[redacted] DECLASSIFIED

NRL Report 4224

COPY NO.

PRELIMINARY INSTRUCTION BOOK FOR SONAR RECEIVER R404(XB-1)/UQ

[redacted]

Transducer Branch
Sound Division

UNCLASSIFIED

DECLASSIFIED by NRL Contract
Declassification Team
Date: 27 Feb 2017
Reviewer's name(s): H. Do, P. HANNA

Declassification authority: NAVY DECLASS GUIDE / NAVY DECLASS MANUAL, 11 DEC 2012

UNCLASSIFIED

September 8, 1953

[redacted]

NAVAL RESEARCH LABORATORY
Washington, D.C.

DISTRIBUTION STATEMENT A APPLIES
Further distribution authorized by
UNLIMITED only.

[redacted]

[redacted]

DECLASSIFIED

~~SECRET~~
~~SECURITY INFORMATION~~

UNCLASSIFIED

DECLASSIFIED

NRL Report 4224

UNCLASSIFIED

PRELIMINARY INSTRUCTION BOOK FOR SONAR RECEIVER R404(XB-1)/UQ

Kingsley Thompson

Transducer Branch
Sound Division

UNCLASSIFIED

September 8, 1953

UNCLASSIFIED

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

NAVAL RESEARCH LABORATORY
Washington. D.C.

DECLASSIFIED

UNCLASSIFIED

~~SECRET~~

Contents

SECTION 1 - GENERAL DESCRIPTION

SECTION 2 - THEORY OF OPERATION

SECTION 3 - CHARACTERISTICS OF PRESENTATION

SECTION 4 - PHYSICAL DESCRIPTION AND OPERATION

[redacted]

CONTENTS (cont.)

SECTION 5 - ELECTRONIC DESIGN

SECTION 6 - INSTALLATION

SECTION 7 - MAINTENANCE

[redacted]

CONTENTS (cont.)

SECTION 7 - MAINTENANCE (cont.)

APPENDIX - VOLTAGE REGULATOR

[redacted]

PRELIMINARY INSTRUCTION BOOK FOR SONAR RECEIVER R404(XB-1)/UQ

Section 1

General Description

Officially referred to as the Sonar Receiver R404(XB-1)/UQ (Range Rate Indicator), the instrument for the purposes of this Instruction Book will be called the "Graphic Indicator," (G. I.). It exploits the facts that the brain through the eye uses pattern and motion for perception. The sonar signal and noise background are presented simultaneously to the eye on a cathode-ray tube. Since it forms a sensible pattern in the random or contrasting background, the signal is perceptible as order in disorder.

The types of information obtainable with the Graphic Indicator at echo-ranging speeds are as follows:

1. Measurement of range rate with an accuracy of the order of ±1/10 knot.
2. Identification of hull, wake, volume, and bottom echoes.
3. Determination of own ship's speed through the water and over the bottom, thereby making possible the measurement of ocean currents.

This picture on the screen of the cathode-ray tube is a plot with respect to time of the phase of a received signal relative to the output of a local reference oscillator within the instrument. The amount of phase coherence or incoherence of the reflected signal provides information about reflecting areas of a target. The doppler frequency shift of the sonar signal can be measured, thereby giving an accurate value for relative motion. Information is compared and presented from cycle to cycle of the sonar signal rather than from ping to ping.

Figure 1.1 shows the Graphic Indicator and its associated components, power supply, voltage regulator, and ODC (Own Doppler Compensator). The gear occupies 48.8 cubic feet, has a total weight of 147 lbs., and operates on 117 volts, 60 cycles A.C. The power consumed is 235 watts. The frequency range is between 18 and 30 kc.

A commercially manufactured line voltage regulator is used with the equipment. A circuit diagram and instructions from the manufacturer are included in this book. The ODC is not supplied with every Graphic Indicator since it has been shown to be superfluous for ordinary use.

All operational controls for the equipment are on the front panel. Plugs on the rear of the unit are for primary power input, remote power supply, ODC and signal input.

[redacted]

DECLASSIFIED

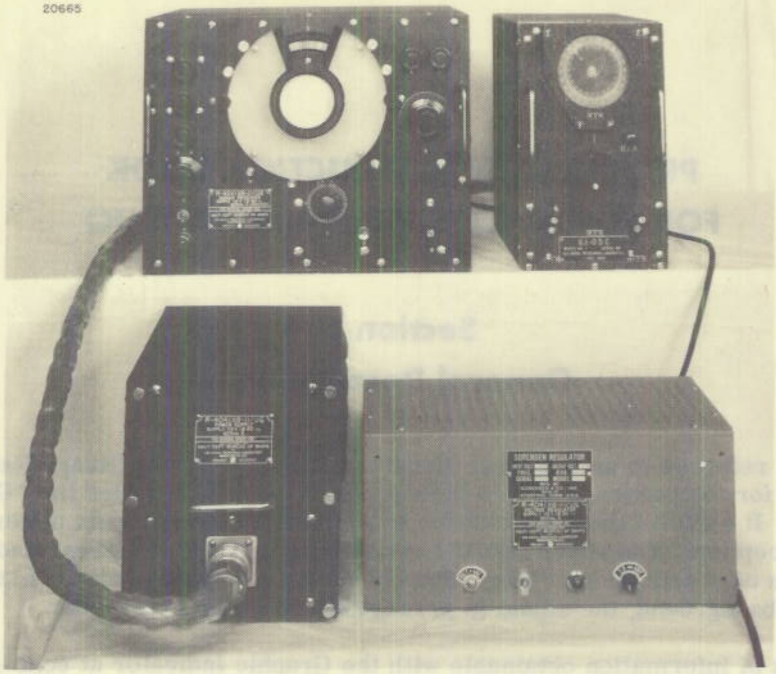


Figure 1.1. Units of the Graphic Indicator Equipment

* * *

DECLASSIFIED

Section 2

Theory of Operation

THEORY OF PRESENTATION

A typical Graphic Indicator pattern is confusing when first observed since it is so different from displays emphasizing signal intensity, as for example in the Plan Position Indicator (PPI). Association of meanings with the pattern however soon resolves this difficulty.

The Graphic Indicator as the basis of its presentation uses the eye rather than the ear, in the analysis of situations of a complex nature. Since the eye can handle more bits of intelligence, more quickly, and with greater sensitivity, it is advantageous to utilize this fact in sonar equipment. By presenting a display designed especially for the capabilities of the eye, more information can be obtained from the sonar signal than has been possible in the past. This does not mean the sonar information presented to the ear is not useful, for it has been found that an operator is aided in detection and tracking if the sonar aural information is also made available to him.

The eye-sensitive factors contributing to the GI pattern are size, shape, location, brightness or darkness, motion, and the area density of bit groups. Pattern structure, as well as pattern-structure change, makes possible the rapid perception and analysis of the target situation. The sensation of motion is caused by systematic changes of slope and indicates a source of signal frequency variation.

The brightness of the pattern is produced by pulses (bits of energy) of equal amplitude and width. These are generated at those successive positive crests of the signal which are above a threshold. This threshold is controlled by the envelope of the rectified signal. The brightness is a constant for each pulse (bit) and varies according to the distribution of "bits" on the screen.

The amplitude of the generated pulse is independent of the amplitude of the sonar signal. However, if the amplitude of the signal decreases at a rate too great for the time constants that affect the automatic adjustment of the threshold, there will be an absence of pulses. If periodic, these absences will produce perceptible patterns of darkness. These can have just as much significance as patterns of brightness.

The block diagram of the system (Figure 2.1) and wave forms (Figure 2.2) are helpful in the understanding of how the signal is processed. A sound wave of frequency F_s is picked up by the transducer. The transducer produces an output voltage of frequency F_s (Figure 2.2a). This voltage is amplified by a bandpass amplifier so that the

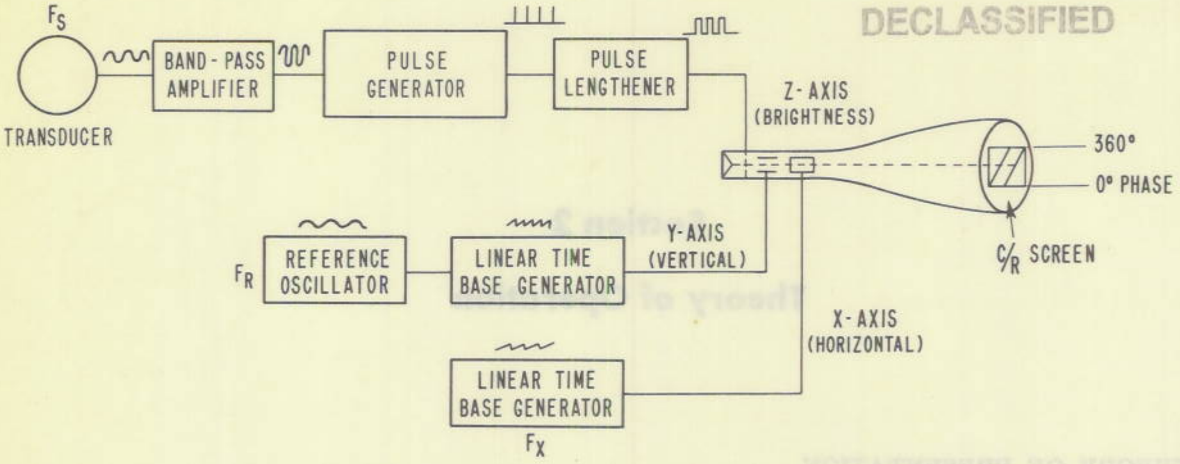
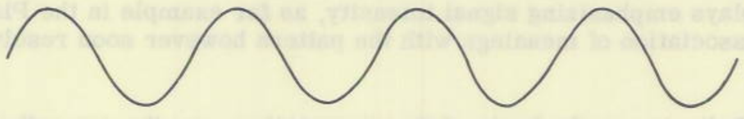
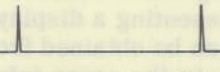


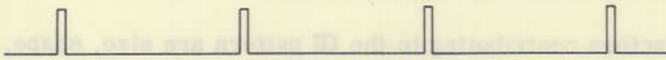
Figure 2.1. Block diagram of Sonar Graphic Indicator



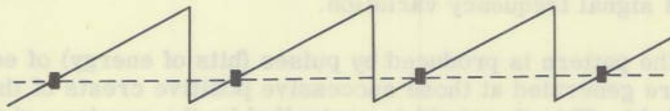
(a) INCOMING SIGNAL



(b) OUTPUT OF PULSE GENERATOR



(c) OUTPUT OF PULSE EXPANDER



(d) POSITION OF SPOT RELATIVE TO Y-AXIS SWEEP (EXPANDED)

Figure 2.2. Wave forms

amplitude is increased while the frequency remains unchanged. The output of the band-pass amplifier is applied to a pulse generator which forms pulses of equal amplitude and of the same polarity at the positive crests of the alternating voltage (Figure 2.2b). The intelligence in the sound wave is thus converted into a train of pulses significantly spaced in time, and the spacing between pulses is the period of the signal wave. The pulses are operated on by a pulse lengthener which expands them individually to the length desired without affecting the time-spacing or repetition frequency of the pulses (Figure 2.2c). The expanded pulses are applied to the Z or intensity axis of a cathode-ray oscillograph, so that the intensity of the spot on the scope screen is raised to the level of visual perception each time a pulse occurs (Figure 2.2d).

FREQUENCY DIFFERENCE

Application of linear sweeps of appropriate frequencies to the X- and Y-axes of the oscilloscope, then, results in the combination of individual spots appearing as a continuous line or lines (Figure 2.3). If the frequency applied to the Y-axis, which may be designated the reference frequency (F_r) is the same as the incoming signal frequency, a horizontal line appears on the cathode-ray screen (Figure 2.3). Under this condition, a zero rate of change of phase exists, or a zero frequency difference between the reference frequency and the incoming sinusoidal signal frequency.

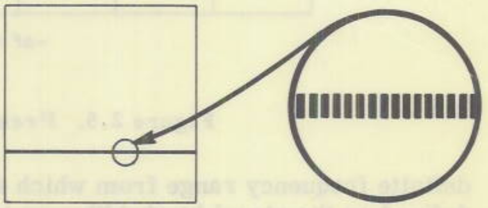
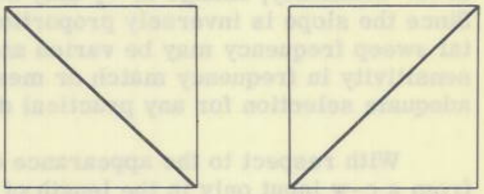


Figure 2.3. Composition of presentation, $F_s = F_r$

Since the spot deflections in the Y or vertical direction are against a linear phase scale extending from 0° to 360° referred to F_r, the position of the line on the screen remains constant if the phase difference between the incoming signal and the reference signal is constant. If ΔF (which is equal to $F_r - F_s$) is less than or greater than 0, the line assumes a slope whose difference from zero depends on the extent of the frequency difference. For example, if the frequency of an incoming signal is one cycle per second greater than the reference frequency, the phase will advance 360° during a one-second interval, or at the rate of one cycle per second over the reference signal. With an X-axis sweep of one cycle per second and a square raster, a line will be produced making a negative angle of 45° with the X-axis, as shown in Figure 2.4a. Likewise, when the incoming signal frequency is one cycle per second less than the reference frequency, the line will make a positive angle of 45° with the X-axis as shown in Figure 2.4b.



(a) F_S -1 cps GREATER THAN F_R. F_X = 1 cps

(b) F_S - 1 cps LESS THAN F_R. F_X = 1 cps

Figure 2.4. Frequency indication

As ΔF increases beyond one cycle per second, the rate of phase change becomes greater than 360° per second and, for a one-second horizontal sweep, additional sloping lines in a parallel set appear in the square raster. The angles from the horizontal which are characteristic of this set for several values of ΔF are shown in the following tabulation:

ΔF (cps)	Approximate Angle ø (degrees)
1	45
2	63
3	71
10	84

The slope of the line or tangent of the angle ø is directly proportional to the frequency difference, ΔF.

As the slope increases, the number of lines increases, and the spacing between the lines decreases until the eye is unable to resolve an individual line, as illustrated in Figure 2.5. From the standpoint of an observer, this can be considered the edge of the visual bandwidth. As ΔF increases above or below a center frequency ($F_o = F_r$), a

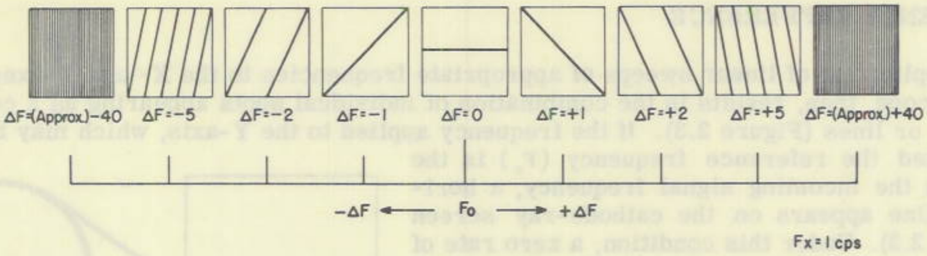


Figure 2.5. Presentation over a frequency range

definite frequency range from which intelligence can be perceived is traversed. This is defined as the visual bandwidth; any information not resolved by the observer is outside of the visual bandwidth.

If the angle measured from the horizontal is designated as $\emptyset$, the frequency difference as ΔF, and the horizontal sweep frequency as F_x, then

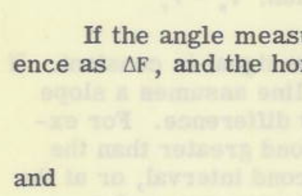
$$\Delta F = F_r - F_s \tag{1}$$

and

$$\emptyset = \tan^{-1} \frac{\Delta F}{F_x} \tag{2}$$

Thus the slope of the line, in a square raster, is directly proportional to the frequency difference, ΔF, and inversely proportional to the horizontal sweep frequency, F_x. Hence, if the slope is adjusted to zero by varying F_r, F_r is matched to F_s. Thus F_s is measured. Similarly, change in F_s may be matched by change in F_r, and thus measured. Since the slope is inversely proportional to the horizontal sweep frequency, the horizontal sweep frequency may be varied and used to control both the visual bandwidth and the sensitivity in frequency match or measurement. The sweep control provided allows for adequate selection for any practical doppler shift.

With respect to the appearance on the screen, an r-f pulse* signal input differs from a c-w input only in the length of the signal trace; otherwise the conditions are precisely the same as for a c-w signal input. The slope of the signal line remains the same, but the length of the line segment varies with the r-f pulse length. This length can be controlled by the horizontal sweep. For example, in Figures 2.6a and 2.6b, if a signal of 0.2 second duration is applied with the horizontal sweep at one cycle per second, the signal line will extend, in projection on the X-axis, through approximately 0.2 of the horizontal width of the raster. If a change in the frequency of the received signal occurs, for given r-f pulse length, changes result in the length and slope of the signal line or lines in the pattern observed. The change of pattern is utilized by the eye in sensing the frequency change in the acoustic signal. Motion is introduced in the display by angular rotation of the signal line.


(a) HORIZONTAL SWEEP, I cps PULSE LENGTH, 200 M sec. $\Delta F = 0$

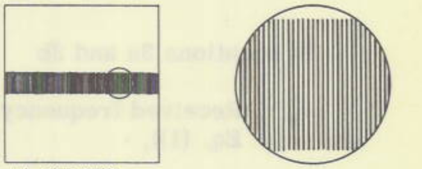
(b) HORIZONTAL SWEEP, I cps PULSE LENGTH 200 M sec. $\Delta F = 2$ cps.

Figure 2.6. Effect of expanded pulse on a signal

---

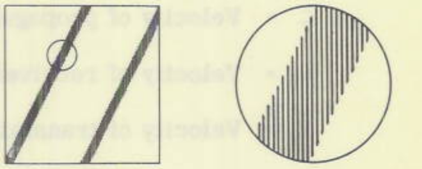
*"Radio-frequency pulse: a radio-frequency carrier modulated by a pulse. . ." (Standards on Pulses; Definition of Terms. Proc. IRE, June 1951, 39, 624-626.)

The pulse expander, which gives control over the duration of the pulses applied to the Z or intensity axis of the scope, allows for the choosing of an optimum length of pulse to brighten the slot used to develop the signal trace or line on the cathode-ray screen, because the brightness of an individual dot is a function of the acceleration voltage on the tube and of the length of time the voltage is applied. When the pulses are lengthened in time, the individual dot on the screen is elongated from a dot to a line; and the signal line, composed of many elongated dots, is broadened in the vertical direction. The width of the composite signal line is also a function of the frequency difference, ΔF. When ΔF is small, the presentation appears as a broad line (Figure 2.7a); as ΔF increases, the line assumes a slope, and is narrowed by the method of plotting on the screen (Figure 2.7b). In some cases, when the pattern is composed of a set of parallel lines at a large slope, the ability to achieve instantaneous detection of the pattern is enhanced by the use of expanded pulses, thus increasing the width and the effective brightness of the signal traces.



(a) BROAD TRACE - HORIZONTAL $\Delta F = 0$

CIRCLED PORTION EXPANDED



(b) BROAD TRACE - SLOPED $\Delta F = 2$cps

CIRCLED PORTION EXPANDED

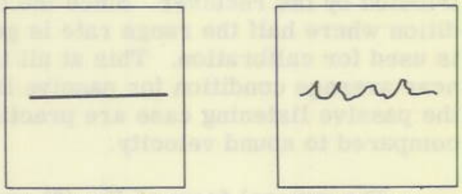
Figure 2.7. Composition of display with expanded pulse

PHASE CHARACTER

The lines (or traces) in the signal pattern may deviate from the clear sharp line or lines characteristic of a strong signal of fixed frequency and constant cycle-to-cycle period. Such deviations are caused by variations of phase or period within the signal's duration, or by apparent variations due to distortion by noise of the signal phase or periodicity (Figure 2.8).

With signal in a high noise background, the writing dots do not fall precisely at the signal wave crests, and the signal trace is a broadened line or band of randomly spaced dots. The dispersion tends to center on the line which would have been developed had the noise level been lower relative to the signal.

If the signal is volume reverberation or bottom reverberation, changing variations of phase are real and appear in the signal traces or pattern. In the case of volume reverberation, line segments of moderately varying slopes are developed. The breaks from one segment to the next tend to be sharp, showing phase discontinuities. Despite the breaks and the varying slopes of the signal-line segments, a characteristic or mean slope is well enough defined for measurement of the reverberation frequency.



(a) CONSTANT PHASE SIGNAL

(b) SIGNAL WITH RANDOM PHASE MODULATION

Figure 2.8. Phase presentation

Thus the phase character in the signal presentation has meaning, and enables the trained observer to differentiate between signals. In bottom reverberation, there is less phase variation and it is contained within narrower limits.

DOPPLER SHIFT AND RANGE RATE MEASUREMENT

In sonar applications, the doppler shift of frequency is a result of the velocity components along the sound path between the source and reflector or receiver, i.e., between the echo-ranging vessel and the reflecting target or listening vessel. These velocity components are given in each case by the product of forward speed and the cosine of the relative angle.

The change in frequency, ΔF, due to the doppler effect is given by the general formula

$$\Delta F = F_R - F_s \tag{3a}$$

and

$$F_R = F_s \left(\frac{C \pm V_R}{C \mp V_s} \right) \tag{3b}$$

In equations 3a and 3b

F_R = Received frequency (not to be confused with F_r, reference frequency of Eq. (1)),

F_s = Transmitted frequency,

C = Velocity of propagation in the medium,

V_R = Velocity of receiver through the medium, and

V_s = Velocity of transmitter through the medium.

The sign of V_R is positive when V_R is in the direction of the source, and negative when V_R is away from the source. The sign of V_s is negative when the source is moving in the direction of the receiver, and is positive when the source is moving away from the receiver.

It is assumed that the velocity of the medium is zero since in practice the velocity measurements are made relative to the medium. Actual operating conditions may range from where all the doppler is contributed by the transmitter to that where it is all contributed by the receiver. Since the effect for these two occurrences is different, the condition where half the range rate is generated at the transmitter and half at the receiver is used for calibration. This at all times represents the case for echo ranging. It is a near average condition for passive listening, and the error introduced at the extremes in the passive listening case are practically negligible because the ship's velocity is small compared to sound velocity.

The general form of Eq. (3) applied to the Graphic Indicator is

$$V = C \, \frac{F_{rf} - F_{ri}}{F_{rf} + F_{ri}}, \tag{4}$$

where

V = Individual velocity component or sum of velocity components to be measured,

F_r = Reference oscillator frequency,

F_{ri} = Initial value of F_r,

[redacted]

F_{rf} = Final value of F_r, and

C = Velocity of propagation in the medium.

In operation, F_{ri} is set to equal the transmitted-pulse frequency when measuring range rate and ship's speed. For measuring the velocity component of a reflecting target, F_{ri} is set equal to the volume reverberation frequency. F_{rf} is set to equal the frequency of the doppler-shifted signal under measurement.

In calibrating the range rate dial of the instrument, the doppler-shifted frequencies are calculated from equation (3b) for a number of range-rate points in the operating range covered (0-35 knots, opening and closing, for echo ranging; and 0-70 knots, opening and closing, for listening to another ship's sonar signal). In these calculations, the F_s used is the operating frequency of the sonar equipment with which the instrument is to be associated. These calculated frequencies are then introduced into the instrument from a standard-frequency source and a plot is made of the range rate versus angular position of the dial (for horizontal signal line). From this plot, a direct-reading range-rate dial is engraved. This method of calibration includes corrections for small variations of the electronic components in the system. For operation at other frequencies and sound velocities than those for which the instrument is calibrated, a set of correction curves is provided. Two range-rate dials are incorporated in the instrument, one for echo ranging and the second for passive operation (listening).

