocell Drum Camera	- 40 $\pm$ 5

A coding as indicated in Fig. was therefore chosen and the receiving end equipment designed to decode this pulse series.

Before the final experiments these requirements were amended. The Marley Camera Expt. was abandoned and the B L Spectroscope was moved forward as: -

Place	Instrument	Milliseconds
N 10^4 N 10^4	B + L Spectroscope	- 40 $\pm$ 1
N 10^4	Photocell Drum Camera	
N 10^4 W 10^4	Hilger Spectroscope	- 16.8 + 1

[redacted]

[redacted]

Thus the same coding could be used but another decoding system was required.

6) Fast Timing, i.e. Accuracy + 0.1 microsecond

For the Wilson-Rossi Experiments a pulse rising 300 volts in less than 0.1 microsecond and exactly related in time with respect to the firing pulse supplied to the gadget to $\pm$ 0.1 microsecond was required. Such a pulse was derived from the pulse sharpening circuit at the tower and was supplied over 1000 yds. of RG9U coaxial cable from the tower to the N 1000 revetment. This cable was correctly matched at the receiving end so that its input impedance was purely resistive and provided a suitable load for the pulse-sharpening circuit.

SENDING END EQUIPMENT

1. Sawtooth Generators and Discriminators, Fig. 4, Dwg. 724.

A relay closure effected by the Rotating Drum system at $(t_0 - 0.1)$ sec applied e.m.f. to the relay coil energizing S_1 and S_2.

Closure of S_1 throws the 8 μf condenser charged to -150v in series with the 4 μf condenser in the grid circuit of V_1. A transient pulse of -100v is applied to the grid of V_1 cutting off this tube. The transient condition finally gives way to the steady state valve of grid voltage of -75v determined by resistors. As soon as V_1 ceases to conduct its plate potential, which had been caught at +10 volts by the diode V_{15}, leaps to a value equal to the product of the current in V_1 before cut off and the 25K resistor in the C.R. coupling to ground -- i.e. a voltage step of 10 volts.

Thereafter the plate voltage of V_1 rises linearly through the standard "boot strap" feedback circuit including V_3 ~~and V_2~~.

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The slope of the linear sawtooth appearing at the cathode of V_3 can be varied by adjusting the variable 70K in the plate of V_1. The sawtooth at the cathode of V_3 is applied directly to the grid of V_4 which in conjunction with V_5 comprises an a.c. coupled discriminator circuit.

The grid potential of V_5 can be varied between some 10 -- 160 volts by means of a linear wire around G.R. 100 K potentiometer. Suppose it is set at + 100v, then V_5 will be conducting and its cathode will be at some 105v (say).

Since the grid of V_4 is connected to the cathode of V_3 which in the static condition is at about 20v ground it follows that V_4 is cut off. When the sawtooth rises the grid of V_4 begins to carry current thereby applying a negative pulse to the grid of V_5. Cathode regeneration then provides a rapid change over of current from V_5 to V_4. The sawtooth is not distorted because the cathode of V_4 continues to follow up and grid current is not drawn. The positive voltage rise at the plate of V_5 is used as the output signal. The amplitude of this wave decreases the higher the grid voltage of V_5 but the circuit constants are chosen for its minimum value to be sufficient.

A constant output pulse can be obtained from this circuit by replacing the 150K cathode load by a constant current device -- pentode or saturated diode but this was not deemed worth the extra complication.

The time at which the pulse is generated at the plate of V5 is related to the closure of S1 according to the position of the G.R. pot and a 0-100 scale on this spot can be calibrated to read milliseconds directly by adjusting the SLOPE (70K plate circuit of V_1) and ZERO controls.

V_{11}, V_{12}, V_{13}, and V_{14} are exactly similar discriminator circuits

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except that in these cases the slope and zero adjustments are both located on the potentimeter chain.

In practice the discriminator V_4 and V_5 is used to initiate a second sawtooth 80 milliseconds after the closure of S_1. The negative gate at the anode of V_4 cuts off V_7 which together with V_8 and V_6 form a fast sawtooth generator identical in principle with the slow one. To maintain V_7 permanently cut off the A.C. coupling from the plate of V_4 is insufficient and the input relay switches S_2 from position 1 to 2 which, through the diode V_{17}, eventually holds the grid of V_7 at -75v RE ground.

The sawtooth rises 150 volts in some 20 milliseconds and by means of the slope and zero settings the potentiometer of the discriminator V_9, V_{10}, is calibrated to read 0-20 milliseconds directly.

The positive pulse generated at the anode of V_{10} is used as the t_o signal and occurs exactly 100 m secs after S_1 closes.

The second sawtooth was considered necessary to improve the accuracy of timing near to t_o - the steeper sawtooth providing providing improved firing of circuits driven from it. Normally, the discriminators V_{11}, V_{12} were operated from the slow sawtooth i.e. in the interval $(t_o - 0.1)$ secs to $(t_o - 20)$ millisecs and V_{13}, V_{14} operated from the fast sawtooth to provide signals in the range $(t_o - 20)$ ms to t_o. Provision is made to switch discriminators V_{12} and V_{13} to either the slow or fast sawtooth channels. The unit thus allows pulses to be generated in the 100 ms period before t_o, each pulse being phasable with respect to the t_o pulse.

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2. <u>Four Channel Line Driver, Fig. 5, Dwg. 725</u>

Three identical channels of this unit comprised pulse forming circuits, pulse amplifiers, pulse inverters and driver stages capable of mixing positive and negative signals and transmitting them over the twisted pair lines to the remote stations.

Two only of these channels were used, one to send to N10,000 and the other to send information to the W10,000 station. The third channel was a stand-by.

The drawing shows one of these channels. Discriminator pulses put in at sockets 1, 2, or 3 are mixed in V_1, V_2, V_3 which are normally cut off. A positive discriminator input pulse drives V_1 into grid current, the input time constant determining the pulse duration (in this case about 1.5 milliseconds).

The wave appearing at the anode of V_1 is a negative rectangular wave of amplitude 175_v which is used to cut off V_{10} providing a positive rectangular pulse of 300 volts amplitude at its anode. This positive pulse is applied to the line at low impedance through the cathode follower V_8.

Insertion of the discriminator pulses in sockets 4, 5, 6 provides similar negative pulses at the anodes of V_4, V_5, and V_6 which are D.C. coupled to the inverter V_7 which is operating at $E_g = o$. The negative pulse appearing at the grid of V_7 cuts it off completely providing a 200 volt positive pulse at the grid of V_9 which is driven into grid current and provides a negative pulse of amplitude about 250 volts to the line.

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The twisted pair lines were not terminated at the receiving ends in order to take advantage of the voltage gain at the end of a line terminated in a resistance large compared with its characteristic impedance. These lines therefore behaved as capacitative loads on the driver circuits.

At the receiving end, after transmission over 12 miles of twisted pair, the peak amplitude of the pulse was about 110 volts rising in 1/2 ms. With circuits tripping at a 30-volt level and including the undetermined transmission time on the line -- about 150 microseconds -- the tie-in with the sending end was considerable better than 1/2 ms.

The fourth channel of the equipment provided t_o signals to measure equipment in the same shelter (S10,000).

The output pulse from the t_o discriminator was fed through a cathode follower V_{11} to fire a 2050 thyratron V_{12}. The 250-volt fast positive cathode pulse was supplied to the detonator line driver and also to the pulse stretcher V_{13}. The lengthened pulse from V_{13} was supplied to three cathode followers $V_{14, 15, 16}$ in parallel which provided the signal to the various customers over short lengths of twisted pair. Grid current limiting resistors were provided for V_{13} and V_{14}.

V_{17} is a pair of cathode followers convenient as buffers for feeding discriminator pulses to various points.

V_{18} and V_{19} are thyratron pulse sharpeners accepting a positive input pulse and providing exceedingly fast 300 v output pulses at the cathodes.

3. Detonator Line Driver, Fig. 6, Dwg. No. 614

This unit, located at S10,000, accepts the local t_o signal from the line driver unit and delivers a 1500 volt signal to the coaxial firing

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firing line. The pulse has a rise time of less than 0.1 microsecond and an exponential tail falling to 1/e in 2 milliseconds. The six miles of unterminated coaxial cable provides a capacitative cathode load but the anode storage condenser is chosen to be large in comparison to this so that practically the full voltage is developed across the line.

The pulse at the receiving end of the RG54AU cable had a peak amplitude of 700 volts and rose to peak in 5 microseconds i.e. is badly distorted by the line. Since this wavefront is too slow it was sharpened at the base of the tower and the resulting steep wave front used as a time datum.

The present 4C35 circuit is self-quenching and a neon indicator enables an external check to be made of satisfactory firing and also that the peak output pulse exceeds a certain level. The tube has a peculiar characteristic in that, on firing, the grid initially leaps up to plate potential before taking up a mean potential in the plasma. This, coupled with the elevated cathode potential following on conduction, causes a strong, fast positive pulse to be fed back into the driving circuit which over-drives the local t_0 cathode followers.

