A WAVE VELOCITY INDICATOR FOR TESTING OF CONCRETE

by

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INTRODUCTION

For a number of years the relationship that exists between the elastic properties of materials and the velocity of propagation of sound has been recognized. The relationship is:

$$V = \left(\frac{E\,(1-u)}{p\,(1-2u)\,(1+u)}\right)^{\frac{1}{2}}$$

Where, E = Modulus of elasticity
V = Velocity of sound
p = Density
u = Poisson's ratio

Only recently, however, have any attempts been made to build sonic devices that use this relationship for the purpose of determining modulus of elasticity. A few that have been built show at least a limited degree of success.

Sonic testing devices have also been developed for the purpose of investigating internal voids and cracking conditions in materials, metals and concrete in particular. In the case of metals, sound pulses are injected into the medium and reflections from voids return to the point of injection. By measuring the time of the return of the reflection, the distance from the point of injection to the void can be determined. Furthermore, the strength of the reflection gives an accurate indication of the size of the void. Cracks and voids in concrete are usually studied by passing sound pulses around the crack or void as illustrated in Fig. 1, and determining distance of travel, or by noting the interruption of the pulses when an extensive void lies between the points of pulse injection and reception. This latter method is illustrated in Fig. 2.

One of the more successful sonic testing devices now in use is an electronic device known as a sonoscope. This instrument, although primarily intended for use on concrete, shows considerable promise of being adaptable to other materials. The sonoscope was originally introduced by the Hydroelectric Power Commession of Ontario, Canada.[1] Although the Canadian sonoscope shows rather questionable ability for determining elasticity modulus, it has proven quite useful for location of voids. For this reason, the State Highway Commission of Kansas has sponsored the development of a sonoscope more capable of measuring sound velocity to a sufficiently high degree of accuracy to make it practical for modulus of elasticity measurements.

The method used to develop a new and better sonoscope was to determine the limiting factors of the Canadian sonoscope which made it of so little value for modulus of elasticity measurements, and then to redesign the system to eliminate them.

SURVEY OF THE CANADIAN SONOSCOPE

Principle of Operation

The sonoscope, as developed by the Hydroelectric Power Com-

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[1] J. R. Leslie and W. J. Cheesman, "An Ultrasonic Method of Studying Deterioration and Cracking in Concrete Structures," Journal of the American Concrete Institute, 46:17, September, 1949.

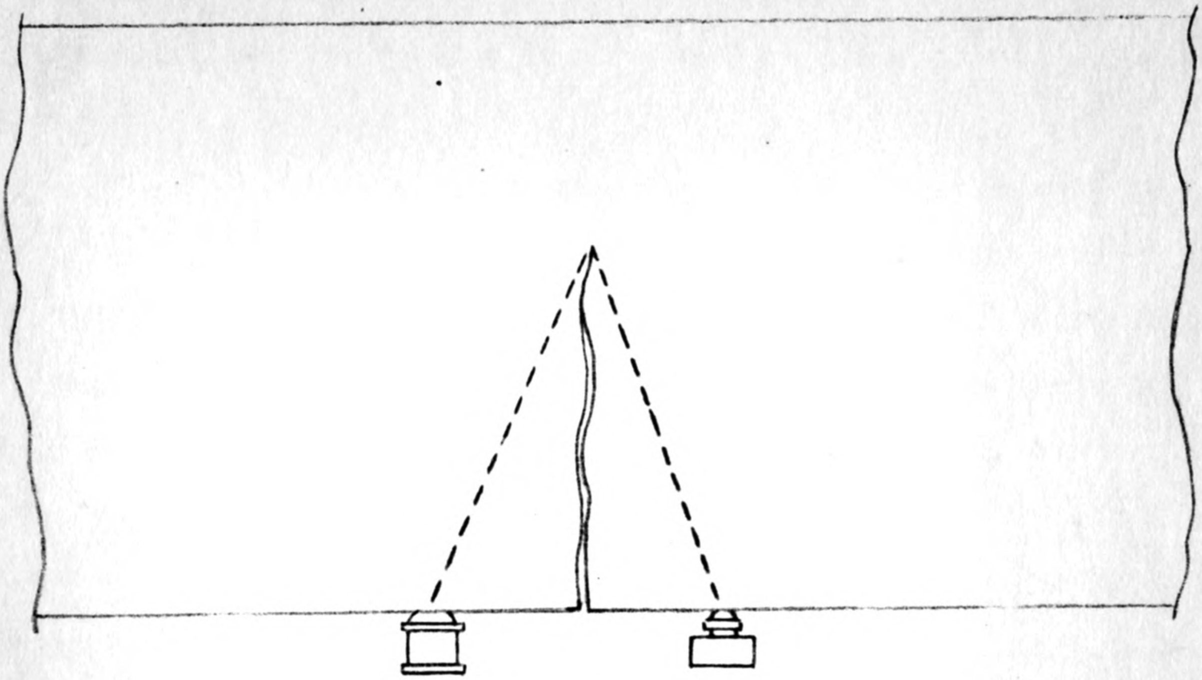

Fig. 1. Placement of transducers for determining depth of crack.

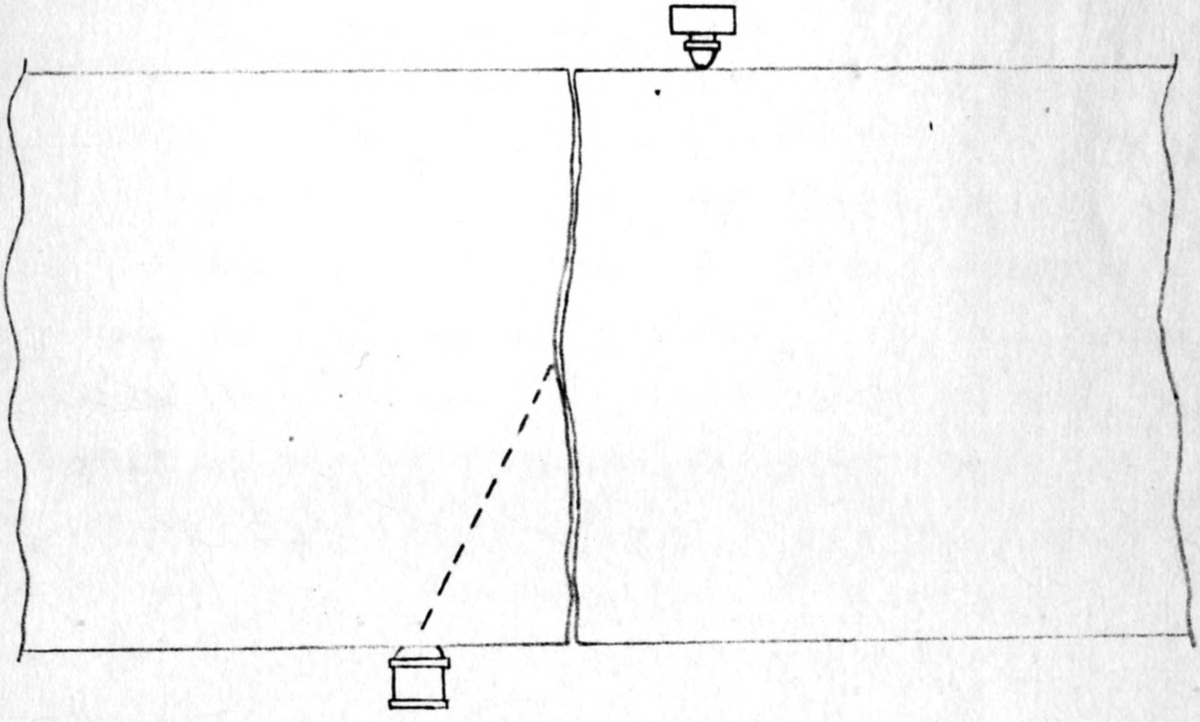

Fig. 2. Placement of transducers for determining existance of crack.

mission of Ontario, is shown in block diagram form in Fig. 3. The waveform diagram of Fig. 4 illustrates the function of each component.

The 100 kilocycle crystal oscillator forms the time standard for the system. The 100 kilocycle standard frequency is divided by a factor of ten by the LC frequency divider to form a 100 microsecond secondary standard. The output of the LC frequency divider is also used to trigger the master multivibrator which produces the pulse repetition frequency of 100 cycles per second for synchronization of the system. The output of the master multivibrator, shown as waveform "c" of Fig. 4, is differentiated and delayed from zero to one hundred microseconds by the low range delay multivibrator as shown by waveform "d" before it is fed to the gate generating circuit. The gate generator produces a square pulse of approximately one hundred microseconds duration as shown in waveform "e" which pulses in the pulsed variable frequency oscillator producing waveform "f" as illustrated. This short burst of oscillation is then amplified to approximately 625 volts peak-to-peak before being fed to the conventional type Rochelle salt crystals in the driver transducer shown in Fig. 6. The mechanical vibrations thus produced by the piezoelectric crystals pass through the concrete and are picked up by the receiver transducer where they are amplified producing a waveform illustrated by waveform "g." The driving pulse (waveform "f") and the received pulse (waveform "g") are then combined to form waveform "h" which is fed to the upper deflection plates of the twin beam cathode ray oscilloscope.

In addition to triggering the master multivibrator, the out-

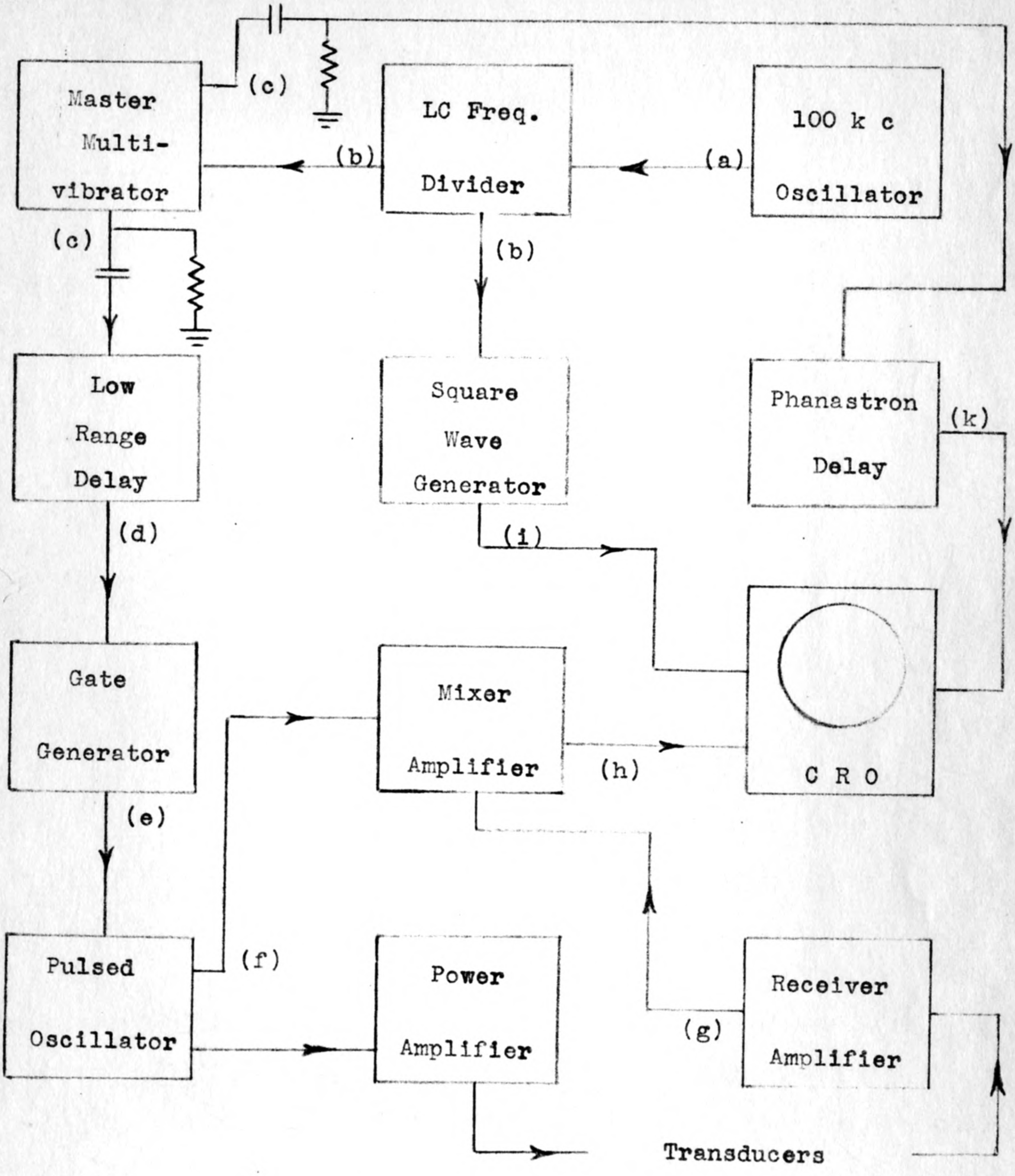

Fig. 3. Block diagram of Canadian sonoscope system.

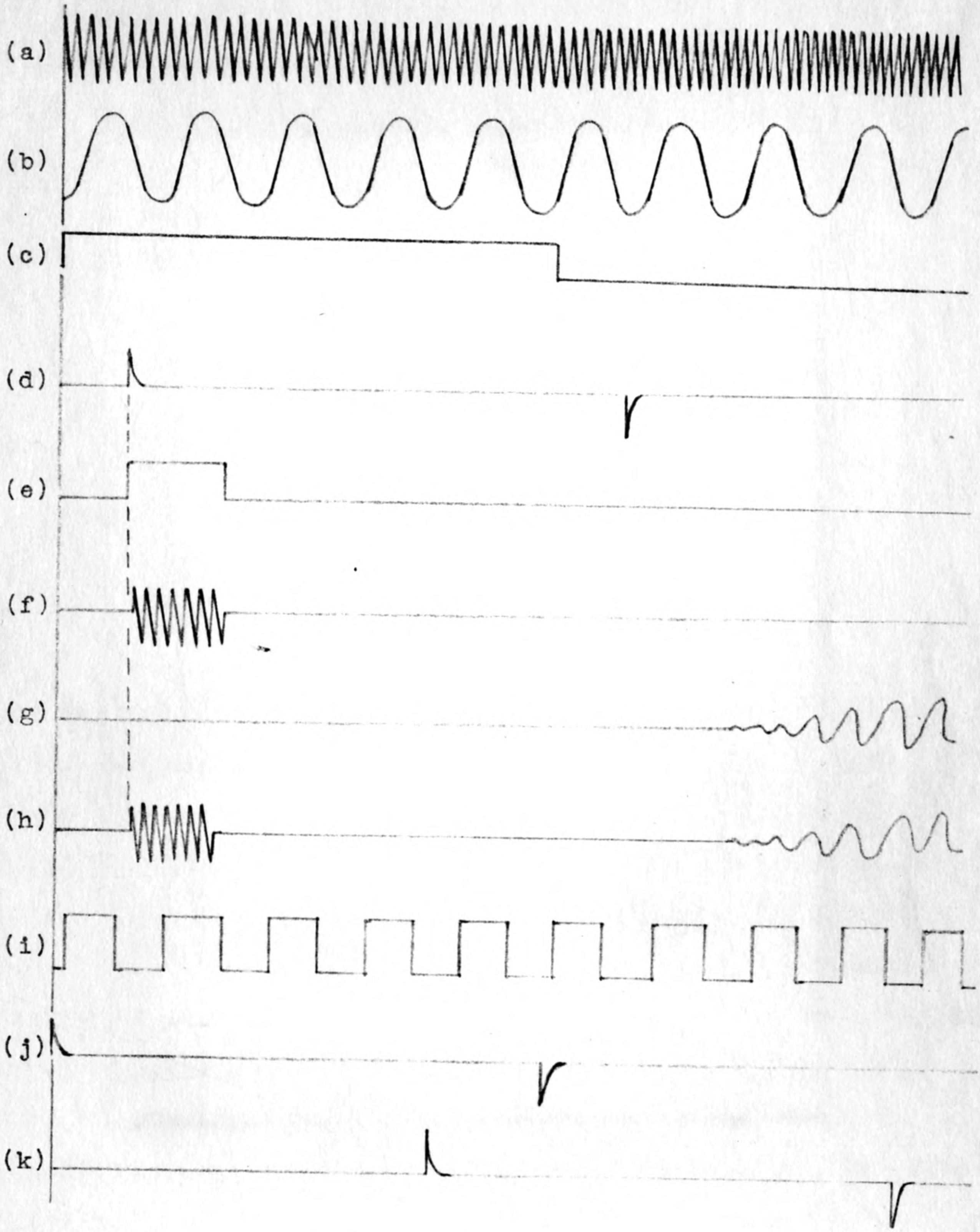

Fig. 4. Waveform diagram of Canadian sonoscope.

put of the LC frequency divider is amplified and clipped by the square wave generator to form waveform "i" which is placed on the lower deflection plates of the cathode ray oscilloscope to provide the secondary standard of time. Thus, intervals of time between points of the upper trace may be measured by comparing them with the square wave of known period on the lower trace. Since the time interval between the driving pulse and the received signal is long compared to the period of the cathode ray oscilloscope's driven sweep, the long range delay circuit is used to delay the differentiated output of the master multivibrator in order that any portion of the trace may be viewed on the cathode tube.