* * *

[redacted]

Section 3

Characteristics of Presentation

Because the Graphic Indicator's visual presentation method is quite different from conventional sonar presentation methods, a description and analysis is in order. The three parameters involved are amplitude, frequency differences, and phase.

AMPLITUDE

Figure 3.1, which is an example of the Graphic Indicator presentation when there is no signal input to the instrument, represents the characteristic appearance of receiver noise and/or water noise. It is identical to that of a television raster when no signal is received with the receiver video gain at maximum. Close examination of the raster reveals that it is made up of many bits of brightness distributed in a random manner. Any departure from the random distribution of these bits will cause bit groups to be formed. This results in a redistribution of the bright areas bounded by dark areas, and in the formation of patterns. Such is the case when a c-w signal equal to noise is added, as shown in Figures 3.2a and 3.2b. Close examination of Figures 3.2a and 3.2b reveals that the pattern produced is made up of many bits which have begun to group. The grouping is not yet completely coherent since the signal is not strong enough to overcome all the noise peaks, and a wide distribution of the coherent bits results. As the signal-to-noise ratio decreases, the bit distribution becomes wider because of the noise, until the point of no visible coherent grouping is reached. When the signal-to-noise ratio increases, the bit noise distribution decreases until the bit grouping is completely coherent, forming a signal line as is shown in Figure 3.3. As the bits become more and more coherent, there is an appearance of increasing brightness. The reason for this is that

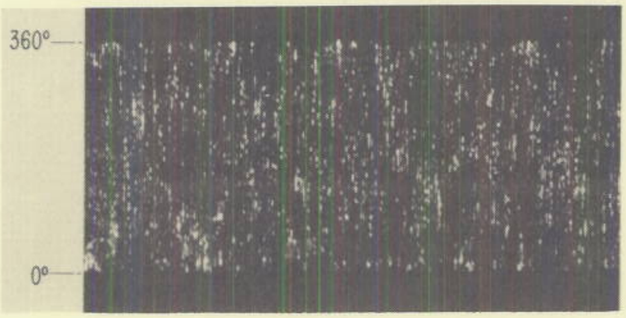


Figure 3.1. Noise

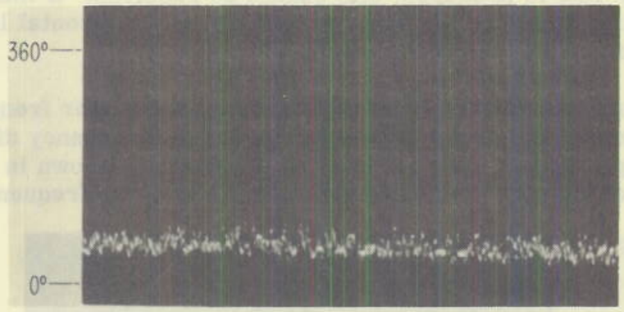


Figure 3.2a. Signal and noise, $F_s = F_r$

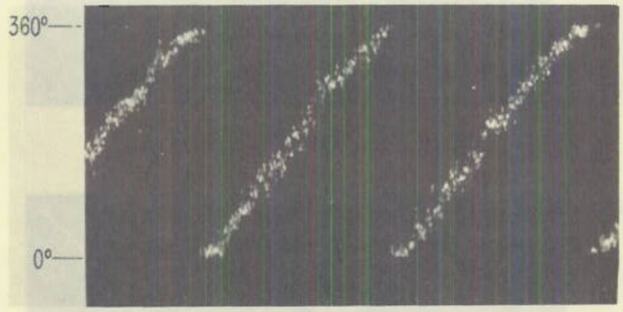


Figure 3.2b. Signal and noise, $F_s < F_r$

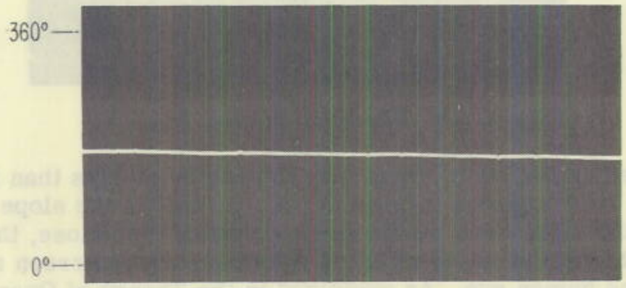


Figure 3.3. Signal, $F_s = F_r$

although the intensity is constant for each bit, the area over which the bits are distributed becomes less and less, and the intensity per unit area increases. As coherence increases, the bits fall closer and closer together until a limit of resolution is reached, and the individual bits cannot be resolved. This is a function of the cathode-ray tube area and the spot size, as well as a characteristic of the patterns presented and of the acuity of the human eye, as is evidenced by comparing Figures 3.2a, 3.2b, and 3.3.

FREQUENCY DIFFERENCE

Figures 3.4 through 3.9 serve to illustrate how frequency differences are presented.

Figure 3.3 has shown the pattern produced by a c-w signal (F_s) greater than noise and equal in frequency to the reference oscillator frequency (F_r) in the Graphic Indicator.

A horizontal coherent line is produced; bits cannot be resolved. If this signal were pulsed, the presentation would be the same except that the horizontal line would have a definite length proportional to the pulse length.

If the signal frequency differs from the reference oscillator frequency, the line produced is not horizontal but assumes a slope; and if the frequency difference is great, a set of several steeply sloping parallel lines is produced as shown in Figures 3.4 and 3.5. The magnitude of the slope indicates the magnitude of the frequency difference, and its sign indicates whether the signal frequency is greater or less than the reference frequency. The greater the frequency difference, the greater is the slope and the number of lines in the set, and the closer are they spaced. If spaced too close, the individual lines cannot be resolved, the resolution limit being a function of the screen area and spot size, and of the acuity of the human eye. As explained in the Theory of Operation (Section 2), the frequency band within which line resolution is possible, is called the visual bandwidth.

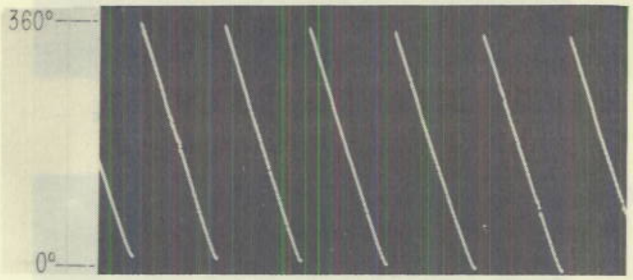


Figure 3.4. Signal, $F_s > F_r$

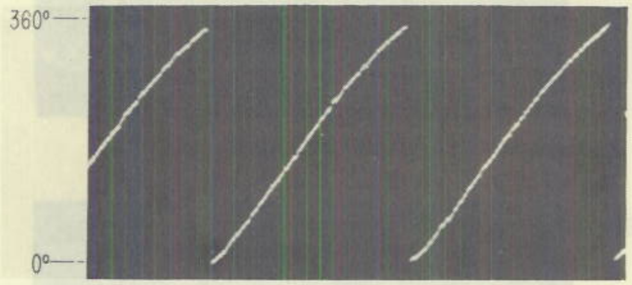


Figure 3.5. Signal and noise, $F_s < F_r$

The ability to resolve and to measure frequency differences is important, for it is this which makes possible the determination of such quantities as speed over the bottom and through the water, target velocity, and velocity of an ocean current.

It is interesting to observe what occurs when two signals are mixed linearly ahead of the Graphic Indicator input. Figure 3.6 is a photograph of the presentation when two c-w signals (F_1 and F_2) of nearly equal amplitudes but differing in frequency by 100 cps, (F_1 = 25.6 kc and F_2 = 25.5 kc) are added.* The reference frequency, F_r, in the Graphic Indicator was set equal to F_1. The F_1 signature appears as a broad horizontal pattern

---

*Amplitudes of both signals were chosen to be within the linear range of the bandpass amplifier for all cases described.

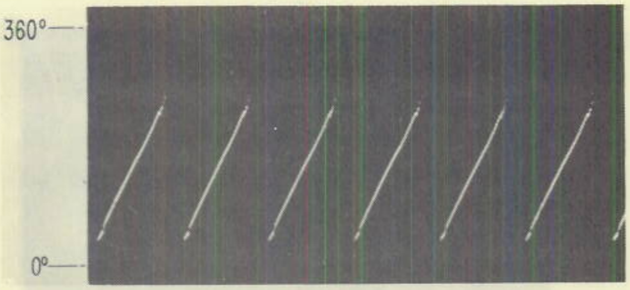


Figure 3.6. Two signals linearly added, $A_1 \approx A_2$, $F_1 = F_r$

composed of a series of sloping lines. The period between each line is equal to the period of the frequency difference between the two signals. The positive slope of the lines indicates that F_2 is lower than F_1. Figure 3.7 is a photograph of the presentation when $F_r = F_2$. Notice the opposite slope of the lines indicating the presence of F_1.

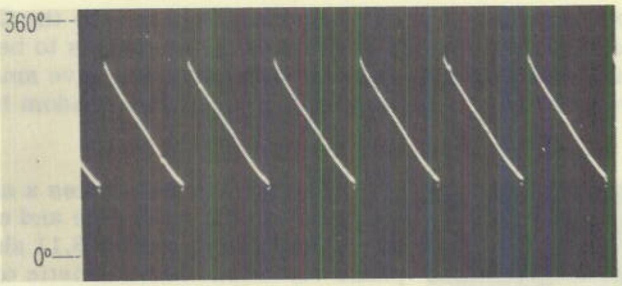


Figure 3.7. Two signals linearly added, $A_1 \approx A_2$, $F_2 = F_r$

In Figure 3.8, the amplitude of F_2 has been decreased by 10 db and the reference frequency set equal to F_1 and in Figure 3.9, $F_r = F_2$.

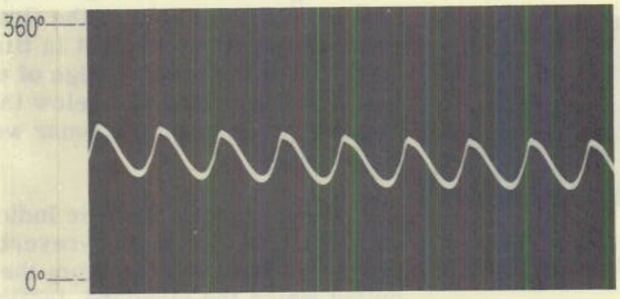


Figure 3.8. Two signals linearly added, $A_1 > A_2$, $F_1 = F_r$

The capacity of the Graphic Indicator to resolve more than one frequency with mixed signals is important for such applications as distinguishing between hull and wake returns, and recognizing own signal return in the presence of other echo-ranging ships.

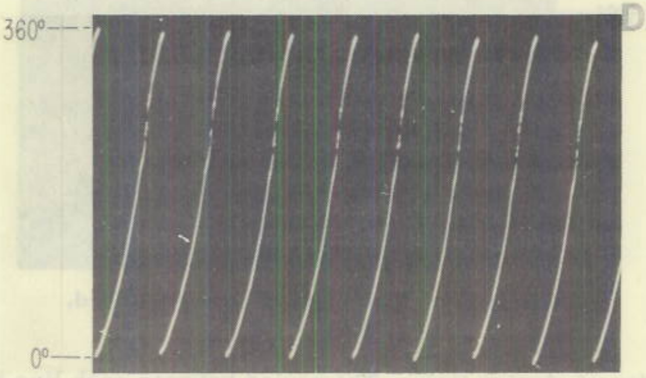


Figure 3.9. Two signals linearly added, $A_1 > A_2$, $F_2 = F_r$

PHASE

Probably the most important signal parameter displayed by the Graphic Indicator is phase. It is this parameter that enables properties of the targets to be determined for classification purposes. For instance, bottom reverberations have smaller phase variations than volume reverberations, and wake echoes are more random in phase than hull echoes.

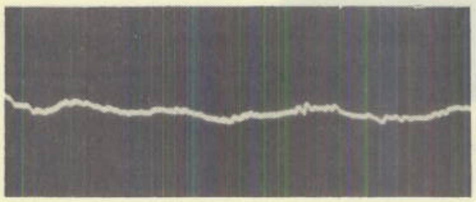


Figure 3.10. Echo signal from submarine hull

Figure 3.10 illustrates a signal (F_s) equal in frequency to the reference and nearly perfect in phase coherence; Figure 3.11 shows the random phase variation characteristic of volume reverberations; and Figure 3.12 shows minor phase variations such as one observes in bottom reverberations.

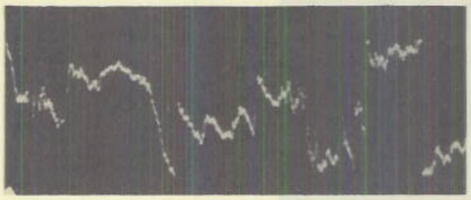


Figure 3.11. Short-range volume reverberations

SIGNALS OBTAINED IN ACTUAL OPERATIONS

Figures 3.13 through 3.18, inclusive, are a series of photographs of the Graphic Indicator presentation stretched out in time. The strips were cut at the leading edge of each transmitted pulse and arranged one below the other in sequence.* A scanning Sonar was used during these runs.

Note that the Graphic Indicator presentation in each strip, of the ping-reverberation-echo sequence, is developed from the same transducer output which the standard, tactical range recorder presents as a line of varying darkness, drawn by the stylus on the recorder paper in one traverse. The difference in the amount of detail is striking, – the more so, when the significant additional information provided is appreciated.

---

*It is to be noted in Figures 3.15, 3.16, 3.17, and 3.18 that the slope of the line is reversed from that observed in the normal operation of the Graphic Indicator. This occurred because of an error during the photographing.

High-Speed Attack Run

The series of "pings" shown was made during a surface-to-submarine simulated attack run. The speed of the surface ship was 23 knots and that of the submarine approximately 7.5 knots. Because of the projector bearing and target aspect, the resultant of velocity vectors gave, at the start of the run, a range rate of about 15 knots. The run was begun with the submarine 15° off the starboard bow with bearing changing quite rapidly as the surface ship closed on the submarine. The surface ship, a destroyer, has located the submarine, and has already begun the attack run.

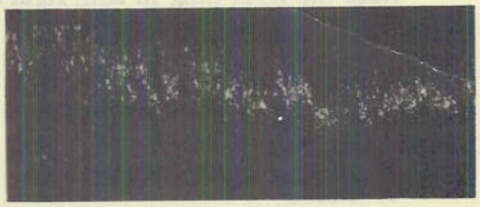


Figure 3.12. Long-range bottom reverberations

For the pings shown in Figure 3.13, the reference oscillator in the Graphic Indicator was set to the hull echo frequency of the submarine target and was caused to track the hull frequency throughout the run; for the pings shown in Figure 3.14, the reference oscillator was caused to track the volume reverberation frequency. The two sets of pings shown are for the same run, and those bearing the same number are the same ping. Thus a comparison of the two presentations for a given ping is possible.

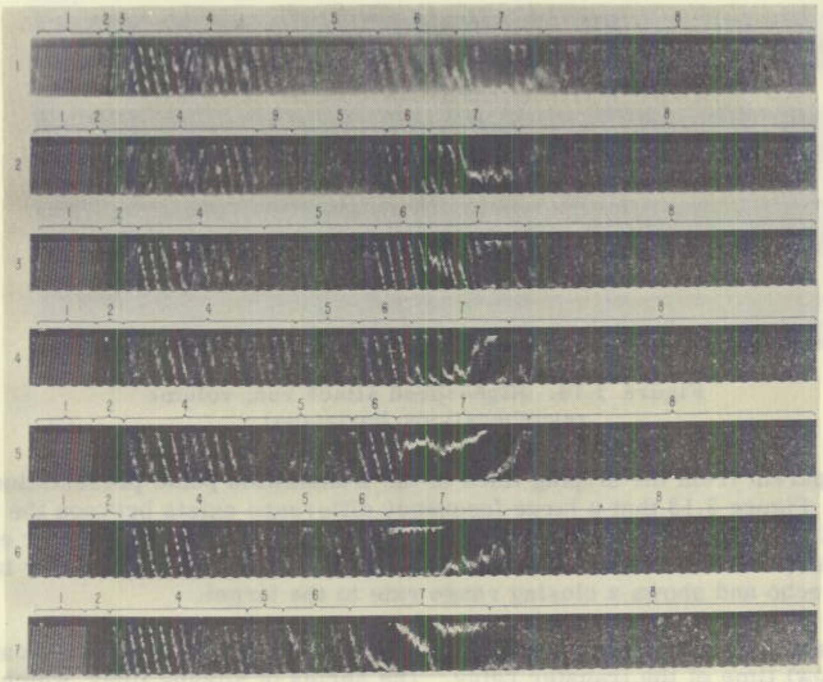


Figure 3.13. High-speed attack run, target horizontal

Note the first ping in both figures, and observe that information in the following chronological order is presented:

1. Transmitted pulse
2. Transfer relay throw time
3. Echo from own ship's hull
4. Volume reververation
5. Noise
6. Echo from submarine wake
7. Echo from submarine hull
8. Noise
9. Ping from another echo-ranging ship in area (see ping 2)

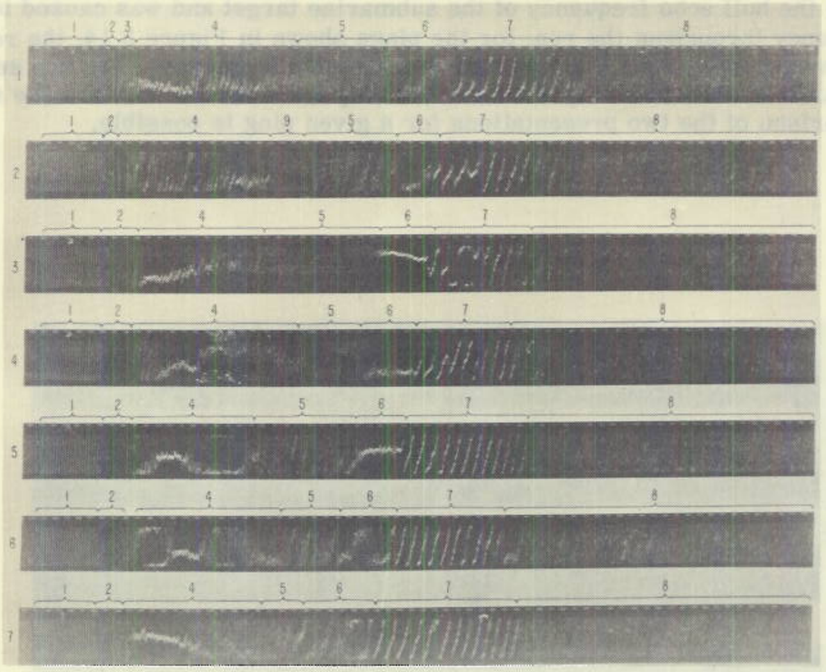


Figure 3.14. High-speed attack run, volume reverberations horizontal

It is apparent from the sloping lines in the transmitted pulse presentation of the first pings in Figure 3.13 that a large frequency difference exists between the transmitted pulse and the target-hull-echo frequency. This is a result of the doppler effect. The direction of slope of these lines indicates that the transmitted pulse is lower in frequency than the hull echo and shows a closing range rate to the target.

The absence of any signal immediately after the transmitted pulse indicates the transfer (throw) time of the transfer relay. The series of sloping lines, which are equal in slope to the transmitted pulse lines appearing directly after this dead time, is an echo

[redacted]

from the hull of the echo-ranging ship. Note in the succeeding pings that this condition disappears when the projector is trained more and more abeam.

In the first pings of Figure 3.13, the volume reverberations are seen as lines sloping closely together with the slope opposite in sign from that of the transmitted pulse lines. This indicates that the echo-ranging ship has a large closing range rate with respect to the water. The indication that this is a closing range rate is shown directly by the same ping in Figure 3.14. Here the reverberation frequency is equal to the reference frequency. Note also that the ship's closing range rate with respect to the water is greater than her closing range rate on the submarine. The difference is the opening range rate of the submarine with respect to the water.

After the reverberations die out in the first pings, noise becomes apparent and then what seems to be more reverberation appears. These are not reverberations, however, but echoes from the submarine's wake. Notice how the slope of this wake is the same as the slope of the volume reverberations since the wake is dead in the water. This wake return is high in amplitude but has a random phase character. Because of its amplitude, it is often mistaken for the hull of the target when observed on conventional sonars. As a result, the sonar operator trains the transducer on this area. The error results in incorrect target bearing and range information. This condition is evident in a large number of the pings shown. The hull of the target can be seen as a nearly horizontal line following the wake area.

In the pings shown in Figure 3.13, the hull echo of the target can be seen as a nearly horizontal line following the wake signature. Because of the fact that the projector is not trained directly on the hull in some of the pings shown, the hull echo is modulated in phase and in amplitude by the wake echo, and the line is not straight. Notice the similarity between the pattern of the mixed wake and hull echoes and that of the addition of two signals shown previously. (Figures 3.6, 3.7, 3.8, 3.9)

In ping 2, near the end of the reverberation, a series of fine lines of large slope may be seen. These are the result of echo ranging from another ship and represent that ship's transmitted pulse.

In pings 5, 6, and 7, the transducer has been trained more on the hull echo so that the modulation due to wake is considerably lessened and a cleaner hull echo is obtained.

Low-Speed Tracking Run in Presence of Extra Wake

In this run a destroyer is echo-ranging on a submarine. From the figure, it is determined that the destroyer is closing through the water in the line of sight of the submarine at a rate of 4.1 knots and that the submarine is opening through the water at the same rate, with the net result of a zero range rate. During this run, the range rate changes with a slight opening range rate at the end of the series of pings shown.

One of the most interesting features of this run is the presence of a wake stretching abeam of the destroyer. The first part of the wake at approximately 200 yards has a predominate zero range rate slope. This is followed in range or time by a closing slope indicating a position forward of abeam. The third portion has an opening slope indicating a position aft of abeam. This wake is not in the beam of the QHBa equipment, but the energy return from the wake is sufficiently high to override the beam selectivity. The presentation of the wake portion gave a pronounced impression of motion in the form of angular rotation of the line as the sound returned by the wake came progressively from different bearings.

[redacted]

[redacted]

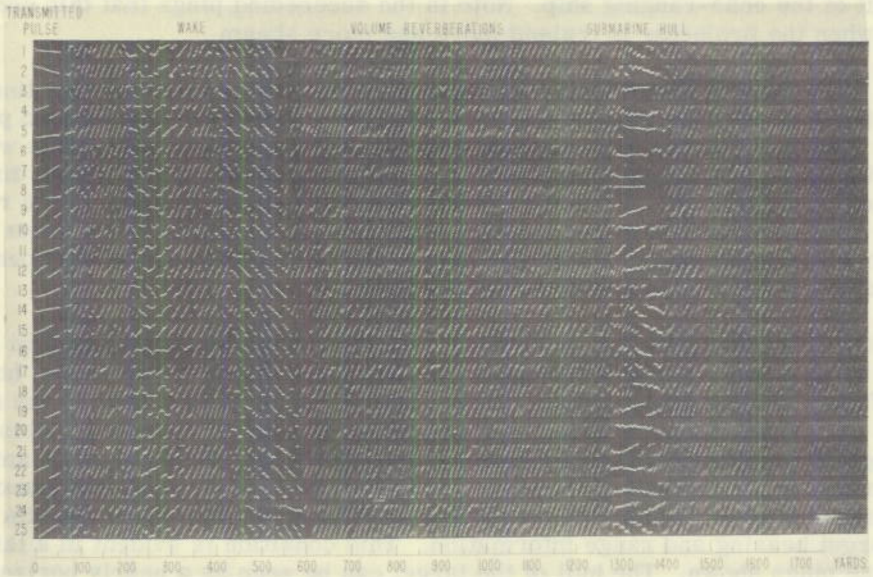


Figure 3.15. Ping sequence for tracking run, target horizontal

Center bearing on the hull of the submarine varies from very good in pings 5, 6, 7, 8, and 9 to very poor in pings 1, 15, 16, 17, and 25. The target range is approximately 1250 yards. In addition to the range rate through the water, indicating a quarter or stern aspect, increased reverberations from the submarine's wake are seen just prior to the hull target in pings 1, 3, and 18.