4. Counter Chronograph, Fig. 7, Dwg. 719

The circuit employs a conventional scale-of- 2^{10} circuit embodying the 6SL7 unit. The pulses fed to the scaling circuit are shaped by the discriminator V_1 and V_2 which is set to "fire" on the positive slope of the positive slope of the positive half cycle of the sine wave. If the grids of V_3 are switched to ground a rectangular voltage wave is generated at the plate of V_2 every cycle and this wave is fed directly to the scaler unit

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S_1 which feeds S_2, etc. --- S_{10}. S_{10} can be employed to drive V_6 which operates a mechanical counter.

A counter is not generally used, however, since interpolation on N_1, N_2 --- N_{10} enables all intervals up to 100 ms to be measured directly. With the grids of V_3 unclamped fromground (switch open) the static grid voltage of V_3 is such that the cathode of V_3 elevates the grid of V_2 by a few volts.

The negative pulse appearing at the anode of V_1 per cycle of the sine wave looks into the low impedance of V_3 and is therefore heavily attenuated. The small positive pulse resulting at the anode of V_2 is then far below the level required to operate the first scaler S_1. The circuit is thus "clamped".

For free running (calibration, etc.) the circuit can be unclamped by closing the switch and maintaining the grids of V_3 at ground potential. V_3 is thus cut-off and the signal at the grid of V_2 is not affected by it.

Electronic unclamping and clamping are effected by means of tube V_4 and V_5.

A positive signal applied at input 1 causes the anode voltage of V_4 (1st half) to fall thereby cutting off V_3 and unclamping the discriminator. Meanwhile the fall in plate voltage of V_4 (1st half) and V_5 (1st half) triggers the univibrator V_5 and the plate of V_4 (1st half) is held down and hence the circuit is unclamped for a period depending on the a.c. coupling constants of the univibrator. This period is chosen to be 150 milliseconds i.e. greater than any interval to be measured. A.C.

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coupling is used as a precaution against the circuit accidentally being tripped into a wrong stable condition.

A second (later) positive signal applied at input 2 reclamps the circuit as follows: - The tubes V_4 (2nd half) and V_5 (2nd half) conduct and their plate voltages fall. The univibrator is thus kicked back into its stable state, the plate voltage of V_4 and V_5 (1st halves) rise and V_3 is again brought into conduction to reclamp the discriminator V_1 and V_2.

Receiving-End Equipment

General

A code of positive and negative pulses appears at the receiving end of the lines. Usually a switching action is required on one only of these pulses. The method of approach is therefore to count the pulses of one sign and arrange for circuit operation on the appropriate count.

The completely general circuit would be able, by prearrangement, to initiate on any of the 1st, 2nd, 3rd ---- positive pulses or 1st, 2nd, 3rd ---- negative pulses. This would make the system completely flexible.

The counting can be achieved most readily by means of conventional scale-of-two circuits and an inverter makes positive and negative pulse acceptable. Switching is usually effected by means of a thyratron.

In the present case, since the operations to be performed were fixed and known in advance it was unnecessary to make the circuits completely flexible and thus much time was saved and more compact units achieved. In what follows, however, the general principles of a flexible scheme are illustrated.

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1. Bausch and Lomb Clutch Driver, Fig. 8, Dwg. 645

The circuit is arranged to apply a.c. power to a re..y which throws in a mechanical clutch at a time related within ± 1/2 ms with t_o. Closure of the clutch causes the velocity of the film flow through the spectroscope to be reduced according to a $\frac{1}{T}$ law thereby providing correct exposure throughout the light flash. (See LAMS Report by Julian Mack).

The circuit has two functions according to the position of the switches S1 and S2.

Switch Position 1

The first positive input pulse drives the grid of V_6 positive through the cathode follower V_1. V_6 fires thereby closing the contacts of the relay (Advance 204 AM or BM) in its anode circuit. One contact of this relay completes the clutch power circuit but is insufficient to carry the steady current. The other contact is therefore used to apply a.c. to the coil of the Dunco IXBX relay. On closure this takes over the duty of carrying the current (one pole) and meanwhile the other contact is used to perpetuate current flow in its coil thereby maintaining it closed. Meanwhile the 204AM relay opens when V_6 extinguishes.

The circuit is reset i.e. the IXBX relay opened by applying a short circuit across the "Relay Reset" terminals thereby opening the normally closed Dunco CRTX or IXBX relay momentarily.

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Switch Position 2

In this position the first input positive pulse is cathode followed through V_1 inverted by V_2 and used to drive a single 6SN7 scaler stage (Fig. 9, Dwg. 247). The negative pulse developed at the anode (pin 3) applied through the cathode follower V_5 is ineffective in firing V_6. However, on receipt of the second positive input pulse the rise of plate potential at pin 3 provides a positive pulse delivered through V_5 which fires V_6.

Thus the circuit operates on the second positive pulse. Before use the scaler unit has to be "reset" in order that it shall not accept the first positive pulse. This is achieved by allowing the point p8 to rise positively by opening the "reset" switch.

Indication of the unit being in its correct equilibrium position is given when the neon bulb connected from pin 3 to B + through 1MΩ is extinguished.

The time delay between the receipt of the firing pulse and the closure of the clutch circuit was checked using the counter chronograph and, after manipulation of the 204 BM relay, was reduced to 1.6 milliseconds.

Reproducibility of this delay was to ± 1/16 millisecond and well within the requirements.

The three circuits (one $N10^4$, one $W10^4$ and the spare) were trimmed up to be identical and these delays were added in as constants in setting the discriminator circuit.

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2) Hilger Solenoid Operator, Fig. 10, Dwg. 619

This circuit has to reject positive pulses and accept the first negative pulse.

V_1 is a diode connected to the grid of V_2 which is a straight amplifier. The cathode of V_1 is biassed to + 12 volts to prevent the negative "tail" of a positive pulse from feeding trough. The amplitude of such tails is kept low by maintaining the input time constant at a value large compared with pulse duration.

Capacity feed through V_1 is negligible since the input capacity of V_2 is large due to the Miller effect. Receipt of a negative pulse at the input drives the grid of V_2 negative producing a positive pulse at its anode and hence at the grid of V_3. When fired V_3 discharges 400 μf into the solenoid operating the shutter plunger (which is an inductive load in the cathode circuit) thereby providing fast operation. By allowing the plunger to close an electrical circuit the delay and consistency of operation where examined using the counter chronograph and were found to be 1 ms $\pm$ 1/16 ms.

Peak current limiting resistors were included in the plate circuit of V_3 which was self quenching.

3) Marley Camera Shutter Release, Fig. 11, Dwg. 641

These circuits to be located at W800 and N800 had to be powered by batteries since no A.C. was available and therefore had to be remotely controlled by relays. Minimax batteries are used for B + (applied at - 1 min) and storage batteries for cathode heating (applied at -10min).

The circuit fires on the first positive pulse and is self explanatory.

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4) Galvo Step Wave Timer, Fig. 12, Dwg. 616

In general at N10,000 the whole of the pulse sequence was put onto one recording channel of the Heiland Mechanical Oscillographs and hence all records were related with respect to the firing pulse.

At S10,000 the t_o signal alone was supplied to all recorders to provide a time fiducial.

In one case at N10,000 a step wave was required on the record in known time relation to the t_o signal.

The circuit of Dwg. 616 was built to provide this service. The first positive signal arriving at N10,000 fired the 2050 thereby closing the relay in the plate circuit which connected a 1 1/2v. cell in series with resistance across one galvanometer of the Heiland recorder. A step deflection was produced. The delay in closure of the relay was measured and hence the time relation of the step wave with respect to t_o could be given to $\pm$ 1/2 ms.

5) Buffer Pulse Unit, Fig. 12, Dwg. 649

As discussed earlier the firing pulse arriving at the tower on the 54AU cable had an amplitude of 600 volts and rise time of 6 microseconds. The purpose of the present unit is to sharpen this wave front.

The incoming signal is used to fire the 4C35 thyratron providing a 700 volt pulse at its cathode. This pulse rises in considerably less than 0.1 microsecond and is supplied over 100 ft. of cable to the Electric Detonator (so-called "Raytheon") unit on top of the tower which fires the bomb. A fraction (1/20) of the same positive pulse is carried over 1000 ft. of RG U cable.([illegible]) terminated correctly in the N1000 shelter. This

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pulse was used to intensify the measuring scopes, start sweeps, etc. Since the delay in the detonator set, H.E. train, coaxial cables, etc., were known this pulse had a time relation known with respect to the nuclear explosion.

The 4C35 in this unit was self-quenching and all a.c. supplies were 400 cycle from a generator operated at the base of the tower. The filament supply was turned on remotely at -10 minutes and the a.c. to the B + transformer at -90 secs to allow 60 secs. heating time for the 5U4 rectifier.

6) Time Fiducial, Fig. 14, Dwg. 624

This unit, located at N1000, accepted the fast positive pulse from the Buffer pulse unit and supplied it through the cathode follower V_1 to fire the thyratron V_2. The 300 volt pulse appearing at the cathode of V_2 was utilised to start sweep circuits meanwhile a fraction of the same pulse, delayed 1 microsecond in the delay line #12647, was applied to the y - axis deflector system of the C.R.O. to provide a time fiducial.