Limiting Factors

Although this system represents a high degree of sonic instrument development, it has two inherent limitations which make it essentially incapable of measuring the modulus of elasticity. Time intervals are determined by counting the number of square waves between the left edge of the driving pulse and the beginning of the received pulse. Thus for measurements of greater accuracy than multiples of 100 microseconds, it is necessary to interpolate between end points of the 100 microsecond interval in which the received signal starts. Measurements of greater accuracy than multiples of ten microseconds are difficult if not impossible. Furthermore, this instrument does not concentrate the driving energy in the early portion of the driving period, and therefore fails to produce a sharp wave front. This causes the time the received signal is first received to appear very indefinite. An-

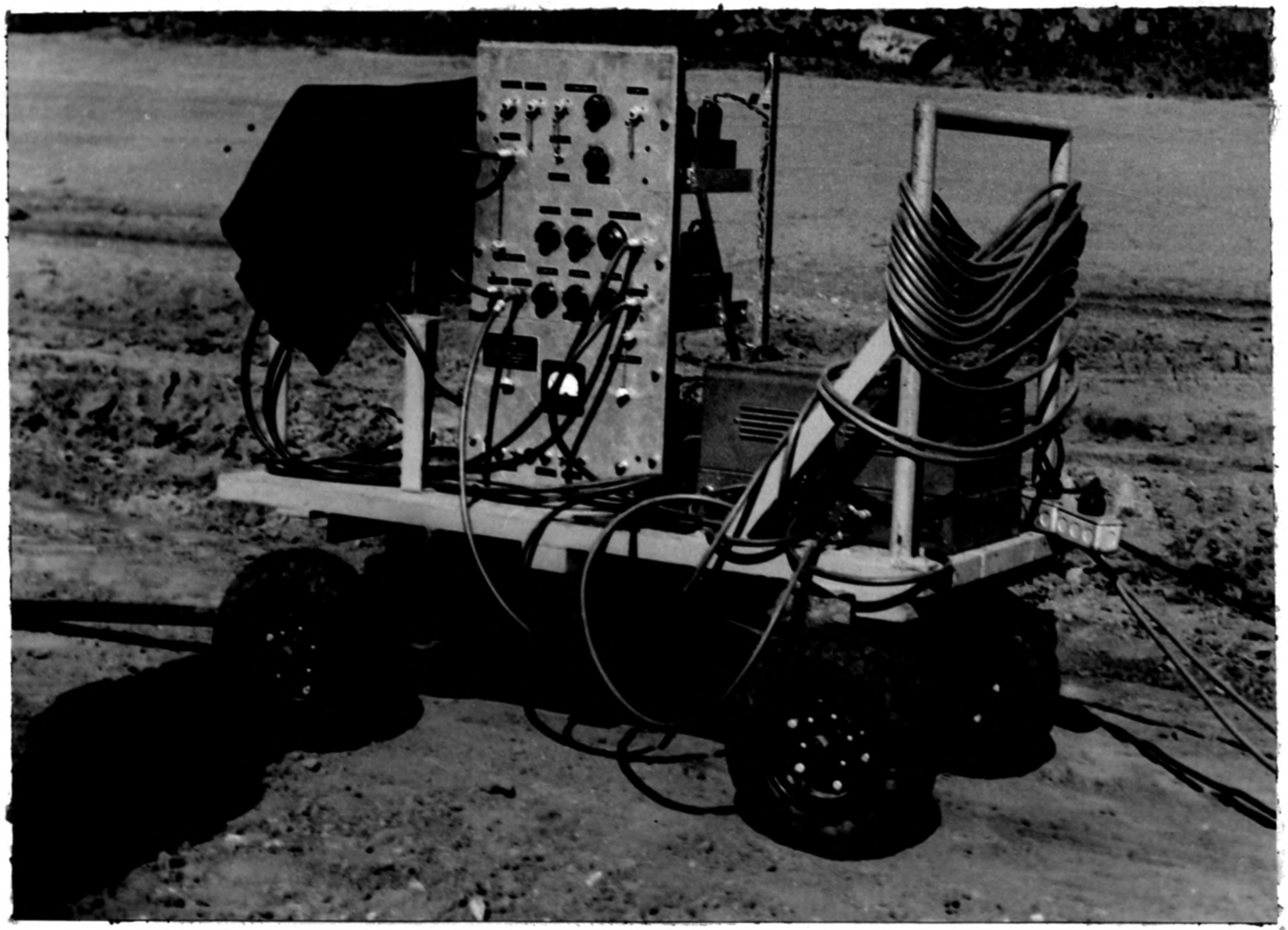

Fig. 5. Canadian sonoscope as it was operated in the field on a section of highway slab.

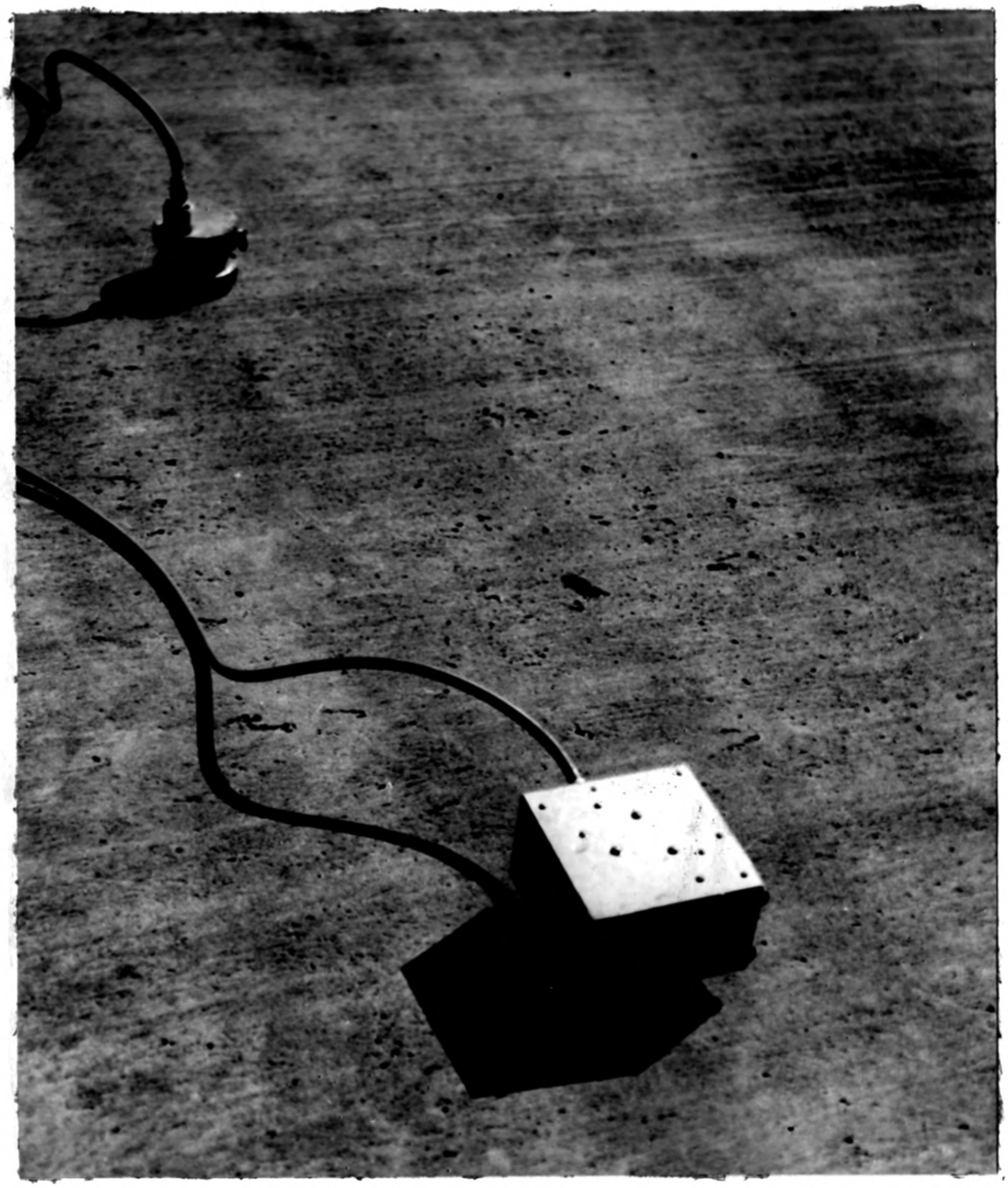

Fig. 6. Conventional type Rochelle salt crystal transducers. The driver is the one in background.

other disadvantage of the Canadian sonoscope, although it would not be considered a limitation as far as operation is concerned, is its excessive weight and bulk. It is shown in Fig. 5 set up for operation on a section of highway slab.

DEVELOPMENT OF THE IMPROVED SONOSCOPE

In setting up the research project for the purpose of developing a better sonoscope, the State Highway Commission of Kansas was primarily interested in producing a much sharper wave front in order that the time of reception of the received signal would be more definite than that produced by pulsed sinusoidal oscillators. Also, they were interested in a time measuring system capable of discriminating between time differences of the order of one microsecond. It was furthermore desired to package the system into a single unit weighing not more than 75 pounds in contrast to the Canadian system of three separate units weighing a total of over 200 pounds.

The Improved Driving System

In measuring the transit time of a sound pulse passing through a medium, it is necessary to measure the elapsed time between the generation of a certain point of the pulse and the reception of the same point. Since the leading edge of the received pulse is the most easily recognized, it is obviously the most practical point on the pulse to use. For this reason, it is desirable to produce a steep wave front in the driving system. In fact, if the front of the pulse is to be used the shape or duration of the pulse is of no further interest. Though the most ideal driving condition should be realized by instantaneously applying a force to the concrete, this condition can only be approximated with any practical transducer. In this case, the steep wave front is obtained by striking the crystals with an electrical impulse. This is in radical contrast with the Canadian sonoscope which employed a sinusoidual pulse of about 100 kilocycles and duration of about 100 microseconds.

When the rochelle salt crystals are driven with an impulse, the strength of the impulse must be sufficiently low in order that vibration of the crystals resulting from one impulse will be damped out before the next impulse occurs. Otherwise, the wave front of the received signal will be obscured. Since the voltage height of the impulse is limited by the avaliable plate supply voltage, the strength of the impulse is controlled by the duration time. Fig. 7 shows the circuit used to produce an approximation to an electrical impulse by firing a hydrogen thyratron (3C45) causing its plate voltage to drop 600 volts in about 1.5 microseconds. The small thyratron (2D21) generates the triggering pulse for the hydrogen thyratron as well as isolating it from the previous stage. The experimentally determined plate voltage waveform having the desired strength is shown in Fig. 8 superimposed on the plate voltage waveform produced by the thyratron discharge. Both impulses are limited to 600 volts in heighth. The experimental waveform was determined by varying the pulse width of a multivibrator using type 807 tubes operating with a plate swing of 600 volts until that pulse width was found that made the crystals vibrate for

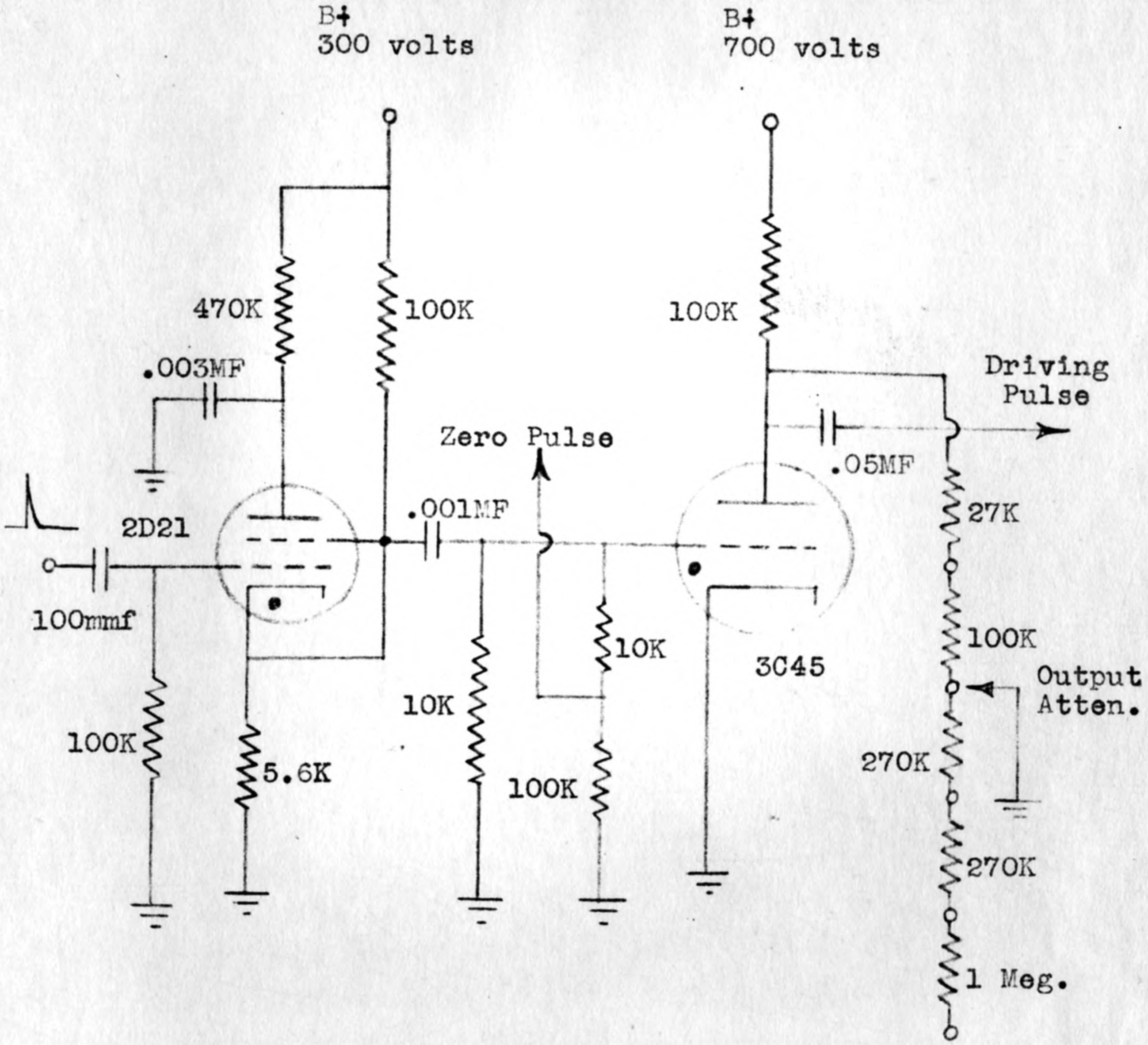

Fig. 7. Circuit diagram of the improved driving system.

