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Audio-Frequency Sweep Equipment **Downgraded to UNCLASSIFIED**

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Prepared by:

Robert G. Mills
Robert G. Mills, Contract Employee

Reviewed by:

R. B. Meyer
R. B. Meyer, Principal Radio Engineer,
Chief of Section

A. Hoyt Taylor, Head Physicist,
Superintendent, Radio Division

Approved by:

A. H. Van Keuren, Rear Admiral, USN,
Director, Naval Research Laboratory

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ABSTRACT

The audio-frequency sweep equipment has been developed at the Naval Research Laboratory for use in jamming enemy c-w signals. To produce this jamming, the jamming transmitter carrier is tuned to the frequency of the enemy signal. The sweep equipment then causes the transmitter carrier to be swept, at random, through an audio-frequency range. The resultant disturbance in a receiver is very effective in preventing a receiving operator from copying the keyed signals. This report describes in detail the functional theory, the method of operation, and the results of the tests performed on this equipment.

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AUTHORIZATION

1. The development of the audio-frequency sweep equipment was carried out under the authority granted in reference (a). The classification of this problem was changed from "SECRET" to "CONFIDENTIAL" by reference (b).

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INTRODUCTORY

2. The audio-frequency sweep equipment was designed for use in jamming c-w signals of enemy origin. A system was desired whereby c-w signals could be jammed effectively with a minimum of jamming power. To effect this, it was essential to eliminate side bands to as great an extent as possible and to derive the jamming effect from the carrier itself rather than from modulation side bands. In the proposed system, the carrier is frequency-modulated by a sawtooth wave. The amplitude of this modulation is adjustable within a specific range. Calibration points are provided for adjustment to 100, 250, or 500 cycles per second peak swing either side of the carrier frequency. The length of the sweep is set at 0.2 second, which is optimum for jamming c-w signals operating at keying speeds between fifteen and thirty-five words per minute. The occurrence of the frequency sweeps is random, and the repetition rate is adjustable. The output of the jamming transmitter is illustrated in Plate 2.

3. The effect of this jamming system is twofold:

(a) The randomly recurring sweeps in transmitter frequency have the effect of interrupting the carrier. This leaves intermittent periods of uninterrupted carrier which simulate keying. Thus, when the jamming transmitter is tuned to the same frequency as the communication transmitter, these rest periods act as an interfering keyed signal overlying the communication signal.

(b) The frequency sweeps cause random chirps in the receiver which are mentally tiring and very distractive to the receiving operator. Any attempt to distinguish the tone of the communication signal through the disturbance caused by these chirps produces a great mental strain.

4. This equipment is quite effective and, with careful operation, it is possible to jam a c-w signal with less jamming signal strength at the receiver than communication signal strength.

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5. The audio-frequency sweep equipment is designed to operate from a 115-volt 60-cycle a-c power source and is suitable for sweeping Models TBK, TBL, TCK, TDE, or similar transmitters in which a dynamic condenser has been connected across the frequency-controlling tank circuit of the master oscillator. A communications receiver is used in adjusting the equipment for operation. Addition of the dynamic condenser alters the calibration of the transmitter; therefore, it is necessary to recalibrate a transmitter in which the dynamic condenser has been installed.

DESCRIPTION OF EQUIPMENT

6. Plate 1 shows a block diagram of the sweep equipment. The operation is explained briefly in the following paragraphs.

7. The random pulse generator produces sharp, positive pulses at random to be used to trigger a single-pulse multivibrator circuit. The output of the multivibrator is a square wave. This square wave is applied to the sawtooth pulse converter which alters it to a sawtooth wave with its static zero level halfway up the slope of the wave. This sawtooth wave is applied to the current amplifier, which amplifies it and sends a similarly-shaped pulse of current through the coil of the dynamic condenser mounted in the transmitter. The dynamic condenser is a small unit (Plate 9 is larger than actual size) which functions in a manner similar to a permanent magnet dynamic speaker. However, instead of activating a paper cone, the movable coil moves the variable plate of the condenser. Consequently, the capacity of the condenser varies with the current through the coil. The condenser, when connected across the oscillator grid tank of the transmitter, by virtue of variations in the current through the dynamic condenser coil, changes the frequency of oscillation. Since the change of capacity is small compared to the total capacity in the tank circuit, the change of frequency is essentially linear with current change. The sawtooth current, therefore, causes the deviation of the transmitter output frequency illustrated in Plate 2. This output frequency swing may be the same as the oscillator swing or it may be some multiple of the oscillator swing if frequency multiplication is used in the transmitter.

8. The indicator and audio oscillator are auxiliary units used in adjusting the equipment as described in paragraphs 17 and 18 below. The power supply is rated at 250 volts and delivers up to 250 milliamperes of direct current.

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DETAILS OF CIRCUIT FUNCTIONS

9. Plate 10 is a schematic diagram of the entire circuit. Reference is made to this diagram in describing the circuit functions.

Random Pulse Generator

10. The primary source of random pulses is the shot-effect and ionization noise generated in the Navy Type 2050 thyatron, V201. This noise is amplified by a Navy Type 6J5 tube, V202. R202 is a gain control on the amplifier and functions as the random pulse rate control, as explained in paragraph 11 below. R205 and C201 form a decoupling filter to improve stability. The amplified pulses are applied to the grid of another Navy Type 2050 thyatron, V203. Bias for this tube is provided by voltage divider R207-R208. When a pulse of sufficient amplitude arrives at its grid, V203 fires activating relay K201 and precipitates a number of events as indicated:

(a) The plate voltage is normally connected to V203 through the closed contacts "b" and "c." When the relay coil, K201, is energized, contacts "b" and "c" open (C206 prevents sparking) and contacts "a" and "b" short out the coil, reopening the relay immediately.

(b) When V203 fires, condenser C206 charges. When contacts "b" and "c" open, an arc across the contacts will result if the current through the relay coil, K201, is suddenly interrupted. However, the charge on condenser C206 provides the current through the coil when the d-c voltage supply is interrupted, so that arcing is prevented. However, if the condenser is sufficiently large to effectively eliminate arcing, it will contain sufficient charge to permit a current flow through the thyatron, V203, for a period of time sufficiently long to permit the "b" contact to short out the relay coil and return to "c" before the tube has deionized. If this happens, the cycle repeats itself, and the relay vibrates out of control. Therefore, a mechanism is provided to assure deionization of the thyatron when the relay operates. Contacts "d," "e," and "f" perform this function. Condenser C205 is normally charged to a high voltage through contacts "e" and "f." When the relay operates, the charged condenser is connected through contacts "d" and "e" across resistor R209 in the cathode circuit of V203. This action raises the cathode potential instantaneously far above the tube plate potential and the tube is deionized before d-c voltage is again applied to the plate through contacts "b" and "c."

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(c) The triggering pulses are formed in the circuit containing relay contacts "g," "h," and "i." In the deenergized position of K201, C207 is shorted through contacts "h" and "i." When the relay is cycled, C207 is charged to the voltage determined by the voltage divider R212-R213. The charging current flows through R211 forming a pulse. C208 is a filter condenser on the voltage divider R212-R213. This pulse is passed through C209 to trigger the multivibrator.

11. Since the noise pulses produced in V201 occur at random and since their amplitudes fall in a normal probability distribution, the average rate of ignition of V203 can be controlled by the gain control, R202. This control is located on the top of the upper chassis (See Plate 7). A certain minimum pulse amplitude is necessary to fire V203. As the gain control is advanced, more and more pulses are amplified to this value, and the average rate of the ignition is increased.

12. By using a relay circuit, the noise circuits are electrically isolated from the triggering pulse circuit. If it is attempted to trigger the multivibrator directly from pulses derived by amplifying and clipping the noise itself, difficulty is encountered. When the multivibrator trips, it passes and amplifies the noise and this disturbs the wave shape of the output pulse. For this reason the triggering pulse is isolated electrically from the random noise source.

Multivibrator

13. V204 is a Navy Type 6SN7-GT tube used as a multivibrator. The second section of the tube, to the grid of which the triggering pulse is fed through C209, is normally nonconducting, while the other section is conducting. When the triggering pulse arrives at the grid, the tube becomes conducting and remains so for a period of 0.2 second. This action results in a square pulse of voltage of negative polarity at the plate of V204 which is passed through C211 to the grid of V205, the sawtooth converter.