V_3 and V_4 utilise the termination of the delay line as a common cathode load and allow four further signals to be mixed together and presented on the y - axis deflector system of the scope. To prevent reflection of these signals from the input of the delay line the input, as well as output, is loaded with a resistance equal to the characteristic impedance of the line.

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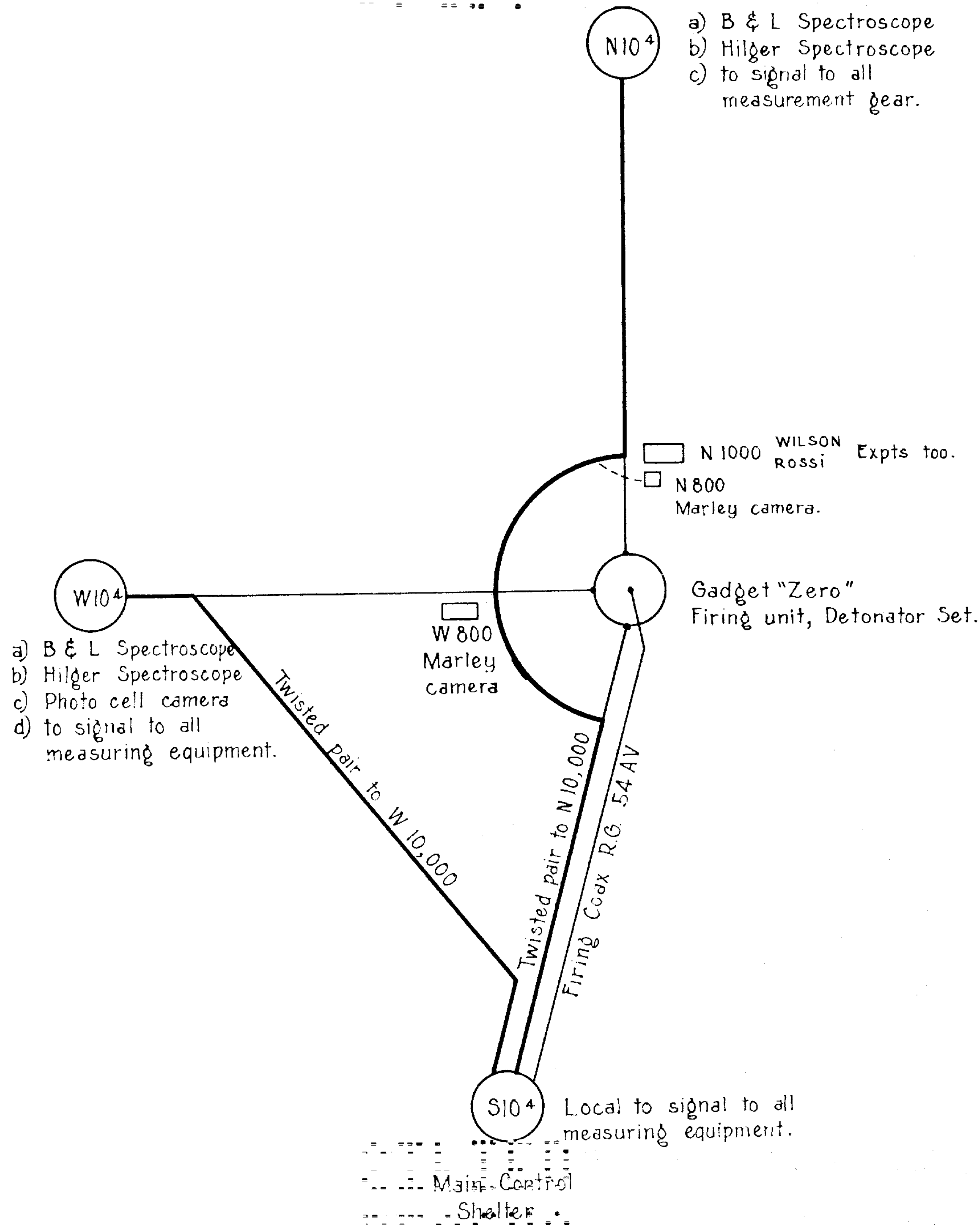
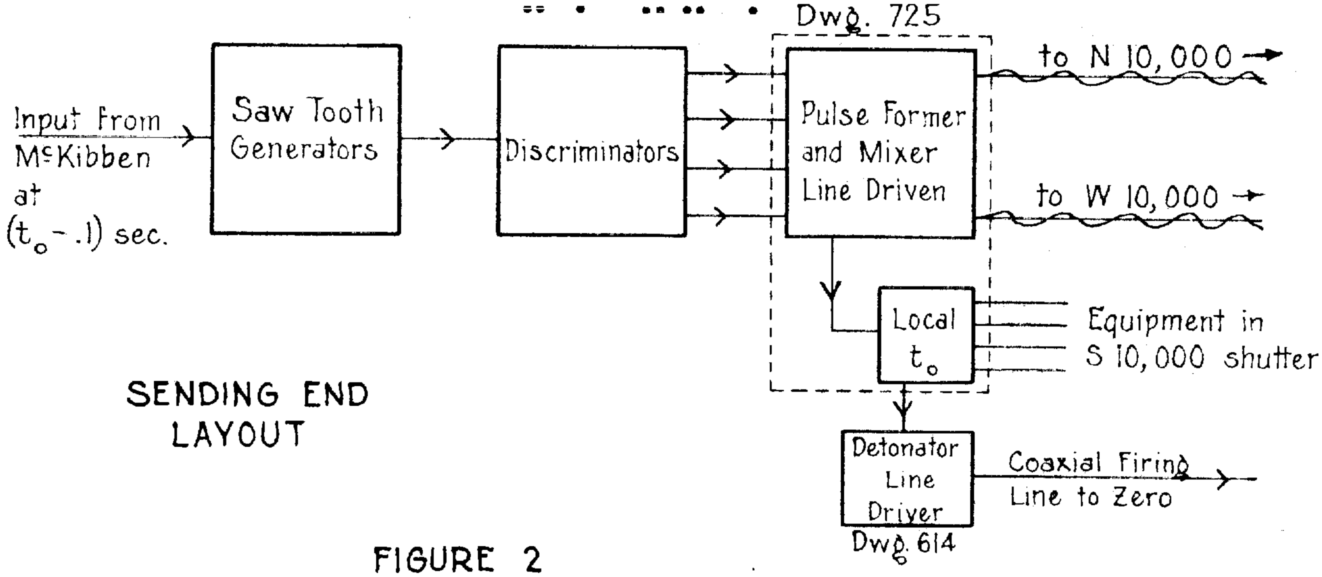
FIGURE 1