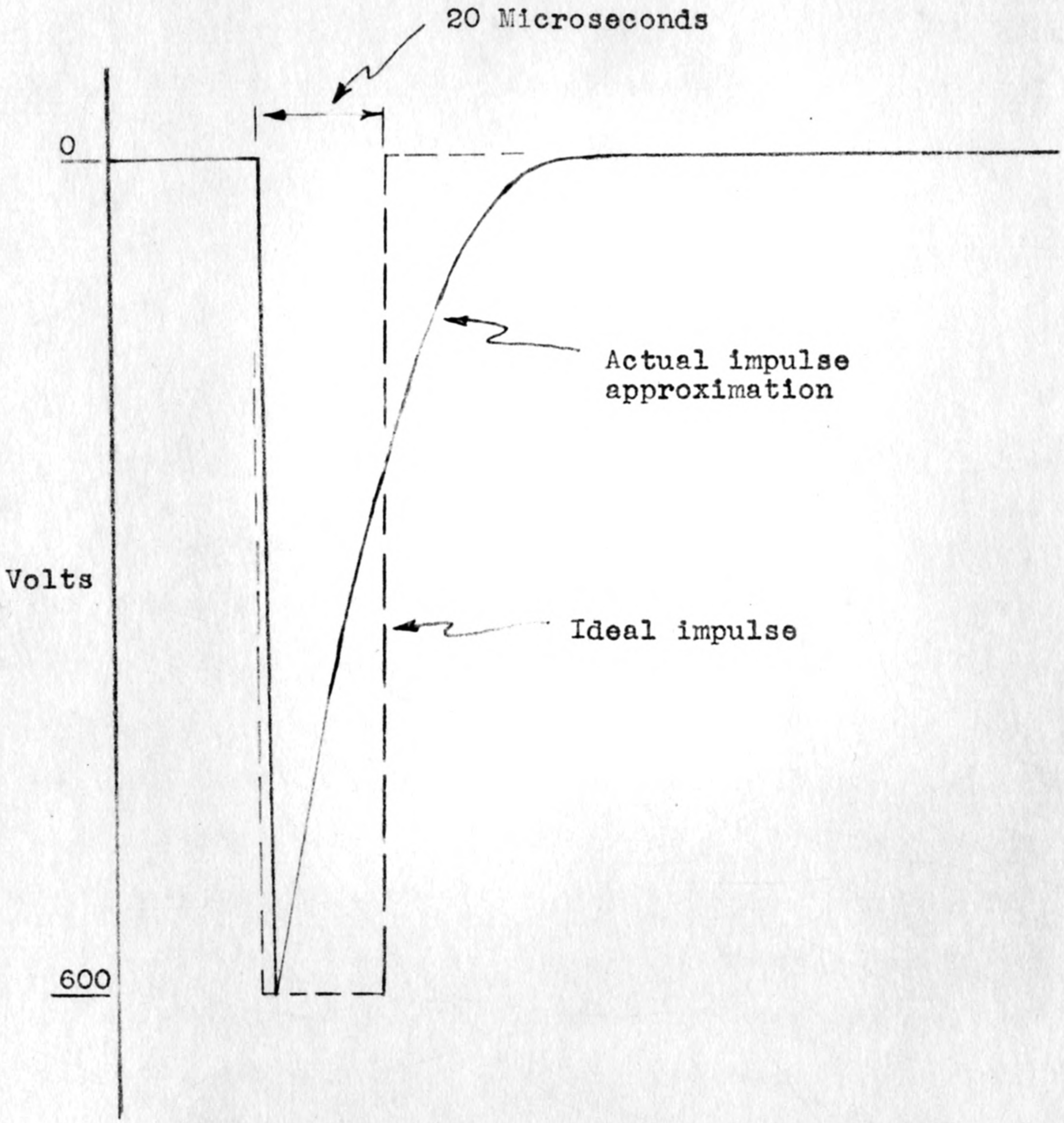

Fig. 8. Voltage waveform of the improved driving system compared with the ideal driving impulse.

approximately one-half the pulse repetition period. As indicated by Fig. 8, the actual impulse strength is slightly weaker than the ideal impulse. It is to be recognized that the sharpness of the wave front produced in the concrete will not be nearly as sharp as the electrical impulse fed to the crystals since the former is also a function of the crystal response. The present system of driving leaves something to be desired in the way of transducers with higher frequency response.

The Improved Timing System

With the thyratron discharge type of driving system a sufficiently steep wave front is produced so that the time measuring system becomes the limiting factor with regard to accuracy of measurement. The square wave comparison system used by the Canadians would assure measurments of no greater accuracy than within 10 microseconds of the true value. With the new driving system, however, the leading edge of the received pulse can be recognized within an interval of approximately one microsecond more or less depending upon the nature of the material under test. In developing a more accurate timing system it is also important from a practical standpoint to have a system in which the reading is taken from a calibrated dial so that the operator does not need a knowledge of square wave period as in the case of the Canadian sonoscope.

Fig. 9 shows the time measuring system that was designed to replace the square wave system used by the Canadians. It consists of a conventional Miller integrator circuit to produce a linear

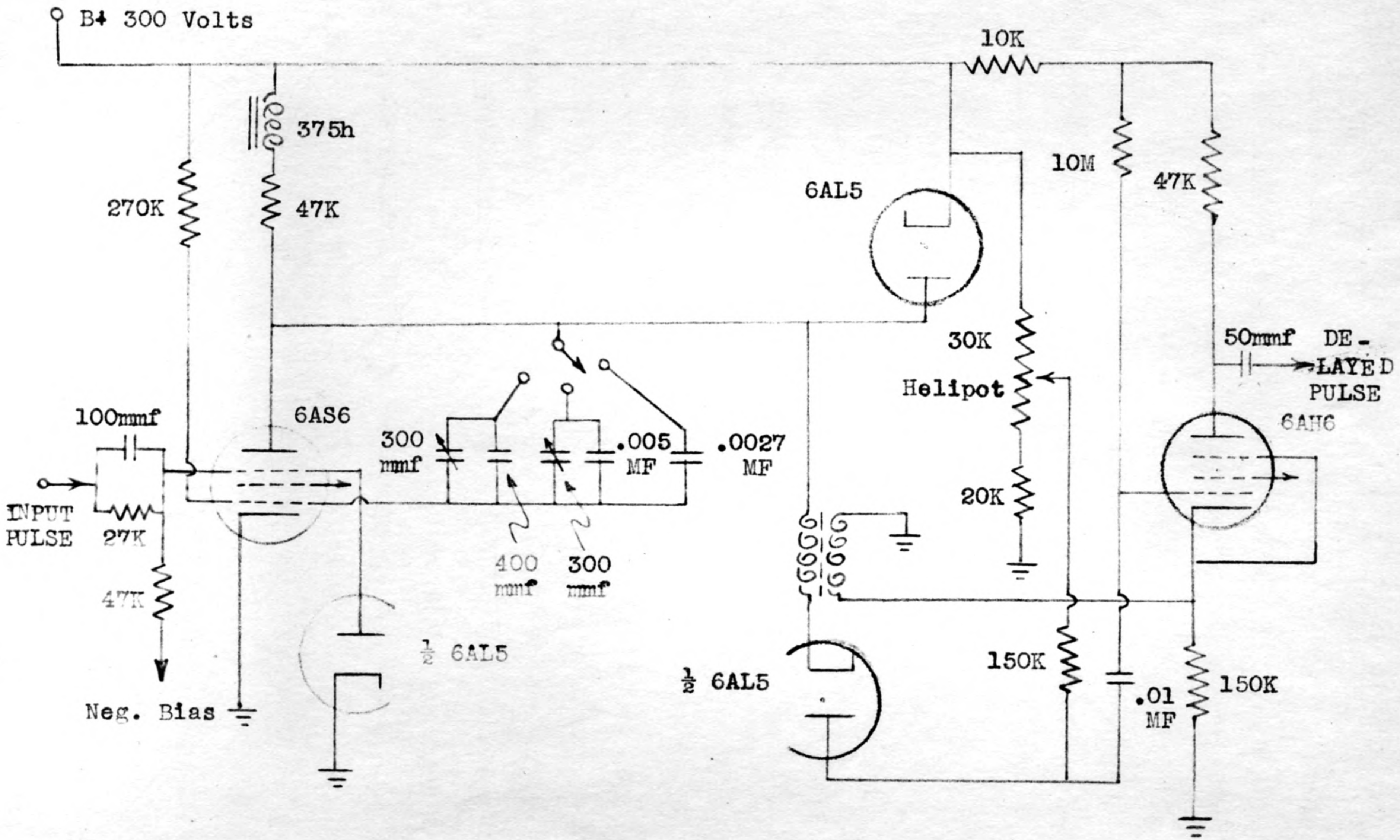

Fig. 9. Phanastron delay circuit calibrated for time measurement. Screen grid circuits are omitted for clarity.

saw tooth of voltage and a diode pickoff and blocking oscillator circuit in which the pickoff voltage may be varied linearly with the ten-turn-helipot. This system is commonly known as a "phanastron"[1] time measuring system. The time interval between the initiation of the saw tooth by the input pulse and the actuation of the blocking oscillator may be varied linearly with the helipot. Furthermore, by adjustment of the plate to grid capacitors of the 6AS6, the slope of the saw tooth can be varied such that the helipot dial will read microseconds of delay directly and no calibration curves are needed. In this particular case, however, it was desired to have more than one range for the time delay dial so that the instrument might be usable for a few inches of concrete between the transducers or as much as 50 feet. By switching between three sets of plate to grid capacitors in the Miller integrator, the delay dial has scale factors of 0.1, 1, and 5.

Although this time measuring system is a considerably more accurate one than the Canadian system, it suffers from lack of linearity, which would demand the use of calibration curves for the most accurate work. An alternate timing system has been developed to correct this defect. It is discussed later.

Present Form of the Sonoscope

With the two significant changes considered, the sonoscope in its present stage of development is shown in Fig. 10 in block

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[1]Chance, B., Hulsizer, R. I., Mac Nichol, E. F. and Williams, F., <u>Electronic Time Measurements</u> (New York: McGraw-Hill Book Company, Inc., 1947) p. 68

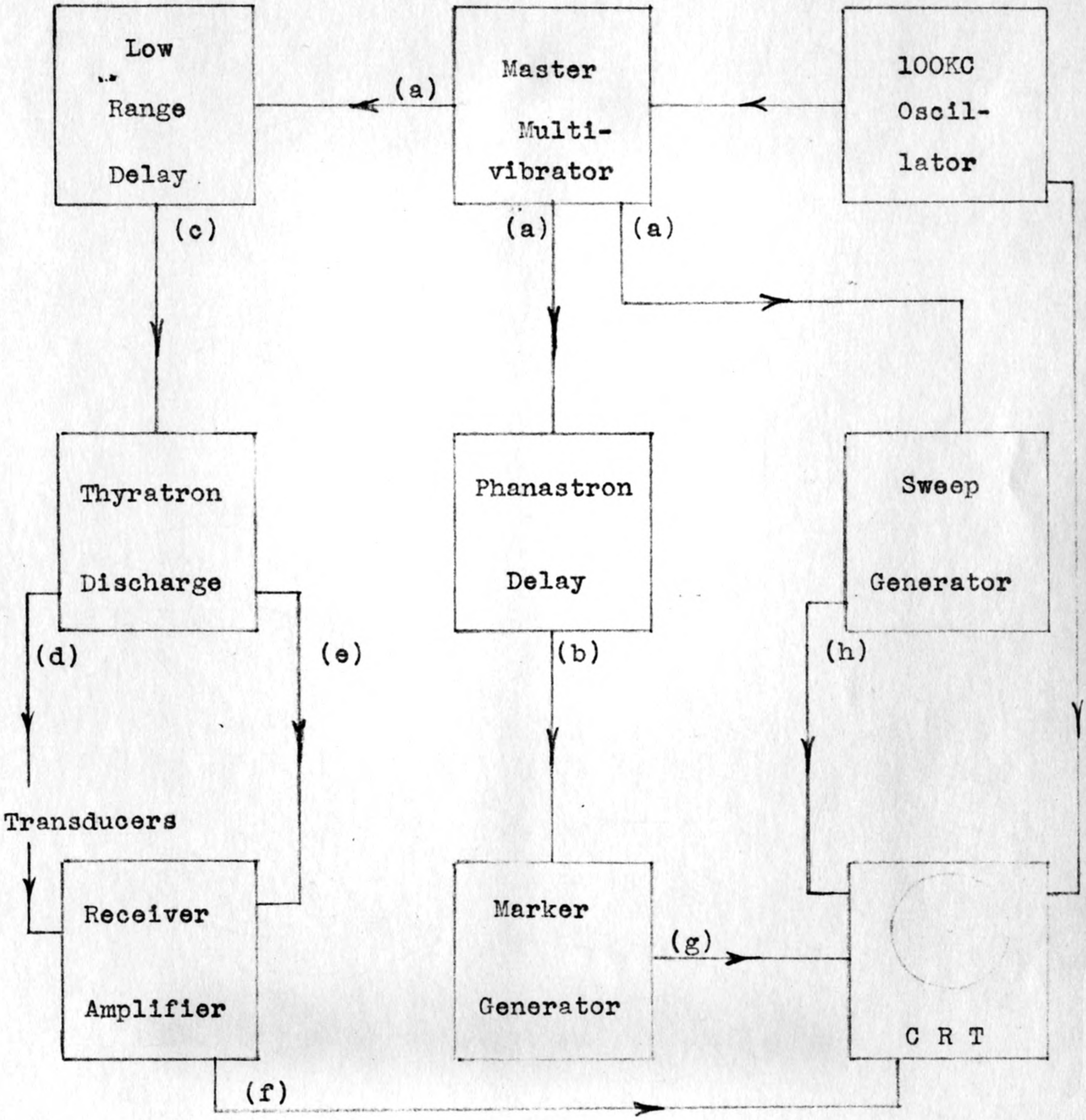


Fig. 10. Block diagram of sonoscope in its present form.