Sawtooth Pulse Converter

14. V205 is a Navy Type 6SN7-GT tube with the two sections connected in parallel. This tube operates without bias and is normally fully conducting. However, when the square negative pulse arrives at the grid, V205 cuts off and the voltage across it tends to rise; but C212, which is connected across the tube, charges exponentially with a rise in voltage. The time constant is long enough so that the 0.2 second nonconduction period is completed before the sawtooth form of voltage change across the condenser becomes appreciably nonlinear. This action results in a sawtooth pulse of voltage at the plate of V205.

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However, the static zero level of the sawtooth is at the bottom of the wave envelope rather than halfway up the slope as is desired. To move the zero level, the sawtooth pulse is shifted downwards by mixing it with the square negative pulse from the plate of the multivibrator. The mixing is done through R225-R227 and R226-R228. R227 and R228 are variable resistors mounted on the rear of the upper chassis (See Plate 4). They are used to adjust the symmetry of the wave shape. An oscilloscope, connected across the dynamic condenser leads, is used to make the adjustment. Since the pulse rate is slow, the oscilloscope sweep is not used, but rather the spot is observed as it jumps up and down. R227 and R228 are adjusted until the spot is displaced an equal amount above and below the static position. When once set, this adjustment does not have to be made again; therefore, for normal operation, the use of an oscilloscope is not required in the field.

Current Amplifier

15. The sawtooth voltage pulse is applied through C213 to the gain control of the current amplifier. The gain control, R229, is labeled "Deviation Adjust" and is located on the front panel (See Plate 3). Since the principal frequency components of the sawtooth wave are in the subaudio region (the fundamental being 5 cycles per second), conventional output coupling devices are not suitable. Furthermore, the current through the dynamic condenser coil must reverse. These difficulties were solved by using a bridge circuit. The four legs of the bridge are a Navy Type 6L6-G tube (V206), R231, R236-R237, and R232, and the dynamic condenser terminals are connected in series with the zero-center meter across the bridge. The use of this circuit necessitates leaving the negative high-voltage supply ungrounded. The dynamic condenser frame is grounded to one side of the condenser and one side of the coil; since the condenser is connected across the tank circuit in the transmitter, it has to be grounded. Consequently, the cathode of V206 must be grounded and the negative plate voltage must be below ground. The three-position switch, S202, is normally in the center or "Operate" position. It is used in connection with the indicator, as will be discussed in paragraph 18 below. C215 is a 500-microfarad, 25-volt electrolytic condenser connected across the dynamic condenser coil terminals. If the wave shape of the voltage across the dynamic condenser coil is observed on an oscilloscope when C215 is not connected, a high-frequency damped oscillation appears at the beginning of the linear rise and just after the return to normal; in other words, after the diaphragm of the condenser has received a sudden displacement. Evidently these sudden displacements shock the diaphragm into mechanical oscillation, and these oscillations produce a damped oscillating counter voltage. The 500-microfarad condenser provides sufficient damping so that the diaphragm does

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not vibrate. The result is a sawtooth pulse of voltage across the condenser coil which approximates the shape shown in Plate 2.

16. With no signal on the grid of V206, the bridge is balanced by adjustment of R237, which is the screwdriver control located on the front panel (See Plate 3), until no current flows through the condenser coil. When a signal appears on the grid, the bridge is unbalanced, and a current flows through the condenser coil in one direction or the other, depending on whether the grid is going positive or negative with respect to the static zero level.

Indicator

17. The indicator circuit is used in conjunction with the audio oscillator in adjusting the equipment to the desired frequency swing. The procedure for adjusting the equipment with the aid of the indicator is as follows. After the oscillator of the jamming transmitter is warmed up and in a stable operating condition, its frequency is brought to the frequency of the signal to be jammed by zero beating the two in a communication receiver. Then the peak swing of the jamming transmitter is adjusted with the aid of the indicator to either 100, 250, or 500 cycles per second, depending upon which audio-frequency swing is desired. With the random pulse generator turned off, the three-position switch, S202, located on the front panel (See Plate 3), is turned to the left-hand or "Set" position. The vacuum tube leg of the bridge is thus replaced by the voltage divider R233-R234-R235, and variation of R234, the "Deviation Set" control (See Plate 3), produces a static unbalance of the bridge causing a current to flow through the condenser coil. Since the jamming carrier previously has been tuned to zero beat with the communication or enemy carrier, this static current through the condenser coil alters the jamming transmitter frequency, and an audible beat is heard in the receiver phones. R234 is adjusted until this tone is the same as the one selected by the audio-oscillator switch S103, as judged by aural comparison.

18. The adjustment of R234 produces a definite voltage across R231 which is applied to the indicator thyatron, V207, a Navy Type 2050 tube. The bias on V207 is selected by R243, the "Deviation Indicator Operating Level" (See Plate 3). R243 is adjusted until V207 is just caused to fire, which is indicated by V208, a neon bulb, lighting up. The bulb can be extinguished by turning S202 to the center, or "Operate," position, since this opens the cathode circuit. With the "Deviation Indicator Operating Level" control adjusted to the proper level, S202 is turned to the "Adjust" position. The

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random pulse generator must be energized. The "Deviation Adjust" control, R229, is now advanced until V207 again just fires. It will fire when the peak swing of voltage applied to it is the same as the static value applied when the "Set" adjustment was made. When this condition is obtained, it is known that the frequency output of the jamming transmitter is swinging above and below its static value by an amount equal to the audio-oscillator calibrating frequency employed; i.e., 100, 250, or 500 cycles per second.

Audio Oscillator

19. A conventional Hartley oscillator circuit is used to produce the audio tone required for adjustment purposes. Its frequency is varied by changing capacity by means of S103, a four-position switch (See Plate 3). It utilizes a Navy Type 6J5 tube, V107. R109 is connected in series with the output to avoid overloading the oscillator and R110 is the output control (See Plate 3). The phone jack is for a standard set of 600-ohm Navy headphones. When making the audio tone comparison these phones are placed near the communication receiver phones and the tone from each is noted.

Power Supply

20. The line switch, S101, energizes all the filaments and the green pilot light, I101. The plate switch, S102, lights the red pilot light, and connects the negative line of the power supply to the remainder of the circuit. The power supply uses a Navy Type 5R4-GY rectifier tube, V101. Regulation is obtained through three Navy Type 6B4-G tubes connected in parallel, V102, V103, and V104. Grid voltage for these tubes comes from the plate of a Navy Type 6SJ7 tube, V105, the cathode voltage of which is held constant by a Navy Type VR-90/30, V106, voltage regulator tube. Output voltage is controlled by the "Plate Voltage Adjuster," R106, mounted on the rear of the lower chassis (See Plate 6). Condenser C102 assures rapid action of the regulator and improves filtering.

DESIGN REQUIREMENTS

21. It was required that a means be developed for automatically varying the carrier frequency of Navy transmitters 100 to 500 cycles either side of the static frequency. The variation was to be at a random rate and its amount controllable. The present equipment will sweep a band width up to a kilocycle or greater, depending upon the type transmitter and operating frequency. The amount of sweep is continuously variable and the sweeps recur at a random rate.

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22. The equipment was required to operate on regular Navy transmitters between 2 and 18 megacycles. It was to be small in size and capable of easy installation. The installation of the present equipment is extremely simple. The dynamic condenser is mounted within the temperature-controlled oscillator compartment; the condenser terminals are connected to the grid tank circuit; and two leads are brought out from the coil terminal and ground and connected to the equipment. The capacity added by this condenser changes the calibration of the master oscillator, requiring slight readjustment. The model equipment was purposely built larger than necessary to permit convenient inspection. Anticipating the requirement of multiple transmitter operation, sufficient output was incorporated in the equipment to operate a number of dynamic condensers when the coils are connected in series.

23. Design problems encountered in the development of the audio-frequency sweep equipment included producing sharp, well-defined, and completely random pulses, generating a sawtooth wave of voltage with zero level halfway up the wave slope, coupling a current wave of this type into the coil of the dynamic condenser, and providing indicating and adjusting circuits to simplify the operation of the equipment.