Tracking Run in Presence of Another Echo-Ranging Vessel

These two figures from another tracking run of a destroyer on a submarine illustrate the Graphic Indicator presentation in two conditions as did Figures 3.13 and 3.14. In the first condition, Figure 3.16, the reference oscillator is made to track the volume reverberations. Figure 3.17 demonstrates the same pings with the target frequency tracked by the reference oscillator. In this run it is noted that there are several pings received from another echo-ranging vessel. These signals are shown as blocks of uniform fine lines in pings 8, 10, 12, 14, 16, 18, and 20.

From this illustration, it was also determined that the destroyer was closing with respect to the water at 14.3 knots, with the submarine also closing with respect to the water at 4.6 knots. This resulted in a total closing range rate of 18.9 knots. This is further evidenced by the decrease of range to the target from 920 yards in ping 1 to 360 yards in ping 25. An energy return from the wake appears after the hull presentation. Since the target had a bow aspect, a portion of the wake immediately aft of the submarine was shielded, resulting in the appearance of the wake further aft.

Tracking Run with Towed "FXR"

Figure 3.18 illustrates the presentation of a tracking run with an FXR equipment towed by the destroyer. The target echo can be readily distinguished and the range rate measured, although the presentation is broken at intervals with high noise bursts.

[redacted]

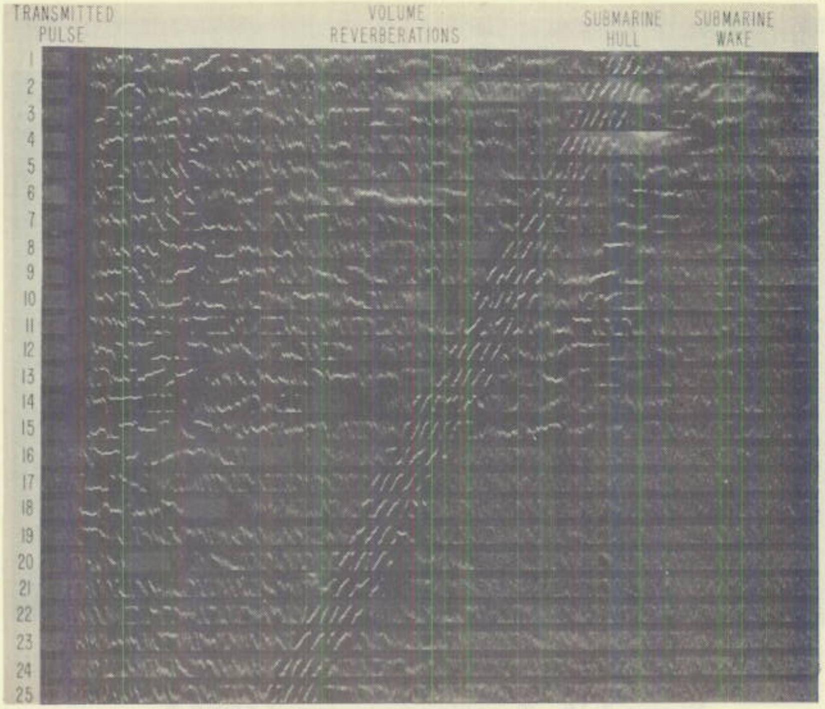


Figure 3.16. Ping sequence for attack run, volume reverberations horizontal

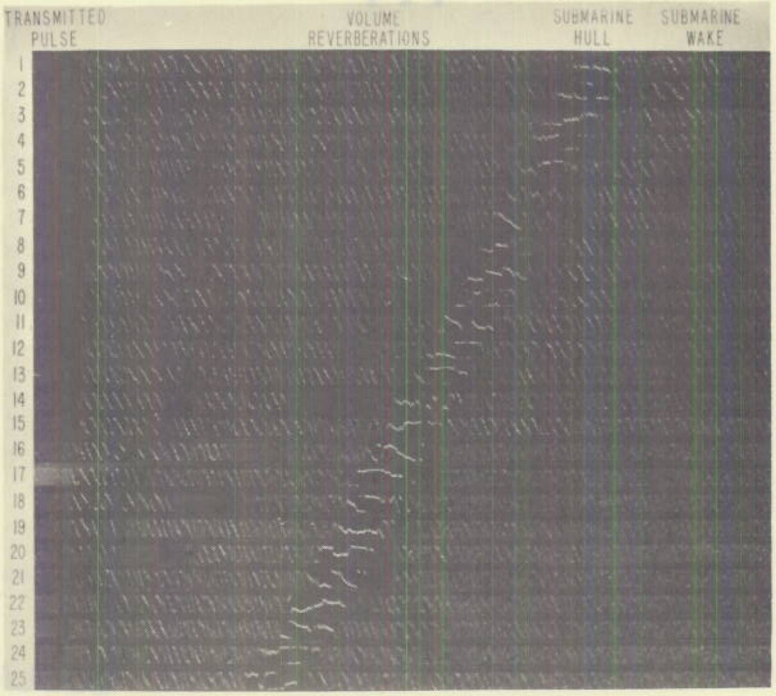


Figure 3.17. Ping sequence for attack run, hull echo horizontal

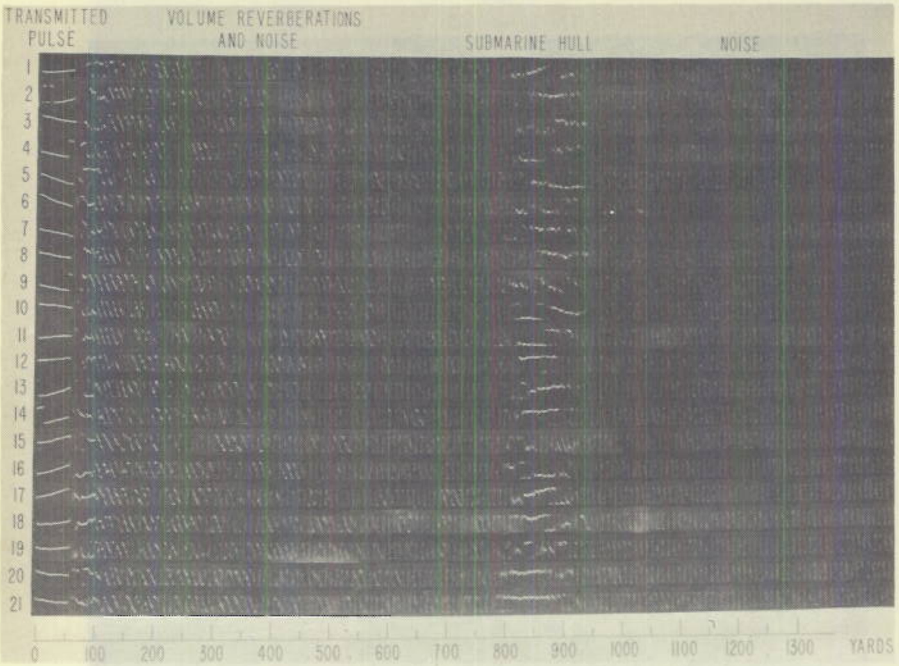


Figure 3.18. Tracking run - towed "FXR,"
hull echo horizontal

* * *

Section 4

Physical Description and Operation

PHYSICAL DESCRIPTION

This Section includes physical descriptions of the Graphic Indicator and its major associated components, a statement on power requirements, identification of, and comments on, the front panel controls of the Indicator, step-by-step operation procedures, and a table on internal adjustments.

Graphic Indicator

Dimensions - 12-3/4" by 16" by 17"

Weight - 45 lbs.

Figure 4.1 shows the front panel where are located the operation controls, the indicator tube, and all semi-permanent adjustment controls. A detailed account of this panel and internal adjustments of the Indicator are included in this Section.

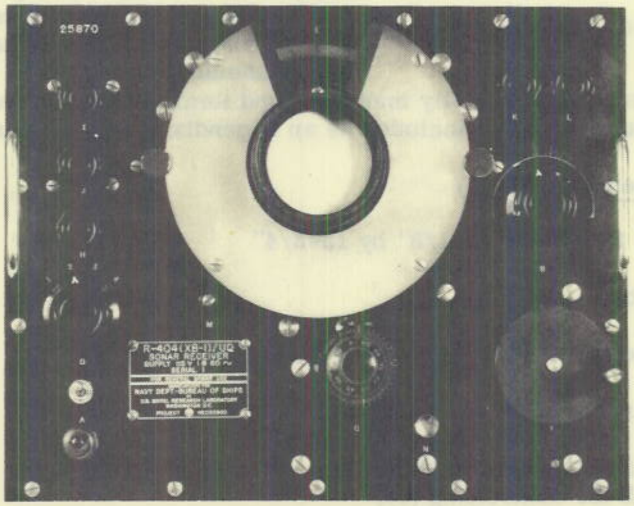


Figure 4.1. R-404 sonar receiver, front view

[redacted]

The rear panel contains the receptacles for the ODC, fuse, power supply, voltage regulator, signal, and the external gate. There are no external gates supplied at the present time.

There are two potentiometer screws, used for adjusting the zero reference push-button, visible through holes in the right hand side of the box.

Power Supply

Dimensions - 8-1/2" by 10" by 14"

Weight - 32 lbs.

Figure 4.2. R-404 power supply

Figure 4.2 shows the front panel where its only external connection is located, the receptacle for the power cable. There are no external controls or adjustments, however there are two internal adjustments that are described in Section 7 of this instruction book.

Voltage Regulator

Dimensions - 7-1/2" by 8-1/2" by 16"

Weight - 50 lbs.

Figure 4.3 shows the front panel where the voltage adjustment, on-off switch, indicator light, and fuse are located.

Figure 4.4 shows the rear panel where the power cord for the ship's 110 to 120 volts a-c supply, and two output receptacles are located. Power cords extend from these receptacles to the ODC and the Graphic Indicator. The output voltage should be adjusted to 117 volts. This voltage regulator is a commercially manufactured item. Copies of the manufacturer's instruction book and circuit are included as an appendix to this Instruction Book.

Own Doppler Compensator (ODC)

Dimensions - 8-1/8" by 13-1/8" by 13-3/4"

Weight - 20 lbs.

Figure 4.5 shows the front panel where are located:

a) sonar-bearing indicator dial,
b) ODC sonar bearing matching dial,
c) own ship's speed in knots dial,
d) crank for controlling (c),
e) crank for controlling (b), and the
f) switch for controlling dial lights.

[redacted]

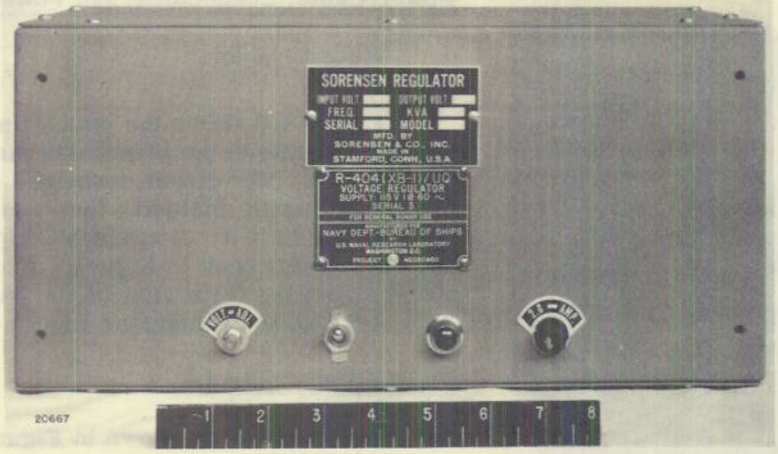


Figure 4.3. R-404 voltage regulator, front view

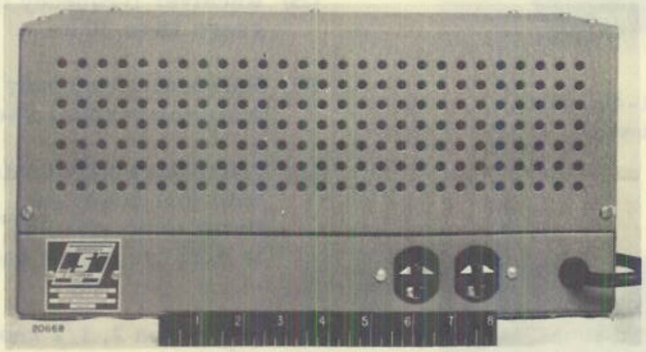


Figure 4.4. R-404 voltage regulator, rear view

The back panel contains the receptacles for power cord, sonar bearing repeater cable, and cable leading to Graphic Indicator. The identification relating the sonar-bearing-repeater-receptacle pins with the common selsyn (synchro) wiring notation is as follows:

Pin A for R_1
Pin B for R_2
Pin C for S_1
Pin D for S_2
Pin E for S_3

A description of the construction, purpose and usefulness of the ODC is included in the Electronic Theory (Section 5).

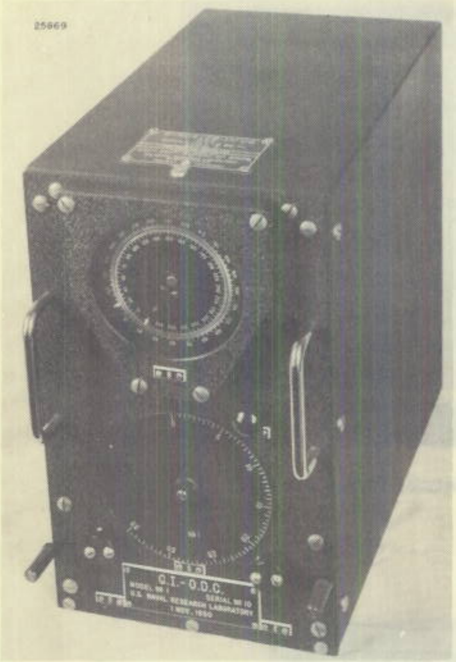


Figure 4.5. R-404 ODC, top front view

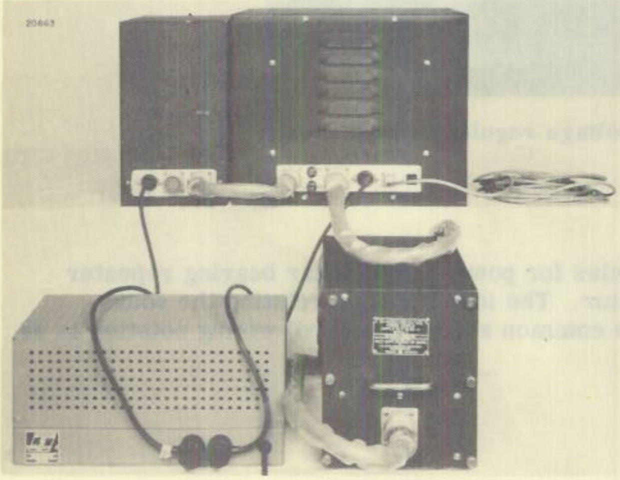


Figure 4.6 Power connections between component parts

Power Cable, Connectors, and Power Requirements

Weight - 4 lbs.

Figure 4.6 shows the power lines and cables connected between the previously mentioned component parts. The power consumed is approximately 235 watts, including the regulator, at 117 volts 60 cycles a-c. It might be helpful for the reader to refer back to Figure 1.1 on page 2, which shows the front view of the four units, at the same time he is considering Figure 4.6.

Front Panel Controls

The controls as shown in Figure 4.1 are as follows:

(A) On-off power switch with indicating light for 117 volts, 60 cycles.

(B) Receiver frequency tuning dial with range 18 to 30 kc.

(C) Reference frequency control which adjusts the vertical sweep.

(D) Horizontal sweep rate selector control with four positions. Position 1, 1/4 knot Range Rate gives 45° slope, equivalent to 4.25 cycles per second.

Position 2, 1/2 knot Range Rate gives 45° slope, equivalent to 8.5 cycles per second.

Position 3, 1 knot Range Rate gives 45° slope, equivalent to 17.1 cycles per second.

Position 4, 3 knots Range Rate gives 45° slope, equivalent to 51.3 cycles per second.

The slower the horizontal sweep rate, the more sensitive the instrument becomes to phase changes. Thus Position 4 enables the operator to locate the signal frequency and Positions 3, 2, 1, permit tracking any change in frequency with increasing sensitivity.

(E) Dials for reading range rates directly.

There are three dials—one above the other which may be selected by a shutter controlled by (M). The upper dial is calibrated in range rate (0 to 60 knots on each side of center) for passive listening. The middle dial is calibrated in range rate (0 to 30 knots on each side of center) for echo ranging. Closing range rate is read clockwise and is numbered in red figures. Opening range rate is read counterclockwise and is numbered with black figures. The lower scale is marked in degrees each side of center and is used only in the calibration procedure which is described in Section 5.

(F) Tracking Control Hand Wheel

This turns dial E, and is actually a fine adjustment on the reference frequency which permits reading of range rate from ping to ping. By returning dial E to zero original adjustment on C is re-established.

(H) Visual Sensitivity Control

Adjusts the amount of light entering lucite ring surrounding indicator tube, and is therefore a means of relieving eye strain in very dark compartments.

(I) Brightness Control on Cathode-ray Screen

(J) Focus Control on Cathode-ray Screen

(K) Pulse-Width Control

Adjusts vertical height of the trace on the cathode-ray screen. For best conditions height should be approximately 1/16" for a horizontal trace.

(L) Receiver Gain Control

Adjusts the amplitude of amplifier output before signal is processed by pulse generator.

(M) Shutter Control

By means of this control the various scales of dial E can be selected.

(N) Zero Reference Push Button

By means of this button the fine adjustment of F can be temporarily cancelled bringing the system back to the original reference frequency established with C.

OPERATION PROCEDURE

Echo Ranging

To prepare the Graphic Indicator for own ship echo-ranging the following steps should be taken:

(1) Turn on Voltage-Regulator Switch.

(2) Turn on Power Switch A. (Allow for one hour warm-up time)

(3) Adjust Indicator Light located below Switch A.

(4) Adjust Visual Sensitivity Control H to comfort of operator.

(5) Turn Shutter Control M to expose middle scale of Dial E.

(6) Turn Receiver Gain Control L to maximum.

(7) Adjust Brightness Control I until noise is noticeable on cathode-ray screen.

(8) Adjust Focus Control J for sharpest definition.

(9) Turn Tracking Control Handwheel F until Scale E reads zero.

(10) Switch Horizontal Sweep Rate Control D to position 3.

(11) Adjust Reference Frequency Control C until outgoing pulse presentation on cathode-ray screen becomes single horizontal line.

(12) Adjust Receiver Frequency Tuning Control B for best definition of return pulse or reverberation on cathode-ray screen.

(13) Adjust Receiver Gain Control L for best definition of return pulse or reverberations on cathode-ray screen.

(14) Push in Zero Reference Push Button N while holding down key of sonar driver a few seconds at a time.

(15) Observe screen to see if outgoing pulse presentation is horizontal under condition (13). If it is, skip to (17). If not, proceed with (16) below.

(16) Adjust potentiometers with screwdriver until outgoing pulse presentation is horizontal with N depressed. These two potentiometers (R109 and R115) are located on the right hand side of the cabinet. They should both be used. Turn them in the same direction. Turn them both the same amount. (Make sure E is set on zero while doing (16).)

(17) Proceed to echo range.

Passive Listening

To prepare the Graphic Indicator for passive listening the following steps should be taken:

(1) Turn on Voltage-Regular Switch.

(2) Turn on Power Switch A. (Allow one hour warm-up time.)

(3) Adjust Indicator Light located below switch A.

(4) Adjust Visual Sensitivity Control (H) to comfort of operator.

(5) Turn Shutter Control (M) to expose upper scale of dial E.

(6) Turn Receiver-Gain Control (L) to maximum.

(7) Adjust Brightness Control (I) until noise is visible on screen.

(8) Adjust Focus Control (J) for sharpest definition.

(9) Turn Tracking Control Handwheel (F) until Scale E reads zero.

(10) Switch Horizontal Sweep Rate Control D to position 4.

(11) Proceed with passive listening.

When a signal is detected proceed as follows:

(1) Adjust signal presentation to a horizontal position with the Reference Frequency Control C.

(2) Switch Horizontal Sweep Rate Control D to position 3.

(3) Adjust Receiver Frequency Tuning Control B for best definition of signal on cathode-ray screen.

(4) Adjust Receiver Gain Control L for best definition of signal on cathode-ray screen.

(5) Measure change in range rate by keeping signal horizontal with Tracking Control Handwheel F.

Determining Own Ship's Speed Through the Water

Own ship's speed through the water with an accuracy of the order of 0.1 knot can be determined in both the forward and lateral directions by measuring the frequency difference between the transmitted pulse and the returning volume reverberations. The steps for this procedure are given below.

For forward speed:

(1) Prepare equipment for echo ranging.

(2) Obtain transducer bearing 000° (relative).

(3) Set Range Rate Dial E at zero using Tracking Control Handwheel F.

(4) Adjust the outgoing pulse to a horizontal position with Reference Frequency Control C.

(5) Echo-range.

(6) Observe volume reverberations from immediately ahead of the vessel.

(7) Adjust the volume reverberations to horizontal position by turning Tracking Control Handwheel F so that Range Rate Dial E indicates closing range rate (red figures).

(8) Read forward speed from Dial E.

For lateral speed or drift follow the procedure for forward speed with the following modifications:

(1) Obtain transducer bearing 090° (relative) or 270° (relative).

(2) Read lateral speed as closing or opening range rate depending on conditions.

The ship's speed through the water can be caused by the combined effect of propulsion and wind. The measurement described here does not distinguish between the two effects, but gives the sum.

Determining Own Ship's Speed Over the Bottom

Own ship's speed over the bottom with an accuracy of the order of 0.1 knot can be determined in both the forward and lateral directions by measuring the frequency difference between the transmitted pulse and the returning bottom reverberations. The steps for this procedure are given below.

For forward speed:

(1) Prepare equipment for echo ranging.

(2) Obtain transducer bearing 000° (relative).

(3) Set Range Rate Dial E at zero.

(4) Horizontalize outgoing pulse with C.

(5) Echo-range.

(6) Identify bottom reverberations.

(7) Horizontalize bottom reverberations with F.

(8) Read forward speed over bottom from E.

For lateral speed follow the procedure for forward speed with the modification that the transducer bears 090° (relative) or 270° (relative).

The ship's speed over the bottom can be caused by propulsion, wind and current. The measurement described here does not distinguish between the three effects, but rather gives their sum.

Distinguishing Between Volume and Bottom Reverberations

Figure 3.11 (page 14) and Figure 3.12 (page 15) in Section 3 should be referred to when considering the subject of how to distinguish between volume and bottom reverberations. They are examples of reverberations for a particular sea condition. The degree of discrimination varies with the sea conditions (i.e. depth of water, temperature gradients, currents, and sea state) and speed of the ship, but in most cases the reverberations are easily resolved.