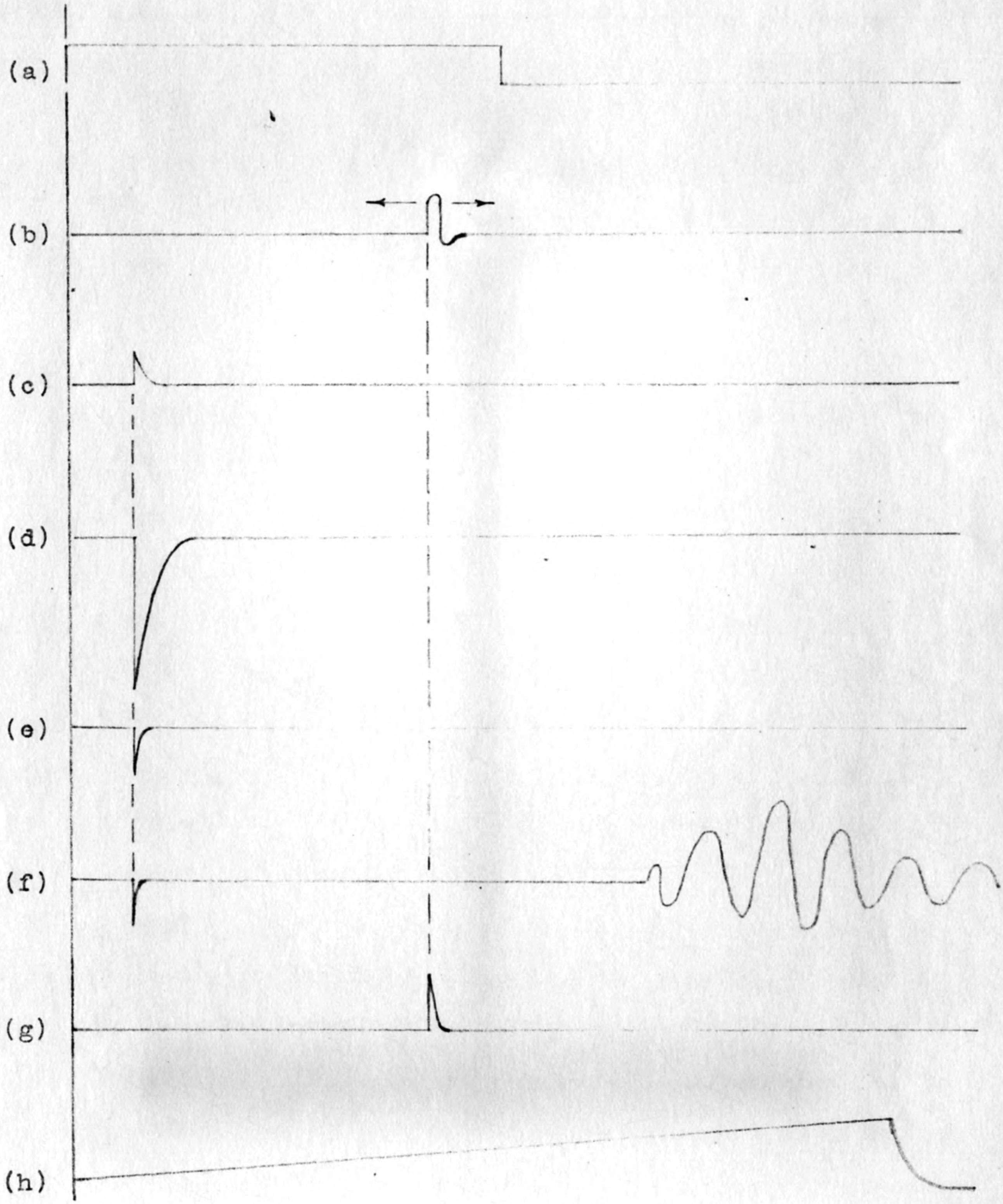


Fig. 11. Waveform diagram of sonoscope in its present form.

diagram form. The waveform diagram shown in Fig. 11 gives an indication of the operation of the various components. The master multivibrator determines the pulse repetition rate by its driving the time measuring system, the driving system, and the sweep circuit of the cathode ray tube all in synchronism. The pulse repetition rate is approximately 80 pulses per second allowing sufficient time between driving pulses for the rochelle salt crystals to damp out. The strobe generator circuit following the calibrated delay circuit consists of a one shot multivibrator to delay the output of the calibrated delay circuit from 20 to 50 microseconds. This allows the output pulse of the delay circuit to be seen on the cathode ray tube when the calibrated delay is set at zero delay. The 2D21 thyratron of the strobe generator shapes the pulse into one of fast rise time and short duration making it suitable for use as a marker pulse on the cathode ray tube.

The pulse position delay circuit preceding the thyratron output circuit delays the driving pulse in order that its rising edge might be seen on the cathode ray tube.

The receiving system consists of two stages of 1S5 pentodes and three stages of 6AH6 pentodes, giving an overall voltage gain of the order of 10^5.

The 100 kilocycle oscillator built into the sonoscope serves as a time standard for the purpose of calibrating the instrument. This is accomplished by removing the driving and receiving pulses from the upper deflection plates of the cathode ray tube and feeding the plates with the 100 kilocycle sine wave. By tying the master multivibrator in with the oscillator, as shown in the wiring diagram, each pulse repetition starts when the 100 kilocycle wave

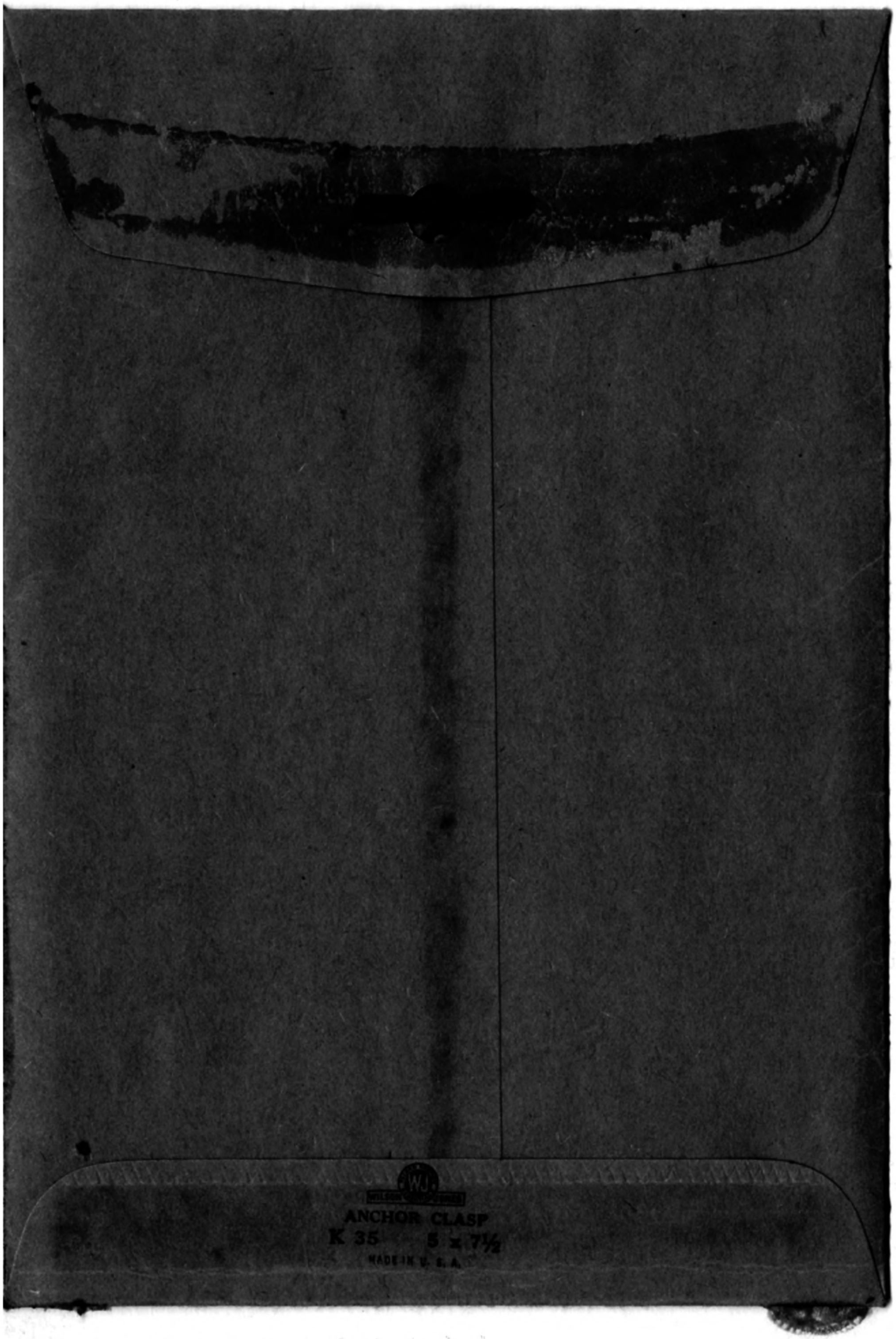
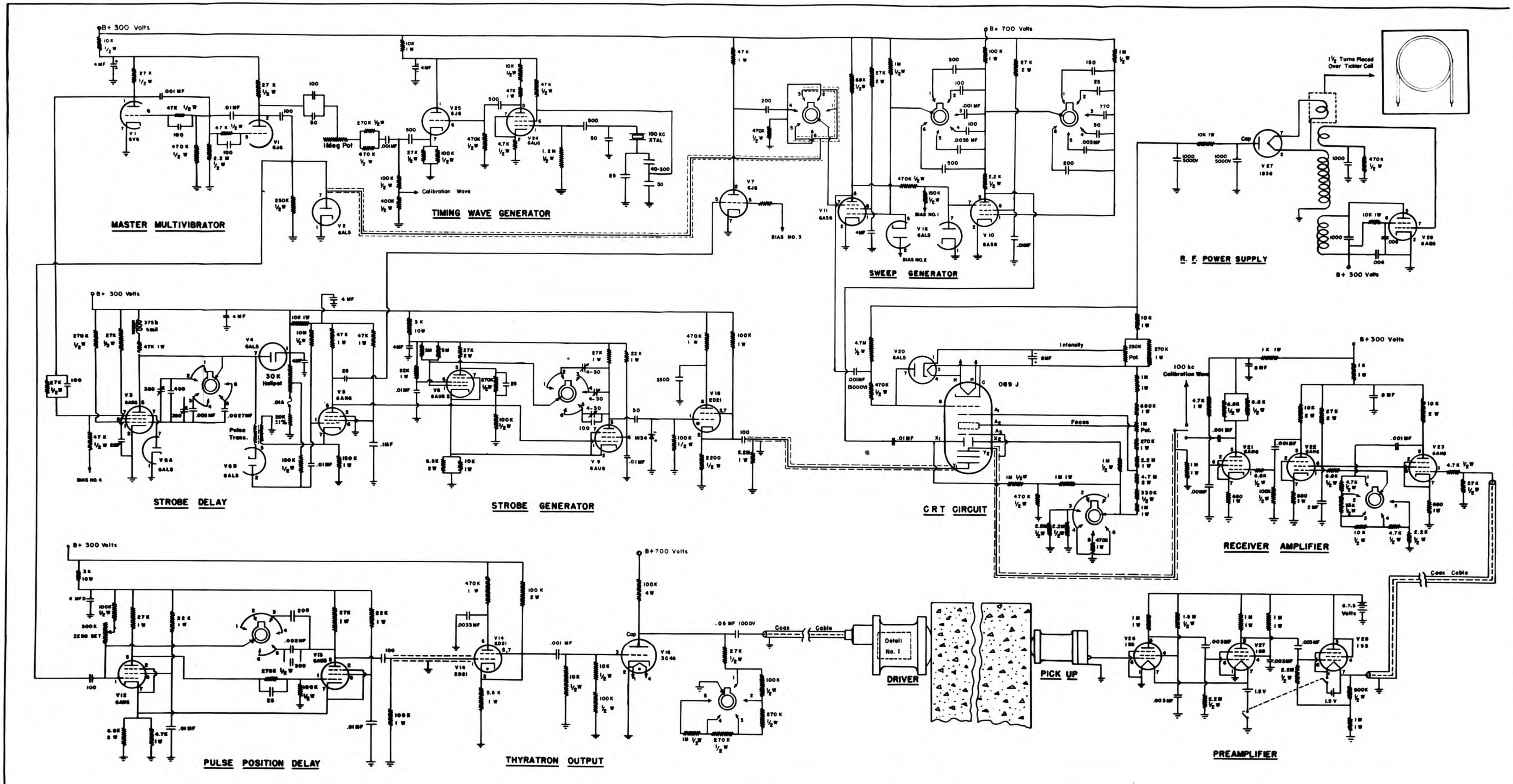
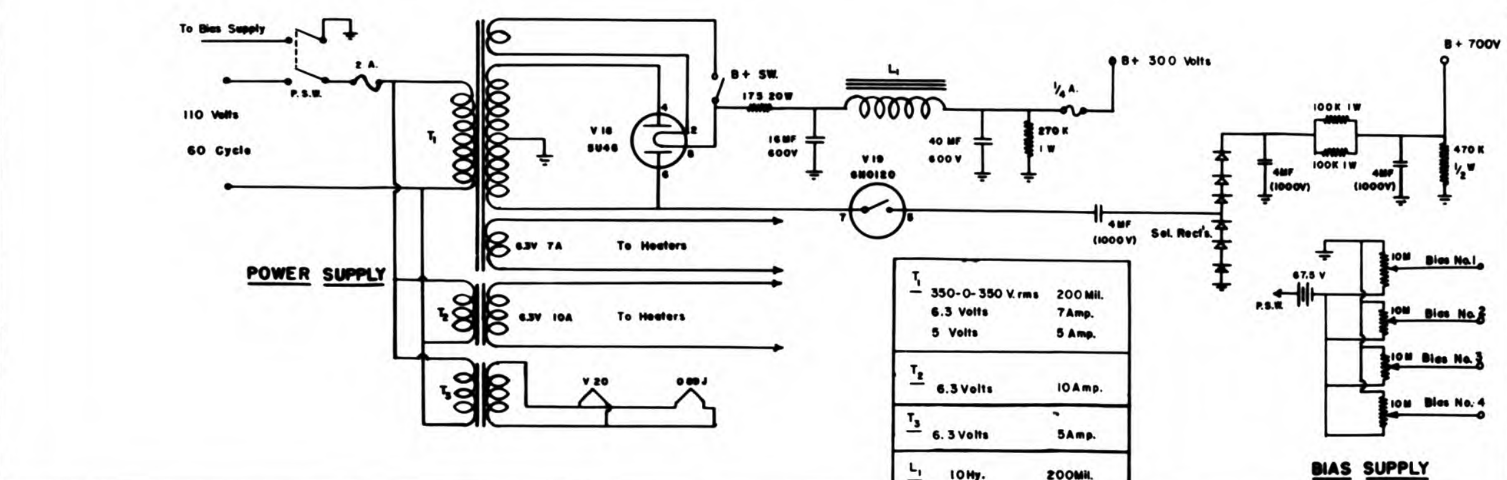


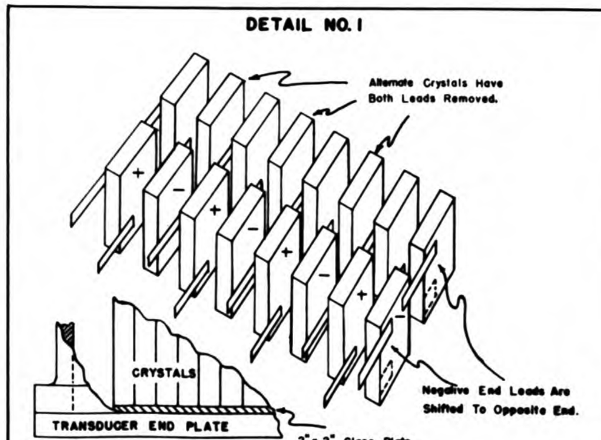
Fig. 12. Wiring diagram of present sonoscope.





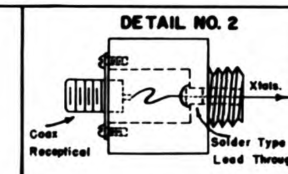
T_1	350-0-350 V. rms	200 Mil.
	6.3 Volts	7 Amp.
	5 Volts	5 Amp.
T_2	6.3 Volts	10 Amp.
T_3	6.3 Volts	5 Amp.
L_1	10 Hy.	200 Mil.

DETAIL NO. 1

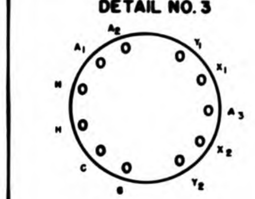


CRYSTAL PHASING PATTEN

DETAIL NO. 2



DETAIL NO. 3



0 89 J Socket (Back View)

RANGE TABLE

Range Switch Position	Strobe Range (Micro Sec)	Sweep Length (Micro Sec)
1	200	200
2	200	50
3	1000	1000
4	1000	100
5	5000	5000
6	5000	500

STATE HIGHWAY COMMISSION OF KANSAS

DEPARTMENT OF MATERIALS

SONISCOPE NO. 3

SCHEMATIC WIRING DIAGRAM NO. 1

DRAWN AND TRACED

Date: December 15, 1950

By: J. L. Chubbuck [signature]

Engr. of Materials.

is at a maximum. Thus the 100 kilocycle wave appears to stand still on the cathode ray tube. In this way the delay of the calibrated delay circuit may be compared with the frequency standard at 10 microsecond intervals. For the purpose of calibration, the sweep circuit is triggered from the output of the calibrated delay circuit and a very fast sweep speed (50 microseconds per inch) is used. With this setup the marker pulse appears to stand still on the scope and the 100 kilocycle wave appears to move by it to the left with only a few cycles showing at a time on the cathode scope. The six position range switch uses the positions 1, 3, and 5 with respective periods of 100, 1000, and 2500 microseconds for operation and positions 2, 4, and 6 for calibration of the three ranges.