24. Numerous circuits for generating random pulses were investigated before the circuit using a relay was adopted. The previous circuits consisted principally of amplifying and clipping operations which attempted to trigger a multivibrator from pulses derived directly from a noise source. Some of these worked satisfactorily, but when the multivibrator triggered it amplified the noise on the grid of the multivibrator, causing spurious discontinuities on the resulting sawtooth waveform. Sufficient clipping to eliminate this disadvantage required more tubes than used in the present circuit, which isolates the triggering pulse from the noise source.

25. The type of sawtooth waveform required was achieved by mixing an ordinary sawtooth waveform with a square negative pulse of the same time duration as the sawtooth. This action shifts the entire sawtooth waveform downwards so that the zero or reference level is moved up. Manipulation of the mixing adjustments controls the symmetry of the wave.

26. Loading of the current amplifier into the dynamic condenser coil was a further problem. The fundamental frequency of the waveform is about 5 cycles per second, and the impedance of the condenser coil is of the order of 5 ohms. Transformer or capacity coupling was out of the question because of the very low frequency involved. The condenser coil could not be connected in series with the current amplifier because the current through the coil was required to reverse. At first a

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push-pull circuit was tried with the condenser coil connected between the cathodes of the two tubes. A potential drop across the coil was produced by a resistor in the cathode circuit of each tube. One was made variable for balancing purposes. This is actually a bridge circuit; so one tube was eliminated and a fixed resistor substituted. This resulted in the simple bridge circuit used in the present equipment.

27. While in the development stage, the equipment had to be adjusted with the aid of a frequency drift indicator and a dispersion meter. To make the system practical, a single indicator had to be devised to facilitate adjustments. One method of accomplishing this is to attach a voltage indicator of some type to a part of the bridge circuit. Experiments were made using an electron-ray indicator tube, but it was rather difficult to judge the exact point of closure of the eye when the multivibrator was being triggered intermittently. Therefore, use was made of a thyratron which could be adjusted to fire on the peak swings of operating voltage. A full explanation of the operation of the indicator circuit appears in paragraphs 17 and 18 above.

RESULTS OF TESTS

28. A number of tests were conducted to determine the stability of the apparatus under various conditions of temperature and humidity, its versatility in operation with one or more transmitters, and its effectiveness as a jammer; the results of the tests follow.

Effectiveness of Jamming

29. Table 1 shows the relative level in decibels of jamming signal strength to communication signal strength at various static frequency differences between jammer and communication carriers. The data presented in this table were obtained by establishing the condition at which the communication signal in a receiver was still readable, but at which any jamming level increase began to eliminate the signal characters. This condition was established for the various carrier frequency differences, and the relative powers of the communication and jamming carriers were measured in terms of receiver input. Since the condition at which jamming was incipient was judged by listening tests, the error factor of the human ear entered into the results, which accounts for certain inconsistencies in the data. For example, a carrier difference of plus 300 cycles per second appears to require more than twice the jamming power than does a difference of minus 300 cycles per second. Obviously this condition resulted from the inability of the human ear definitely to define a border-line condition; as a result, identical data were not obtained under similar

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conditions. However, Table 1 is a good approximation of the jamming power requirements. The tests to determine the jamming effectiveness of the system (which were all made at 500 cycles per second deviation above and below the static carrier frequency) show the need for maintaining wave shape symmetry, since an unbalanced wave shape pulls the mean frequency of the transmitter away from the static level to which it was set. This reduces the jamming effect, since it is equivalent to establishing the carrier frequency to one side or the other of zero beat. When the wave was symmetrical and when the frequency of the jamming transmitter was tuned to the frequency of the communication signal, jamming (i.e., elimination of a portion of the characters) began when the power ratio of jamming signal to communication signal was approximately one to three at the receiver. When the power ratio was one to one, jamming was complete. Tests were made comparing the effect of a 0.2 second sweep period to a 0.1 second sweep period. When the transmitter was held to the same carrier frequency or at least to within 50 cycles per second of that frequency, no difference was detected between the two timings. However, at a 250 cycles per second difference between the two carriers, the 0.2 second sweep period was more effective in jamming. This length of sweep is also easier to balance in the converter stage. For these reasons a 0.2 second sweep time was chosen.

Effect of Dynamic Condenser on Model TBL-4 Transmitter Frequency

30. Table 2 shows the results of a test made to determine the transmitter calibration error introduced by the addition of the dynamic condenser to the oscillator circuit. Before the frequency readings were taken, the transmitter had been operating for over an hour and was in a stable condition. The run represents the entire tuning range of the 2 megacycle band. The calibration adjustment of the transmitter tested has a total range of only 12 kc at 2200 kc, so it cannot be used to compensate for the 50-60 kc error introduced by the added capacity. Therefore, since frequency compensation cannot be made, a transmitter in which a dynamic condenser is mounted must be recalibrated.

Simultaneous Use of More Than One Dynamic Condenser

31. Since the resistance of the dynamic condenser coil is very low and the resistance of the bridge is large, more than one condenser coil can be added in series across the bridge with negligible effect on the operation of the circuit. In other words, because of the high impedance of the bridge elements, the bridge acts as a constant current generator as long as the impedance of the load is kept low. To substantiate this conclusion, the apparatus was set up with the output of

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the jamming transmitter being received in the communication receiver and producing an audible beat note with the beat-frequency oscillator. Under this condition, any small change in the current through the condenser coil would have caused a change in the beat note, since the transmitter frequency varied with the current through the dynamic condenser coil. To determine the loading effect, another dynamic condenser was used, and its coil connected in series with the first dynamic condenser. Alternate shorting of the coil terminals of the second condenser caused very little change in the beat note. This proved that the apparatus was capable of driving two condensers just as easily as one. The second condenser coil was then connected in parallel with the first. The beat note then changed considerably because, although the total output current was about the same, the current through one condenser coil was reduced to one-half because of the paralleling of the two. This test indicates that multiple operation of the dynamic condenser requires series connection of the units.

Current Drive Needed for Various Transmitters

32. Table 3 shows the peak currents necessary through the coil of the dynamic condenser to swing the frequency of the Model TBL-4 over the range of 100, 250, and 500 cycles per second. From these data, it was desired to find out whether the audio-frequency sweep equipment had enough drive to swing the frequency of the Models TBK, TDE, and TCK by the required amount. Since the Models TBK and TBL have identical oscillator grid circuits, the frequency change of the TBK will be identical to that of the Model TBL. From the instruction books, it was learned that the total tank circuit capacity of the Model TDE is approximately 1200 ppf, while that of the Models TBL and TBK is 1400 ppf in each case. These capacity values are for 2000 kc tuning. Therefore, since the TDE has less total capacity, it will be easier to drive. The instruction book for the Model TCK does not contain the value of the tuning capacity. However, from graphs in letter report S-S67/A10(381) Serial 2685, a comparison is given between the effects on a TBL-4 and a TCK by the addition of an identical capacity to the m-o frequency controlling tank circuit. This shows that the Model TCK requires about 10/7 more capacity change to alter its frequency a particular amount than does the TBL-4. Therefore, if 32 ma are necessary to shift the TBL-4 500 cycles per second at 2000 kc, it should require about 45 ma to shift the Model TCK an equal amount. Since the present model of the jammer can drive at least 60 ma through the dynamic condenser coil, the jammer is completely adequate, as far as frequency shifting capability is concerned, for operation on these four transmitter models.

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Power Supply Output Current

33. Table 4 shows the current drawn from the power supply under various conditions of operation. The maximum current drain is seen to be 220 ma, which is well within the 250 ma rating of the power supply. This condition is true when the gain control of the 6L6-G is in the maximum position. Normal operation results in a much lower setting of the gain control, such as indicated in the data for normal operation. This results in a drain of 190 ma from the power supply, showing it to be conservatively rated.

Power Required

34. Table 5 shows the power drawn from the 115-volt, 60-cycle supply line by the apparatus operating under various conditions. The power required under normal operation is about 175 watts.

Line Voltage Variation

35. The line voltage was varied between 90 and 110 per cent of normal (115 volts) and the effect on the various circuits noted:

- (a) The d-c output voltage of the power supply remained quite stable between 251 and 252 volts.
- (b) The frequencies of the audio oscillator were unaffected by voltage fluctuations.
- (c) The indicator operates satisfactorily over the entire voltage range.
- (d) At any setting of the gain control, R202, the rate of the random pulse generator varied as the line voltage was varied. However, the generator operated satisfactorily at any voltage within 90 and 110 per cent of 115 volts when adjusted for that voltage and small or rapid fluctuations did not affect the rate.
- (e) The amplitude of the sawtooth pulse from the current amplifier remained constant over the voltage range of the test.
- (f) The wave shape remained the same throughout the range of the voltage fluctuation.