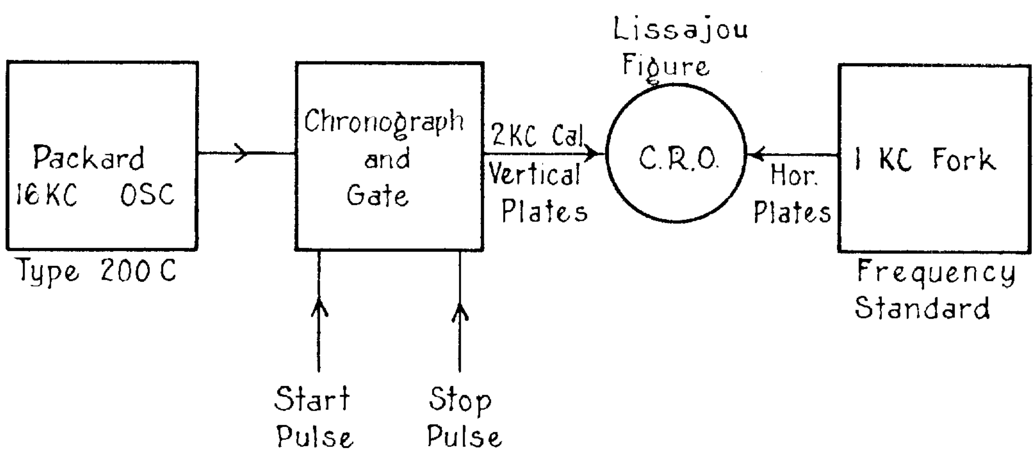
LA-436

FIGURE 3



SENDING END
LAYOUT

FIGURE 2



CALIBRATION
CIRCUITS

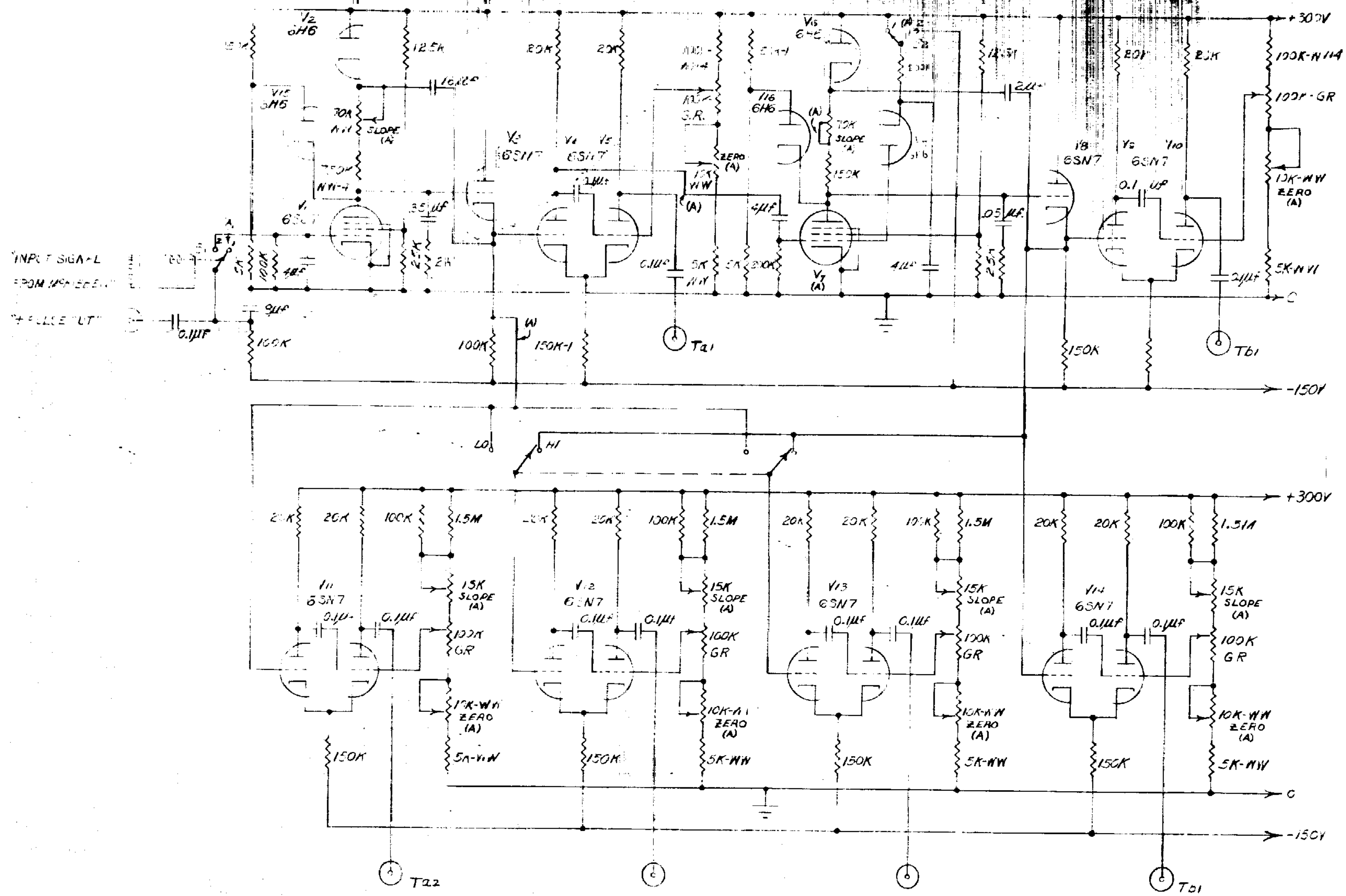


Fig. 4

DESIGNED BY E.W. TITTERTON	GROUP G-4
DRAWN BY HMB	DATE 10/17/45
DRAWING NO. 724	TITLE: SAW TOOTH GENERATOR AND DISCRIMINATORS

APPROVED FOR PUBLIC RELEASE

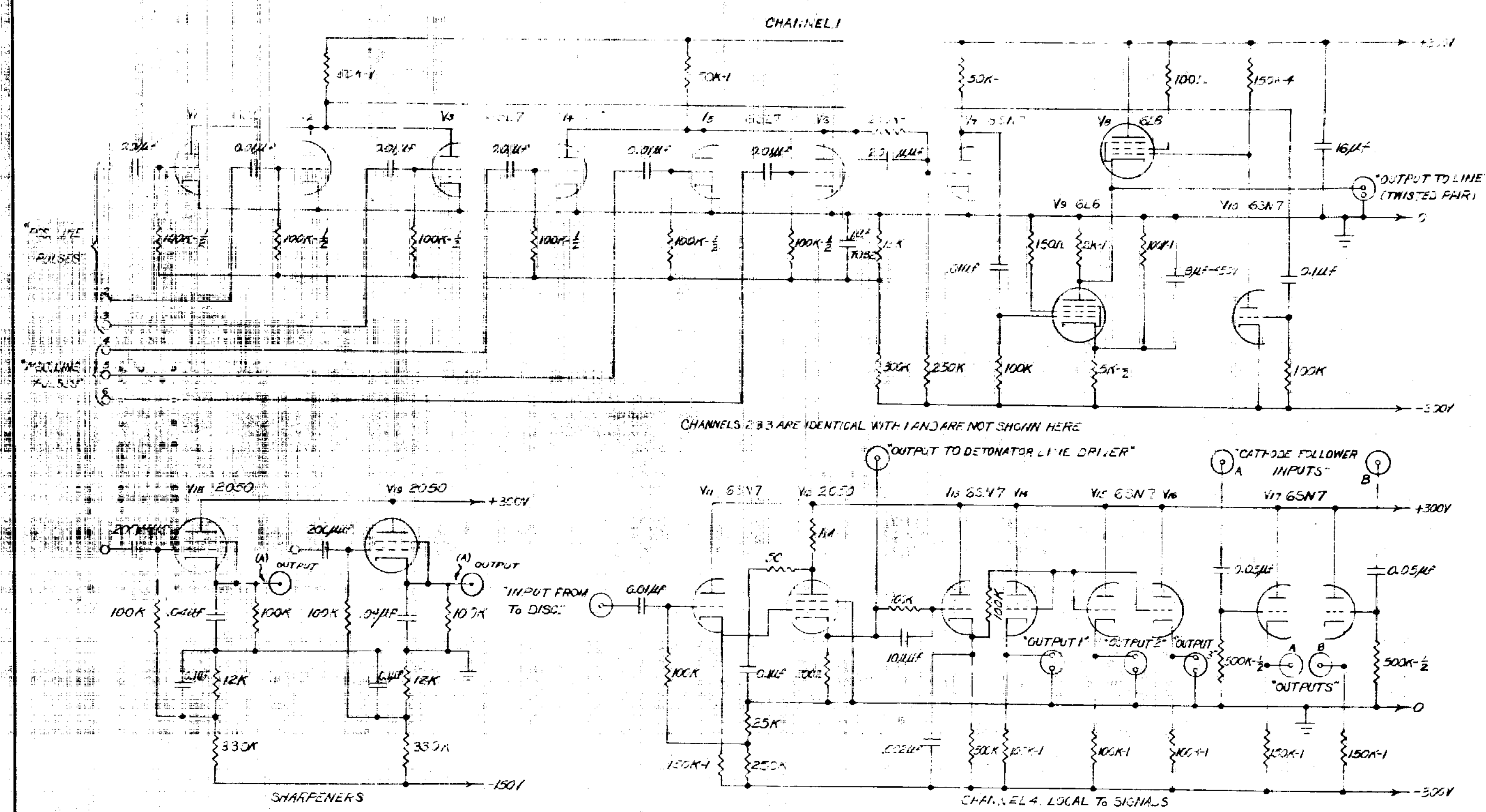
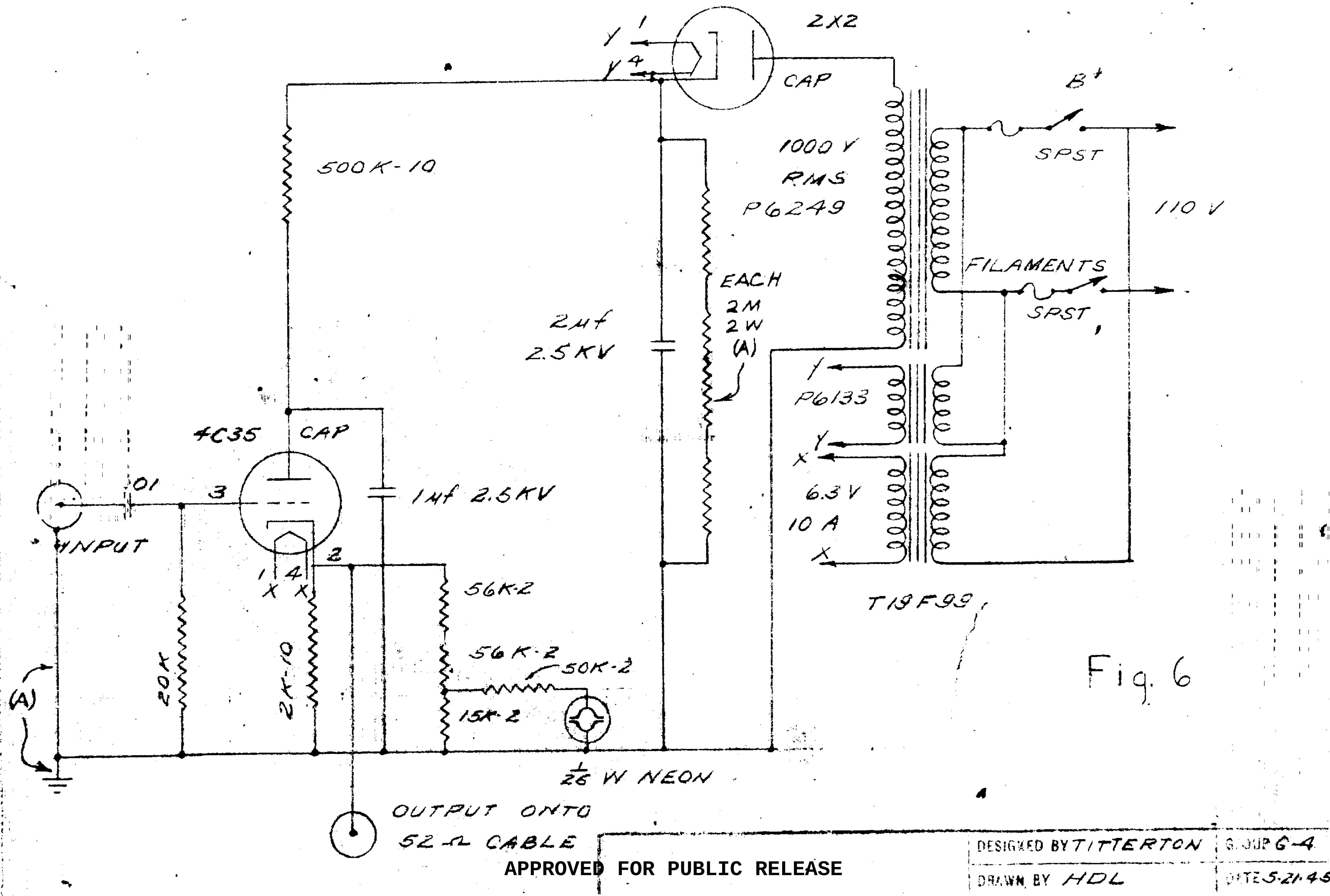