The crystals of the driving transducer are driven by the thyratron discharge through a stepped attenuator for reduction of driving power to avoid sustained vibration of the concrete when used on small beams or thin slabs. The receiving system is provided with a gain attenuator in order that high driving power and low gain may be used under conditions where the concrete is subjected to extraneous vibration.

The sonoscope in its present form consists of a single unit as shown in Fig. 13 mounted permanently in the rear of a panel truck. To the right of the five inch cathode tube may be seen the intensity and focus controls. In the horizontal row of three controls, the receiver gain control is on the left, the range switch in the center, and the drive attenuator on the right. Below the range switch is shown the ten turn calibrated dial, and below that, the zero adjustment for the purpose of bringing the marker pulse

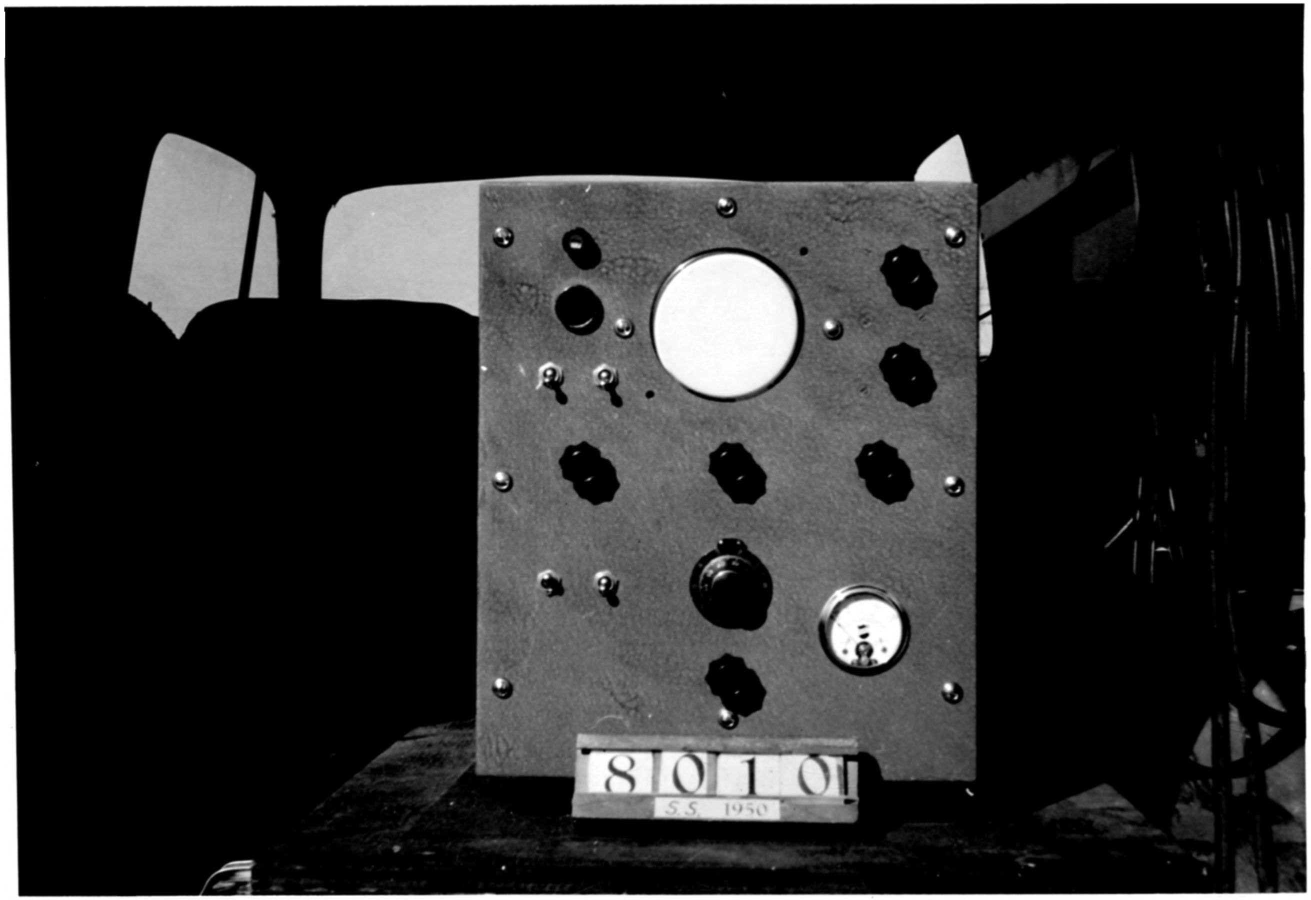


Fig. 13. Present form of the sonoscope shown mounted permanently in the rear of a panel truck.

in coincidence with the driving pulse when the calibrated dial is set at zero. Shown at the right of the sonoscope are the two fifty foot coaxial cables to which the transducers are connected. The sonoscope is operated from a .75 kilowatt motor-generator mounted directly behind it. The total weight of the system (not including the motor-generator) is 77 pounds, and the dimensions are 14 inches wide, 17 inches high, and 19 inches deep. The sonoscope is maintained at nearly constant temperature by a thermostatically controlled, forced-draft blower mounted internally. The sonoscope, as well as the supperting platform, is mounted on sponge rubber sheets in order to absorb the vibration from the truck. Although it is not shown in the photograph of Fig. 13, a viewing hood bolts into the panel over the cathode tube to make the traces visible in the bright sunlight.

THE ALTERNATE TIMING SYSTEM

As previously mentioned, the present timing system is not sufficiently linear to use without a set of calibration curves. Furthermore, the linearity of the time measuring system varies in its calibration from day to day. Another undesirable feature of present sonoscope is the excessive amount of jitter resulting from erratic triggering of the sweep circuit by the master multivibrator. A system for correcting these difficulties has been recently worked out and is included here as an alternate timing and synchronizing system.

The block diagram of Fig. 14 shows the general plan of the alternate system. The wave form diagram of Fig. 15 indicates the

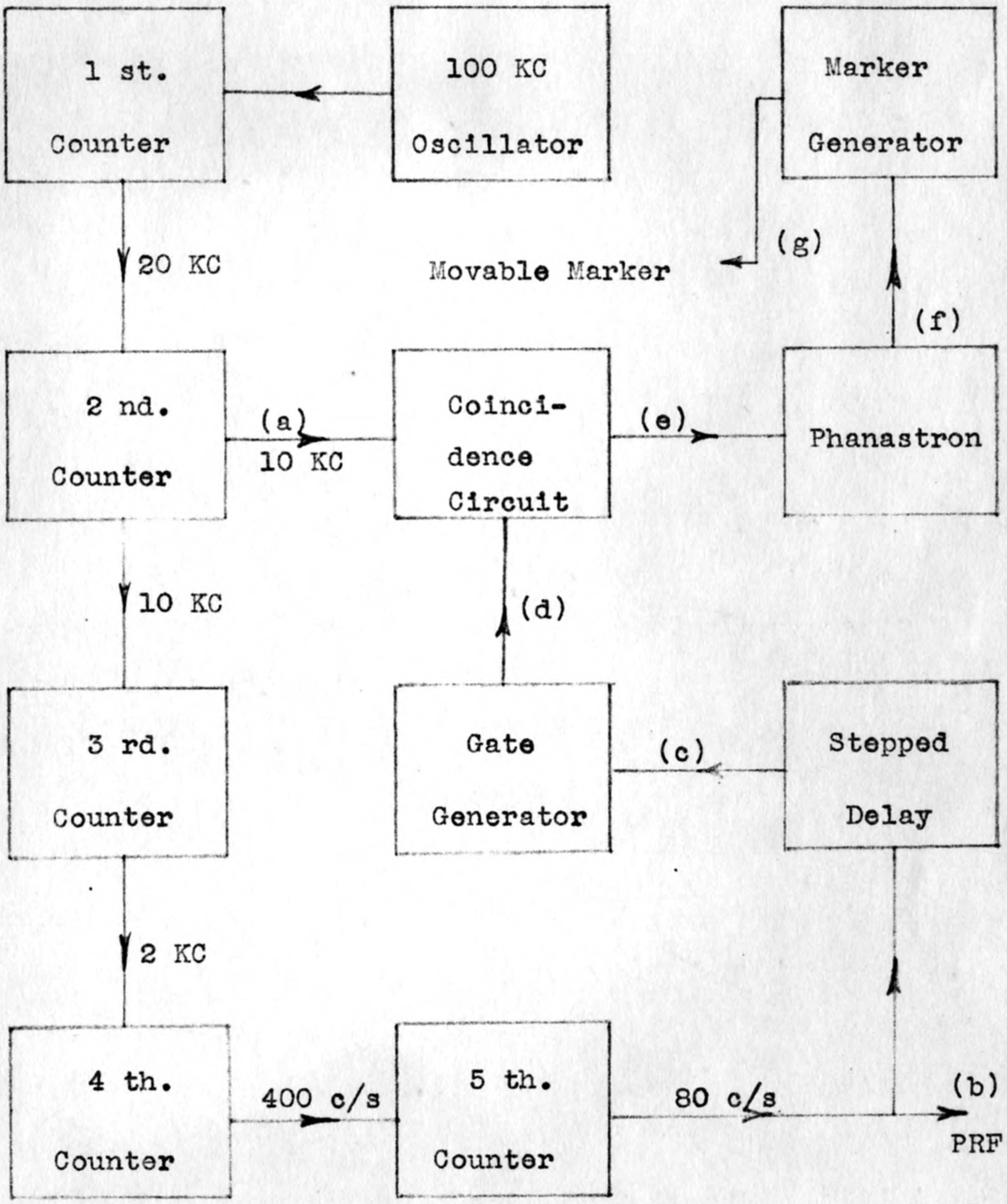


Fig. 14. Block diagram of alternate timing system.

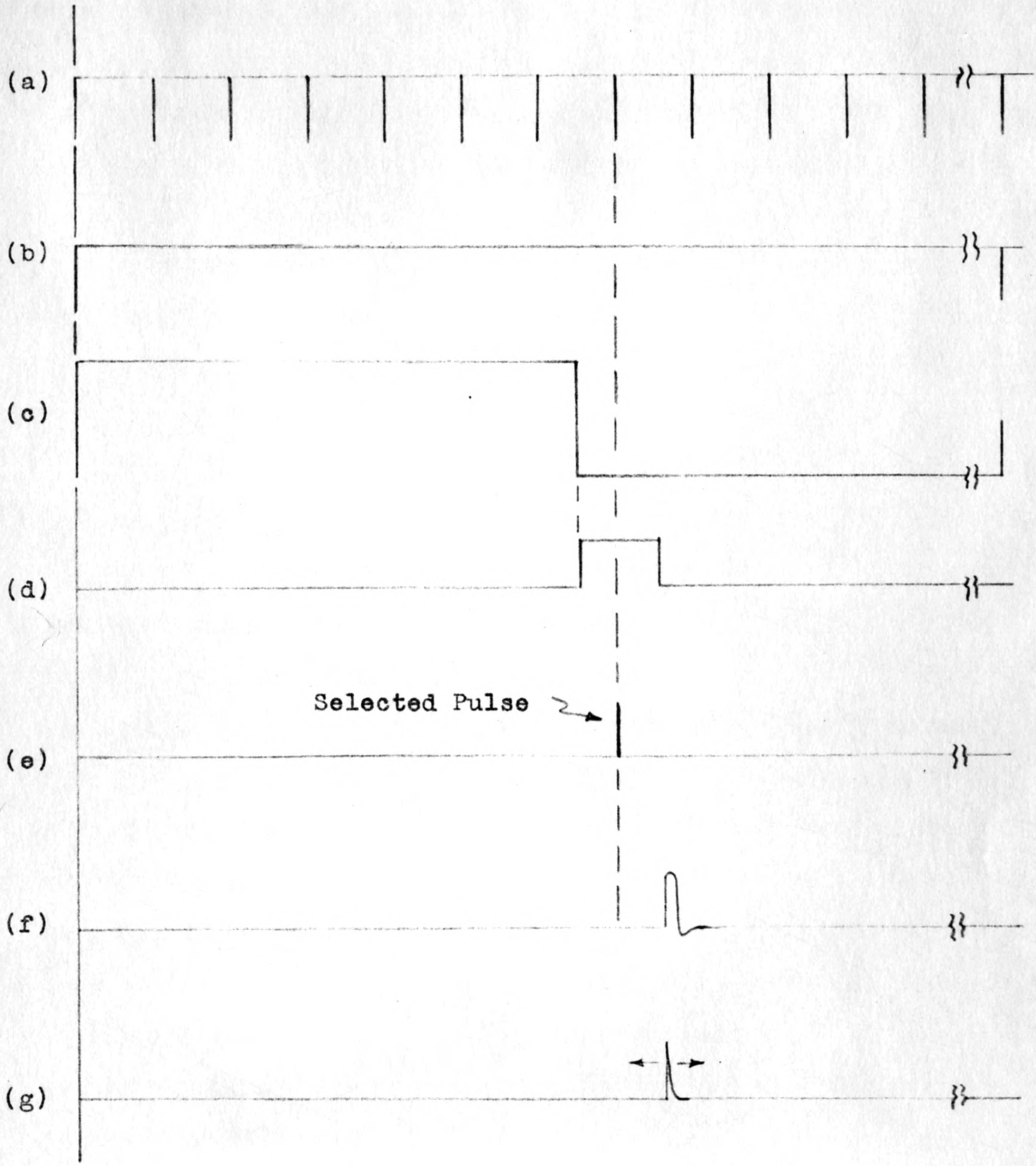


Fig. 15. Waveform diagram of alternate timing system.

function of each component.

As usual, the system uses the 100 kilocycle oscillator as the time standard. This time standard is followed by a series of five counting circuits all adjusted for division by a factor of five except for the second counter which divides by a factor of two. This gives an overall division by a factor of 1250 and thus the output of the fifth counter has a repetition frequency of 80 pulses per second. These pulses are to be used as synchronization pulses in place of those from the present master multivibrator.

The gate circuit consists of a one-shot multivibrator which produces a gate pulse 100 microseconds in width. This gate pulse is delayed by integral multiples of 100 microseconds by the stepped delay circuit, thus making the gate pulse movable over a range of 2400 microseconds. The output pulses of the second counter are fed to the mixer along with the gate pulse thereby allowing only the one counter pulse which occurs in coincidence with the gate to be passed by the coincidence circuit. This provides a series of fixed pulses each 100 microseconds apart which can be selected by the delay multivibrator. The output pulse of the coincidence circuit is then fed to the phanastron delay circuit which delays the pulse linearly from 0 to 100 microseconds. The marker generator simply shapes the pulse into a form suitable for use as a marker pulse.