Temperature and Humidity

36. Table 6 records the temperature test run and Table 7 records the humidity tests. The tests showed the equipment

to be reliable over a wide range of temperature and relative humidity. The only part of the apparatus that was affected to any appreciable extent by a change of these conditions was the indicator circuit. During the tests, the equipment was operated continuously except when readings were taken, at which time the random pulse generator was momentarily deenergized to permit observation of the static current in the dynamic condenser and checking the indicator circuit. All other readings were taken while operating. The static current in the dynamic condenser coil served as an indication of the ability of the bridge circuit to remain in balance under the conditions of the test. The relative output of the current amplifier was observed on an oscilloscope and was found to remain constant with variation of temperature and humidity. The indicator gave a low reading when at 0°C. The setting of the indicator sensitivity control varies over the range of temperatures, but this does not affect the accuracy of the results. The indicator consistently indicated about 15 ma peak swing except when at 0°C. The audio oscillator frequencies remained essentially unchanged throughout the temperature and humidity tests. The greatest percentage change occurred in the 100 cycles per second tone. Following the temperature and humidity tests, the apparatus was given a soak test as follows:

The equipment was turned completely off and the humidity raised to 93 per cent, the temperature remaining at 40°C. These conditions were maintained for an hour. After one hour the temperature was lowered to 20°C and the humidity retained as high as possible (approximately 90 per cent). After maintaining these conditions for an hour, the apparatus was allowed a five-minute warm-up period before a set of readings was taken.

The equipment functioned satisfactorily after this test, and all readings taken were similar to the ones taken during the temperature and humidity runs.

SUMMARY

37. An experimental model of the audio-frequency sweep equipment was developed at the Naval Research Laboratory and subjected to numerous operational tests to determine whether the model fulfilled the requirements of the problem. When a satisfactory circuit had been developed, a demonstration model of the equipment was constructed in a standard light steel commercial rack-mounting cabinet. Because of the priority of the problem and the early completion date requested, it was impractical to build a prototype equipment. Therefore, a demonstration model was constructed which was not suitable

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for actual Naval service conditions. Numerous components were not Navy approved. However, the electrical operation of the equipment is similar to a prototype, and all controls appear as they would in a prototype. A number of electrical tests, as recorded in this report, were performed on the completed model to determine its suitability for Naval service, but no mechanical tests were made because of its construction. With the use of this equipment, it is possible to jam enemy c-w signals completely with a one-to-one signal ratio at the receiver. This condition is true when the jamming signal carrier is tuned to the same frequency as the enemy carrier. As the carrier frequencies diverge, more and more jamming power is required. Test data on the required jamming power appear under paragraph 29 and in Table 1.

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TABLE 1

AUDIO-FREQUENCY SWEEP EQUIPMENT

EFFECT OF CARRIER DEVIATION
ON POWER REQUIRED FOR INCIPIENT JAMMING

Deviation Jammer Carrier Frequency from Communication Carrier Frequency (C.P.S.)	Power Ratio of Jammer Carrier above Communication Carrier for Incipient Jamming	
	<u>Power Ratio</u>	<u>Decibels</u>
+500	180.0	22.6
+300	7.4	8.7
+100	2.0	3.0
+ 50	2.0	3.0
0	0.37	-4.3
- 50	2.0	3.0
-100	3.0	4.8
-300	3.0	4.8
-500	90.0	19.5

Measurement conditions were established by ear and, therefore, the results are subject to considerable error.

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TABLE 2

AUDIO-FREQUENCY SWEEP EQUIPMENT

MODEL TBL-4 TRANSMITTER FREQUENCY DISPLACEMENT
RESULTING FROM ADDITION OF DYNAMIC CONDENSER

Transmitter Tuning Calibration		Measured Frequency (Kc)	Approximate Frequency Shift (Kc)
Dial Setting of Oscillator (Div.)	Frequency Recorded on Calibration Chart (Kc)		
2000	2040	2000.5	-40
3000	2120	2060.3	-60
4000	2200	2142.3	-58
5000	2270	2220.0	-50
6000	2325	2274.0	-51
7000	2350	2303.7	-46

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TABLE 3

AUDIO-FREQUENCY SWEEP EQUIPMENT

FREQUENCY VARIATION OF MODEL TBL-4 TRANSMITTER
WITH CHANGE OF CONDENSER COIL CURRENT

Frequency of Transmitter (Kc)	Current Necessary through Condenser Coil for Sweep Change of		
	500 C.P.S.	250 C.P.S.	100 C.P.S.
2000	32. ma	16. ma	9. ma
4500	5. ma	2.4 ma	1.6 ma
9000	2.5 ma	1.2 ma	0.7 ma
18000	1.2 ma	0.7 ma	---



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TABLE 4
AUDIO-FREQUENCY SWEEP EQUIPMENT
CURRENT DRAIN ON POWER SUPPLY

<u>Random Pulse Generator</u>	<u>Indicator</u>	<u>6L6-G Gain</u>	<u>Remarks</u>	<u>6L6-G Current (ma)</u>	<u>Total Power Supply Current (ma)</u>
Off	Off	Minimum	Minimum current drain.	60	170
On	Off	Minimum		60	190
On	Off	Maximum		60	215
On	On	Minimum		60	200
On	On	Maximum	Maximum current drain.	60	220
On	Off	Gain set to match swing of 115 ma in condenser coil.	Normal operation.	60	190

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TABLE 3

AUDIO-FREQUENCY SWEEP EQUIPMENT SUPPLY LINE POWER REQUIREMENTS

Conditions of Operation					Condenser Input Power Coil Current (Amperes)	Power Drawn from Line (Watts)
Filaments	Plate	Pulse Generator	Audio Oscillator	Indicator		
On	Off	Off	Off	Off	0	79
On	On	Off	Off	Off	0	156
On	On	On	Off	Off	0	170-175
On	On	On	On	Off	0	175-180
On	On	Off	Off	On	0	180
On	On	Off	Off	On	0.2	210

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TABLE 6

AUDIO-FREQUENCY SWEEP EQUIPMENT
TEMPERATURE TEST

Time	Temp. (°C)	Rel. Hum. (%)	Indicator Relative Output of Current Amplifier	Indicator Indicated Peak Condenser Current (ma)	Static Dynamic Capacitor Coil Current (ma)	Line Voltage (Volts)	Plate Voltage (Volts)	Maximum Total Current (ma)	Audio Oscillator Frequency (C.F.S.)
0840	0	--	10	--	-0.2	117	247.	220	105 253 480
0955	-3	--	10	--	0.	116	247.5	215	253
0910	0	--	10	5	+0.1	117	247.5	220	253
0925	-2	--	10	5	+0.1	115	247.5	220	253
0940	-4	--	10	15	+0.1	115	248.	220	105 255 481
1020	10	--	10	--	+0.05	115	247.5	220	105 255 482
1035	10	--	10	--	0.	113	247.5	215	256
1050	12	--	10	--	0.	115	247.5	215	255
1105	14	--	10	--	0.	115	247.5	215	255
1120	10	--	10	15	0.	113	247.5	215	105 255 481
1135	19	21	10	--	0.	112	247.5	215	105 255 480
1150	19	25	10	--	0.	113	247.5	215	255
1205	19	21	10	--	-0.05	112	247.5	215	255
1220	19	21	10	--	0.	113	247.5	215	255
1235	19	21	10	16	0.	112	247.5	215	105 255 480
1300	29	12	10	16	0.	110	247.	213	253
1315	29	16	10	--	-0.05	112	247.	210	255
1330	29.5	32	10	--	0.	111	247.	210	255
1345	29	43	10	--	0.	112	247.	210	255
1400	29	44	10	15	0.	111	247.	210	107 256 481
1415	40	31	10	17	0.	110	247.	210	107 256 481
1430	39.5	37	10	--	0.	111	247.	210	256
1445	39.5	34	10	--	0.	110	247.	210	256
1500	39.5	43	10	--	0.	110	247.	210	257
1515	39.	47	11	15	0.	115	247.	210	108 258 483

(Continued)

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TABLE 6 (CONT'D)

Time	Temp. (°C)	Rel. Hum. (%)	Indicator		Static Dynamic Capacitor Coil Current (ma)	Line Voltage (Volts)	Plate Voltage (Volts)	Maximum Total Current (ma)	Audio Oscillator Frequency (C.P.S.)
			Relative Output of Amplifier	Indicated Peak Condenser Current (ma)					
1520	50	31	10	15	-0.05	110	246.5	210	107 256 481
1540	49.5	34	10	--	-0.05	110	246.5	208	255
1555	49.5	33	10	--	-0.05	111	246-247*	205	255
1610	49	38	10	--	-0.07	111	246-247*	205	255
1625	49	40	10	15	-0.1	111	246-247*	205	110 257 482 **

* Varying.