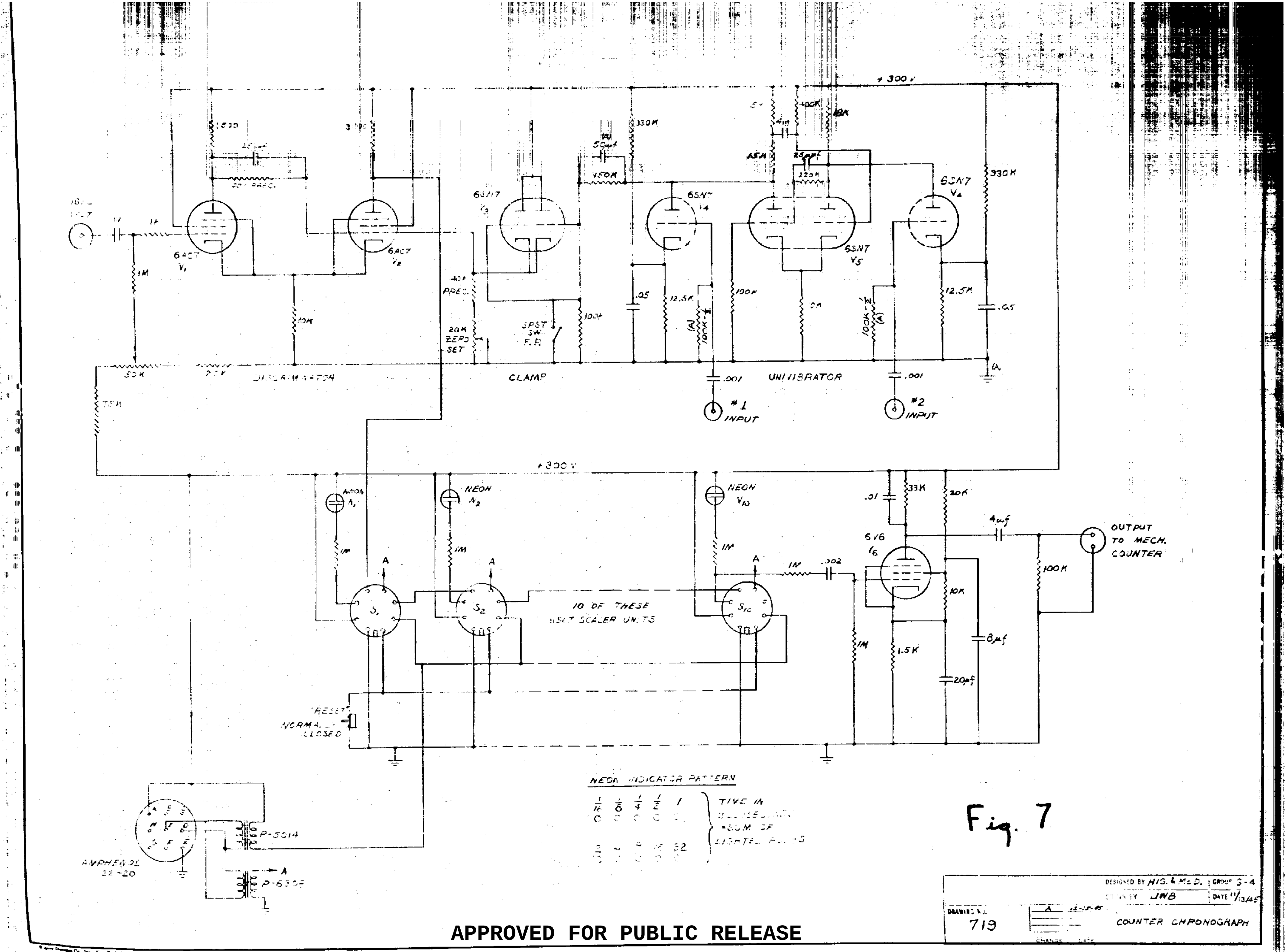
Fig. 5

DESIGNED BY E.W. TITTERTON GROUP G-4
DRAWN BY H.M.B.
725
TITLE 4-CHANNEL LINE DRIVER



2X2
Y 1
Y 4
CAP
B+
1000 V
RMS
P6249
SPST
110 V
FILAMENTS
SPST
500K-10
EACH
2M
2W
(A)
2uf
2.5KV
4C35
CAP
1uf 2.5KV
.01
3
INPUT
2
1 4
X X
56K-2
56K-2
50K-2
15K-2
20K
2K-10
(A)
1/25 W NEON
OUTPUT ONTO
52 Ω CABLE
Y
P6133
Y
X
6.3 V
10 A
X
T19F99
DESIGNED BY TITTERTON
GROUP G-4
DRAWN BY HDL
DATE 5-21-45

Fig. 6


+300 V
6SN7
V_3
6SN7
V_4
6SN7
V_5
6SN7
V_6
6AC7
V_1
6AC7
V_2
DISCRIMINATOR
CLAMP
UNIVIBRATOR
#1
INPUT
#2
INPUT
SPST
SW.
F.R.
ZERO
SET
PREC.
NEON
N_1
NEON
N_2
NEON
V_{10}
10 OF THESE
SCALER UNITS
6V6
V_6
OUTPUT
TO MECH.
COUNTER
"RESET"
NORMALLY
CLOSED
AMPHENOL
P-5014
P-6305
NEON INDICATOR PATTERN
TIME IN
SUM OF
LIGHTED BULBS
Fig. 7
DESIGNED BY HIG. & McD.
JWB
GROUP 3-4
DATE 11/13/45
DRAWING NO.
719
COUNTER CHRONOGRAPH