Table 4.1 summarizes the differences between volume and bottom reverberations. Bottom reverberations have a phase character which appears on the cathode-ray screen as a continuous line but with random change of phase. This variation in phase usually does not exceed a limit of 90°. On the other hand, volume reverberations appear as short bursts of discontinuous phase variations made up from the many reflecting points in the total reverberation area. Although these bursts are of short duration, a general slope is easily distinguished. As the reference frequency is brought into coincidence with the signal frequency, the slope disappears and a random horizontal presentation is observed. Because of their time sequence with respect to the outgoing pulse, volume reverberations always appear on the screen before the bottom reverberations. Whenever, as a result of currents, there is relative motion of the medium with respect to the bottom, the volume reverberations may be distinguished by the difference in slope produced by the velocity or doppler effect.

TABLE 4.1
Points of Distinction Between Volume and Bottom Reverberations When Using G.I.

Presentation Characteristics	Volume Reverberations	Bottom Reverberations
Phase	Short bursts of discontinuous phase variations	Continuous line with random phase change usually less than 90°
Time or Range with respect to outgoing pulse	Appear first	Appear last
Range Rate or Slope	Doppler effect produced by both ship's motion and ocean currents	Doppler effect produced only by ship's motion.

Determining Magnitude and Direction of Ocean Current

The magnitude and direction of any surface current present in the ocean through which the ship is passing is determined with an accuracy comparable to ship's speed determination in the following manner:

(1) In the forward (000°-relative) direction measure own ship's speed through the water and over the bottom.

(2) Subtract these two measurements to obtain the component of current in the forward direction.

(3) In the 090° and 270° directions measure own ship's speed through the water and over the bottom.

(4) From the measurements in (3) determine the beam component of current. (i.e. so many knots in either the 090° (relative) or 270° (relative) direction.)

(5) Add the forward and beam components vectorially to determine the true magnitude and direction of the ocean current.

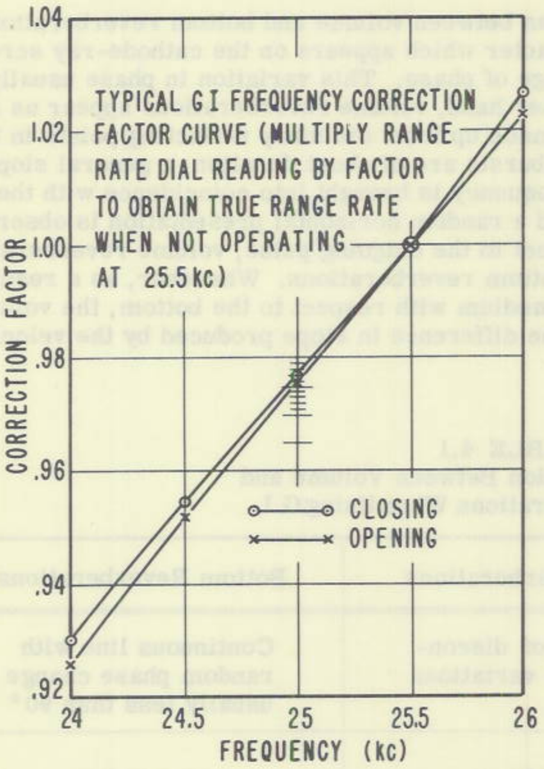


Figure 4.7. Sample calibration curve

Effects of Operating Frequency on Range Rate Dial Calibration

Sonar Receiver R-404(XB-1)/UQ has been calibrated to read accurately at 25.5 kc. If the operating frequency for either active or passive operation differs from the calibrated frequency, a correction factor must be applied to read true range rate. Figure 4.7 is a sample curve taken from the set of calibration curves included with each instrument. This curve shows the correction factor by which the range rate dial indication must be multiplied to obtain a true range rate. For instance; a range rate of 10 knots closing is read from the range rate dial, and the operating frequency is known to be 25 kc. Referring to Figure 4.7 note that the correction factor for 25 kc is 0.97 for closing range rate. The true range rate is therefore 10 x 0.97 = 9.7 knots closing. A similar correction must also be made for water temperature.

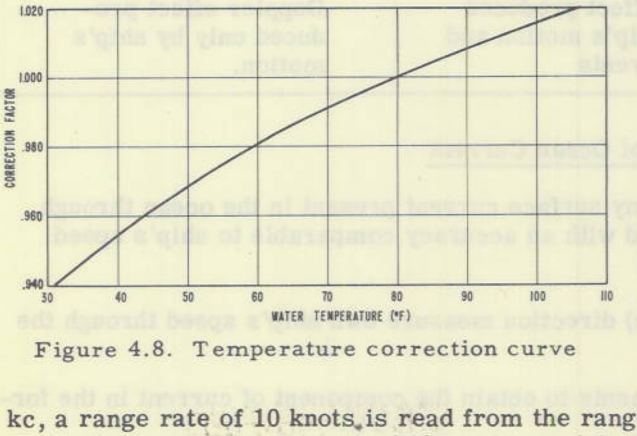


Figure 4.8. Temperature correction curve

Effects of Water Temperature on Range Rate Dial Calibration

The Sonar Receiver R-404(XB-1)/UQ has been calibrated at a frequency of 25.5 kc for a water temperature of 80°F. Since the velocity of sound increases as the water temperature increases, a correction factor must be applied to the dial reading to compensate for this change. Figure 4.8 is a correction curve for this variation due to water temperature and indicates for any temperature between 40 and 100°F the correction factor by which the dial calibration must be multiplied to give a true range rate. For example, suppose at an operating frequency of 25.5 kc, a range rate of 10 knots is read from the range rate dial, and the water temperature at the time of the reading was 70°F. Figure 4.8 shows that the correction factor for 70°F

[redacted]

is 0.992. The true range rate is therefore 10 x 0.992 or 9.92 knots. These temperature curves are included with the calibration curves for each instrument.

For temperatures and frequencies, both differing from the values used for calibration, both correction factors must be applied. The correct value of range rate is then the product of the dial reading and both correction factors. As above 10 x 0.977 x 0.992 = 9.69 knots.

* * *

[redacted]

Section 5

Electronic Design

Individual components of the indicator, shown in the block diagram of Figure 5.1, have been designed to perform respectively the functions set forth in the theory. Basically, the indicator is divided into three channels. The first consists of the bandpass amplifier with automatic gain control (AGC), the base clipper, the pulse generator, and the pulse lengthener. The second contains the reference oscillator, the vertical sweep generator, the amplifiers, and the blanking generator. The third consists of the horizontal sweep generators and the horizontal amplifier.

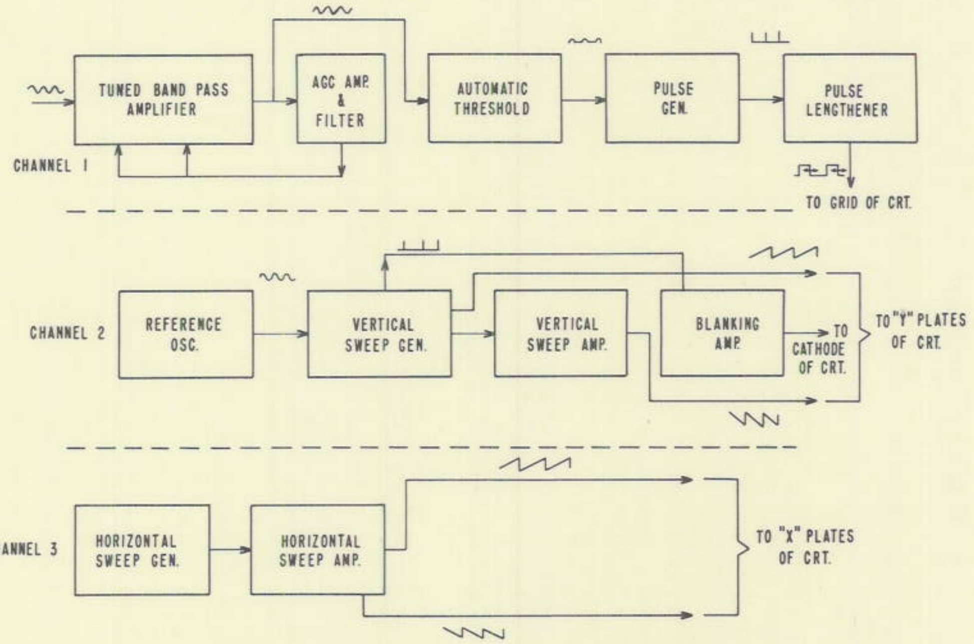


Figure 5.1. Block diagram of Sonar Graphic Indicator

CHANNEL 1

In processing the signal for the generation of the indexing pulses at the signal-voltage crests, the bandpass amplifier serves three purposes: first, to provide sufficient gain (defined below); second, to provide adequate bandwidth for accommodating signal phase variations in a 3-kc band with negligible phase distortion and; third, to

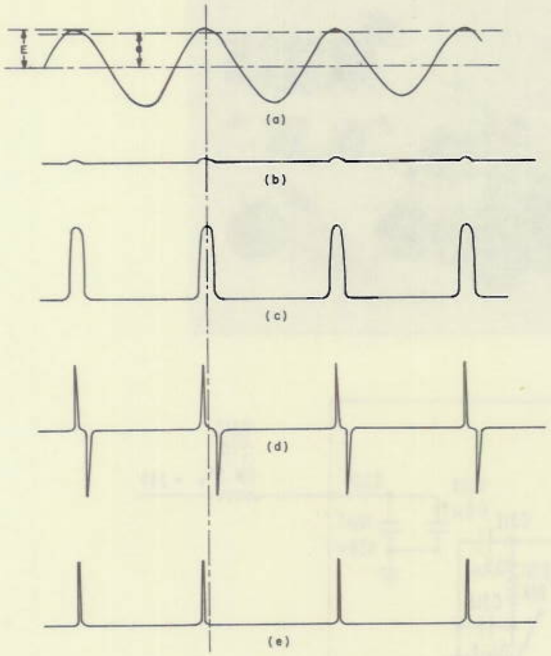


Figure 5.2. Wave forms in signal channel

provide automatically a signal, undistorted except for compression, to the base clipper in the pulse generator, satisfying its limited dynamic range even though the input signal varies in level over an 80-db range. By the fast automatic gain control (AGC) action, variations of the signal amplitude with time are compressed or reduced.

In the pulse generator the first component is a base clipper, which selects a threshold (e in Figure 5.2a) very near the positive crest of each cycle of the sine wave, and isolates the peak as indicated in Figure 5.2b. The threshold level (e) is determined by the peak amplitude (E) of the incoming signal, by grid rectification, and is set within a period of time equal to a few cycles of the signal. The threshold level (e) is effectively an adjustment of the bias in such a way that a vacuum tube will conduct only when the instantaneous signal voltage rises above this bias. The clipped crest of each cycle of the sine wave (Figure 5.2b) is amplified as shown in Figure 5.2c. After amplification, the pulses are differentiated, and a wave form is obtained as shown in Figure 5.2d. The lower half of the wave is discarded to give the wave form illustrated in Figure 5.2e.

Tests have shown that the pulse from the pulse generator shifts less than 2 degrees in phase when an 80-db amplitude variation is imposed on the input signal. Theoretically, the pulse is not generated from the zero slope of the crest, but, for practical applications, it may be so considered over reasonable dynamic ranges.

Bandpass Amplifier

The bandpass amplifier is illustrated in the schematic diagram of Figure 5.3. It consists of an input transformer affording a balanced or unbalanced input at 600 ohms impedance and two tuned stages (V301 and V302) covering the frequency range of 20 to 30 kc. The over-all bandwidth is 3 kc to the 3-db points. The gain and noise figure are such that a c-w signal of 0.5 microvolt may be resolved on the cathode-ray-tube indicator. (Knob B in Figure 4.1 on page 21 controls C304, C310.)

AGC Amplifier and Filter

The AGC amplifier (V303) is a 6AT6 triode, dual-diode tube. The triode section is used to amplify the output of the bandpass amplifier. The triode output is then rectified by the diodes, and the rectified output, after being filtered, is applied as a gain-control voltage to the grids of the amplifier stages. An AGC delay bias is developed and is applied to the common cathode of the multisection tube, thus setting the input level at which AGC action begins. A manual gain control is also provided. (Knob L in Figure 4.1 on page 21 controls R319.)

[redacted]

DECLASSIFIED

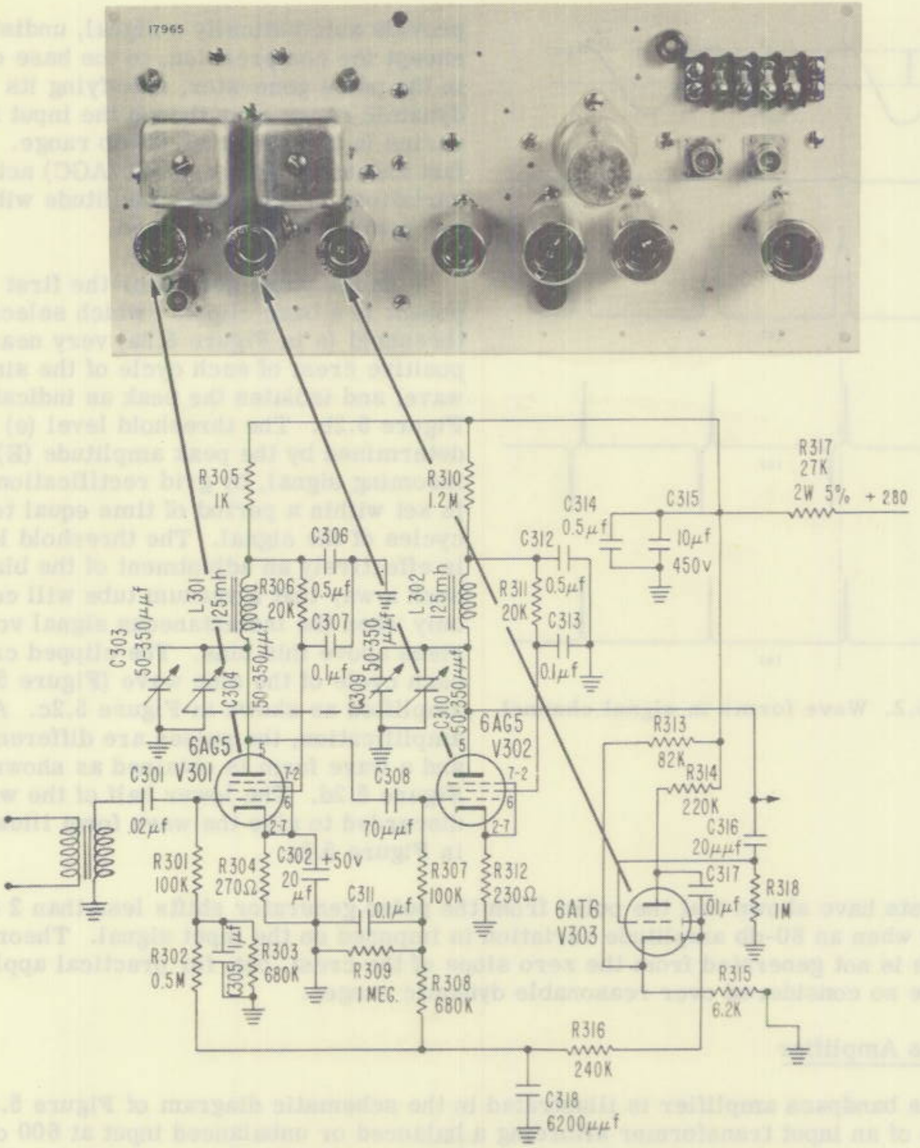


Figure 5.3. Bandpass amplifier

Automatic Threshold or Base Clipper

The base clipper (Figure 5.4) selects a portion of a positive-going signal near the crest of the wave, the portion selected being amplified and differentiated in order to form a sharp trigger for the pulse generator in V305B. The circuit shown in Figure 5.5 fulfills the function of the base clipper. (The Gate shown in this circuit is no longer in use.) Tube V304, a 6AU6 broadband amplifier, raises the signal level for use in the base clipper. The first half of the 12AU7 (V305A) is operated at low plate voltage and no fixed bias, the grid bias being set by the value of signal or signal plus noise. A positive-going impulse greater than the average grid bias is amplified in (V305B) and differentiated to form a trigger for the blocking oscillator.

DECLASSIFIED

[redacted]

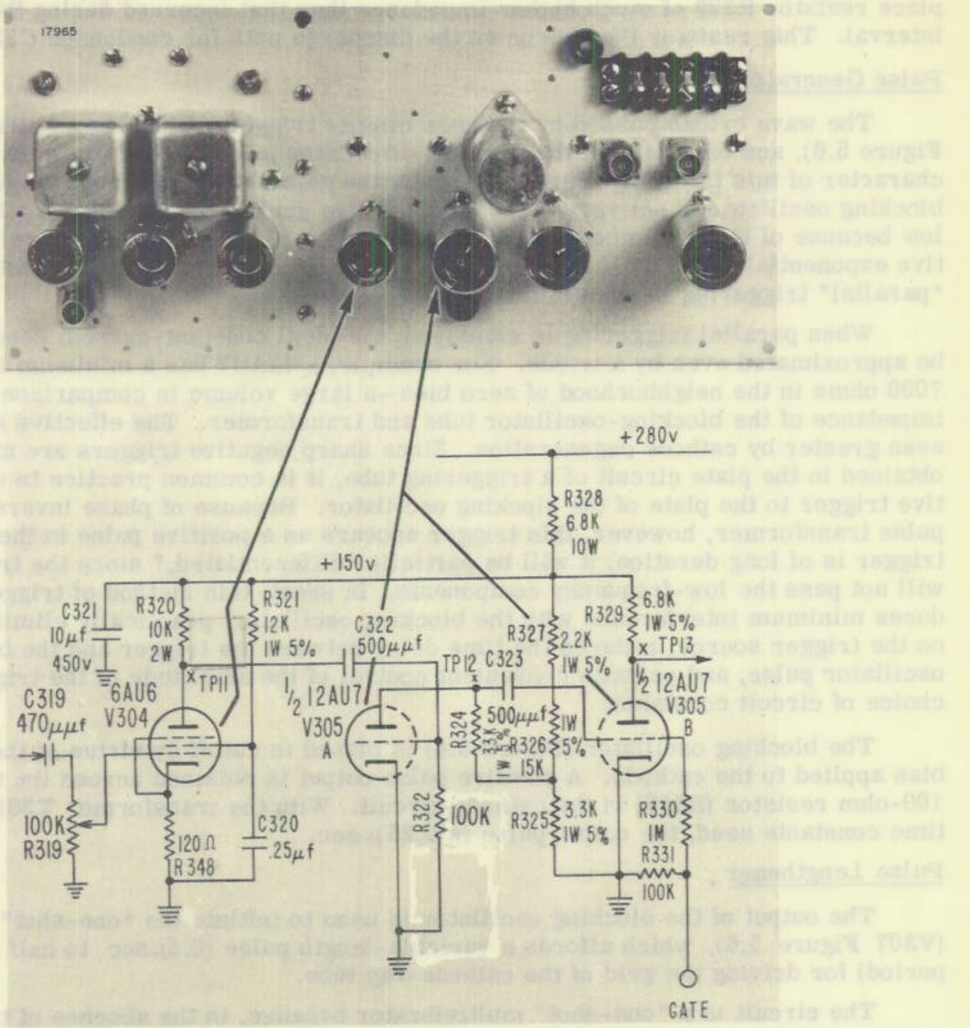


Figure 5.4. Automatic threshold circuits

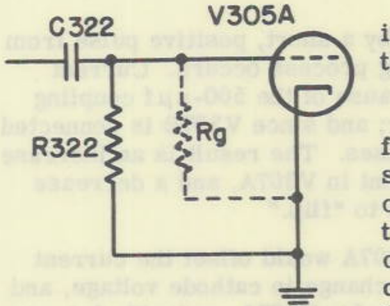


Figure 5.5. Grid circuit of automatic threshold

The time constants in the grid of the base clipper are important in that they determine the nearness of clipping to the crest of a signal.

The triode grid circuit shown in Figure 5.5 is a modification of a grid-leak detector and operates in a manner similar to an automatic switch; that is, during an impulse of positive excursion, the grid of the triode is driven positive. This causes the condenser (C322) to charge because of grid current through the low impedance path R_g. The condenser becomes so negatively charged that the grid of the triode remains at "cutoff" at the removal of the charging pulse. The cutoff voltage effectively opens the low-impedance grid-charging circuit and substitutes in its

[redacted]

place resistor R322 of much higher impedance than that incurred during the charging interval. This resistor then becomes the discharge path for condenser C322.

Pulse Generator

The wave crests passed by the base clipper trigger a blocking oscillator (V306 in Figure 5.6), and the shape of the blocking-oscillator pulse depends largely upon the character of this initiating trigger. Usually the gain around the feedback loop in the blocking oscillator is not very large before heavy grid current is drawn. The gain is low because of the low impedance of the transformer. Rise in potential follows a positive exponential curve until limiting takes place. In order to achieve a fast rise time, "parallel" triggering is used in the blocking oscillator.

When parallel triggering is employed, the ideal constant-current generator may be approximated even by a triode. For example, a 12AU7 has a minimum R_p of about 7000 ohms in the neighborhood of zero bias—a large volume in comparison with the impedance of the blocking-oscillator tube and transformer. The effective R_p is made even greater by cathode degeneration. Since sharp negative triggers are more easily obtained in the plate circuit of a triggering tube, it is common practice to apply a negative trigger to the plate of the blocking oscillator. Because of phase inversion in the pulse transformer, however, this trigger appears as a positive pulse in the grid. If the trigger is of long duration, it will be partially "differentiated," since the transformer will not pass the low-frequency components. In short, this method of triggering introduces minimum interference with the blocking oscillator, practically eliminates reaction on the trigger source, reduces the time delay between the trigger and the blocking-oscillator pulse, and permits convenient control of the amplitude of the trigger by proper choice of circuit constants.

The blocking oscillator (Figure 5.6) is biased to cutoff by virtue of the positive bias applied to the cathode. A positive pulse output is obtained across the unbypassed 100-ohm resistor (R349) in the cathode circuit. With the transformer T301 (132AW) and time constants used, the output pulse is $0.25\,\mu$ sec.

Pulse Lengthener

The output of the blocking oscillator is used to initiate the "one-shot" multivibrator (V307 Figure 5.6), which affords a variable-length pulse (0.5μsec to half the repetition period) for driving the grid of the cathode-ray tube.

The circuit is a "one-shot" multivibrator because, in the absence of trigger pulses, the second half of the 12AU7 triode V307B, having the positive grid return, conducts and raises the potential on both cathodes. The grid voltage of V307A is adjusted to a fairly low value by the choice of the resistor-divider network. Since the cathode is positive with respect to this grid bias, V307A is cut off. (Screw adjustment K in Figure 4.1 on page 21 controls R341.)

The first section of V307A is driven into conduction by a short, positive pulse from the blocking oscillator on the grid. Thereupon, a switching process occurs. Current in V307A causes the plate-to-ground voltage to drop. Because of the 500-$\mu\mu$f coupling capacitor (C330), the grid-to-ground voltage drops equally; and since V307B is connected as a cathode-follower, the cathode voltage likewise decreases. The result is an increase in grid-to-cathode voltage for V307A, an increase in current in V307A, and a decrease in V307B. The regenerative action thus causes the circuit to "flip."

It might at first appear that a current increase in V307A would offset the current decrease in V307B, and that there would, therefore, be no change in cathode voltage, and no switching process. With, however, constant grid voltage for V307A, and with decreasing grid voltage for V307B, the total current through the cathode-resistor must decrease, and therefore the voltage-drop across the cathode-resistor decreases. The current changes in V307A cause cathode-follower V307B to operate into a very low load resistance.