** 100 cycles per second setting subject to slight instability.

Note: (1) The output wave shape was satisfactory throughout the test, but had notched peak.
 (2) The operation of the random pulse generator was normal but quite regular until 1540, when it became more random. From 1555 to 1625 it was slower. At 1625 it again became normal.

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TABLE 7

AUDIO-FREQUENCY SWEEP EQUIPMENT

HUMIDITY TEST

Time	Temp. (°C)	Rel. Hum. (%)	Indicator		Static Dynamic Capacitor Coil Current (ma)	Line Voltage (Volts)	Plate Voltage (Volts)	Max mm Total Current (ma)	Audio Oscillator Frequency (C.P.S.)
			Relative Output Current Amplifier	Indicated Peak Condenser Current (ma)					
0900	40	31	10	15	0	115	249	210	110 256 482
0915	40	31	10	--	0	115	249	210	257
0930	40	31	10	--	0	115	248-249*	210	257
0945	40	31	10	--	0	115	249	210	256
1000	40	31	10	--	0	114	248	210	110* 256 482
1025	40	93	10	15	-	115	249	210	256
1040	40	93	10	16	-	114	248	210	254
1055	40	93	10	--	+0.05	112	248	210	256
1110	40	93	10	--	-	112	248	210	256
1125	40	93	10	--	0	113	248	210	118* 256 482
1205	40	31	11	16	0	113	249	210	108 257 482
1220	42	31	11	13	0	112	249	210	257
1235	40	31	10	--	0	113	249.5	210	257
1250	39	36	11	--	0	111	248	210	256
1305	39	36	11	14	+0.2	110	248	210	120* 257 490

* Varying.

Note: (1) The output wave shape was satisfactory throughout the test, but had small notch.
 (2) The operation of the random pulse generator was normal, quite random.

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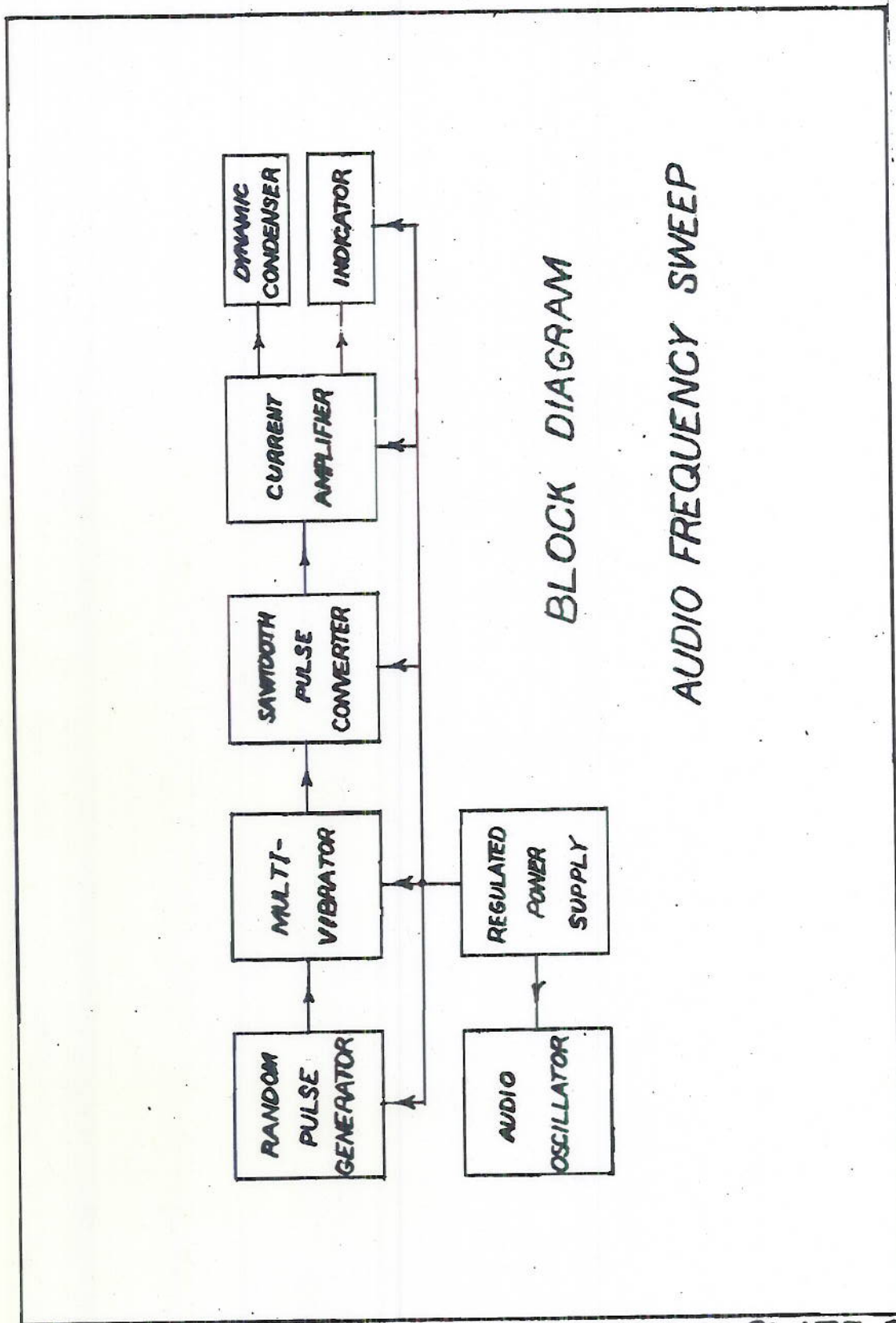
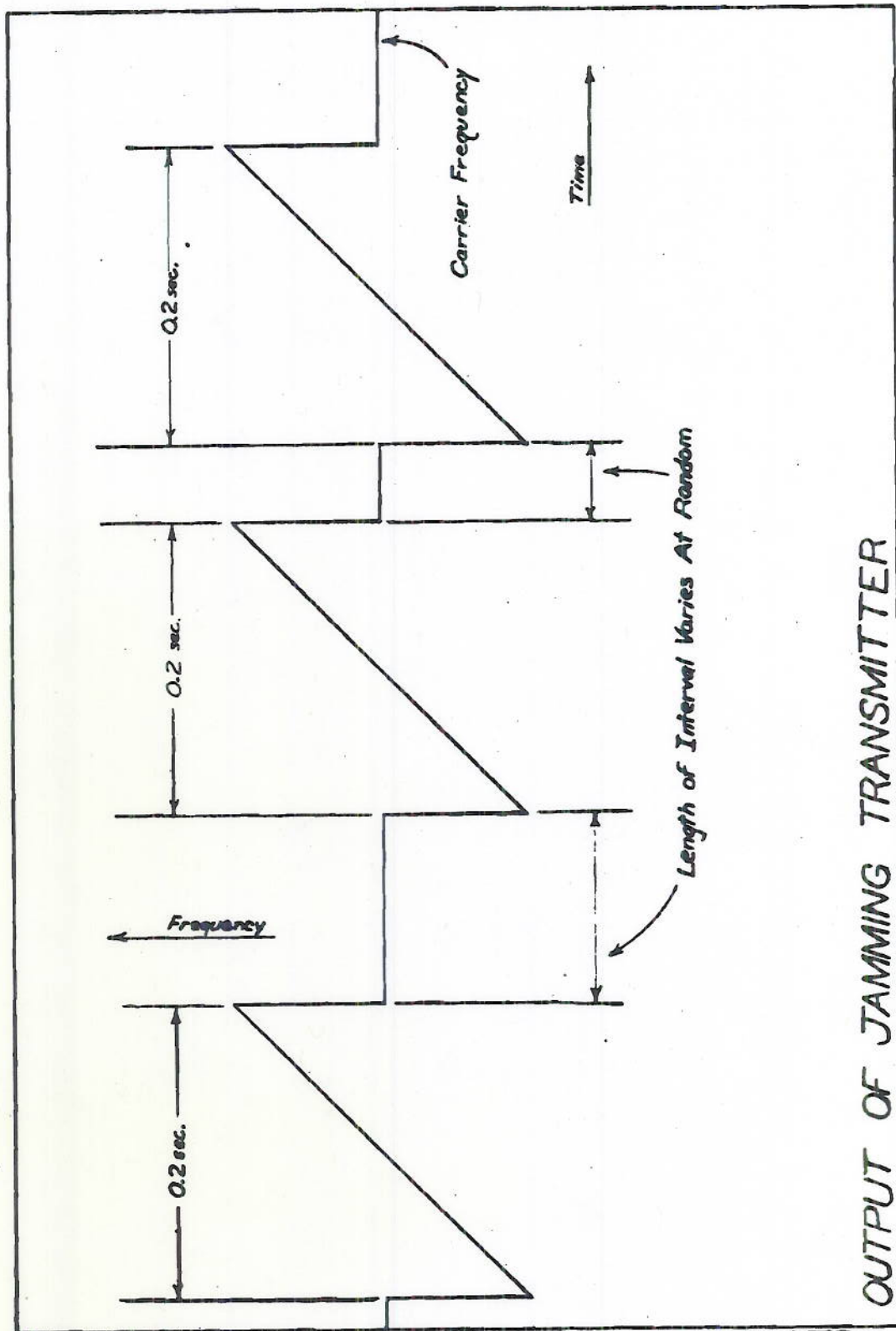