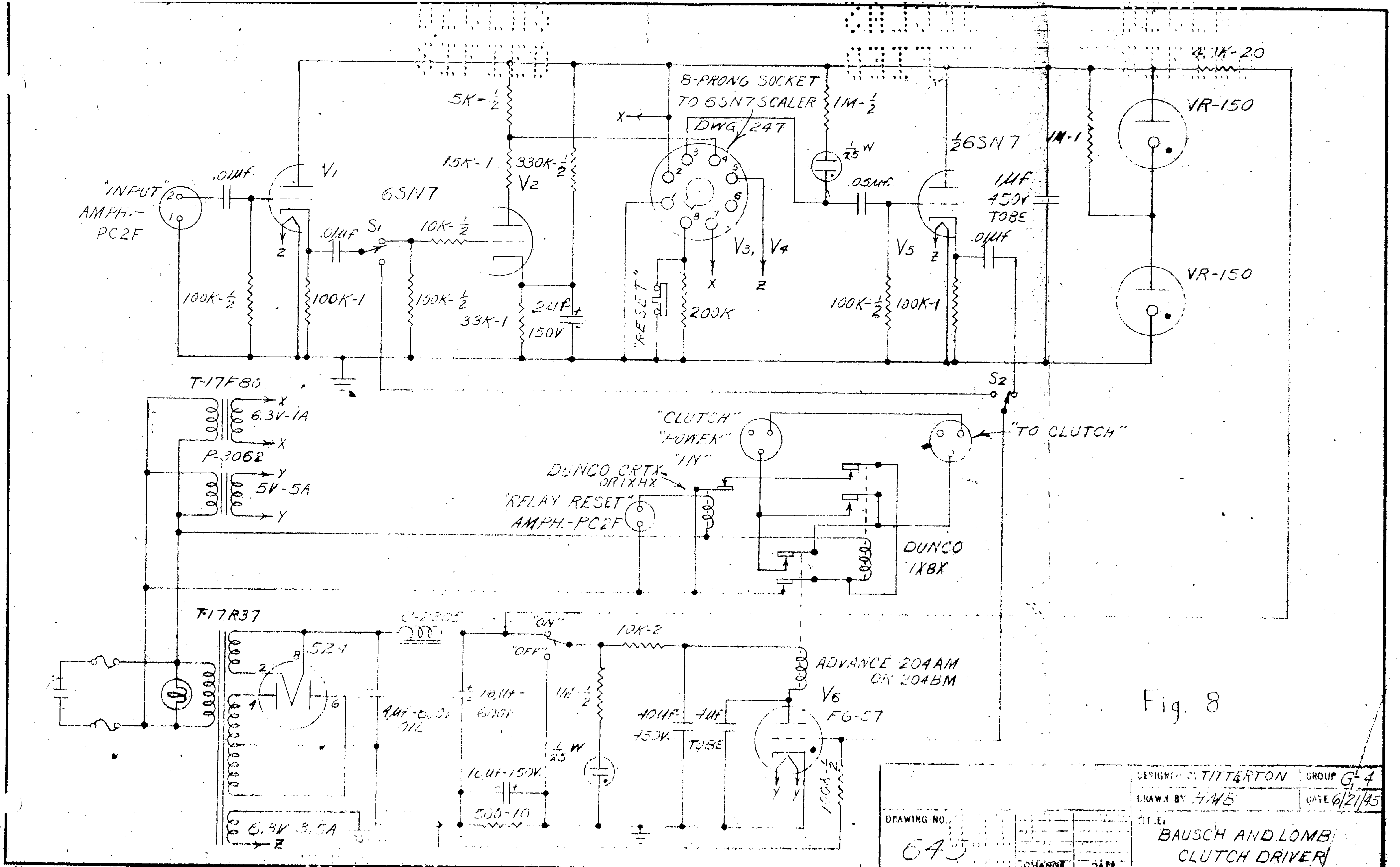

"INPUT"
AMPH.-PC2F
.01μf
V1
6SN7
5K-½
15K-1
330K-½
V2
10K-½
S1
100K-½
100K-1
100K-½
33K-1
2μf 150V
8-PRONG SOCKET TO 6SN7 SCALER
DWG. 247
V3, V4
"RESET"
200K
1M-½
1/25 W
.05μf
½6SN7
V5
100K-½
100K-1
.01μf
1μf 450V TOBE
1M-1
4.1K-20
VR-150
VR-150
S2
T-17F80
6.3V-1A
P-3062
5V-5A
"CLUTCH" "POWER" "IN"
"TO CLUTCH"
DUNCO CRTX-OR 1XHX
"RELAY RESET" AMPH.-PC2F
DUNCO 1XBX
T-17R37
5Z4
C-2305
"ON"
"OFF"
10K-2
ADVANCE 204AM OR 204BM
V6
FG-57
1M-½
1/25 W
40μf 450V
4μf TOBE
10μf-150V
500-10
6.3V 3.5A
DESIGNED TITTERTON
GROUP G-4
DRAWN BY HWS
DATE 6/21/45
DRAWING NO. 645
TITLE: BAUSCH AND LOMB CLUTCH DRIVER
CHANGE
DATE
Eugene Dietzgen Co., Inc., New York, N. Y.