[redacted]

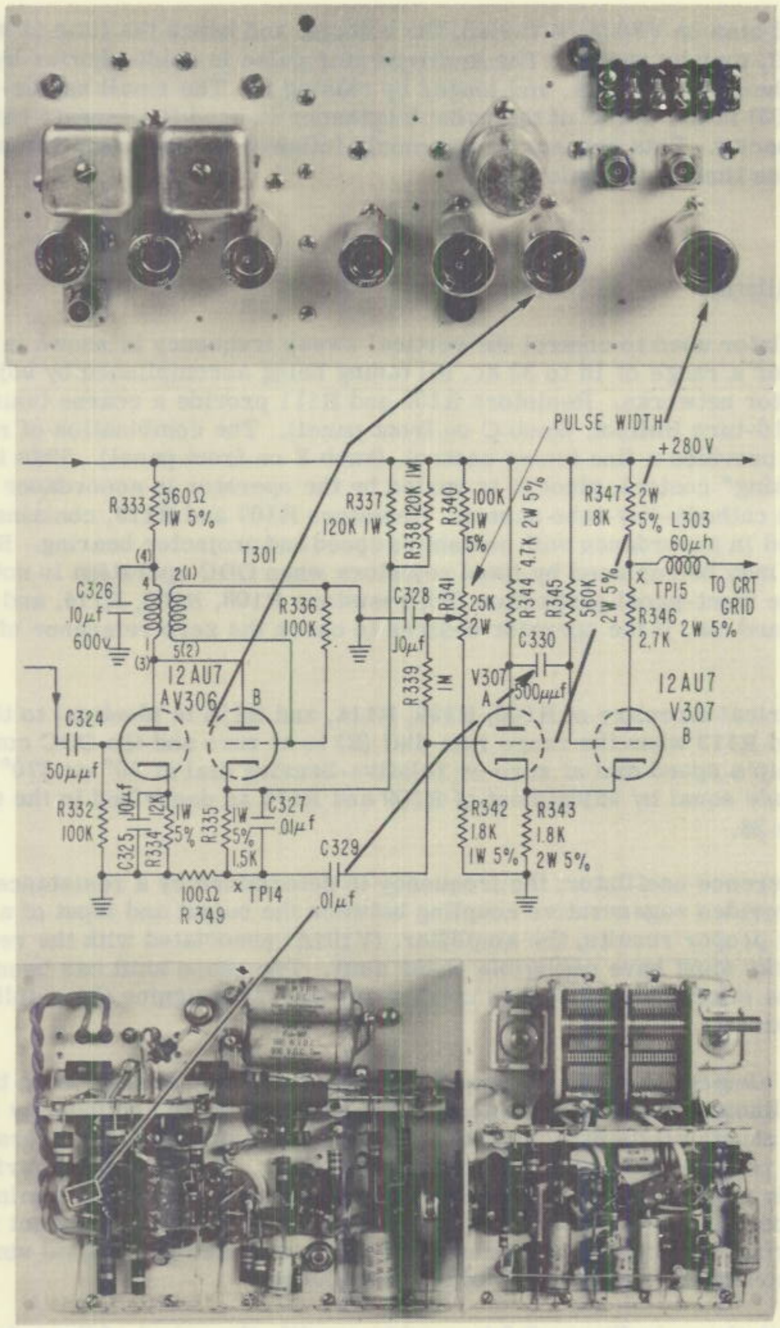


Figure 5.6. Pulse generator

Therefore, the changes in grid voltage of V307B are much greater than changes in the cathode voltage. Once cut off, V307B remains cut off, while the 500-$\mu\mu$f coupling capacitor (C330) discharges until the cutoff point is reached and plate current begins to flow. The current in V307B raises the cathode voltage enough to cut off V307A, and the high plate voltage of V307A helps to turn on V307B. This causes the circuit to "flop" back to its quiescent condition.

If the grid bias on V307A is varied, the voltage, and hence the time at which V307A begins to cut off, may be varied. The multivibrator pulse is made shorter by decreasing the voltage at the grid of V307A, and longer by raising it. The small series-peaking inductance (L303) in the output of the pulse lengthener is used to resonate cable and other stray capacity. This process is commonly followed in video amplifiers to maintain a "fast" rise time in the pulse.

CHANNEL 2

Reference Oscillator

The oscillator used to control the vertical sweep frequency is shown in Figure 5.7. It is tunable over a range of 16 to 32 kc, all tuning being accomplished by adjusting a series of resistor networks. Resistors R105 and R111 provide a coarse tuning control by means of a 10-turn Helipot, (knob C on front panel). The combination of resistors R106 and R112 provides a fine tuning control, (knob F on front panel). This is referred to as the "tracking" control, since it is varied by the operator in accordance with the presentation on cathode-ray-tube screen. Resistors R107 and R113, contained in the ODC, are varied in accordance with own ship's speed and projector bearing. Resistors R107 and R113 may be replaced by fixed resistors when ODC operation is not desired. By means of the front-panel pushbutton (N), resistors R108, R109, R114, and R115 may be switched in and out, if the operator desires to check the zero reference of the coarse tuning.

The electrical circuitry of R108, R109, R114, and R115 is identical to that of R106, R107, R112, and R113 when the range rate dial (E) is at zero and the ODC compensation is zero (own ship's speed dial at zero or relative-bearing dial at 90° or 270°). These circuits are made equal by adjustment of R109 and R115 as described in the Operation Section on page 26.

In the reference oscillator, the frequency is determined by a resistance-capacity network that provides regenerative coupling between the output and input of a feedback amplifier. For proper results, the amplifier, (V101A) associated with the resistance-capacity networks must have negligible phase shift. The phase shift has been made negligible by the elimination of bypass condensers and by designing the amplifier for wideband response.

When one element is varied, frequency nonlinearity may occur. When the variable element is not linear, or when the largest factor contributing to nonlinearity is stray capacity which shunts all tuning elements, choice of precision potentiometers with a linearity of 0.1 percent makes the first factor negligible. Stray capacity varies with frequency and is most pronounced at the higher frequencies where R is a minimum. Its effect may be minimized either by compensation or by careful placement of components and wiring. Condenser C102 should never be adjusted in the field since it is very critical in respect to calibration of the instrument.

The circuit shown in Figure 5.8 is used to amplify the output of the reference oscillator and to generate square waves which are differentiated in the grid circuit of the blocking oscillator to form a trigger for initiating the vertical sweep circuit. Tube V102 is a 6C4 triode. Used as the amplifier, it provides ample signal for driving the square-wave generator. The square-wave generator (V103) is a 6BN6 gated-beam tube, whose characteristics make it an excellent squaring device and one capable of producing a square wave of steep edge, regardless of frequency and amplitude variations.

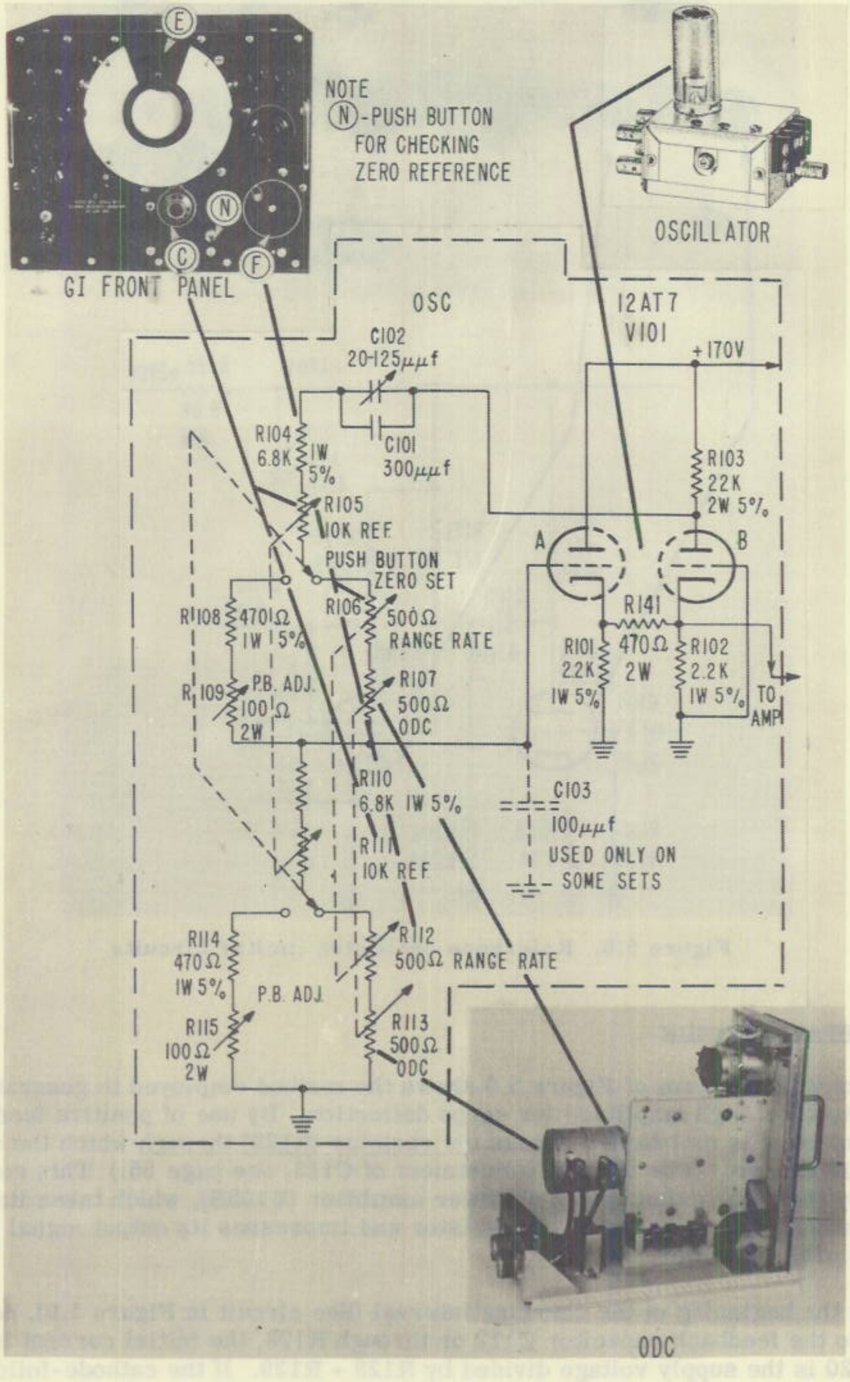


Figure 5.7. Reference oscillator

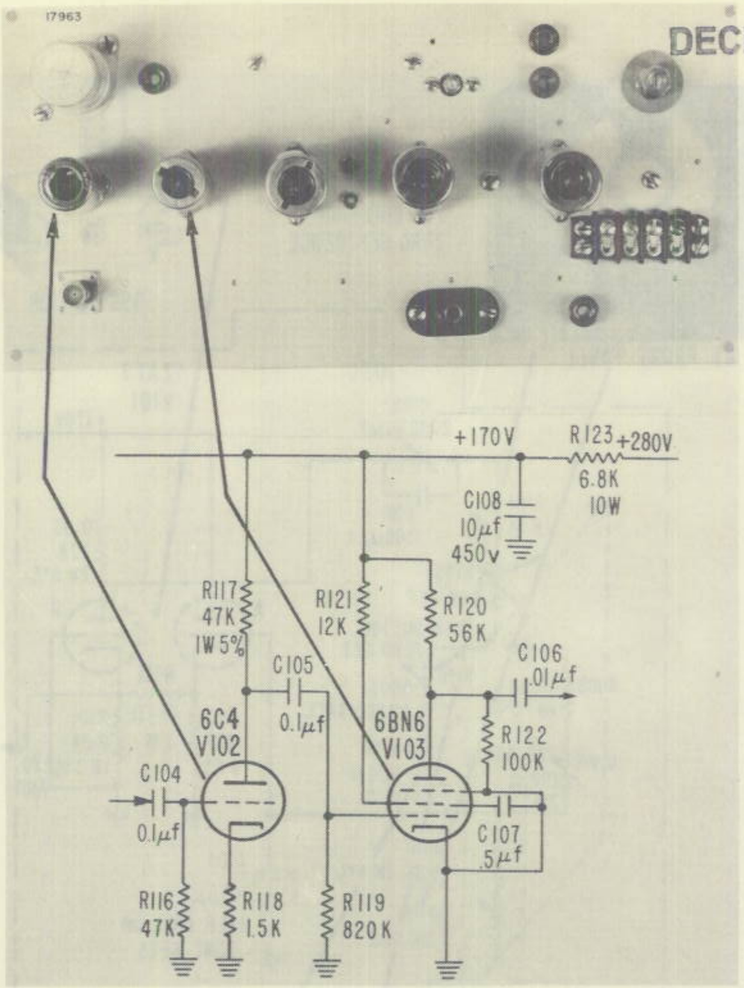


Figure 5.8. Reference oscillator limiter circuits

Vertical Sweep Generator

The circuit diagram of Figure 5.9 shows the method employed to generate a fast, linear sawtooth of high amplitude for scope deflection. By use of positive feedback, a constant potential is maintained across the resistor (R129) through which the condensers C120 + C113 charge. (For internal adjustment of C113, see page 55.) This condition is achieved by the unity-gain cathode-follower amplifier (V105B), which takes its input signal from the condenser end of the resistor and impresses its output signal at the supply end of the resistor.

If, at the beginning of the charging interval (See circuit in Figure 5.9), no current is flowing into the feedback capacitor C112 or through R128, the initial current into C113 + C120 is the supply voltage divided by R128 + R129. If the cathode-follower has a unity gain, and if condenser C112 does not discharge appreciably during a sweep interval, initial current will be maintained. Condenser C112 will not discharge appreciably since C112 $\gg$ C113 + C120 and since the time constants, R128 with C112, and R129 with C112, are large compared to a single sweep.

DECLASSIFIED

UNCLASSIFIED

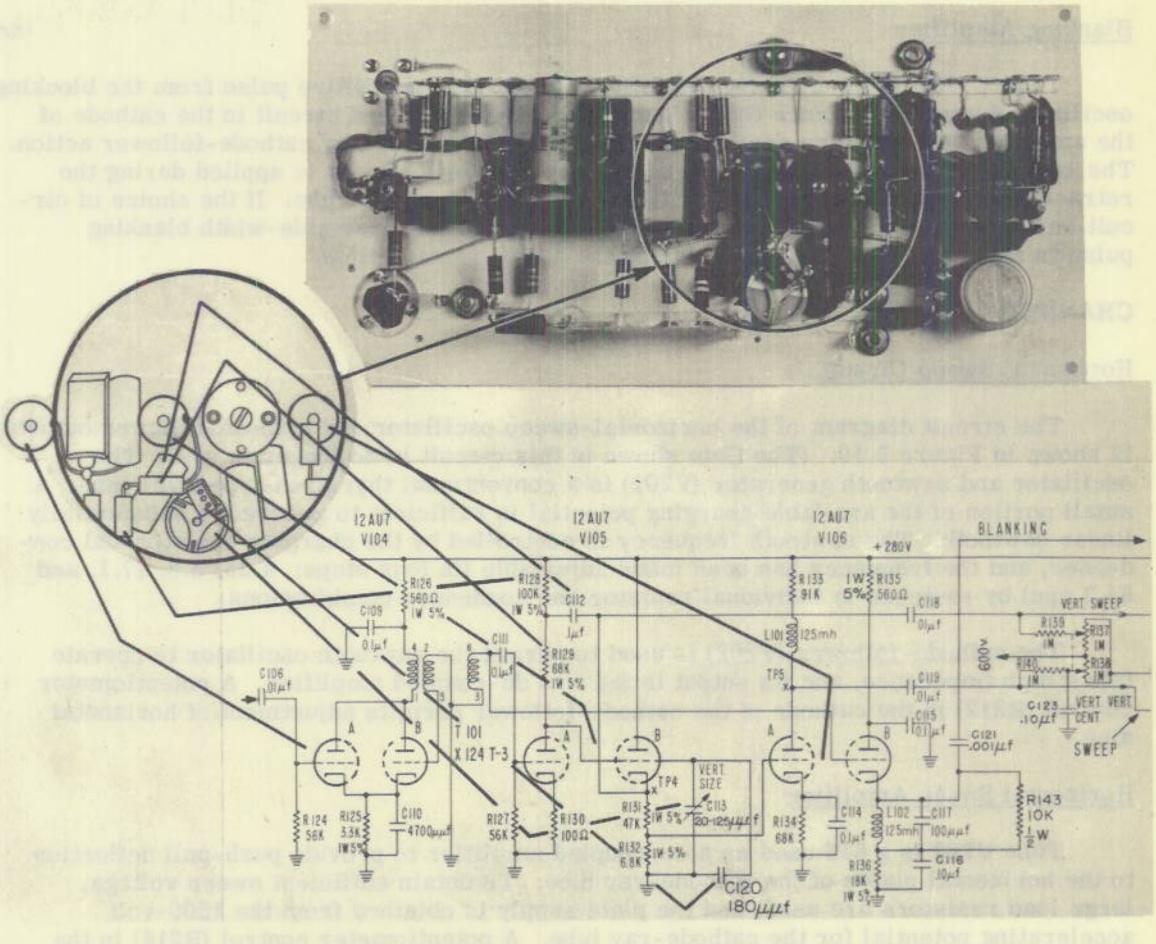


Figure 5.9. Vertical sawtooth sweep generator and blanking amplifier

Discharge of C113 + C120 is through tube V105A when the blocking oscillator is triggered from the differentiated reference square wave. Tube V105A, normally cut off owing to negative grid voltage developed by grid current flowing during the blocking-oscillator (V104) discharge pulse, is driven into heavy conduction by the positive pulse from V104 during the discharge time. The sawtooth amplitude developed by this circuit is approximately 150 volts peak-to-peak (adjustable by increasing or decreasing C113) and has a retrace time of about 4 microseconds. The sawtooth output is taken across the cathode-follower and applied through a coupling condenser to one plate of the cathode-ray tube.

Vertical Sweep Amplifier

Tube V106A is an amplifier which inverts the cathode-follower sawtooth. Its output drives the other vertical deflection plate of the cathode-ray tube through a coupling condenser to provide push-pull deflection.

DECLASSIFIED

SECRET
SECURITY INFORMATION

[redacted]

Blanking Amplifier

Tube V106B is the blanking amplifier. It receives a positive pulse from the blocking oscillator during the retrace time. This pulse rings the tuned circuit in the cathode of the amplifier, the negative cycle of the ring being damped out by cathode-follower action. The large positive pulse thus produced across this tuned circuit is applied during the retrace time of the sawtooth to the cathode of the cathode-ray tube. If the choice of circuit components is varied, the tuned circuit may produce a variable-width blanking pulse to assure adequate blanking during the entire retrace time.

CHANNEL 3

Horizontal Sweep Circuit

The circuit diagram of the horizontal-sweep oscillator and cathode-follower outputs is shown in Figure 5.10. (The Gate shown in this circuit is no longer in use.) The oscillator and sawtooth generator (V201) is a conventional thyratron-type 2D21 tube. A small portion of the available charging potential is sufficient to generate a substantially linear sawtooth. The sawtooth frequency is controlled by the charging resistor and condenser, and the frequency has been made adjustable (in four steps: 4.25, 8.5, 17.1, and 51.3 cps) by switches in individual resistor and condenser combinations.

The cathode-follower (V202) is used to permit the sawtooth oscillator to operate into a high impedance, and its output is fed to a dc-coupled amplifier. A potentiometer control (R212) in the cathode of the cathode-follower permits adjustment of horizontal size.

Horizontal Sweep Amplifier

Tube V203 is a 6J6 used as a dc-coupled amplifier to provide push-pull deflection to the horizontal plates of the cathode-ray tube. To obtain sufficient sweep voltage, large load resistors are used, and the plate supply is obtained from the 1500-volt accelerating potential for the cathode-ray tube. A potentiometer control (R214) in the cathode of tube V203 permits adjustment for astigmatic effects.

CATHODE-RAY-TUBE CIRCUITS (Figure 5.11)

Tube V501 is a 3JP7 cathode-ray tube, a type with a blue fluorescence, a greenish-yellow phosphorescence, and long persistance. The necessary operating potentials are obtained from a resistance voltage-divider network. The intensity of the beam is adjusted by potentiometer R507 so that the negative potential on the grid may be controlled with respect to the cathode. Focusing is accomplished by adjusting potentiometer R505 to provide the correct potential for the first anode.

The horizontal deflection plates are direct-coupled to the plates of the horizontal amplifier, and are at an average potential of 600 volts. In order to avoid astigmatism, the vertical deflection plates are biased to approximately the same potential. They are condenser-coupled, and the bias voltage is obtained from a resistance voltage-divider network from the intensifier voltage supply.

The cathode is operated at a high-negative potential of approximately -1400 volts. With 600 volts applied to the second anode, the second anode-to-cathode potential becomes 2000 volts. But since the intensifier of the cathode-ray tube operates at 1600 volts, the total over-all accelerating potential is 3000 volts. Signals are applied to the grid and cathode for intensification and blanking.