Time Standard and Counting Circuits

The 100 kilocycle oscillator time standard is a conventional crystal oscillator with a one stage saturated amplifier for wave

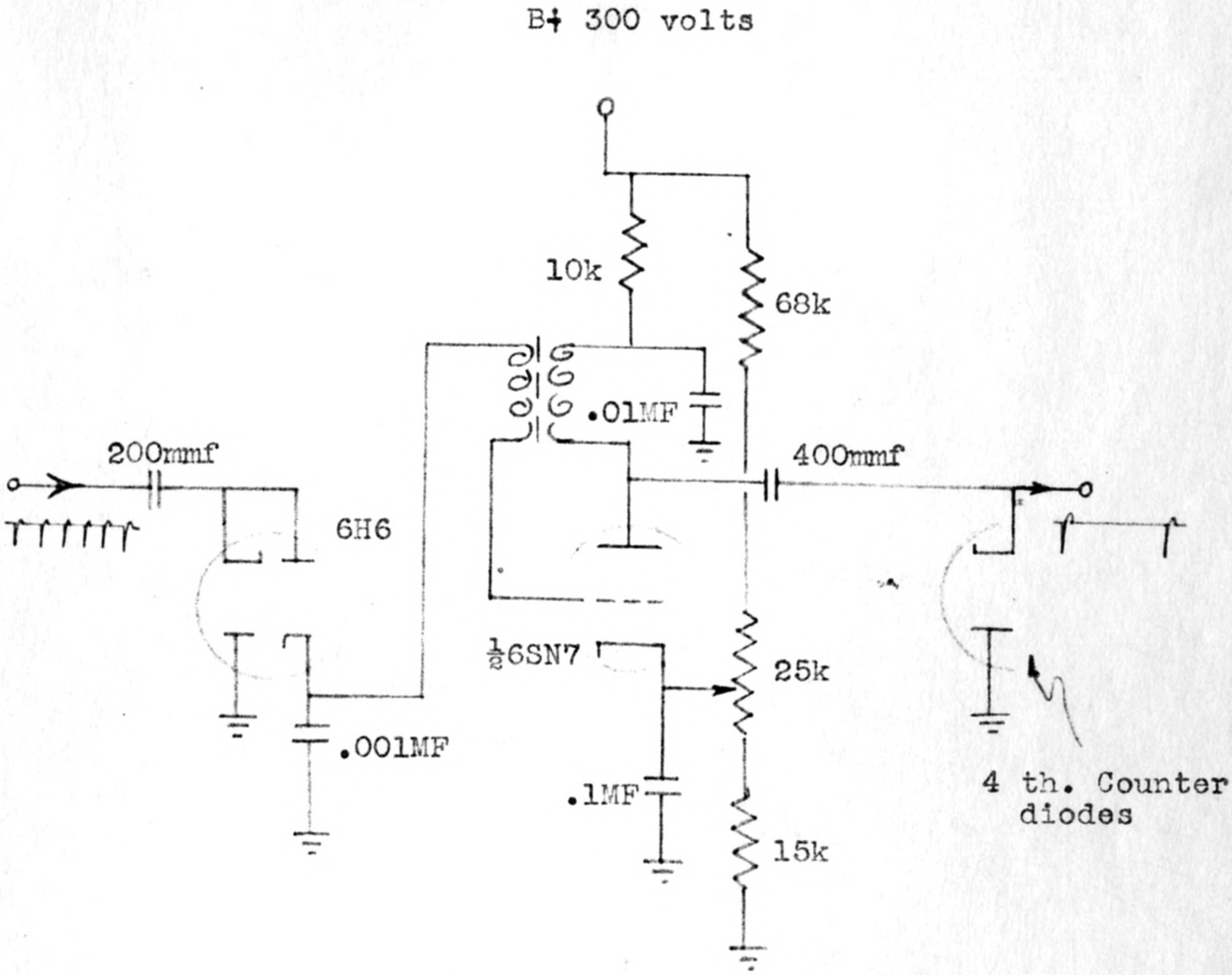


Fig. 16. Counter number three which is typical of all five counting circuits

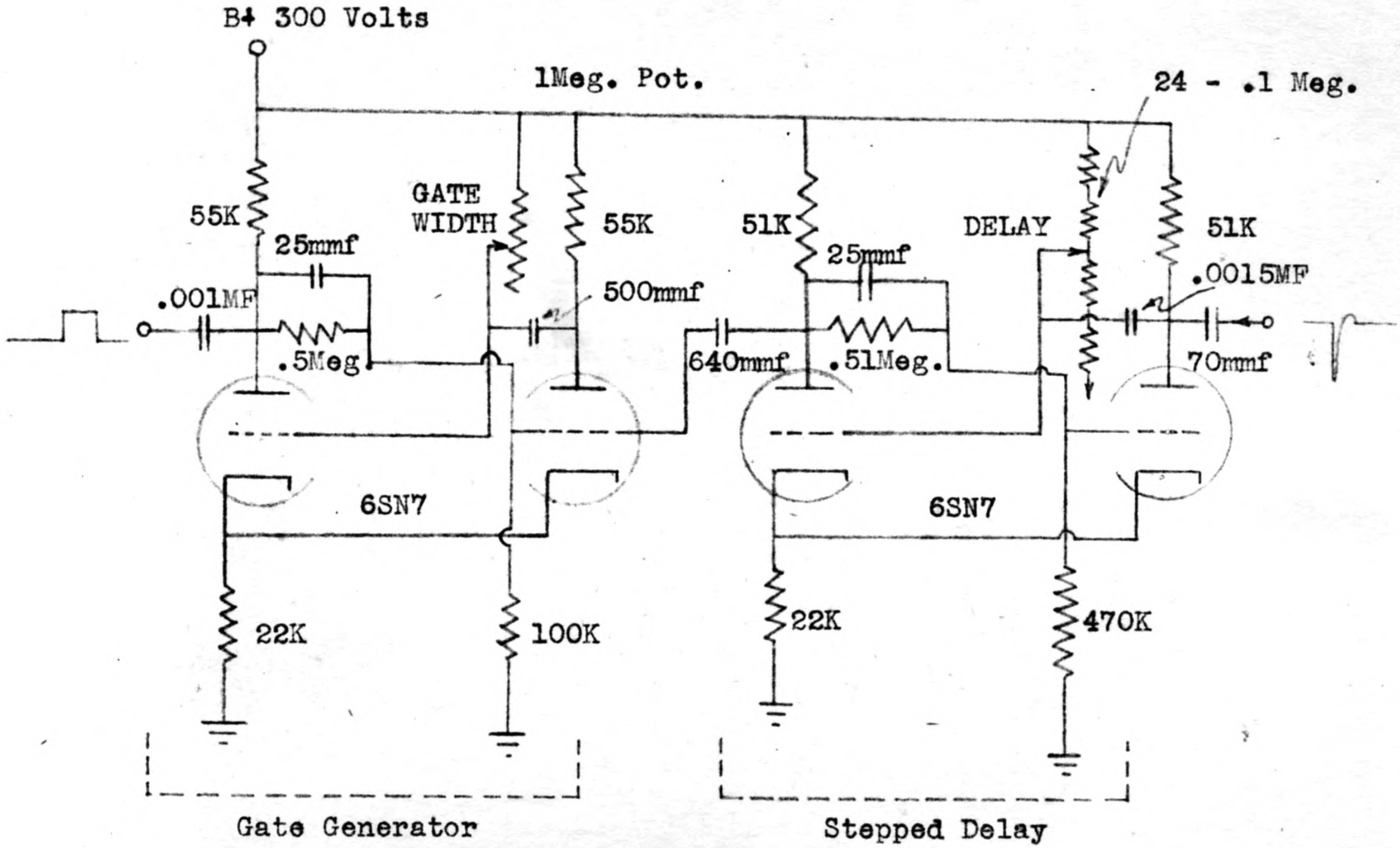


Fig. 17. Circuit diagram of stepped delay multivibrator and gate generating multivibrator.

shaping and isolation purposes. Circuit details are shown in the accompanying wiring diagram of Fig. 26. The five counter circuits are the conventional blocking oscillator type in which a capacitor is charged through a diode in steps until the potential across the capacitor raises the potential of the grid of the blocking oscillator to above cutoff, thus initiating its characteristic function. The circuit diagram of Fig. 16 is typical of the five counting circuits.

Delay Multivibrator and Gate Generator

Fig. 17 shows the circuit diagram of the delay multivibrator and the gate generator. The delay multivibrator is a one-shot multivibrator in which the conducting period of the normally non-conducting section may be varied in steps of 100 microseconds by varying the resistance in the A. C. coupled grid circuit in steps of 0.1 megohms. By differentiating the output of the delay multivibrator, the input pulse is delayed by the conduction period of the normally non-conducting section. As shown by the circuit diagram, the gate generator circuit is similar to the delay multivibrator except that the period of the unstable state is constant at 100 microseconds. Thus the two components provide a gate pulse that may be moved in steps throughout the first 2400 microseconds of the pulse repetition period.

Coincidence Circuit

The coincidence circuit makes use of the special character-

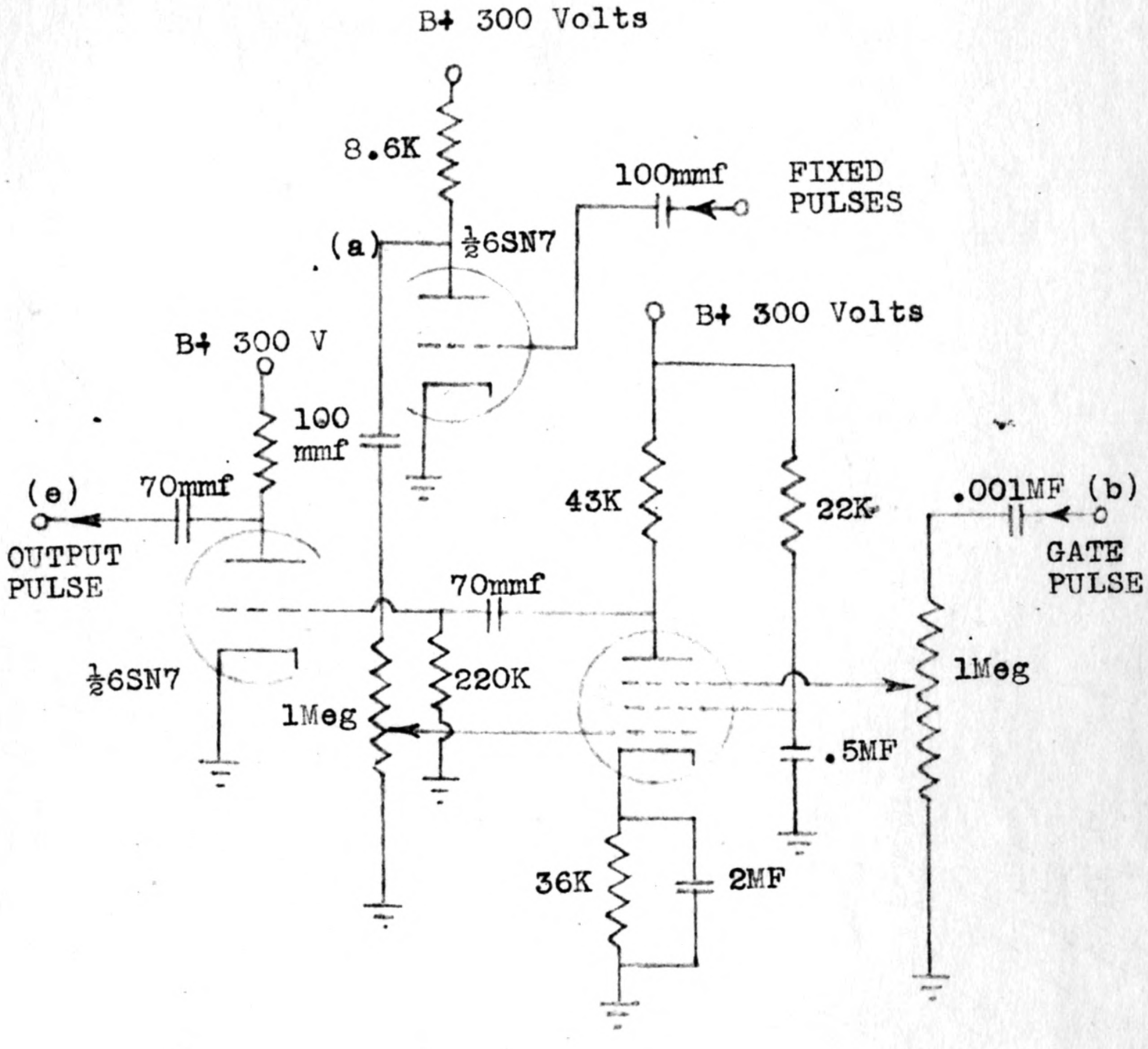


Fig. 18. Coincidence circuit showing inversion of fixed pulses as well as the inversion of the output pulses to obtain positive pulses for triggering the phanastron.

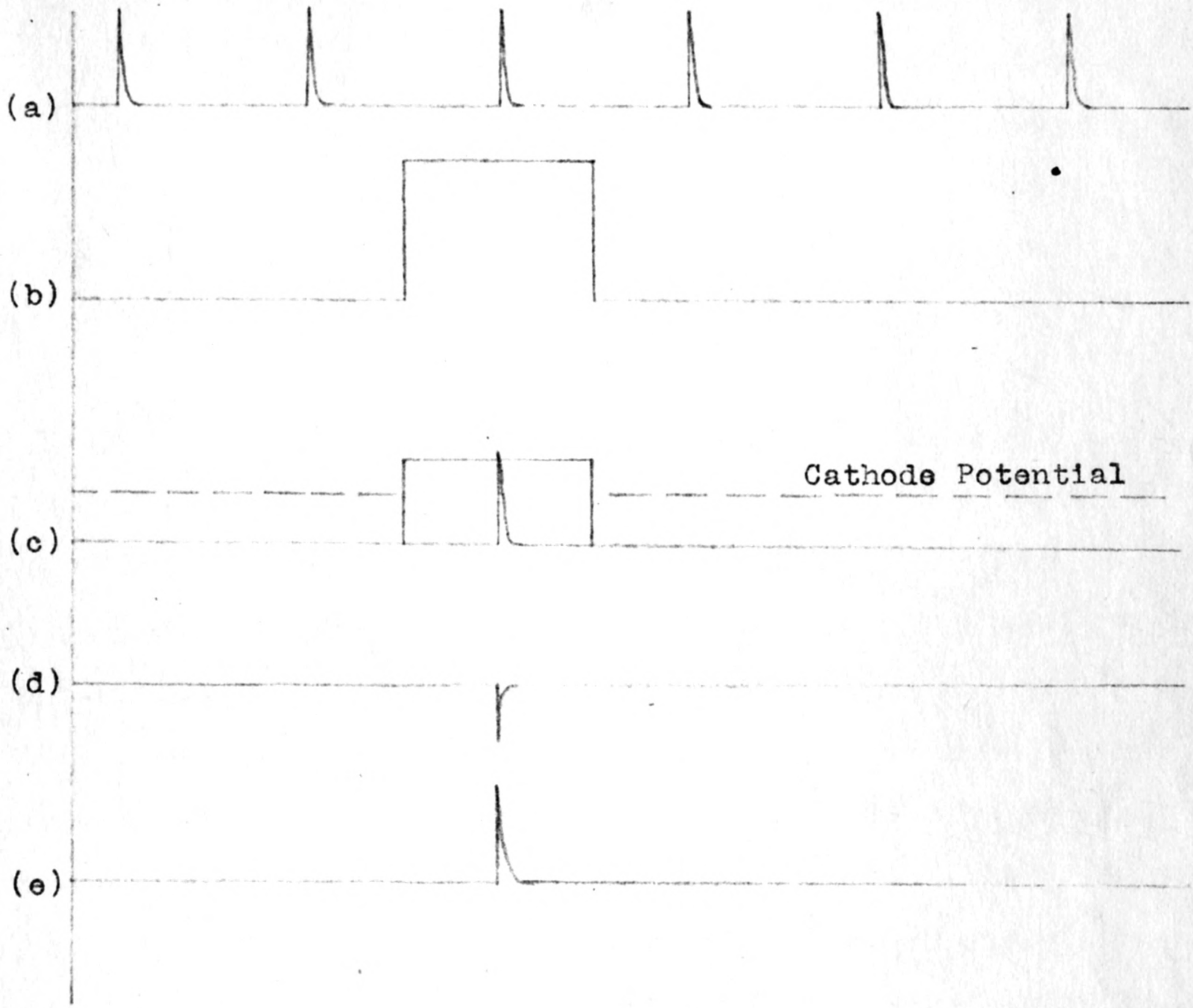


Fig. 19. Coincedence Circuit Waveform Diagram.

istic of the 6AS6 tube in which the suppressor grid displays an unusual amount of control of the plate current. The tube is biased off with respect to both the control and suppressor grids by floating the cathode 35 volts above ground. The 100 microsecond gate pulse is placed on the suppressor grid after being attenuated to a voltage height of 55 volts. The 100 microsecond fixed pulses taken from the output of the second counter and inverted by one section of the 6SN7 shown in the coincidence circuit diagram of Fig. 18. The positive fixed pulses are then placed on the control grid of the 6AS6 after being attenuated to a voltage height of 45 volts. As shown by the waveform diagram of Fig. 19, the suppressor grid keeps the 6AS6 cut off not allowing any of the fixed pulses to cause conduction except the one that occurs in coincidence with the gate pulse. During the gate pulse period, the suppressor grid is will within the conduction potential region, but the tube is cut off by the control grid. Thus, conduction occurs only during the interval when the gate pulse occurs and the fixed pulse is simultaneously above 32 volts with respect to ground. The other section of the 6SN7, shown in the coincidence circuit diagram of Fig. 18, inverts the pulses taken from the plate of the 6AS6 in order to obtain positive output pulses.