Fig. 8

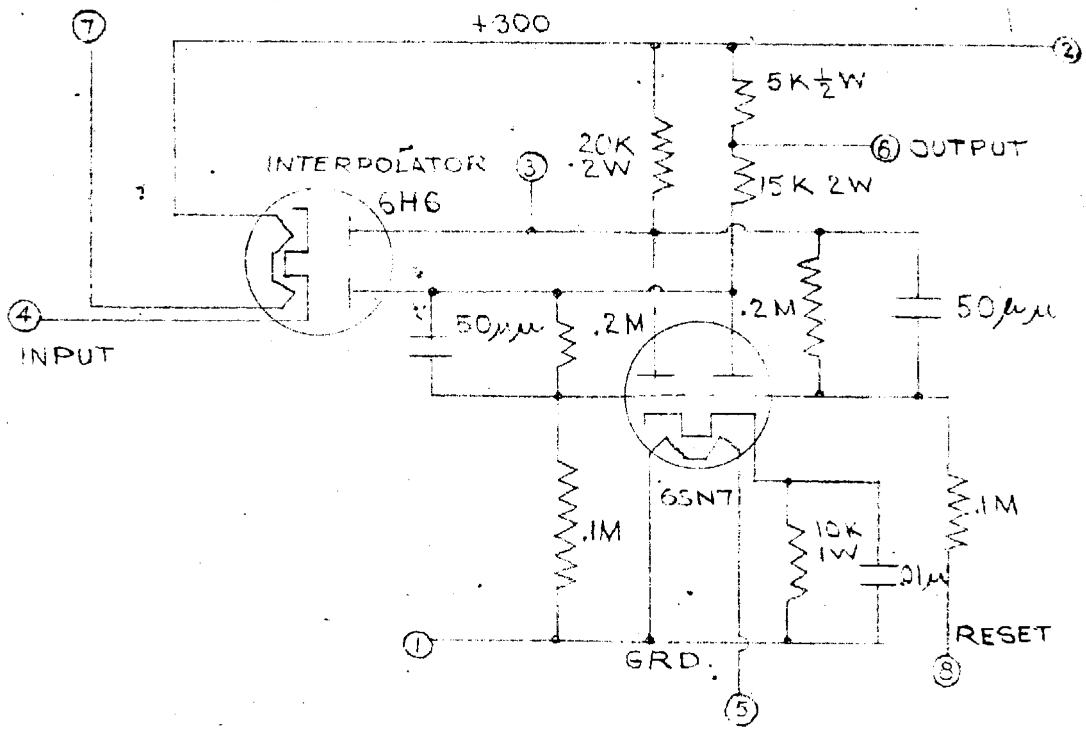


Fig. 9

12/6/44 DRAWING NUMBER
SCALER UNIT CIRCUIT G-4-247

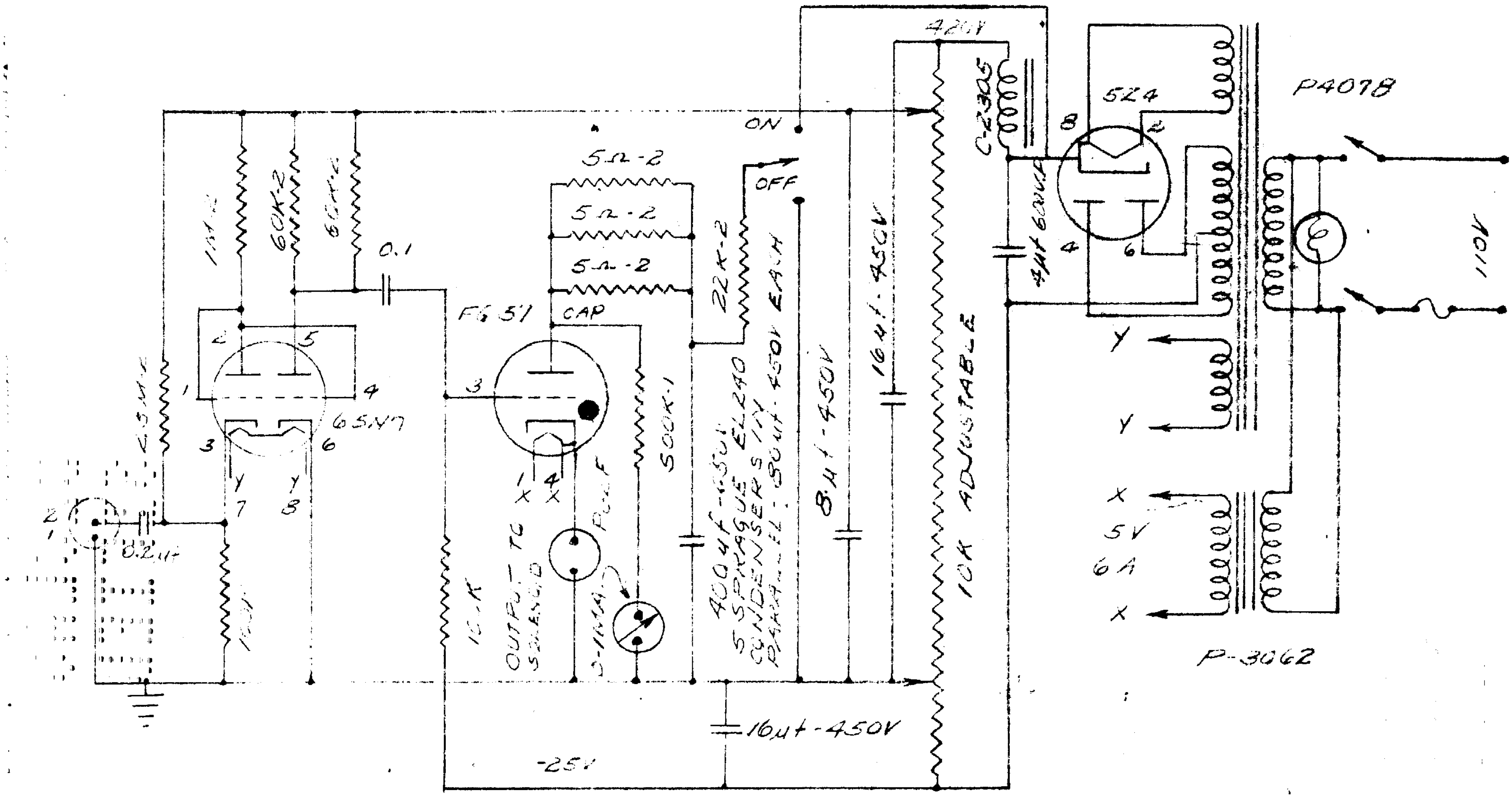


Fig. 10

DESIGNED BY TITTERTON McDANIEL | GROUP G-4
DRAWN BY HDL | DATE 5-29-45
DRAWING NO. 119
TITLE: HILGER SOLENOID OPERATOR

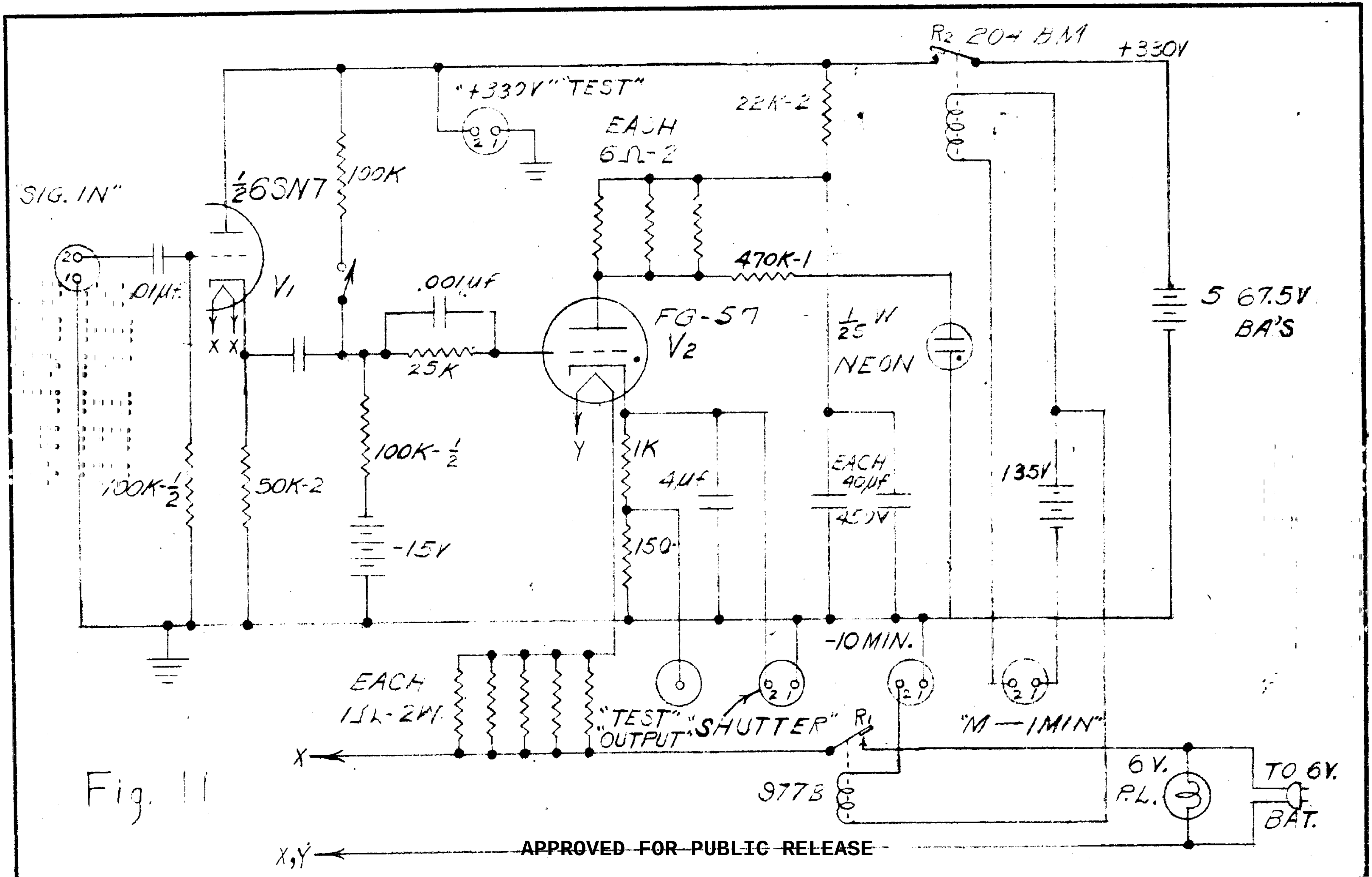
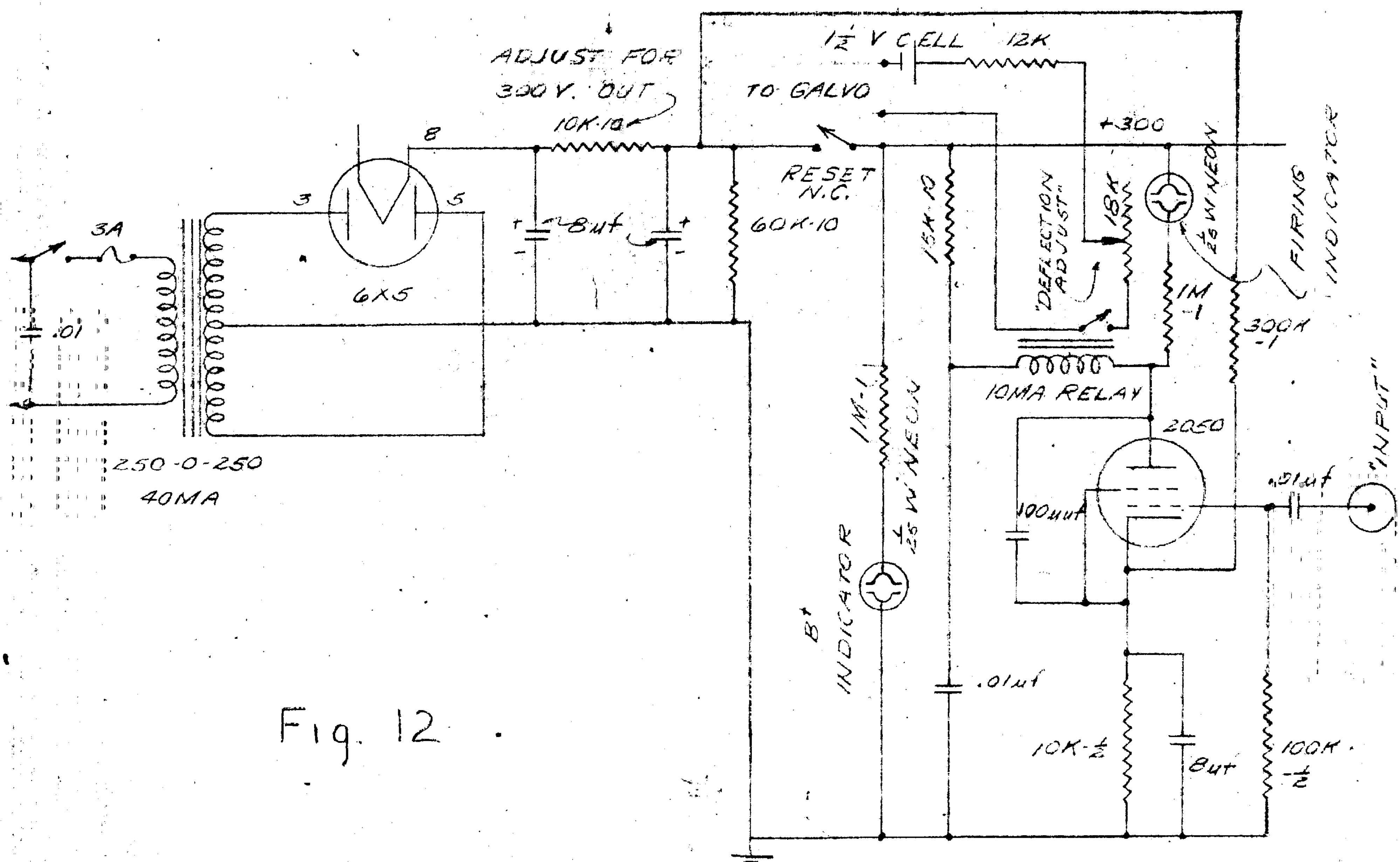