[redacted]

DECLASSIFIED

UNCLASSIFIED

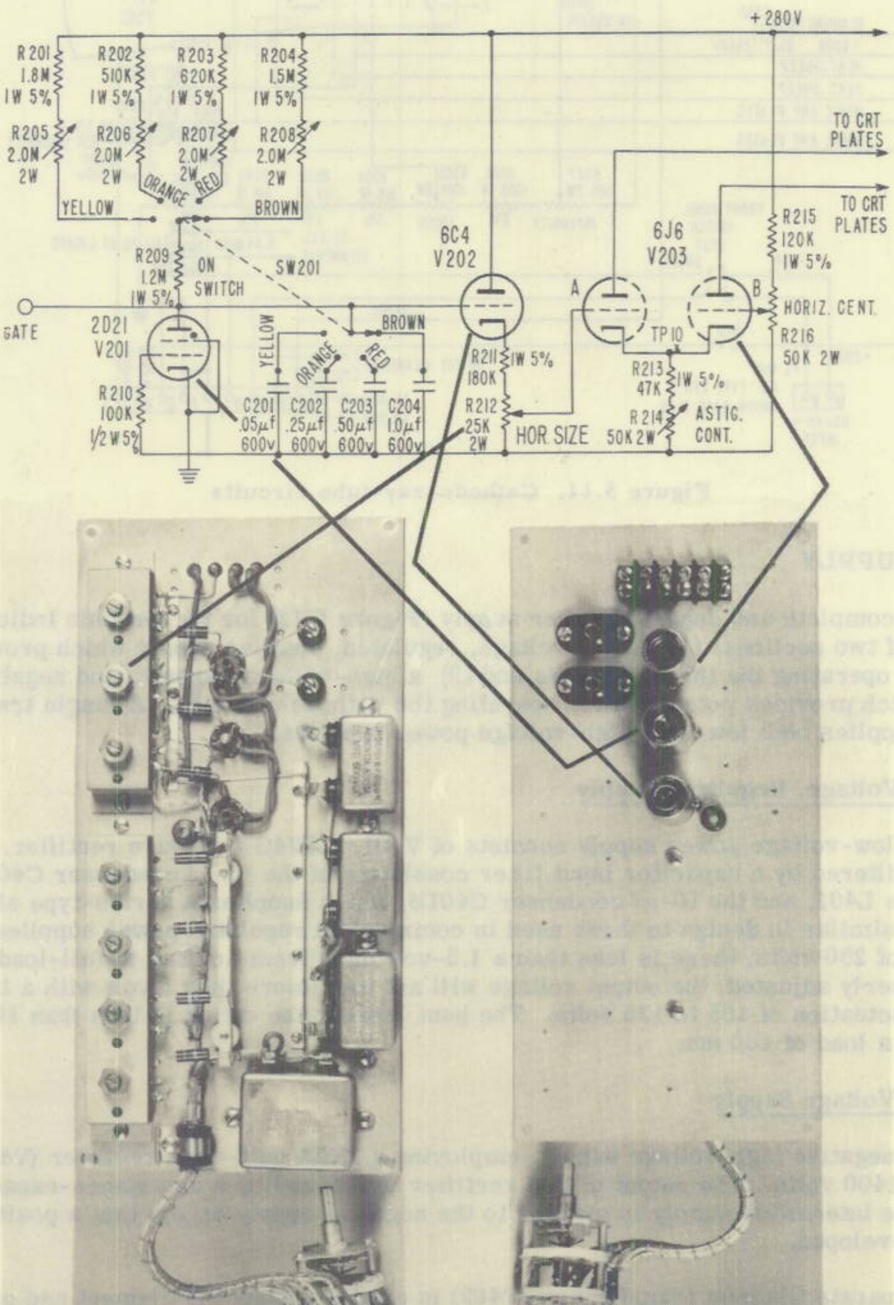


Figure 5.10. Horizontal sweep circuits

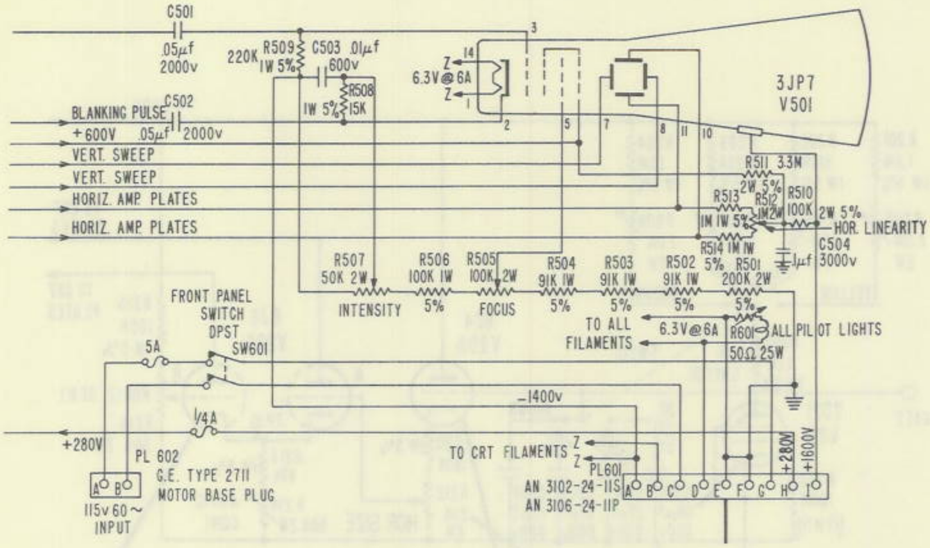


Figure 5.11. Cathode-ray-tube circuits

POWER SUPPLY

The complete and separate power supply (Figure 5.12) for the Graphic Indicator is made up of two sections: (1) A low-voltage, regulated, positive supply which provides power for operating the three channels and (2) a high-voltage, positive and negative supply which provides potentials for operating the cathode-ray tube. A single transformer supplies both low- and high-voltage power supplies.

The Low-Voltage, Regulated Supply

The low-voltage power supply consists of V401, a 5V4G full-wave rectifier. Its output is filtered by a capacitor input filter consisting of the 10-µf condenser C401A, the 10-h choke L401, and the 10-µf condenser C401B, which supplies a series-type electronic regulator similar in design to those used in commercial regulated power supplies. With an output of 280 volts, there is less than a 1.5-volt drop from no-load to full-load (100 ma). When properly adjusted, the output voltage will not vary more than 1 volt with a line voltage fluctuation of 105 to 125 volts. The hum level at the output is less than 10 millivolts with a load of 100 ma.

The High-Voltage Supply

The negative high-voltage supply, employing a 2X2A half-wave rectifier (V407), produces 1400 volts. The output of this rectifier is filtered by a resistance-capacitance filter. The intensifier supply is similar to the negative supply except that a positive 1500 volts is developed.

A separate filament transformer (T402) is used to supply all filament and pilot-light current drawn by the Indicator and by the 6SH7 regulator tube (V404) in the power supply. Alternating current is supplied through the Indicator to the power supply by means of cabling, the a-c switch being located on the front panel of the Indicator. The same cable supplies all filament and low- and high-voltage supplies to the Indicator.

DECLASSIFIED

UNCLASSIFIED

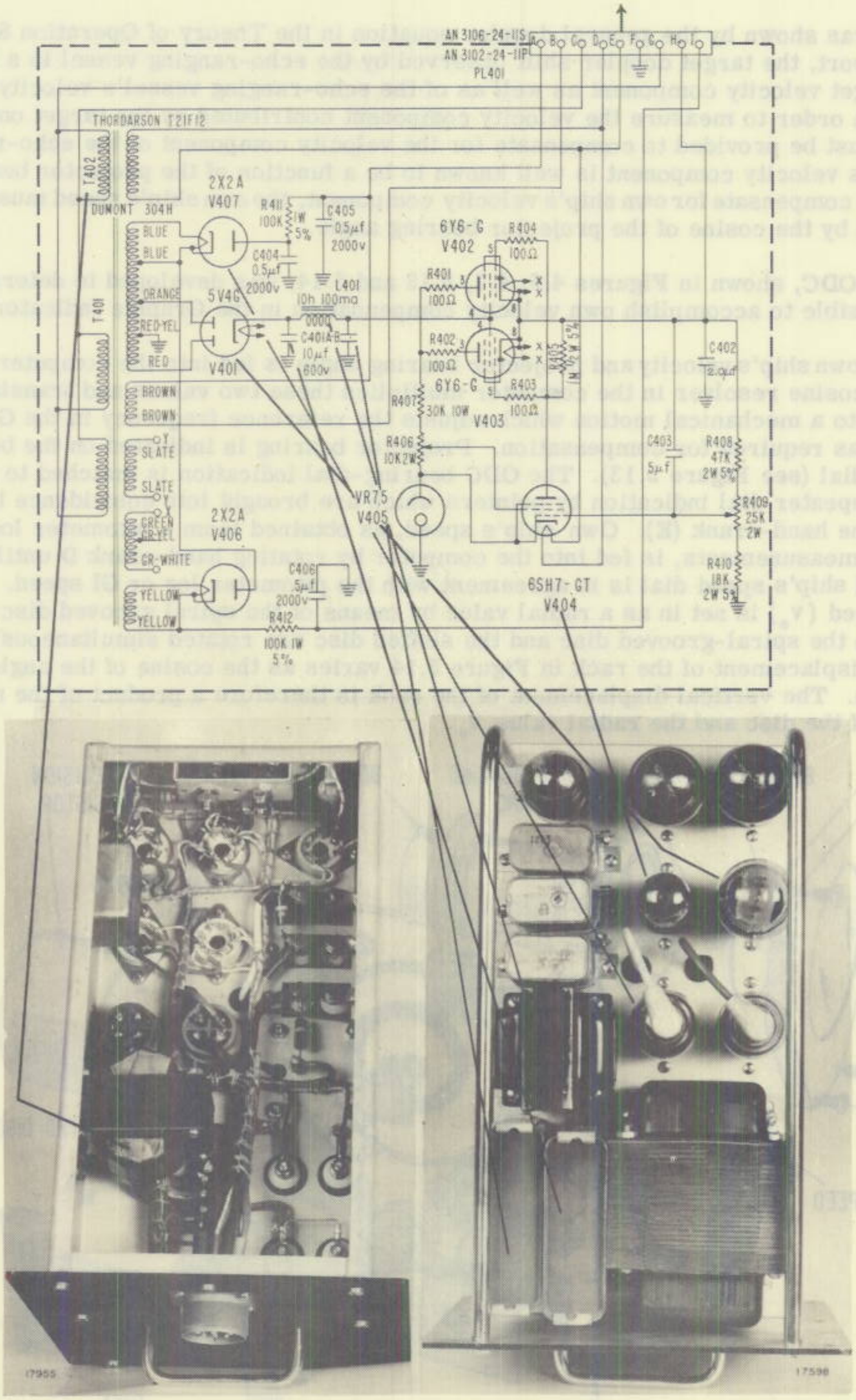


Figure 5.12. Graphic indicator power supply

DECLASSIFIED

DECLASSIFIED

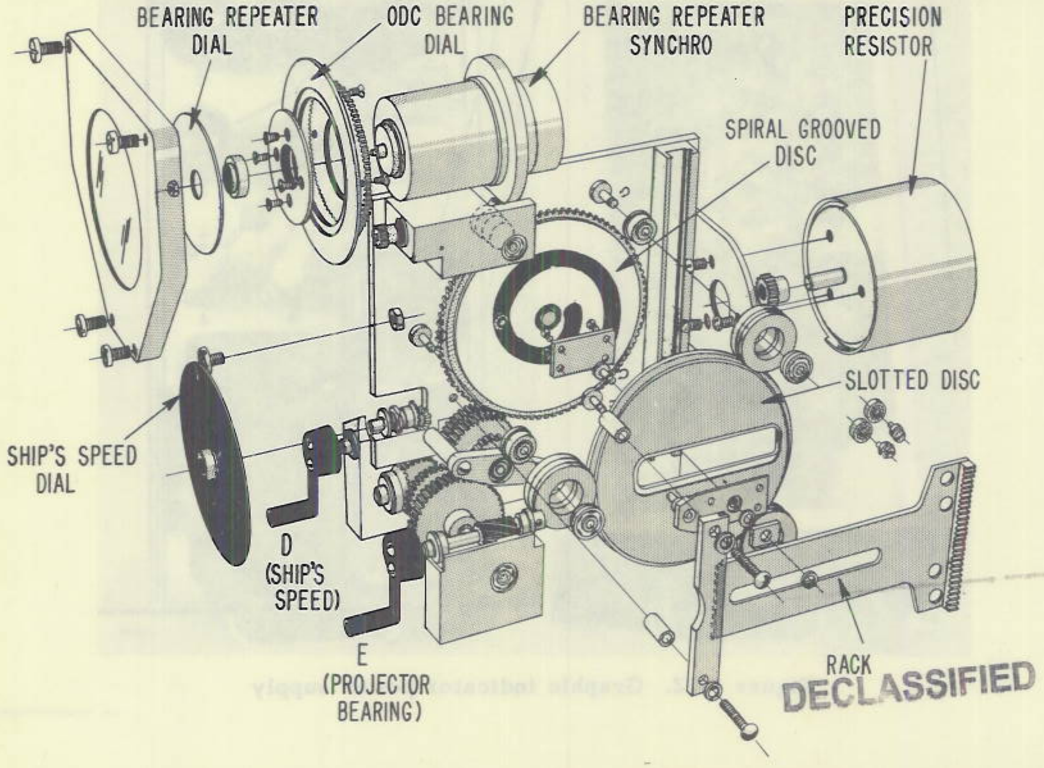
[redacted]

OWN DOPPLER COMPENSATOR (ODC)

As was shown by the general doppler equation in the Theory of Operation Section (2) of this report, the target doppler shift observed by the echo-ranging vessel is a function of the target velocity component as well as of the echo-ranging vessel's velocity component. In order to measure the velocity component contributed by the target only, a method must be provided to compensate for the velocity component of the echo-ranging ship. This velocity component is well known to be a function of the projector bearing; that is, to compensate for own ship's velocity component, the own ship's speed must be multiplied by the cosine of the projector bearing angle.

The ODC, shown in Figures 4.6, 4.7, 5.13 and 5.14, was developed to determine if it was feasible to accomplish own velocity compensation in the Graphic Indicator.

The own ship's velocity and projector bearing angle is fed into the computer manually. A cosine resolver in the computer multiplies these two values and translates the product into a mechanical motion which adjusts the reference frequency in the Graphic Indicator as required for compensation. Projector bearing is indicated on the bearing repeater dial (see Figure 5.13). The ODC bearing-dial indication is matched to the bearing repeater dial indication by pointers which are brought into coincidence by rotating the hand-crank (E). Own ship's speed, as obtained from a pitometer log or initial GI measurements, is fed into the computer by rotating hand-crank D until the calibrated ship's speed dial is in agreement with the pitometer log or GI speed. The ship's speed (v_o) is set in as a radial value by means of the spiral grooved disc. When both the spiral-grooved disc and the slotted disc are rotated simultaneously, the vertical displacement of the rack in Figure 5.14 varies as the cosine of the angle of revolution. The vertical displacement of the rack is therefore a product of the angle of rotation of the disc and the radial value v_o.



DECLASSIFIED

Figure 5.13. Own doppler compensator, exploded view

[redacted]

DECLASSIFIED

UNCLASSIFIED

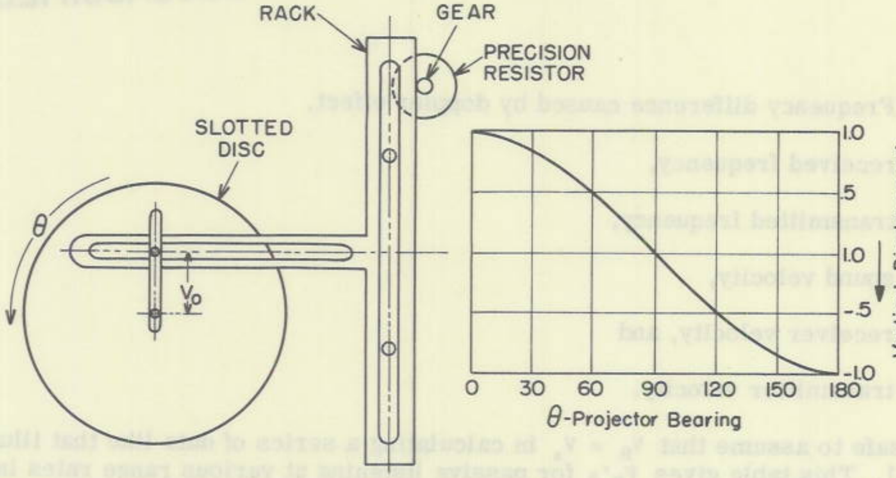


Figure 5.14. ODC cosine resolver

Laboratory and sea trials have shown that the ODC fulfills the function for which it was intended. However, these tests have also shown it to be a superfluous item for most tactical uses. In cases where an ODC is deemed necessary, it should be made entirely automatic. Because of the superfluous aspect, the ODC has been eliminated from all except a few of the R404's in use at the present time (May 1953).

VOLTAGE REGULATOR

Since the voltage regulator is a commercial item, the manufacturer's instructions, and a copy of the circuit diagram, are included as an appendix to this instruction book. The components are included in the parts list given in Section 7.

CALIBRATION

Dial E of the Range Rate Indicators is calibrated for a transmitted frequency of 25.5 kc and a water temperature of 80°F. These conditions were chosen because they are considered average. For accuracy, correction factors should be applied to range rate values obtained with conditions varying from 25.5 kc and 80°F. For example, if the transmitted frequency is off by 1000 cycles, the range rate could be in error by 5% (i.e. 1/4 knot at 5 knots and 2-1/2 knots at 50 knots). If the water temperature falls to 35°F, the error is of the same magnitude. The correction factors vary from instrument to instrument and must be determined individually in the laboratory.

The Graphic Indicator can be calibrated for any temperature and frequency desired by following the procedure described below.

Equations (3a), (3b) as presented in the Theory of Operation, (Section 2), are used in the calibration of the instrument. These are:

$$\Delta F = F_R - F_s \tag{3a}$$

and

$$F_R = F_s \frac{C \pm V_R}{C \mp V_s} \tag{3b}$$

DECLASSIFIED

DECLASSIFIED

where

F = Frequency difference caused by doppler effect,

F_R = received frequency,

F_s = transmitted frequency,

C = sound velocity,

V_R = receiver velocity, and

V_s = transmitter velocity.

It is safe to assume that $V_R = V_s$ in calculating a series of data like that illustrated in Table 5.1. This table gives F_R's for passive listening at various range rates in 5-knot increments up to 70 knots (both opening and closing) for transmitted frequencies (F_s) of 24.0, 24.5, 25.0, 25.5 and 26.0 kc. In addition, the list of multiplication factors to seven places that converts any F_s into the corresponding F_R for the various range rates is given. All of the numbers in Table 5.1 are for a single sound velocity, namely, 5053 feet/second at 80° F water temperature.

Calibration of the instrument requires only a table of calibration frequencies (similar to Table 5.1) and a source of standard frequency with an accuracy of at least ± 1/2 cycle in the range 15 to 30 kc. Additional values can always be calculated using Equation 3b.

Procedure for Calibrating Passive Listening Dial

(1) Substitute a dial calibrated in degrees of rotation for the range rate dial.

(2) Set the dial at zero.

(3) Feed a standard frequency into the GI signal input, for example, a frequency of 25.500 kc.

(4) Tune the reference frequency control (C) to give a horizontal line on the display.

(5) Change the standard frequency input to the frequency corresponding to a particular range rate. In our example, 25.542 kc represents 5 knots closing.

(6) Rotate the degree dial using tracking control (F) until the line is once more horizontal.

(7) Read the number of degrees.

(8) Engrave the passive listening dial for 5-knots closing range rate at this number of degrees.

(9) Repeat process in 5-knot intervals up to 70 knots opening and closing.

DECLASSIFIED

TABLE 5.1
Calibration Frequencies for GI at 80°F Water Temperature for Passive Listening

Range Rate (Knots)	Frequency (kc)					This factor multiplied by any transmitted frequency gives the received frequency for its corresponding range rate.
	24.0	24.5	25.0	25.5	26.0	
70	24,568.2	25,080.0	25,591.9	26,103.7	26,615.6	1.023,675
65	24,527.2	25,038.1	25,549.1	26,060.1	26,571.1	1.021,965
60	24,486.2	24,996.3	25,506.5	26,016.6	26,526.7	1.020,259
55	24,445.3	24,954.6	25,463.9	25,973.1	26,482.4	1.018,555
50	24,404.5	24,913.0	25,421.3	25,929.8	26,438.2	1.016,854
45	24,363.7	24,871.3	25,378.9	25,886.5	26,394.0	1.015,156
40	24,323.0	24,829.8	25,336.5	25,843.2	26,350.0	1.013,460
35	24,282.4	24,788.3	25,294.2	25,800.0	26,306.0	1.011,768
30	24,241.9	24,747.0	25,252.0	25,757.0	26,262.0	1.010,078
25	24,201.4	24,705.6	25,209.8	25,714.0	26,218.2	1.008,392
20	24,161.0	24,664.3	25,167.7	25,671.0	26,174.4	1.006,708
15	24,120.6	24,623.1	25,125.7	25,628.2	26,130.7	1.005,027
10	24,080.4	24,582.0	25,083.7	25,585.4	26,087.1	1.003,348
5	24,040.1	24,541.0	25,041.8	25,542.7	26,043.5	1.001,673
0	24,000.0	24,500.0	25,000.0	25,500.0	26,000.0	1.000,000
5	23,960.0	24,459.1	24,958.3	25,457.4	25,956.6	0.998,330
10	23,919.9	24,418.2	24,916.6	25,414.9	25,913.2	0.996,663
15	23,880.0	24,377.5	24,875.0	25,372.5	25,870.0	0.994,999
20	23,840.1	24,336.8	24,833.4	25,330.1	25,826.8	0.993,337
25	23,800.3	24,296.1	24,792.0	25,287.8	25,783.6	0.991,678
30	23,760.5	24,255.5	24,750.6	25,245.6	25,740.6	0.990,022
35	23,720.9	24,215.0	24,709.2	25,203.4	25,697.6	0.988,369
40	23,681.2	24,174.6	24,668.0	25,161.3	25,654.7	0.986,719
45	23,641.7	24,134.2	24,626.8	25,119.3	25,611.8	0.985,071
50	23,602.2	24,093.9	24,585.6	25,077.4	25,569.1	0.983,426
55	23,562.8	24,053.7	24,544.6	25,035.5	25,526.4	0.981,783
60	23,523.4	24,013.5	24,503.6	24,993.7	25,483.7	0.980,144
65	23,484.2	23,973.4	24,462.7	24,951.9	25,441.2	0.978,507
70	23,444.9	23,933.4	24,421.8	24,910.3	25,398.7	0.976,873

Procedure for Calibrating Echo-Ranging Scale

The scale for echo ranging can be calibrated from the information obtained for the passive scale calibration. All passive angular values are divided by two since the sound path for echo ranging is twice as long as the passive sound path.

Correction Curves

Correction charts, or curves for other frequencies, can be made in the same manner to read knots from a degree scale, or knots from knots at the calibrated frequency, or as a percentage correction from knots at the calibrated frequency. The reader should refer to the calibration folder included with each instrument. A description of how to use correction factors for frequency and temperature departures is included in the Operation Section (4) on page 31.

[redacted]

DECLASSIFIED

Procedure for Calibrating Reference Frequency Dial

The reference frequency dial (C) is calibrated by point-to-point checks with some angular scale in a manner comparable to that used for calibrating the range rate dial.

(1) Set Range Rate dial at E.

(2) Feed in a signal of known frequency into the GI.

(3) Horizontalize the presentation using C.

(4) Record the angular reading corresponding to this frequency.

(5) Repeat process until range of reference oscillator has been covered.

(6) Mark the dial.

An alternative procedure of course would be to measure the outputs at various positions of the reference oscillator directly with a frequency counter.

* * *

DECLASSIFIED

[redacted]

Section 6

Installation

EQUIPMENT UNITS PROVIDED

The Sonar Receiver R404 is complete in three units; the Graphic Indicator, the Power Supply, and the Voltage Regulator. Some installations are provided with a fourth unit, an Own Doppler Compensator (ODC), but it is not necessary for the operation of the Receiver. In addition to the above items, the following cables are supplied: the power cable for connecting the Indicator to the Power Supply, a power cable for connecting the ODC to the Indicator, an a-c line card for connecting the Voltage Regulator to the Indicator and, a shielded two-conductor signal cable, for connecting the signal source to the Indicator. When an ODC is supplied, another a-c line cable is provided for connecting it to the Voltage Regulator.

A kit of spare parts is also provided. In general, this is composed of those parts which are usually in short supply. A list of these parts is given in Section 7.

LOCATION OF EQUIPMENT

There are some factors to be considered when deciding upon the location of the R-404(XB-1)/UQ. It should be in a convenient position for operation, but should not interfere with other equipment. Total darkness is not necessary, but too much light makes it difficult or impossible to see the screen. Sixty-cycle, 110-120 volt, a-c power must be available, and a minimum signal cable length should be used to cut down signal losses. Best results can be obtained when the Graphic Indicator is used in conjunction with an audible signal from the sonar receiver stack. The recommended location of course is in the sonar shack.

INTERCONNECTION OF THE UNITS

Figure 1.1 on page 2 and Figure 4.6 on page 24 will prove helpful in understanding how the units are connected. Figure 6.1 is a block diagram showing the interconnections of the units. The ODC is shown in phantom since its use is not general. The Voltage Regulator adjustments should not be turned since they are preset to give 117 volts to the Indicator. In order to energize the equipment, it is necessary to turn on the Voltage Regulator first and then the Indicator, by means of the power switches on the respective units. The power switch on the Indicator is marked "A".

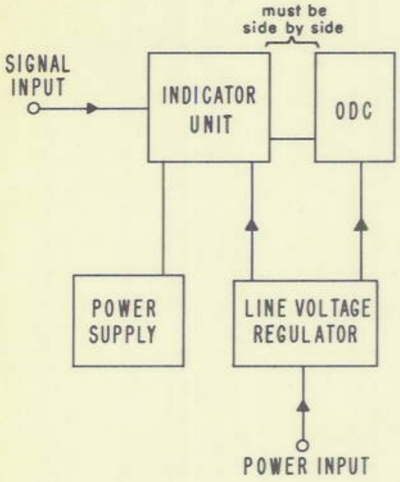


Figure 6.1. Block diagram showing interconnections of R-404 units

The following is a summary of the interconnections:

(1) The Voltage Regulator is connected to any 110-120 v, 60 cps line source.