Phanastron Delay Circuit

The positive output pulses from the coincidence circuit are used to trigger the phanastron delay circuit. The function of the phanastron is to provide a linear delay over a period of 100 microseconds. It is therefore possible to have a continuous delay over

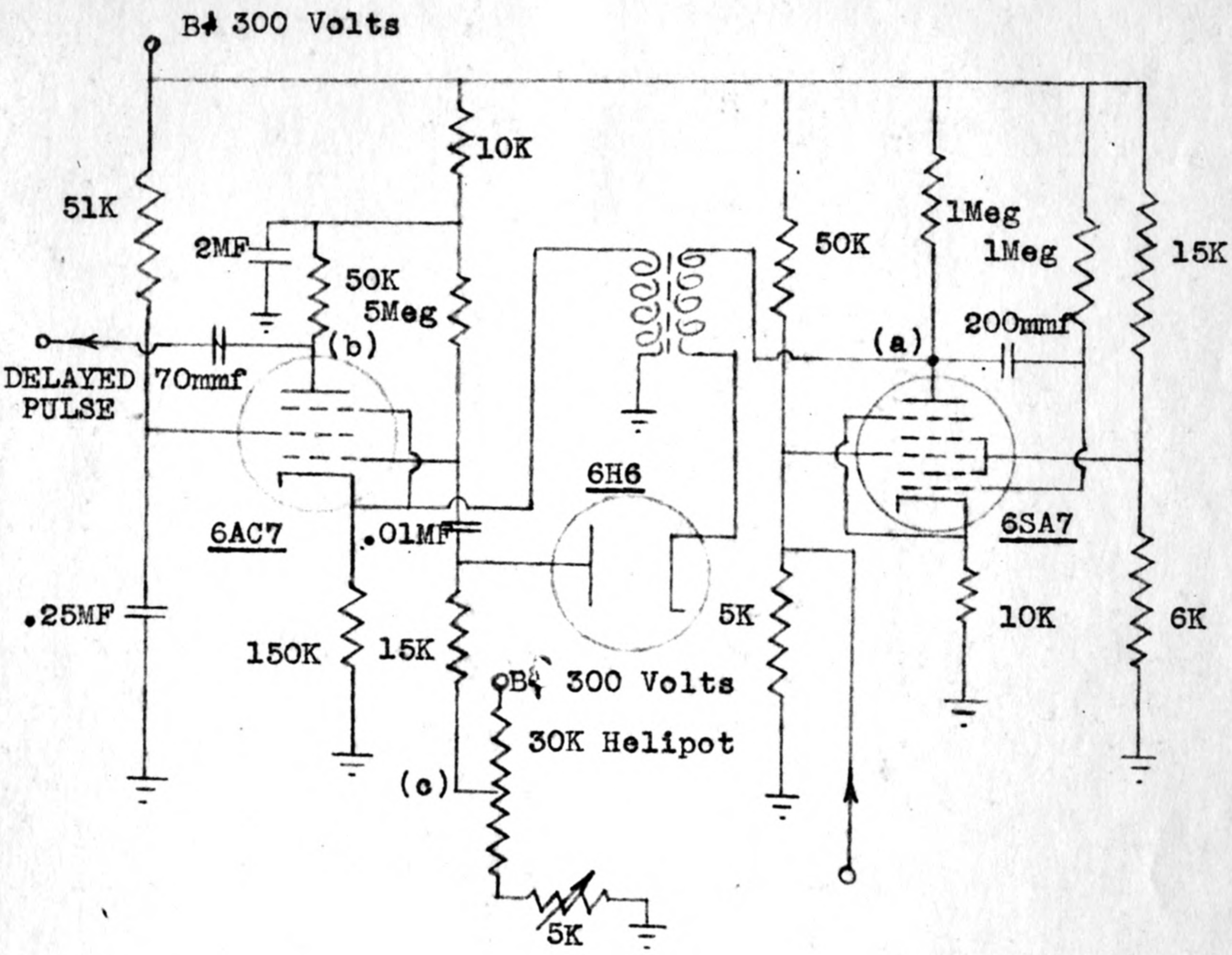


Fig. 20. The revised phanastron delay circuit.

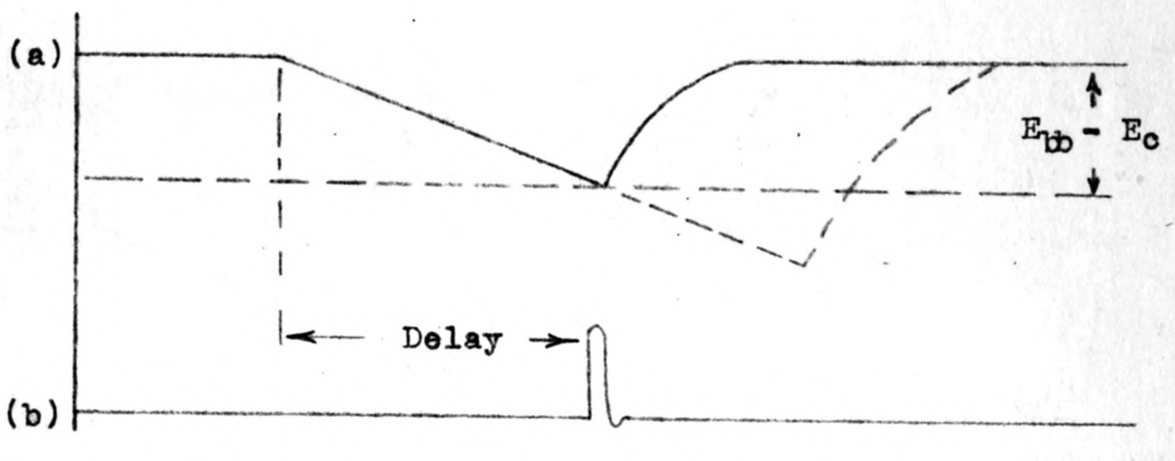


Fig. 21. Waveform diagram of revised phanastron.

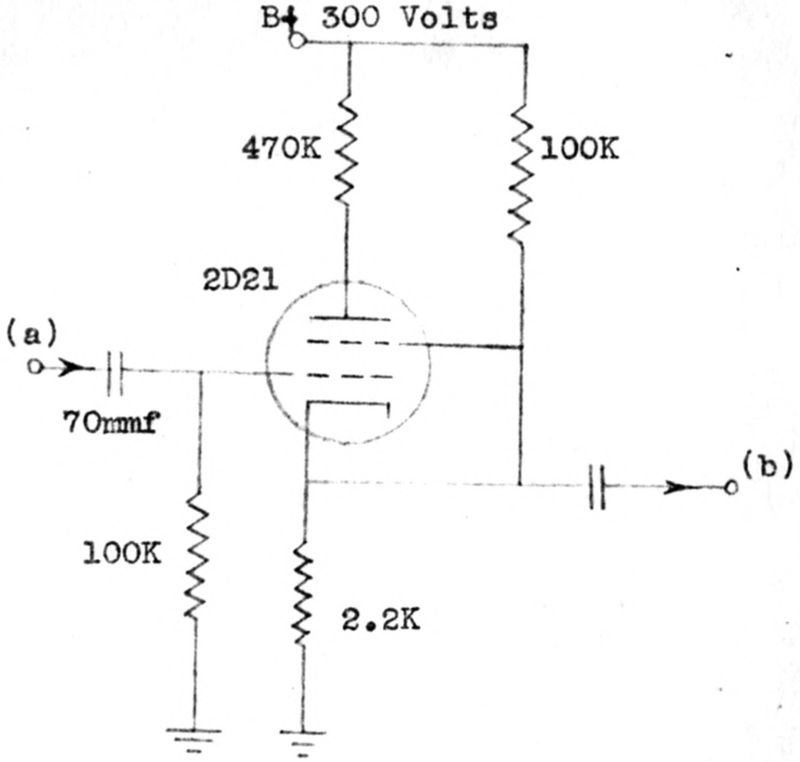


Fig. 22. Circuit diagram of marker pulse generator.

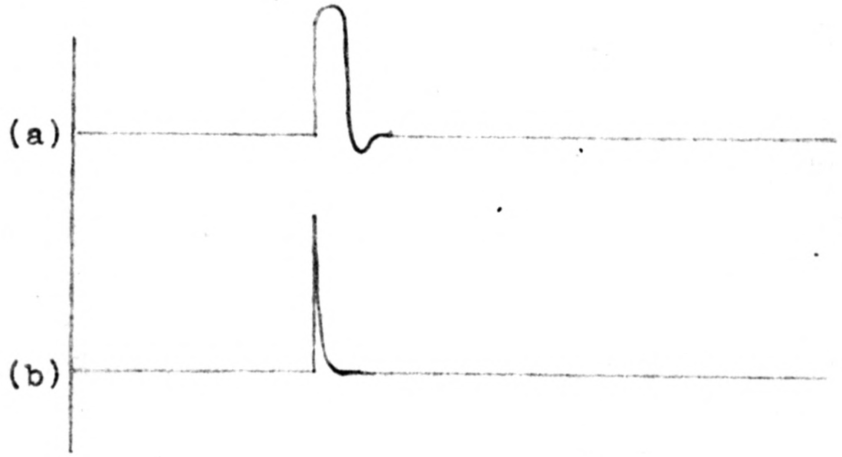


Fig. 23. Waveform diagram of marker pulse generator.

an interval of 2500 microseconds by getting multiples of 100 microseconds delay from choice of fixed pulses selected with the movable gate and completing the delay with the phanastron.

Fig. 20 shows the circuit diagram and Fig. 21 the corresponding waveform diagram of the delay phanastron. The phanastron is essentially the same as the one previously discussed except that all bias levels have been changed to eliminate the negative bias supply from the sonoscope entirely. Also, the plate to grid capacitor is not switched for multiple ranges since the phanastron is operated only in the 0 to 100 microsecond range. Although the linear portion of the Miller integrator plate voltage wave is longer than 100 microseconds, as indicated in the waveform diagram, only a 100 microsecond interval is used. This allows calibration of the helipot simply by placing a small rheostat in series with it.

Marker Generator

Although the output pulse of the phanastron has a relatively short rise time, it is too broad and poorly shaped to use as a movable marker pulse on the lower deflection plates of the cathode ray tube. For this reason, the marker pulse generator shown in Fig. 22 is used to shape the marker pulse as indicated in the waveform diagram of Fig. 23. This component consists of a single 2D21 thyratron that is fired by the phanastron, and on firing the plate voltage drops below the extinction value. The rise time of the cathode voltage is extremely short, making a pulse in which the leading edge forms a very good movable index. The width of the marker pulse after falling to ten per cent of its original value

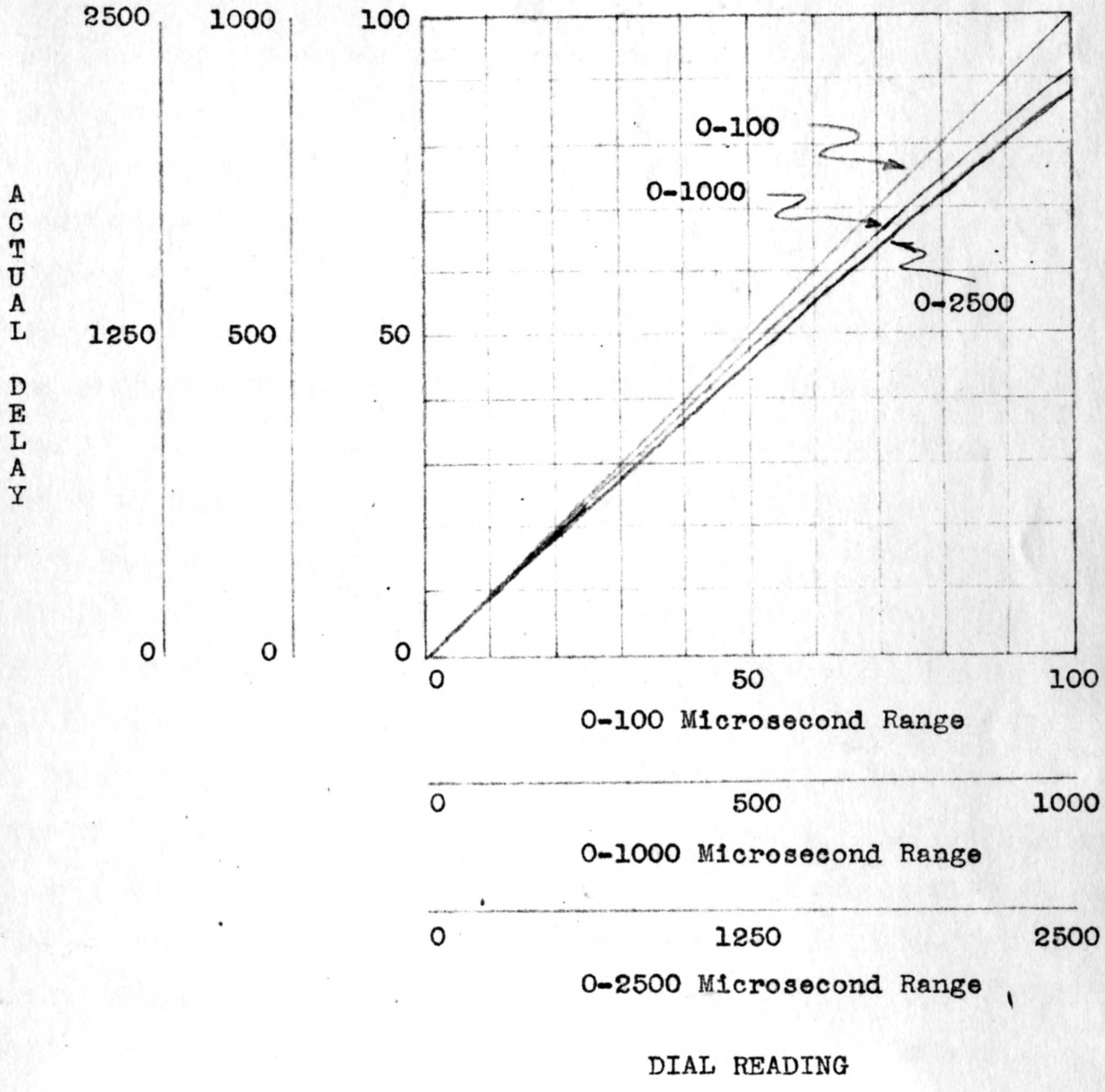


Fig. 24. Delay characteristic of present sonoscope.

is of the order of three microseconds.

Delay Characteristics

As previously mentioned, the purpose of the alternate timing system is to produce a more stable synchronization between the pulse repetition generator and the time standard circuit, and, of greater importance, to provide a time standard circuit, that is more nearly linear and less critical to calibrate than that used in the present sonoscope. The stability factor is achieved here by the inherently stable nature of the five counter circuits. With regard to linearity, it might be well to compare the characteristics of the alternate timing system to that of the present sonoscope.