PLATE 1

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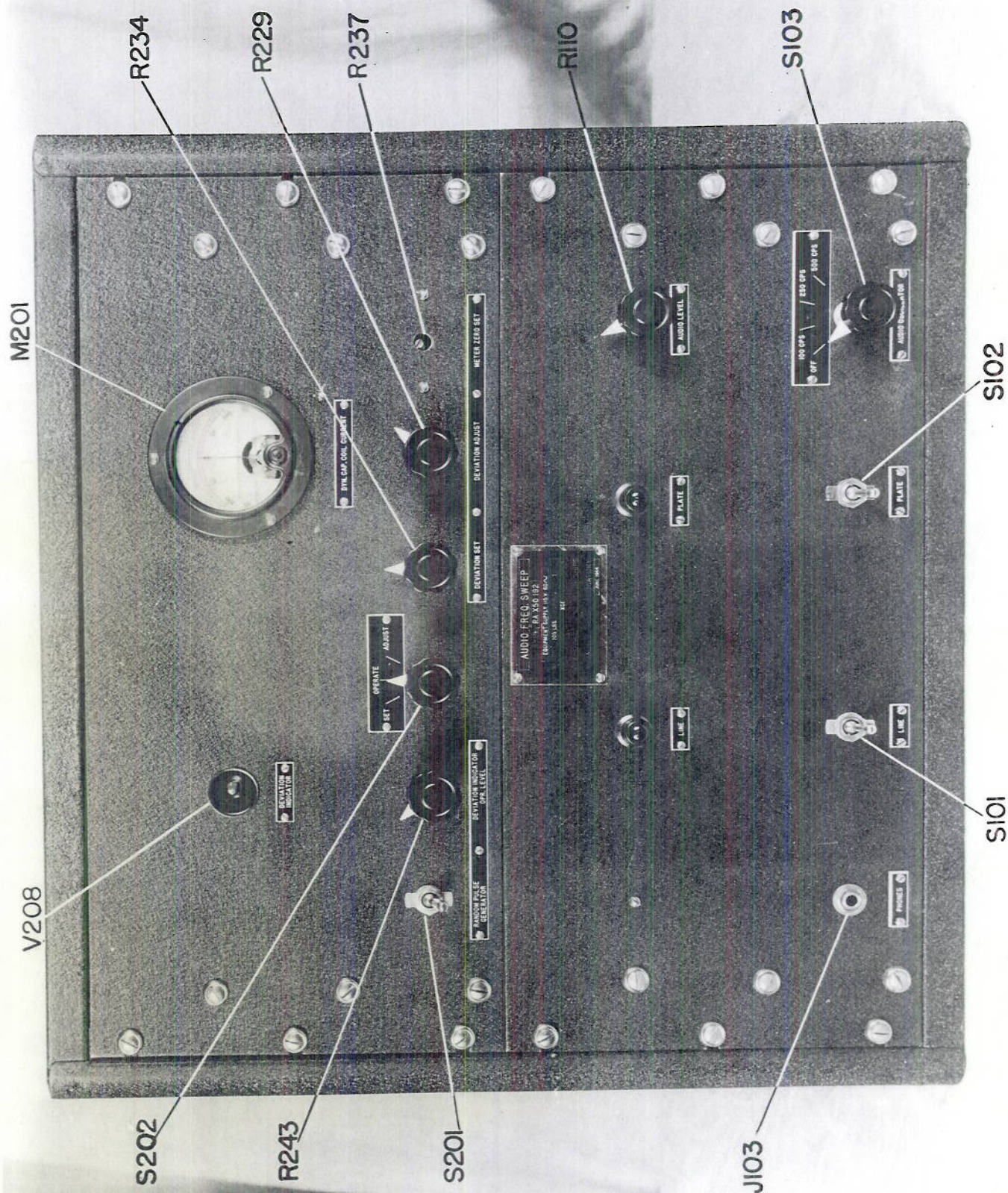