(2) The Indicator and the ODC are connected to the Voltage Regulator by a-c line cords.

(3) The Power Supply is connected to the Indicator with the power cable.

(4) The ODC is connected to the Indicator with the short power cable.

CONNECTION OF THE SIGNAL CABLE TO THE SONAR RECEIVER R-404

The impedance which the Indicator offers to the signal is 600 ohms. The signal which is put into the instrument can be either balanced or unbalanced. A two-wire shielded input cable is supplied with each instrument. Longer lengths of input cable can be used but are not recommended if it is at all possible to use the supplied length. For shorter lengths the supplied cable may be cut to any desired length. For balanced circuits, the two inner wires of the input cable are to be connected across the circuit. The shield can either be grounded or left "floating" depending on which condition gives the least noise at the R-404(XB-1)/UQ.

The input must come from the receiver side of the transfer circuit of any searchlight sonar equipment, or the audio channel of scanning sonar equipment. The sonar circuit:

(1) Must have low impedance. (Note: if low impedance circuit is not available, the input transformer of the R-404(XB-1)/UQ may be eliminated and a high impedance circuit can be fed directly into the receiver chassis.)

(2) Must not be tuned.

(3) Must not carry the direct sonar transmit pulse, but must have sufficient coupling to observe the transmitted pulse.

Table 6.1 may be used as a guide in installing the Graphic Indicator with the types of sonar equipment listed. For example, when using the QCU Sonar Ranging Equipment, the signal cable should be connected to the listening receiver in the following manner:

(1) White lead of signal cable is connected to pin 5 of first r-f amplifier, V402.

(2) Black lead and shield of signal cable is connected to chassis ground. (This places the Graphic Indicator across the 470-ohm cathode resistor R403.)

(3) The other end of signal cable is connected to the balanced input connector (type UG103/U) in the rear of the Indicator).

CAUTION: In some QCU types of equipment, the cathode resistor R403 has across it a by-pass condenser. This condenser should be removed. In some equipments the cathode is grounded; remove the ground before making a connection. Do not connect the Indicator to the BDI receiver.

TABLE 6.1
Guide for Connecting Signal Input to Indicator

Sonar	Terminal Board No.	Location of Terminal Board	Terminal No.
QGB	E	Main Stack	For Balanced Input 1 and 3 Signal 2 Shield GND
QHB	4D	Scanning Switch Assembly	For Balanced Input 5 and 6 Signal 3 Shield GND
Alternate connection for QHB	4A	Scanning Switch Assembly	For Balanced Input 18 and 19 Signal 5 Shield GND
WFA	T101	755 Receiver Input Transformer	For Balanced Input 14A and 15A Signal 13 Shield GND
	Because of the use of bottomside and topside transducers, WFA installations may vary from ship to ship. Care should be taken that the signal to the Graphic Indicator is not lost when switching transducers.		
QCQ QCQ-1 QCQ-2 QCU	Disconnect cathode - bypass condenser of first r-f amplifier and connect R-404(XB-1)/UQ unbalanced in its place. If there is no bypass condenser, the leads are connected across the cathode resistor.		

* * *

Section 7

Maintenance

As an aid to maintenance the following information is included at the end of this Section in pictorial and tabular form:

1. A copy of the complete schematic diagram with test points (TP) marked. (Figure 7.1)
2. A table of both a-c and d-c operating voltages organized by circuits, by tube number, and by pin numbers. (Table 7.3)
3. Sketches of the 15 test point wave forms with voltages. (Figure 7.2)
4. A series of chassis pictures with the component parts labeled. (Figure 7.3 through 7.22 inclusive)
5. A parts list wherein:
    - a) 100 series numbers are for the vertical sweep components,
    - b) 200 series numbers are for the horizontal sweep components,
    - c) 300 series numbers are for the signal channel components,
    - d) 400 series numbers are for the power supply components,
    - e) 500 series numbers are for the scope circuit components,
    - f) 600 series numbers are for the general items,
    - g) 700 series numbers are for the ODC components,
    - h) R prefix designates resistors,
    - i) C prefix designates condensers,
    - j) S prefix designates switches,
    - k) V prefix designates tubes,

l) T prefix designates transformers,

m) L prefix designates inductances,

n) PL prefix designates connectors,

o) F prefix designates fuses, and

p) D prefix designates motors.

6. A list of the items composing the spare parts kit.

INTERNAL ADJUSTMENTS

Table 7.1 is a summary of the internal adjustments which were covered in the Electronic Theory. All of the figures referenced in this table are associated with Section 5. The table is self-explanatory, but special mention should be made on the horizontal-frequency adjustment.

At 25.5 kc, the horizontal sweep is adjusted so that, with the Switch D in the No. 1 position, a 45-degree slope of the signal represents a difference of 1/4 knot on the echo-ranging scale. (Position 2, 1/2 knot; Position 3, 1 knot; Position 4, 3 knots.) The procedure for the Position No. 1 adjustment is as follows:

1. Feed in a stable 25.5-kc signal
2. Place range rate dial (E) at zero
3. Horizontalize presentation with reference frequency dial (C)
4. Crank echo-ranging scale to read 1/4 knot
5. Adjust R205 until presentation is 45° line.

ELECTRONIC COMPONENTS ADJUSTED BY FRONT PANEL CONTROLS

Table 7.2 is a listing of the electronic components affected by the front panel controls. Such a summary is helpful in trouble shooting. The physical location of these components can be determined with the aid of the reference material included in this section.

MAINTENANCE OF RECEIVER

Repairs to the receiver chassis are straightforward. There are no critical components.

Alignment of the receiver requires an output meter with a high impedance input, or an oscilloscope, and a signal generator. The alignment procedure is as follows:

1. Connect signal generator to receiver input
2. Connect output meter to test point 10 or 11 (Figure 7.1)
3. Feed in a signal of approximately 10 microvolts at 25 kc

DECLASSIFIED

TABLE 7.1
List of Controls Located Inside the G.I. Chassis

Purpose	Control No.	Chassis	Method of Alignment
Bandpass Amp. Alignment	C303 & C309	Receiver (Fig. 5.3)	Adj. for max. amp. output at 18 kc with main tuning cond. at maximum capacity setting.
Vert. Size	C113	Vert. Sweep (Fig. 5.9)	Adj. in conjunction with horiz. size control for raster height.
Vert. Cent.	R139-R140	Vert. Sweep (Fig. 5.9)	Adj. for vert. centering
Horiz. Size	R212	Horiz. Sweep (Fig. 5.10)	Adj. in conjunction with vert. size for square raster.
Horiz. Cent.	R216	Horiz. Sweep (Fig. 5.10)	Adj. for centering raster.
Horiz. Lin.	R512	CRT. Strip (Fig. 5.11)	Adj. for most linear horiz. sweep.
Astigmatism	R214	Horiz. Sweep (Fig. 5.10)	Adj. for uniform focus over raster.
B + Voltage	R409	Power Supply (Fig. 5.12)	Adj. for + 280 v on B+ terminal of terminal strip of receiver chassis.
B + Ripple	R406	Power Supply (Fig. 5.12)	Adj. for min. ripple at full load on B+ line.
Horiz. Freq.	R205 R206 R207 R208	Horiz. Sweep (Fig. 5.10)	Adj. R205 for 45° line at 3.0 knot range rate echo ranging. Adj. R206 for 45° line at 1.0 knot range rate echo ranging. Adj. R207 for 45° line at .50 knot range rate echo ranging. Adj. R208 for 45° line at .25 knot range rate echo ranging.

DECLASSIFIED

4. Turn B to middle of its range

5. Adjust trimmer condensers (C303 and C309) for maximum output at test point 10 or 11.

With proper alignment, 1/4 microvolt will produce a recognizable pattern on the cathode-ray screen.

TABLE 7.2
Electronic Components Adjusted by Front Panel Controls

Control Number	Control Name	Affected Electronic Components
A	Power switch	SW601
B	Receiver tuning	C304, C310
C	Reference tuning	R105, R111
D	Horizontal sweep rate	R205, R206, R207, R208 connected and disconnected with SW 201.
E	Dials	None
F	Tracking	R106, R112
H	Visual sensitivity	R601
I	Brightness	R507
J	Focus	R505
K	Pulse width	R341
L	Receiver gain	R319
M	Shutter	None
N	Zero reference	R108, R109, R114, R115 connected and disconnected with SW 101.

MAINTENANCE OF HORIZONTAL SWEEP

Adjustment of the sweep rate has already been mentioned. If the range of adjustment of the horizontal sweep frequency is not sufficient to meet the specifications, the fixed series resistors R201, R202, R203, and R204 may have to be changed.

It is difficult to make any measurement of voltage or waveforms on the horizontal oscillator tube (V201) because of the high impedance of this circuit. This tube (V201) is somewhat critical and some trouble may be experienced in selecting a tube that will oscillate properly in this circuit.

MAINTENANCE OF VERTICAL SWEEP

The only critical component on the vertical chassis is the blocking oscillator cathode resistor (R125). Its value may have to be changed slightly in some cases. Improper value of this resistor will cause either no vertical sweep or a broken vertical sweep.

MAINTENANCE OF REFERENCE OSCILLATOR CIRCUIT

All components of the reference oscillator circuit are critical including tubes, wiring, and interconnecting cables. No attempt should be made to repair the reference oscillator until it has been positively determined that it is at fault. If any component is changed, including the oscillator tube (V101) care must be taken to see that the calibration is not affected. The following procedure must be followed when replacing any component:

1. Set range rate dial E at zero.
2. Set reference frequency dial (C) to some point (determined from its calibration curve) that should give a frequency that is the same as some standard frequency.
3. Feed the standard frequency into the receiver.
4. Set horizontal sweep rate dial (D) to position 4.
5. Replace the defective component with new components until as near a horizontal line presentation as possible is obtained.

If the above procedure cannot be followed, the oscillator must be recalibrated and a new range-rate dial engraved. This should not be attempted unless accurate calibration and engraving equipment is available.

MONTHLY CHECK

The following procedure can serve as a monthly check on the operating efficiency of the Graphic Indicator:

(1) Energize power supply

(2) Check for 117 v ac

(3) Energize GI

(4) Check for 117 volts

(5) Check scope for raster

(6) Energize sonar for echo-ranging

(7) Check for outgoing pulse and reverberations and/or echoes

(8) Horizontalize outgoing pulse with “C”

(9) Turn control F so that horizontal line rotates

(10) Check electrical zero. (Drifting will occur until equipment fully warms up.)

TABLE 7.3
Operating Voltages

Tube No.	Mfg. No.	Pin								
		1	2	3	4	5	6	7	8	9
Vertical Sweep - D-C Voltages										
V101	12AT7	182	0	3.8	H	H	160	Gr.	3.8	H-ct
V102	6C4	78	-	H	H	78	0	3		
V103	6BN6	Gr.	12	H	H	72	Gr.	82		
V104	12AU7	278	0	33.5	H	H	278	0	33.5	H-ct
V105	12AU7	97	-58	0.2	H	H	280	97	110	H-ct
V106	12AU7	160	13.5	22	H	H	280	0	28	H-ct
Vertical Sweep - A-C Voltages (Peak to Peak)										
V101	12AT7									
V102	6C4	25					3.5	0.96		
V103	6BN6		25					45		
V104	12AU7	189	45	43			189	184	43	
V105	12AU7	118	183	29.5				118	98	
V106	12AU7	117	12.5	0.2				183	100	
Horizontal Sweep - D-C Voltages										
V201	2D21	-0.45	Gr.	H	H	-	15	Gr.		
V202	6C4	280	-	H	H	280	15	31		
V203	6J6	520	520	H	H	11.8	9.8	34		
Horizontal Sweep - A-C Voltages (Peak to Peak)										
V201	2D21	0.4					25			
V202	6C4						25	22		
V203	6J6	60	40			8	0	3		
Signal Channel - D-C Voltages										
V301	6AG5	-0.2	1.3	H	H	124	107	1.3	-	-
V302	6AG5	-0.7	0	H	H	11.8	11.3	0		
V303	6AT6	0	9.4	H	H	-0.34	-0.34	129		
V304	6AU6	0	0.94	H	H	80	110	0.94		
V305	12AU7	10	-0.46	Gr.	H	H	110	-3	Gr.	H-ct
V306	12AU7	275	0	22	H	H	275	0	13	H-ct
V307	12AU7	250	21	37	H	H	200	31	37	H-ct
A-C Voltages (Peak to Peak) for 1-mv input at 25 kc										
V301	6AG5					4				
V302	6AG5	3.4				12.25				
V303	6AT6	2.6						.2		
V304	6AU6	10.0				40		2.3		
V305	12AU7	95.0	21				65	18		
V306	12AU7	165	38.5	0.8			165	165	52	
V307	12AU7	62	52.0	25			72-100	58-86	25-32.5	
Power Supply - D-C Voltages (117 V AC input)										
V401	5V4G		440		360 AC		360 AC		440	
V402	6Y6G		280	425	430	240	240	280	280	
V403	6Y6G		280	425	430	240	240	280	280	
V404	6SH7		H	70	67	70	150	H	240	
V405	VR-75		Gr.			70				
V406	2X2A	1320	1320							
V407	2X2A	1260 AC	1260 AC		1260				1260 AC	

PARTS LIST

DECLASSIFIED

I. VERTICAL SWEEP

Resistors

R101	2.2K	1w	5%
R102	2.2K	1w	5%
R103	22K	2w	5%
R104	6.8K	1w	5%
R105	10K	Helipot	Ganged R111
R106	500Ω	TIC	Ganged R112
R107	500Ω	TIC	Ganged R113
R108	470Ω	1w	5%
R109	100Ω	2w	Pot.
R110	6.8K	1w	5%
R111	10K	Helipot	Ganged R105
R112	500Ω	TIC	Ganged R106
R113	500Ω	TIC	Ganged R107
R114	470Ω	1w	5%
R115	100Ω	2w	Pot.
R116	47K	0.5w	5%
R117	47K	1w	5%
R118	1.5K	0.5w	5%
R119	820K	0.5w	5%
R120	56K	0.5w	5%
R121	12K	0.5w	5%
R122	100K	0.5w	5%
R123	6.8K	2w	
R124	56K	0.5w	5%
R125	3.3K	1w	5%
R126	560Ω	1w	5%
R127	56K	0.5w	5%
R128	100K	1w	5%
R129	68K	1w	5%
R130	100Ω	0.5w	5%
R131	47K	1w	5%
R132	6.8K	1w	5%
R133	91K	0.5w	5%
R134	18K	0.5w	5%
R135	560Ω	1w	5%
R136	18K	1w	5%
R137	1M	2w	Ganged Pot. R138
R138	1M	2w	Ganged Pot. R137
R139	1M	0.5w	5%

Resistors

R140	1M	0.5w	5%
R141*	470Ω	2w	5%
R142	2.2M	2w	5%
R143	10K	0.5w	5%
R144**	68K	2w	5%

*Not in order - found between R101 and R102.

**Not in order - found near R123.

Condensers

C101	300µµf	600v	Mica
C102	20-125µµf		Variable
C103	100µµf	600v	Mica*
C104	0.1µf	600v	Paper
C105	0.1µf	600v	Paper
C106	0.01µf	600v	Paper
C107	0.5µf	600v	Paper
C108	10µf	450v	Electro
C109	0.1µf	600v	Paper
C110	4700µµf	600v	Mica
C111	0.1µf	600v	Paper
C112	0.1µf	600v	Paper
C113	20-125µµf		Variable
C114	0.1µf	600v	Paper
C115	0.1µf	600v	Paper
C116	0.1µf	600v	Paper
C117	470µµf	600v	Mica
C118	0.01µf	600v	Paper
C119	0.01µf	600v	Paper
C120	180µµf	600v	Mica
C121	0.001µf	600v	Paper
C122	0.1µf	600v	Paper
C123	0.1µf	600v	Paper

*Used only in some units.

Inductances

L101	125mh
L102	125mh

DECLASSIFIED

Tubes

V101	12AT7
V102	6C4
V103	6BN6
V104	12AU7
V105	12AU7
V106	12AU7

Transformer

T101	X124T3

II. HORIZONTAL SWEEP

Resistors

R201	1.8M	1w	5%
R202	510K	1w	5%
R203	620K	1w	5%
R204	1.5M	1w	5%
R205	2M	2w	Pot.
R206	2M	2w	Pot.
R207	2M	2w	Pot.
R208	2M	2w	Pot.
R209	1.2M	1w	5%
R210	100K	0.5w	5%
R212	50K	2w	Pot. horiz. size control
R213	47K	1w	5%
R214	50K	2w	Pot. astig. control
R215	120K	1w	5%
R216	25K	2w	Pot. horiz. centering

Condensers

C201	0.05μf	600v	Bathtub
C202	0.25μf	600v	Bathtub
C203	0.50μf	600v	Bathtub
C204	1.0μf	600v	Bathtub

Switch

S201	4-position, freq. control 2-section, wafer

Tubes

V201	2D21	Sawtooth gen. (horiz.)
V202	6C4	Cathode follower
V203	6J6	Horiz. amp.

III. SIGNAL CHANNEL

Resistors

R301	100K	0.5w	5%
R302	0.5M	0.5w	5%
R303	680K	0.5w	5%
R304	270Ω	0.5w	5%
R305	1K	0.5w	5%
R306	20K	0.5w	5%
R307	100K	0.5w	5%
R308	680K	0.5w	5%
R309	1M	0.5w	5%
R310	1.2M	0.5w	5%
R311	20K	0.5w	5%
R312	230Ω	0.5w	5%
R313	82K	0.5w	5%
R314	220K	0.5w	5%
R315	6.2K	0.5w	5%
R316	240K	0.5w	5%
R317	27K	2w	5%

Resistors

R318	1M	0.5w	5%
R319	100K	2w	5%
R320	10K	1w	5%
R321	12K	1w	5%
R322	100K	0.5w	5%
R324	33K	1w	5%
R325	3.3K	1w	5%
R326	15K	1w	5%
R327	2.2K	1w	5%
R328	6.8K	10w	--
R329	6.8K	1w	5%
R330	1M	0.5w	5%
R331	100K	0.5w	5%
R332	100K	0.5w	5%
R333	560Ω	2w	5%
R334	12K	1w	5%
R335	1.5K	1w	5%

DECLASSIFIED

Resistors

R336	100K	0.5w	5%
R337	120K	1w	5%
R338	120K	1w	5%
R339	1M	0.5w	5%
R340	220K	1w	5%
R341	25K	2w	Pot. pulse-width control
R342	1.8K	1w	5%
R343	1.8K	2w	5%
R344	4.7K	2w	5%
R345	560K	2w	5%
R346	2.7K	2w	5%
R347	1.8K	2w	5%
R348	120Ω	0.5w	5%
R349	100Ω	1w	5%

Condensers

C301	0.02μf	600v	Paper
C302	20μf	50v	Electro
C303	50-350μμf		Variable Trimmer
C304	50-350μμf		Variable Air
C305	0.1μf	600v	Paper
C306	0.5μf	600v	Paper
C307	0.1μf	600v	Paper
C308	70μμf	600v	Mica
C309	50-350μμf		Variable
C310	50-350μμf		Variable
C311	0.1μf	600v	Paper
C312	0.5μf	600v	Paper
C313	0.1μf	600v	Paper
C314	0.5μf	600v	Paper
C315	10μf	450v	Electro.
C316	20μμf	600v	Ceramic
C317	0.01μf	600v	Paper
C318	6200μμf	600v	Mica
C319	470μμf	600v	Mica

Condensers

C320	0.25μf	600v	Paper
C321	20μf	450v	Electro
C322	500μμf	600v	Ceramic
C323	500μμf	600v	Ceramic
C324	50μμf	600v	Ceramic
C325	0.1μf	600v	Paper
C326	0.5μf	600v	Paper
C327	0.01μf	600v	Paper
C328	0.1μf	600v	Paper
C329	0.01μf	600v	Paper
C330	500μμf	600v	Ceramic

Transformers

T301	143T-3 or 132 AW
T302	UTC-A-11

Inductances

L301	125mh	Shielded
L302	125mh	Shielded
L303	60mh	

Tubes

V301	6AG5	Sig. Amp.
V302	6AG5	Sig. Amp.
V303	6AT6	AGC Amp. Rest.
V304	6AU6	Amp.
V305	12AU7	Threshold Control
V306	12AU7	Blocking OSC
V307	12AU7	Mult. Vib. Pulse Generator

IV. POWER SUPPLY

Resistors

R401	100 Ω	1w	5%
R402	100 Ω	1w	5%
R403	100 Ω	1w	5%
R404	100 Ω	1w	5%
R405	1M	0.5w	5%
R406	10K	2w Pot.	Reg. Adj.

Resistors

R407	30K	10w	5%
R408	47K	2w	5%
R409	25K	2w Pot.	B + Adj.
R410	18K	2w	5%
R411	100K	1w	5%
R412	100K	1w	5%

DECLASSIFIED

Condensers

C401A	10μf	600v	Oil
C401B	10μf	600v	Oil
C402	2.0μf	600v	Bathtub
C403	0.5μf	600v	Bathtub
C404	0.5μf	2000v	Oil
C405	0.5μf	2000v	Oil
C406	0.5μf	2000v	Oil

Tubes

V401	5V4G	Rect.
V402	6Y6G	Reg.
V403	6Y6G	Reg.
V404	6SH7-GT	Reg. amp.
V405	VR-75	Gas tube reg. OA3
V406	2X2A	Positive high-voltage rect.

V. SCOPE CIRCUIT

Resistors

R501	10K	2w	5%
R502	100K	1w	5%
R503	50K	1w	5%
R504	100K	1w	5%
R505	100K	2w	Pot. Focus Cont.
R506	100K	1w	5%
R507	50K	2w	Pot. Intensity Cont.
R508	15K	1w	5%
R509	220K	1w	5%
R510	100K	2w	5%
R511	3.3M	2w	5%
R512	1M	2w	Pot. Hor. Linearity
R513	1M	1w	5%
R514	1M	1w	5%

Condensers

C501	0.05μf	3000v	Paper
C502	0.05μf	3000v	Paper
C503	0.01μf	600v	Mica
C504	0.1μf	3000v	Paper
C505	0.05μf	3000v	Paper

Tube

V501	3JP7	CRT

Tubes

V407	2X2A	Neg. high-voltage rect.

Transformers

T401	Dumont	304H
T402	Thordarson	T21F12

Inductance

L401	10K	100ma.