Fig. 11

APPROVED FOR PUBLIC RELEASE



ADJUST FOR
300 V. OUT
10K-10
8
3
5
6X5
3A
.01
250-0-250
40MA
8uf
60K-10
1½ V CELL
12K
TO GALVO
RESET
N.C.
+300
15K-10
18K
"DEFLECTION ADJUST"
¼/25 W NEON
FIRING
INDICATOR
1M
-1
300K
-1
10MA RELAY
2050
1M-1
¼/25 W NEON
B+
INDICATOR
100uuf
.01uf
"INPUT"
.01uf
10K-½
8uf
100K
-½

Fig. 12

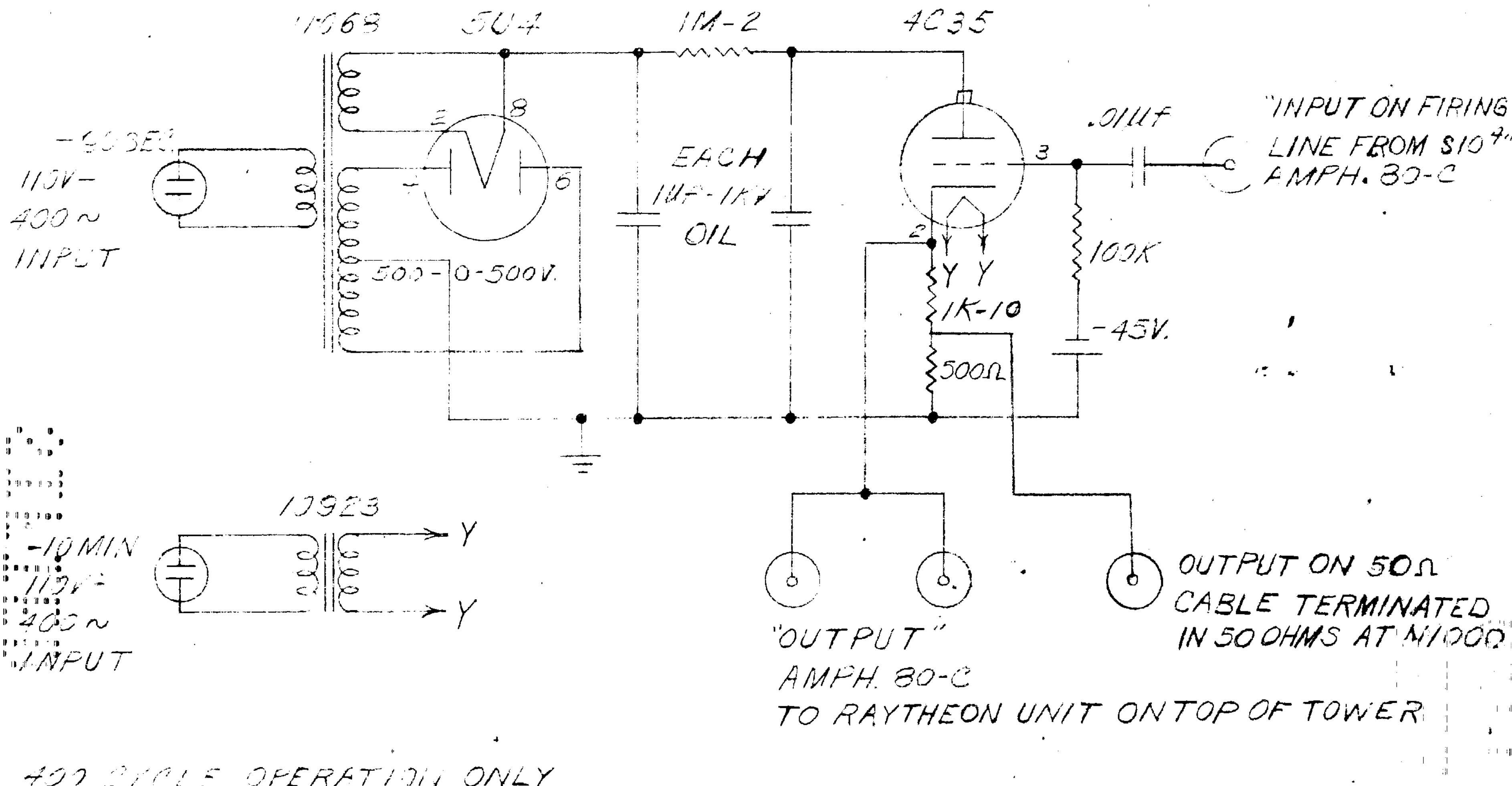


Fig. 13

DESIGNED BY TITTERTON	GROUP G-4	
DRAWN BY HMB	DATE 6/25/45	
DRAWING NO. 649	TITLE: BUFFER PULSE UNIT	
CHANGE	DATE	

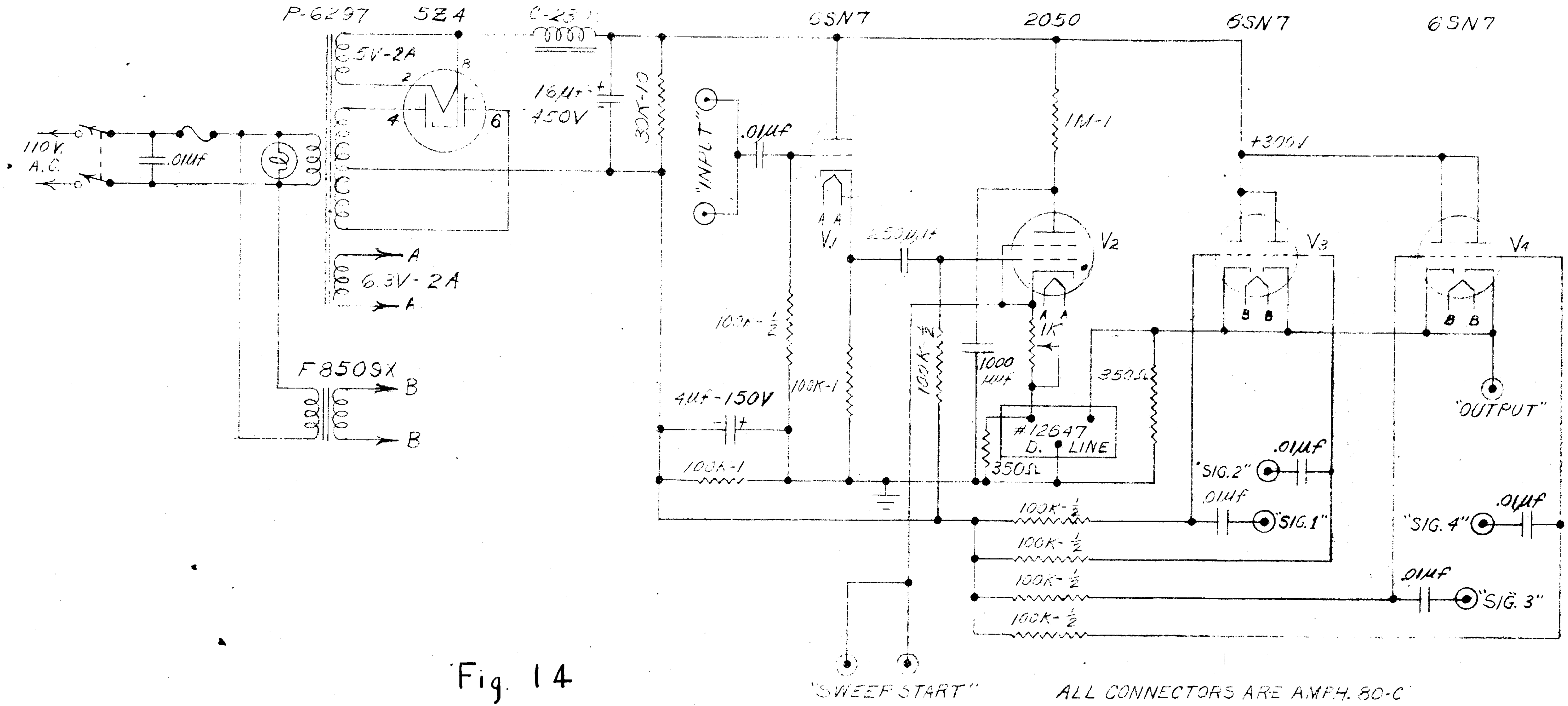


Fig. 14

DESIGNED BY E.W. TITTERTON GROUP G-4
DRAWN BY HMB DATE 6/8/45
DRAWING NO. 624
TITLE: TIME FIDUCIAL
CHANGE DATE

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DOCUMENT ROOM

REC. FROM Gc

DATE 5/8/46

REC. NO. REC. ✓

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