OUTPUT OF JAMMING TRANSMITTER

PLATE 2

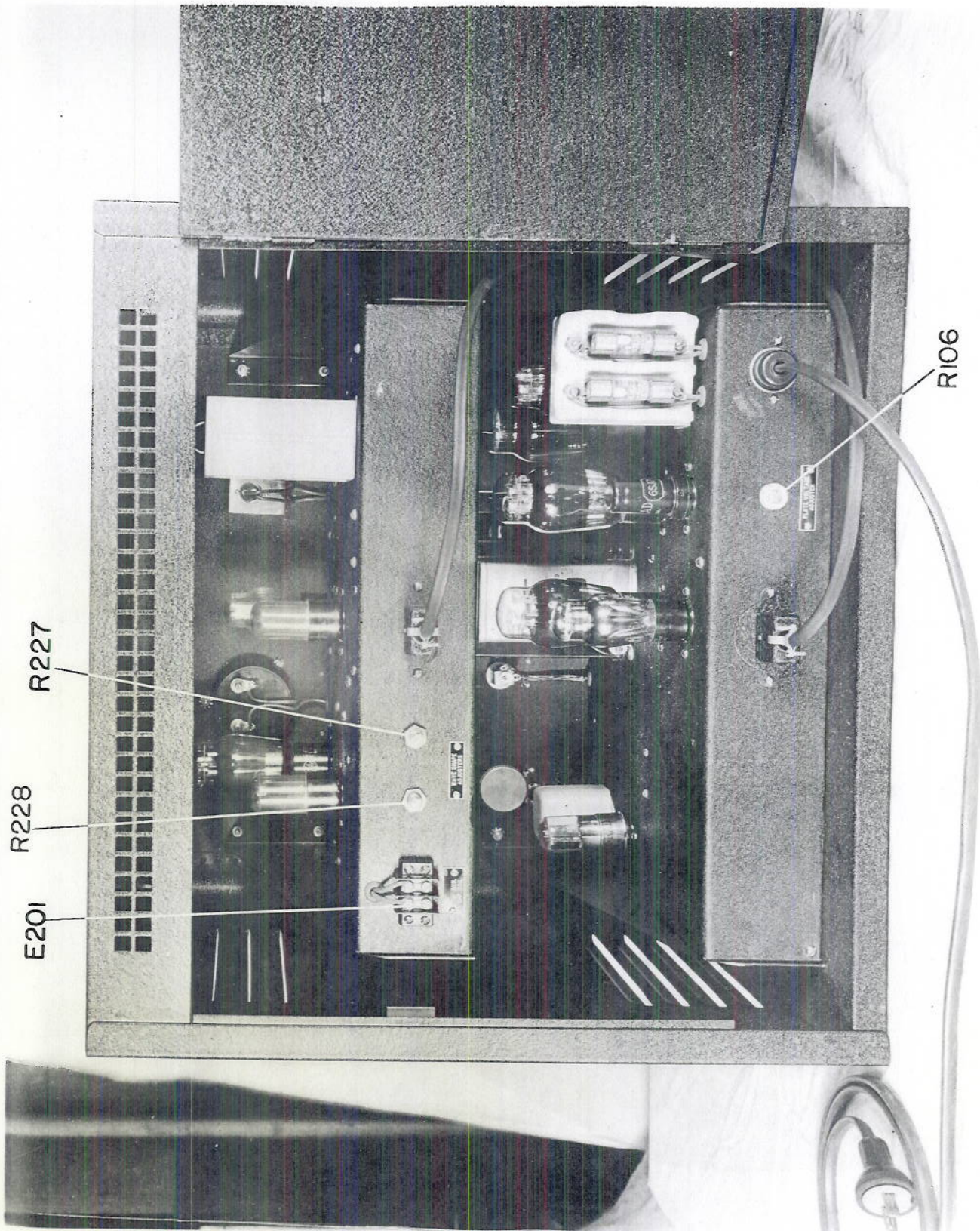
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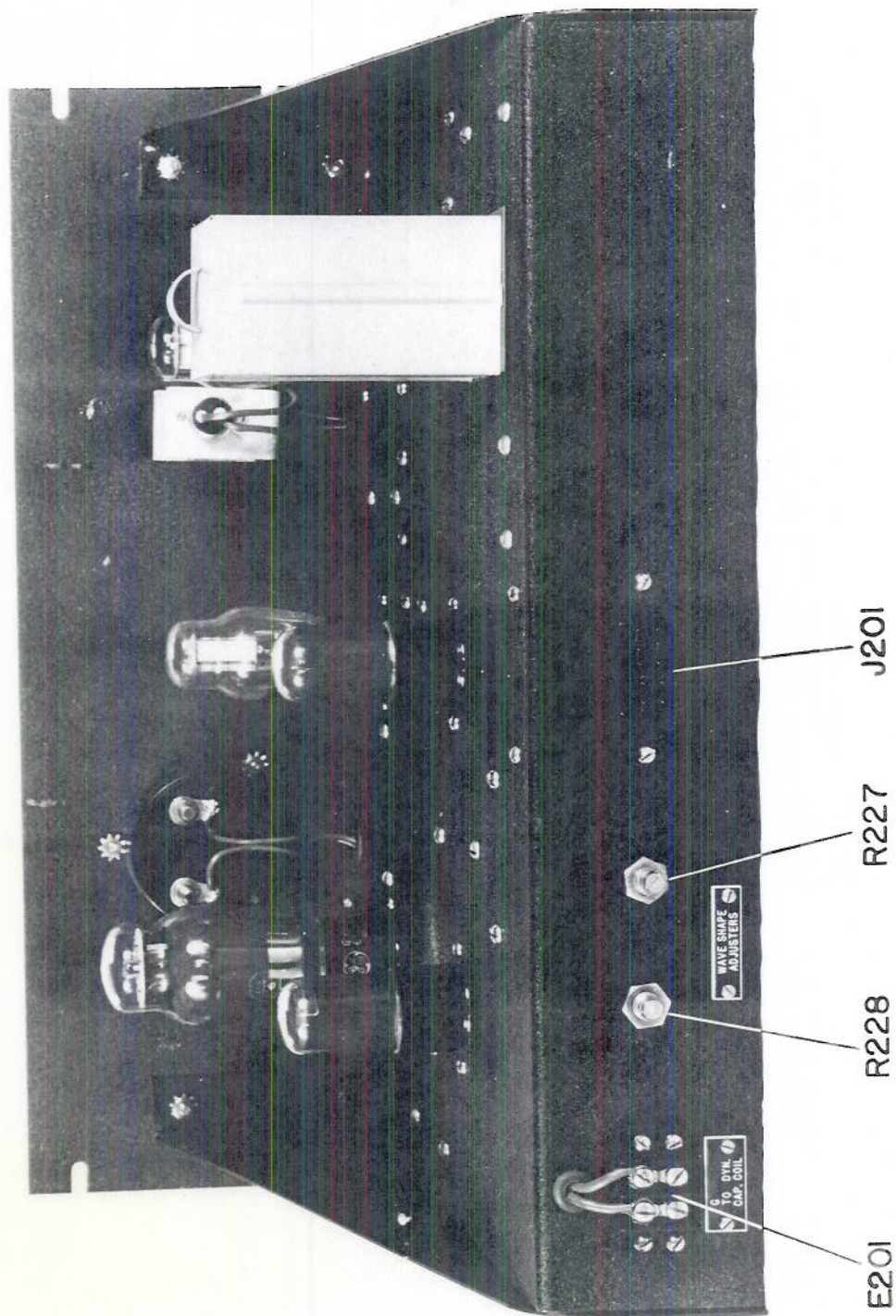