Fig. 24 shows the delay characteristics of each of the three ranges of the timing system in the present sonoscope. Fig. 24 shows the very linear nature of the phanastron when operating in the 0 to 100 microsecond range. In fact, the greatest differential between dial reading and actual delay is approximately 0.2 microsecond. This is obtained by adjusting the slope of the linear portion of the Miller integrator plate voltage wave such that the delay characteristic curve crosses the ideal delay line at approximately 62.5 microseconds. For time measurements up to 100 microseconds, this is quite satisfactory. However, the 0 to 100 microsecond and 0 to 2500 microsecond ranges are not nearly as linear as shown by Fig. 24 which show maximum errors of approximately 17 and 47 microseconds, respecticely.

With the alternate timing system, however, the fixed pulses

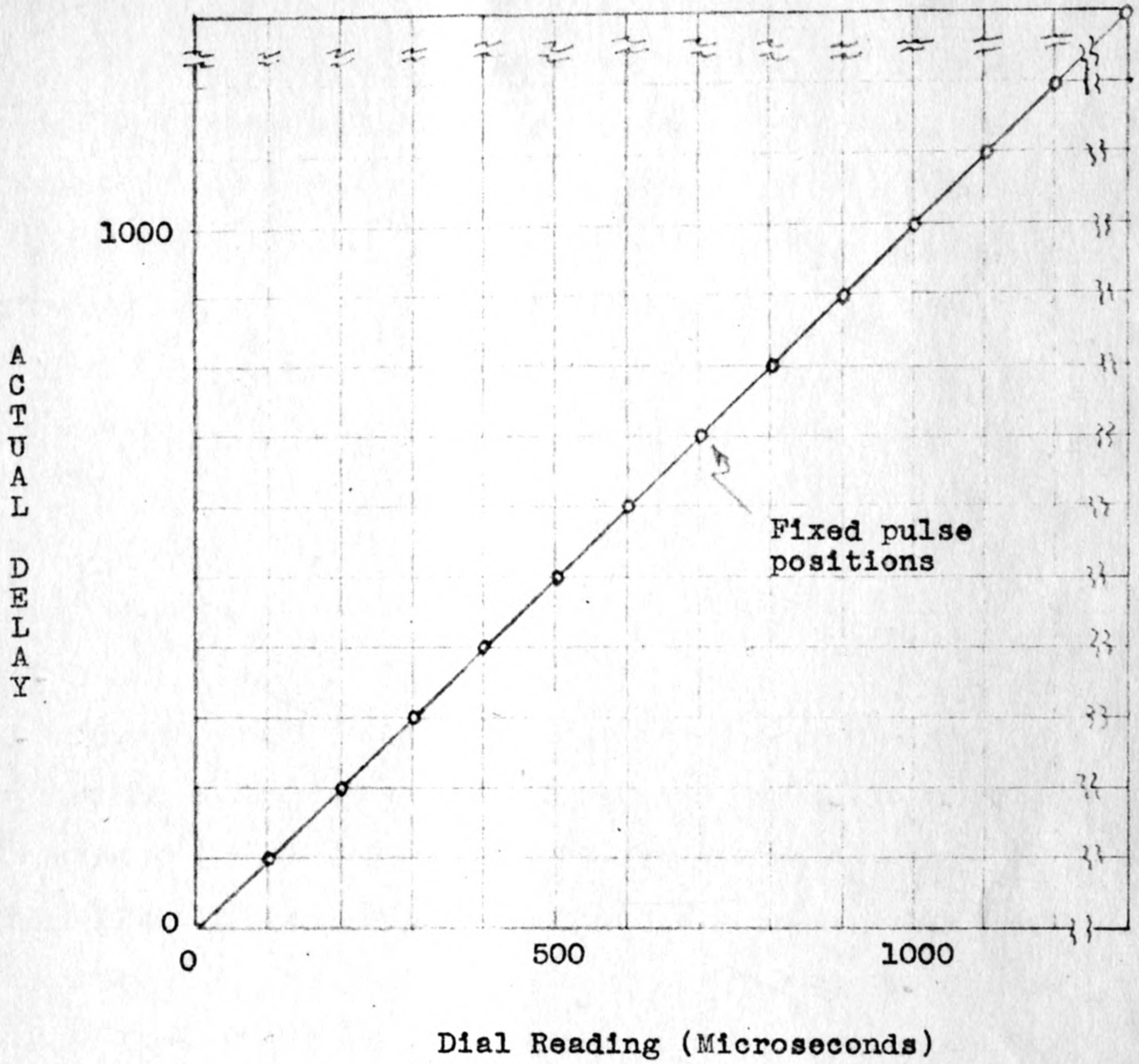


Fig. 25. Overall delay characteristic of alternate timing system.

are inherently calibrated since they are taken from an accurate cycle count from the crystal frequency standard. Thus, at every 100 microsecond interval, the delay is accurately known and free of error. This is illustrated by the points shown in Fig. 25. Between the 100 microsecond points the greatest possible error is approximately 0.2 microsecond; the inherent maximum variation between helipot dial reading and actual delay when the phanastron is operated over a range of only 100 microseconds. The percentage error is therefore quite small, especially when the transit time is of the order of several hundred microseconds, which is usually the case.

CONCLUSIONS

The alternate timing system is quite similar to the system suggested by Chance, Hulsizer, Mac Nichol, and Williams[1] known as a scale-of-two system. It is of interest to note that the 100 microsecond fixed pulses and a sufficiently low pulse repetition rate could have been obtained by using three counters each counting to ten. This was not done because a stable scale of ten counter would demand more elaborate plate voltage regulation than would be justified just to eliminate two counters, especially when the sonoscope is intended to be operated from a portable motor-generator unit.

In adopting the sonoscope to use the alternate timing system,

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[1]Chance, B., Hulsizer, R. I., Mac Nichol, E. F. and Williams, F. Electronic Time Measurements (New York: Mc Graw-Hill Book Company, Inc., 1947) p. 114

it is intended that the driven sweep have but one range of 200 microseconds which will be triggered from the fixed pulse passed by the coincidence circuit. This will allow expansion of the trace without requiring a separate sweep delay to bring the received pulse onto the cathode tube.

The complete circuit diagram of the alternate timing system is shown in Fig. 26.

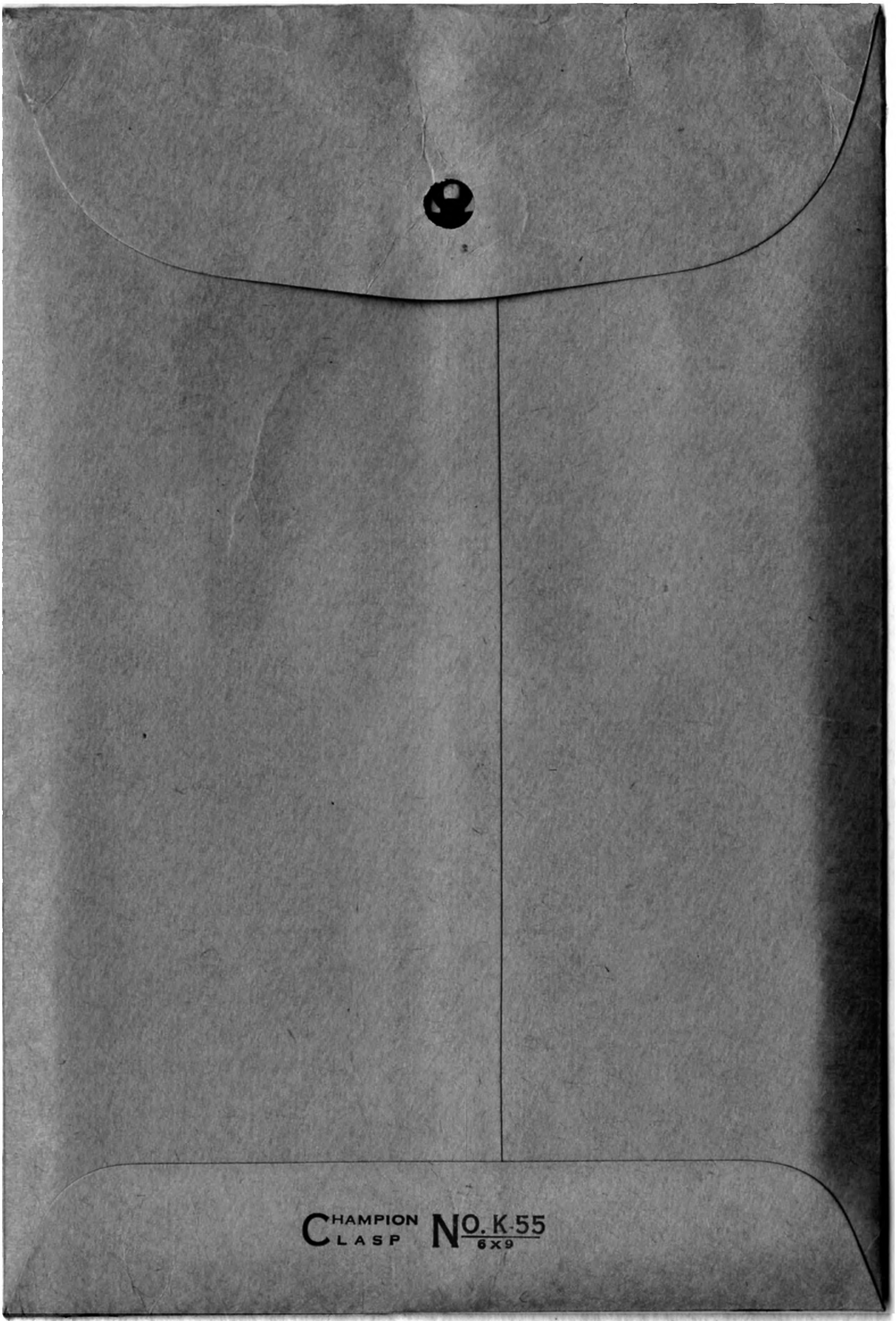

Fig. 26. Circuit diagram of alternate timing system.

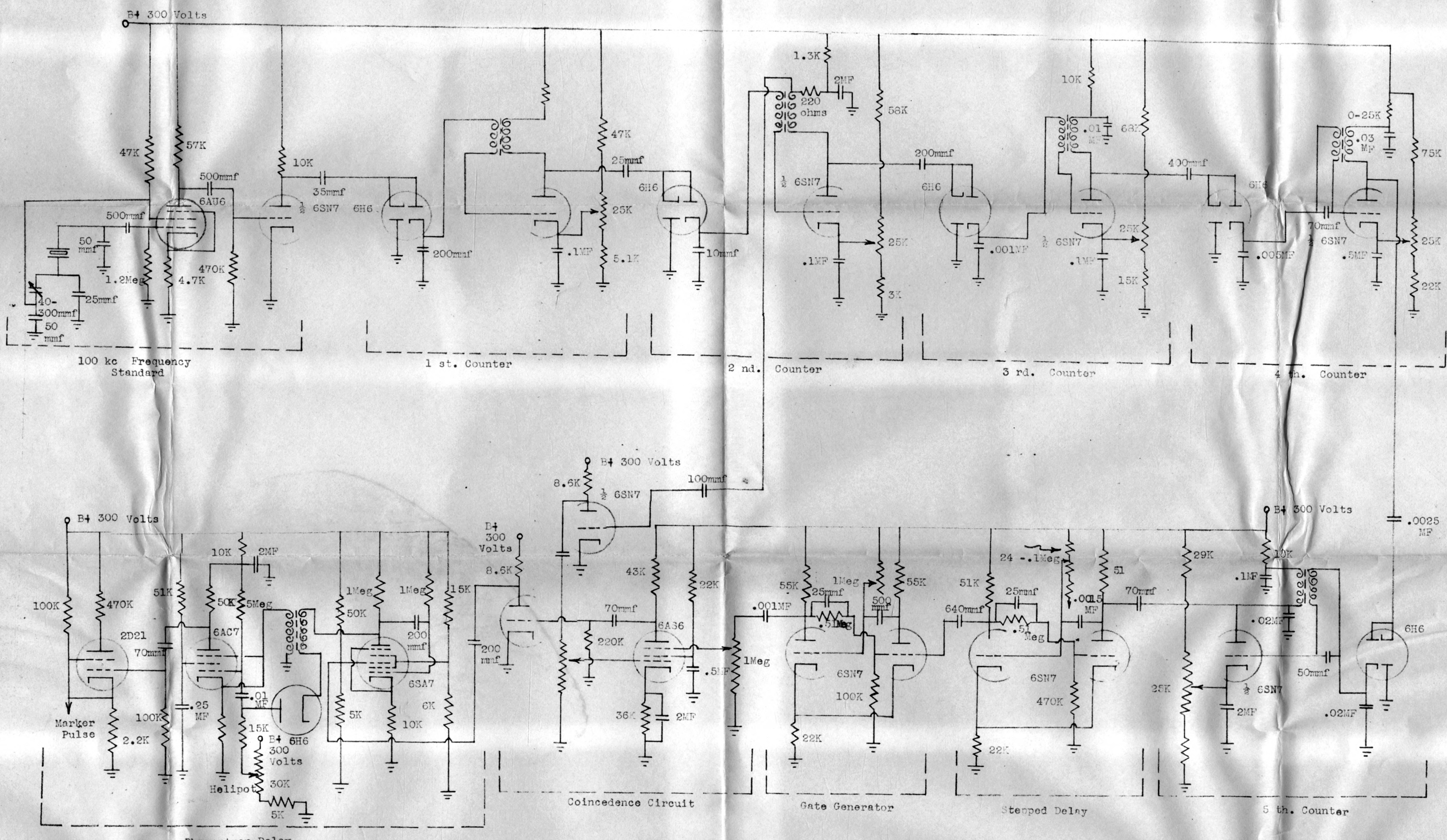

Fig. 26. Circuit diagram of alternate timing system.

ACKNOWLEDGMENT

The writer is indebted to Dr. Louis D. Ellsworth for the assistance received during the latter portion of the work. The writer also wishes to express appreciation for the cooperation given by the Hydroelectric Power Commission of Ontario in loaning one of their sonoscopes for more than a year.

LITERATURE CITED

Chance, B., Hulsizer, R. I., Mac Nichol, E. F. and Williams, F.
Electronic Time Measurements. New York: McGraw-Hill Book Company Inc., 114 p. 1947.

Chance, B., Hulsizer, R. I., Mac Nichol, E. F. and Williams, F.
Electronic Time Measurements. New York: McGraw-Hill Book Company Inc., 68 p. 1947.

Cheesman, W. J. and Leslie, J. R.
"An Ultrasonic Method of Studying Deterioration and Cracking in Concrete Structures," *Journal of the American Concrete* Institute, 46:17 September, 1949.

A WAVE VELOCITY INDICATOR FOR TESTING OF CONCRETE

by

JOHN G. CHUBBUCK

B. S., University of Oklahoma, 1948

AN ABSTRACT

OF A THESIS

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ABSTRACT

The work done in producing a wave velocity indicator, now known as a sonoscope, was conducted in three stages. An instrument developed by the Hydroelectric Power Commission of Ontario, Canada, for the purpose of locating voids in concrete, was analized for features limiting its use for measurements of Modulus of elasticity. A similar instrument was then developed incorporating the necessery modifications, and finally, an alternate timing system was developed which will further improve the utility of the sonoscope, especially for use on large structures.

In serveying the Canadian instrument, it was found that a means of producing sound pulses with a much steeper wavefront than had previously been produced was necessary. Furthermore, the Canadian system for measuring time intervals between pulses was not sufficiently accurate.

The development of the improved sonoscope employed a thyratron discharge pulse driving rochelle salt crystals as a means of producing sound pulses with sufficiently steep wavefronts. A time measuring system far more accurate than that used by the Canadians was obtained by using a calibrated delay phanastron. Advancement of the sonoscope was further realized by greatly reducing the weight and bulk of the instrument.

One undesirable feature of the delay phanastron time measuring system is its excessive nonlinearity at the upper end of the delay range. For this reason, the alternate timing system was developed in which fixed pulses were generated at one hundred microsecond intervals. The phanastron is then used only to cover the intervals

between pulses. It is intended that the next model of the sono-
scope will employ the alternate timing system.