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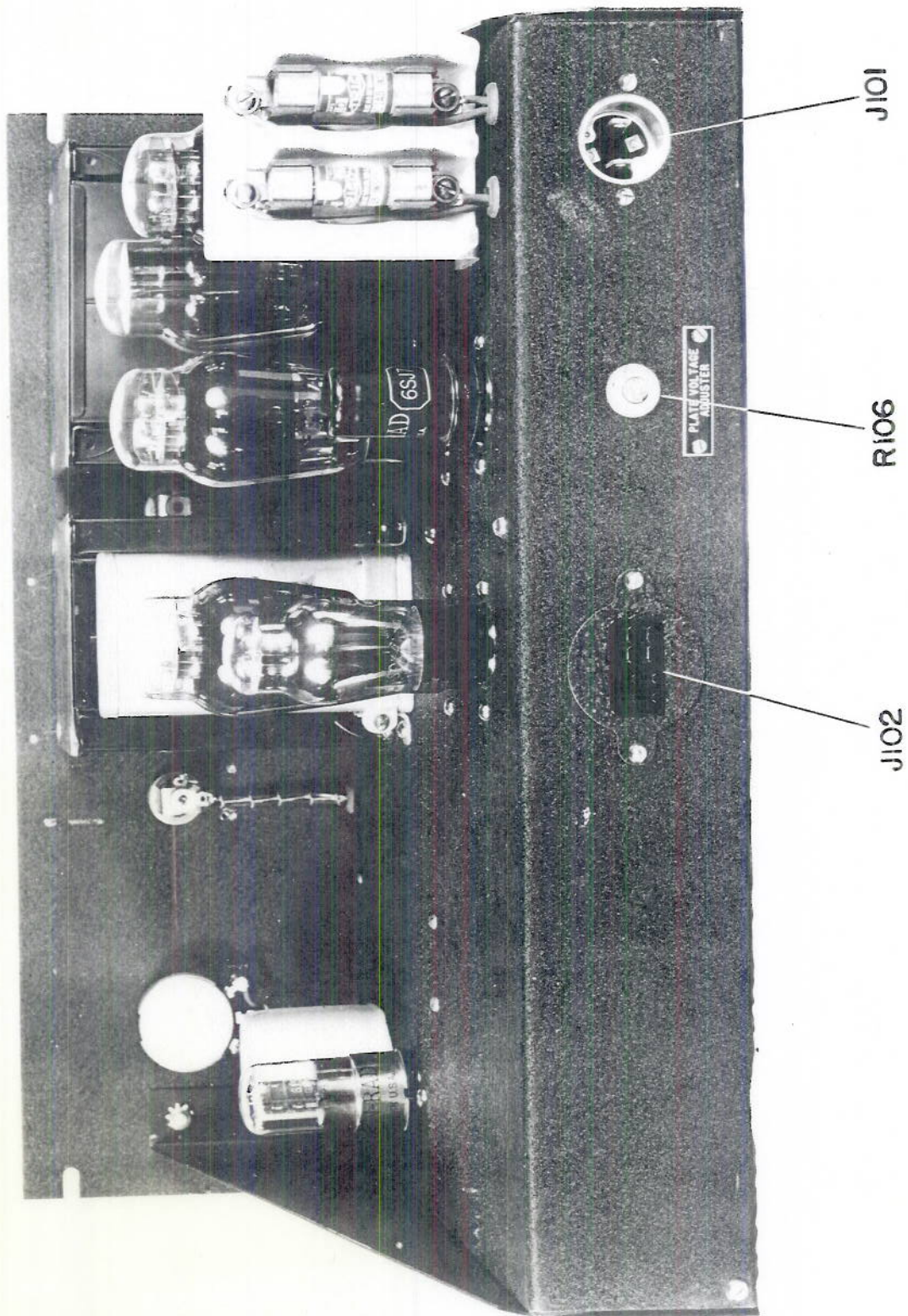
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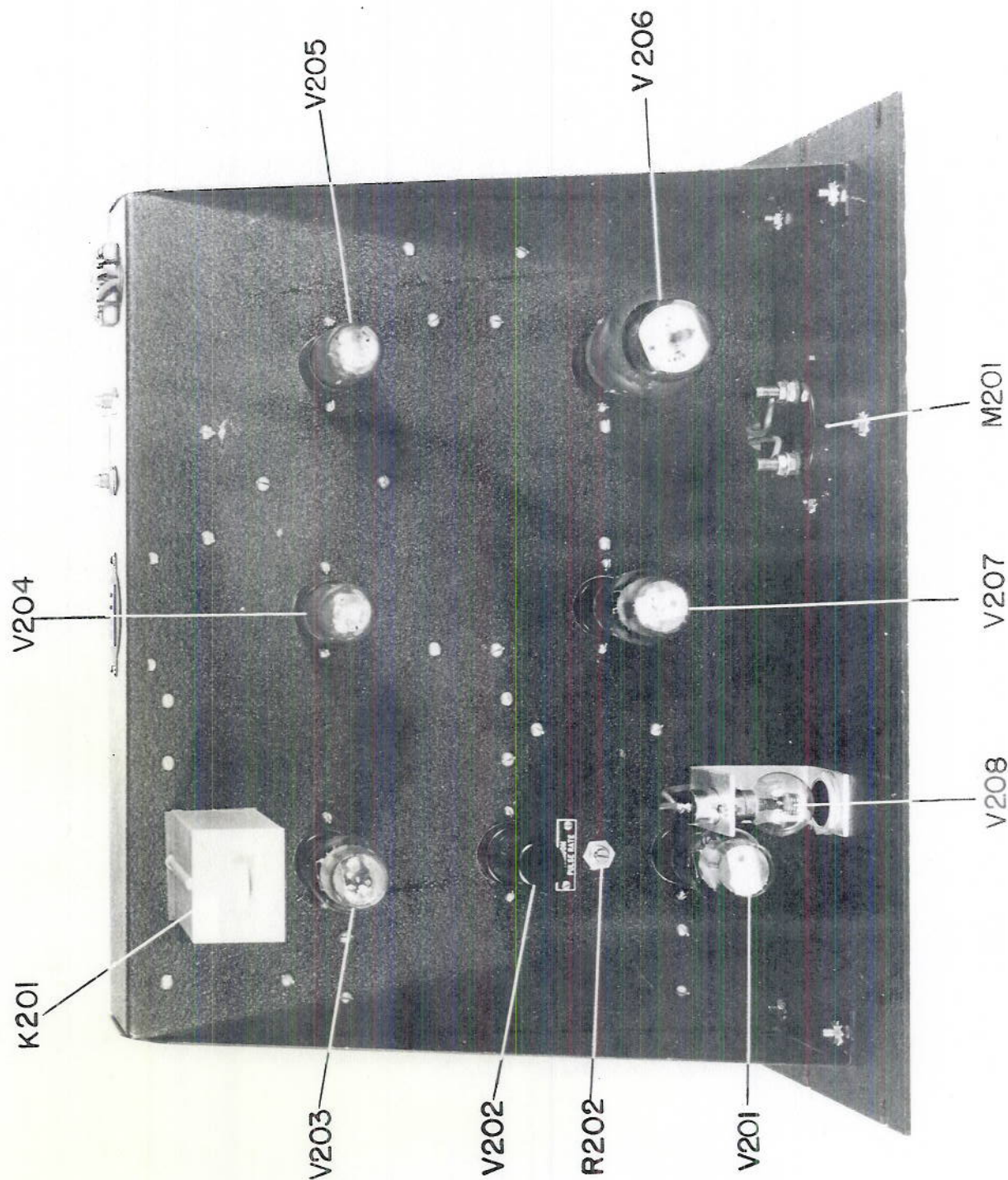


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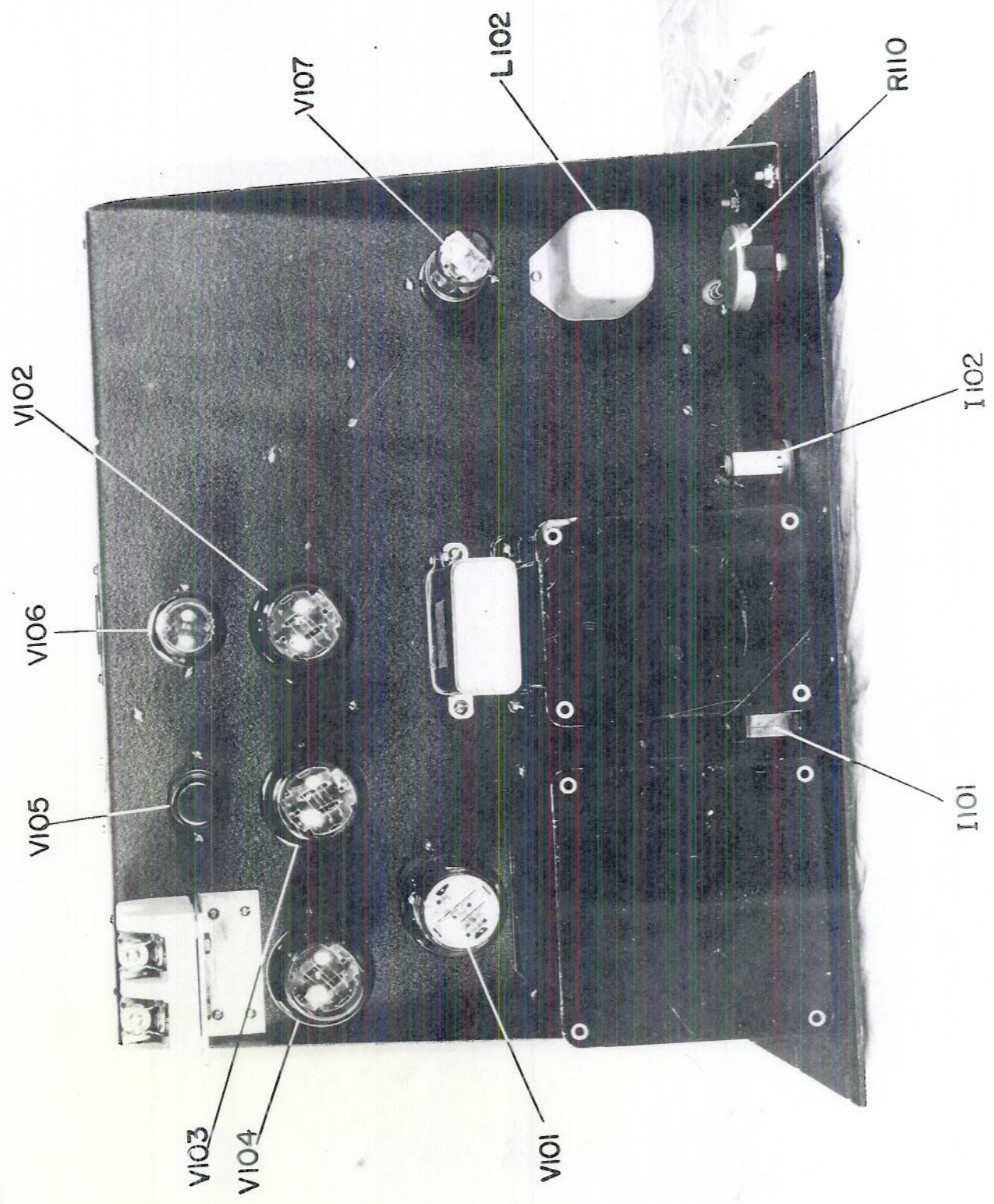
PLATE 6

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