Connectors

PL-401	AN3106-24-11P

General

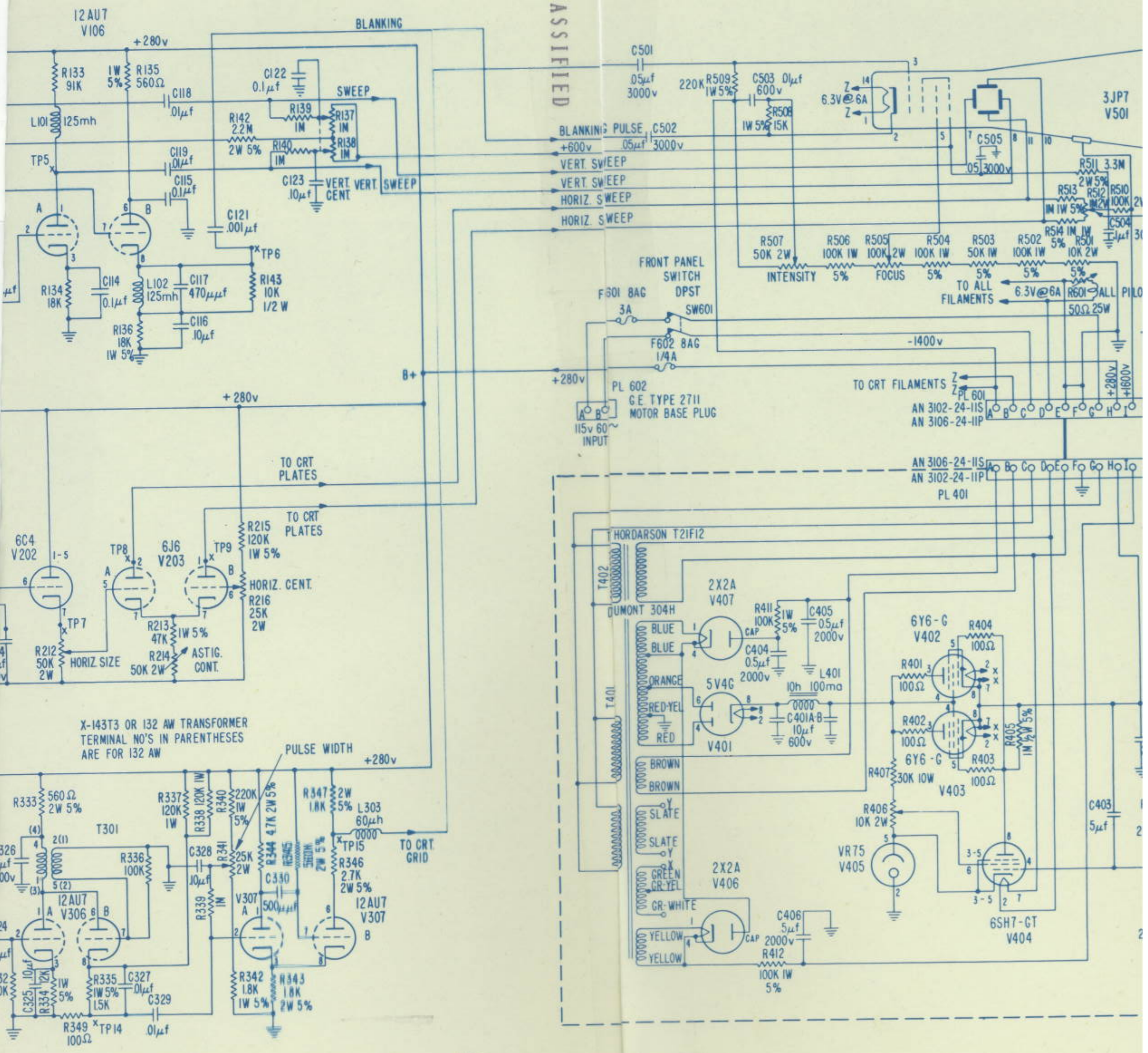
V601	6-8v	0.15-amp lamps	
V602	6-8v	0.15-amp lamps	
V603	6-8v	0.15-amp lamps	
V604	6-8v	0.15-amp lamps	
V605	6-8v	0.15-amp lamps	
R601	50Ω	25w	Var. resist. Pilot & dial light control
SW601	D.P.S.T.	Power switch	
PL601	AN 3102-24-11S		
PL602	Motor base plug GE-2711		
PL603	UG-103/U	Signal	
F601	3A	8AG	Fuse
F602	0.250A	8AG	Fuse

ODC

V701	6-8v	0.15-amp lamp	
V702	6-8v	0.15-amp lamp	
V703	6-8v	0.15-amp lamp	
R701	5Ω	2w	Var. resist. Dial light control
SW701	SPST	Dial light switch	
PL701	AN 3102-20-4PF		
PL702	AN 3102-20-15S		
PL703	Motor base plug GE-2711		
T701	Thordarson T21F08		
B701	Synchronous - Motor Mk 8 Mod 3A Type 1F		

VI. SPARE PARTS

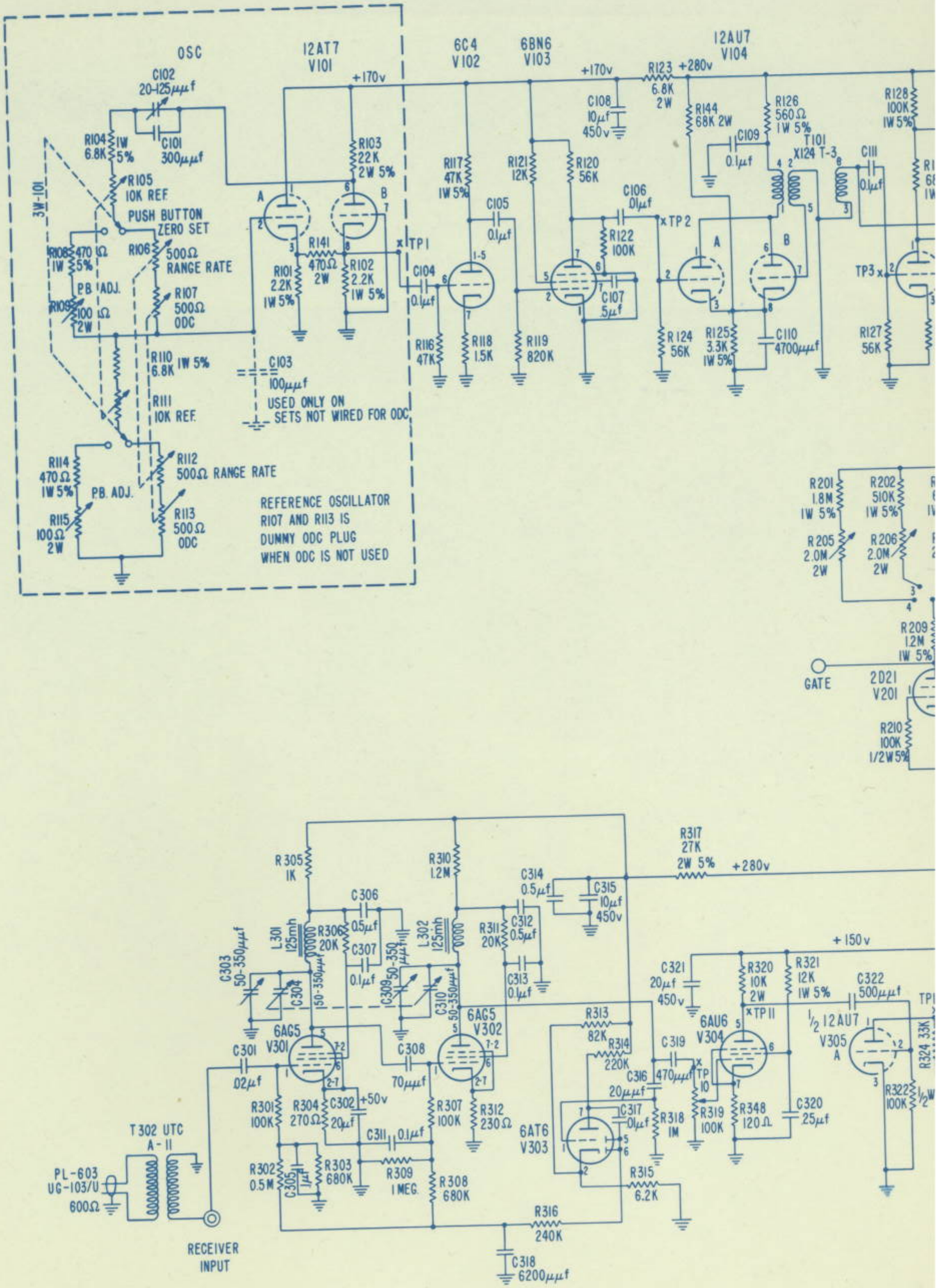
Part Number	Item	Quantity
T101	X124T3	1
T301	132AW	1
T401	Power XFRMR	1
C304, C309	Receiver Tuning	1
C501, C502	0.05μf 3000v	2
F601	3A-SAG or 2A (slow)	5
F602	0.250A-SAG	5
V501	3JP7	1
V103	6BN6	1
V104, V105, V106, V305, V306, V307	12AU7	2
V101	12AT7	2
V301, V302	6AG5	2
V303	6AT6	1
V102, V202	6C4	1
V406, V407	2X2A	2
V402, V403	6Y6	2
V404	6SH7	1
V405	VR75 (OA3)	1
V401	5V4G	1
V1 (Regulator)	2AS15	1
V2 (Regulator)	6L6	1
V3 (Regulator)	5Y3G7	1
V201	2D21	2
V203	6J6	1
V304	6AU6	1



NOTE:
ALL RESISTORS ARE ½ WATT, 5% UNLESS OTHERWISE INDICATED.

hematic diagram for Graphic Indicator

[redacted]



[redacted]

[redacted]

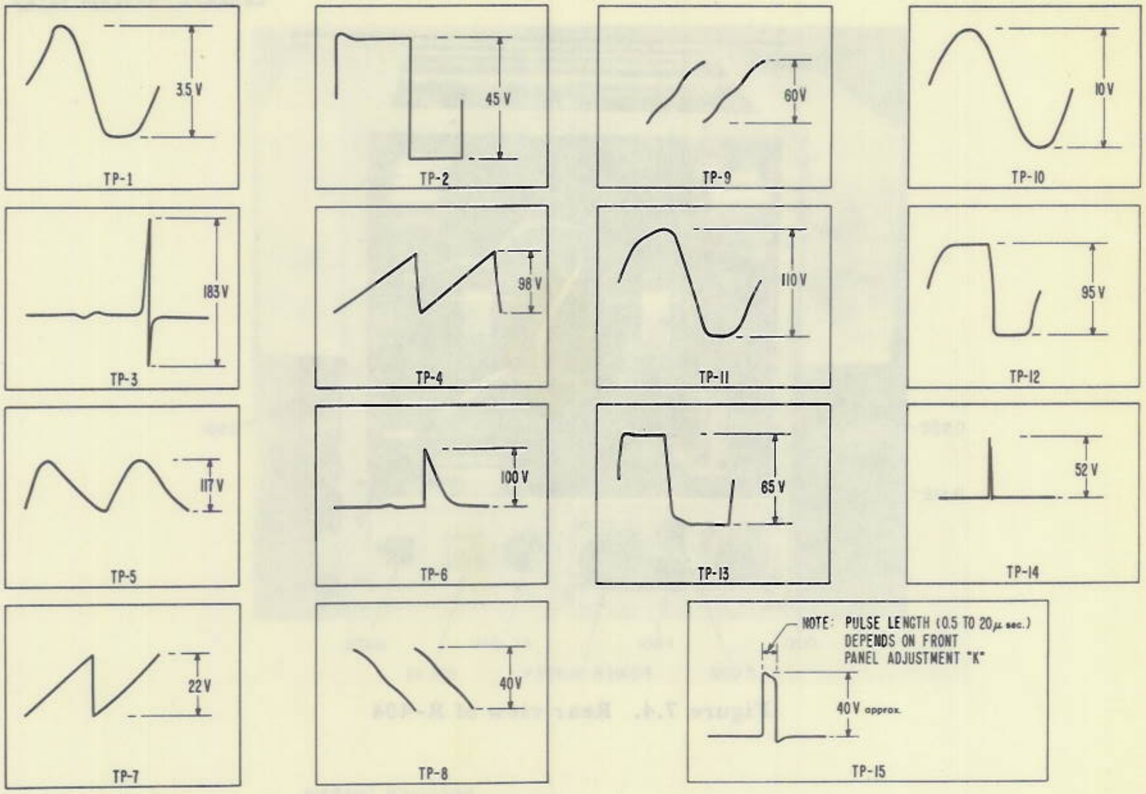


Figure 7.2. Test point wave forms

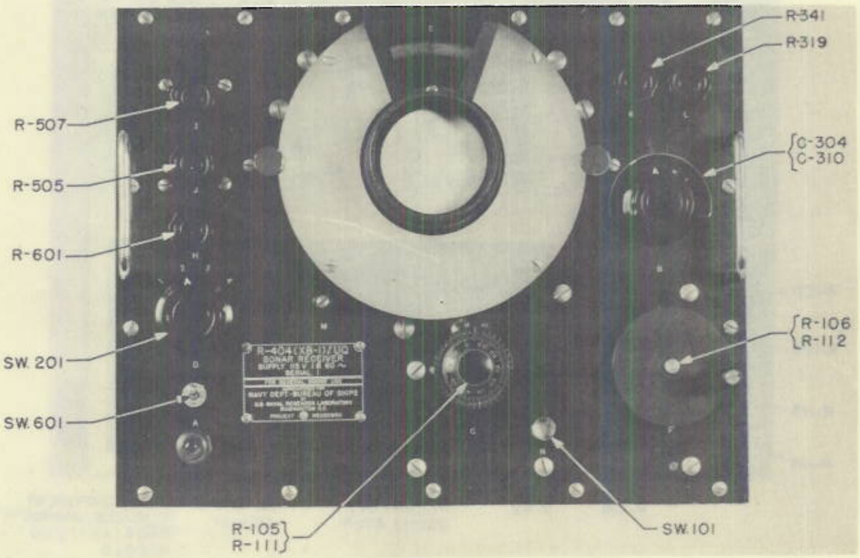


Figure 7.3. Front view of R-404

[redacted]

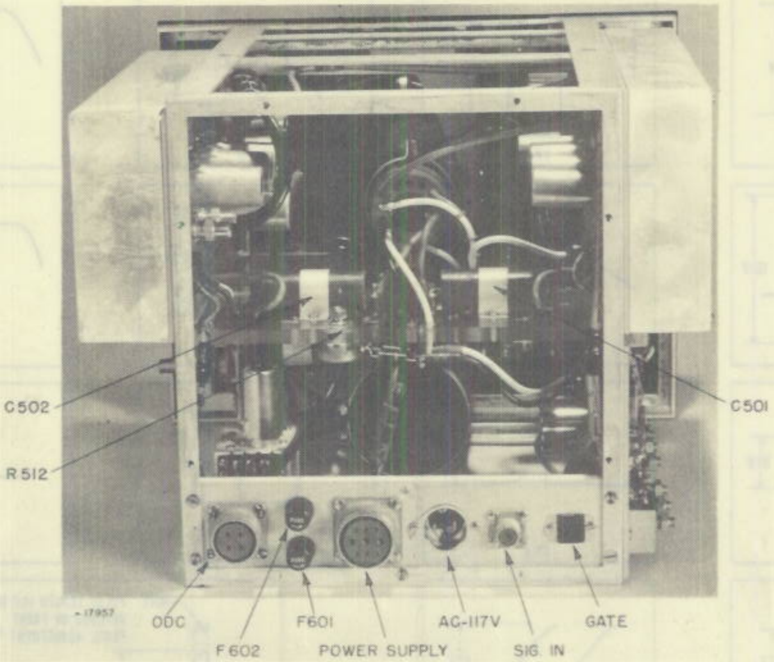


Figure 7.4. Rear view of R-404

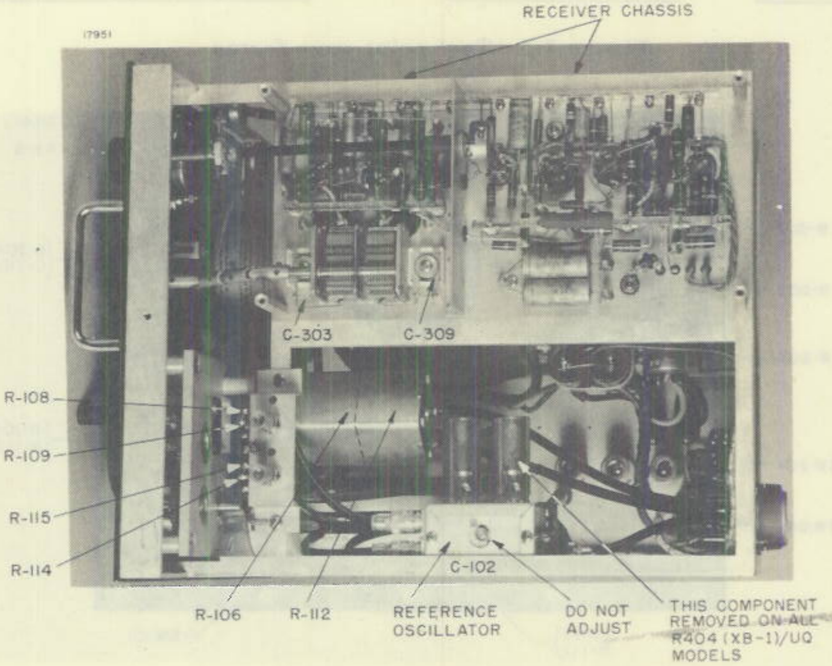


Figure 7.5. Right side of R-404, case and receiver chassis cover removed

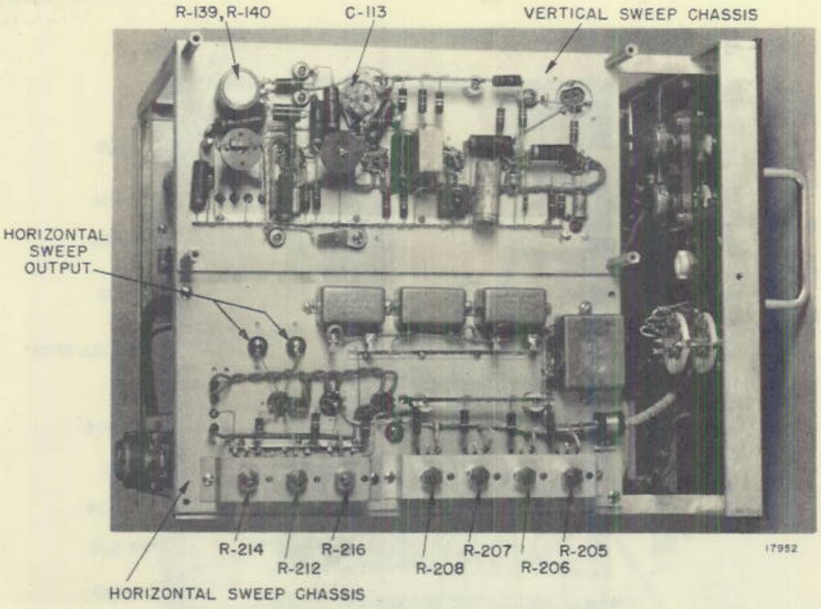


Figure 7.6. Left side of R-404, case and vertical sweep chassis cover removed

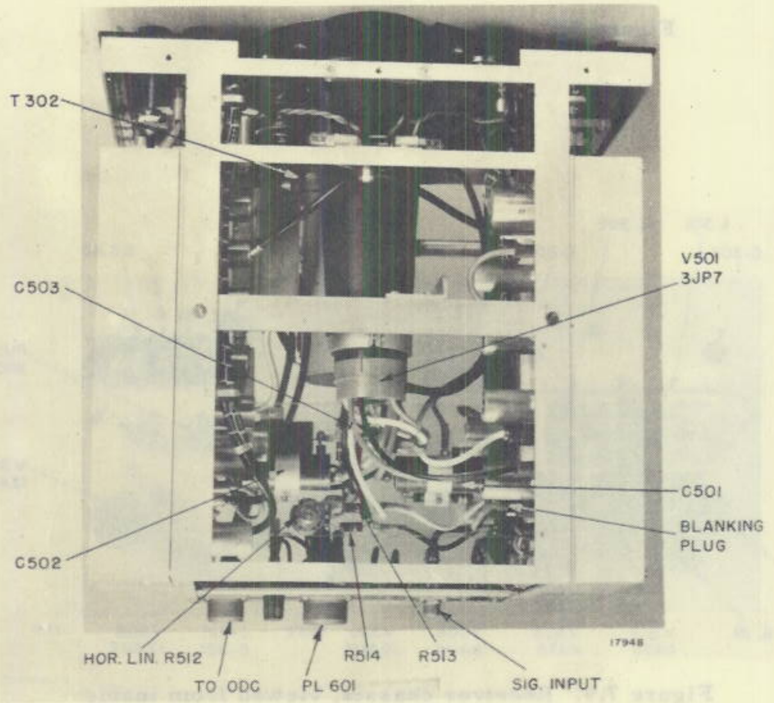


Figure 7.7. Top of R-404, case removed

[redacted]

DECLASSIFIED

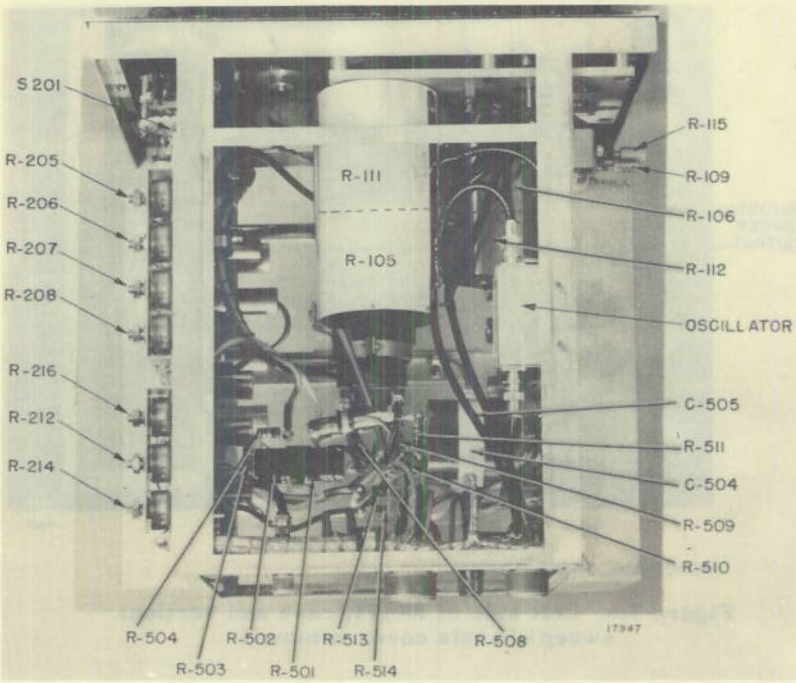


Figure 7.8. Bottom of R-404, case removed

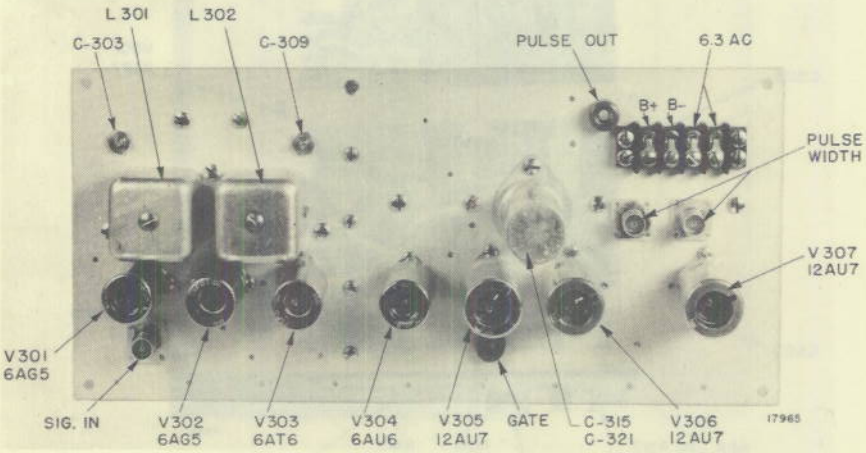


Figure 7.9. Receiver chassis, viewed from inside

DECLASSIFIED

[redacted]

DECLASSIFIED

[redacted]

UNCLASSIFIED

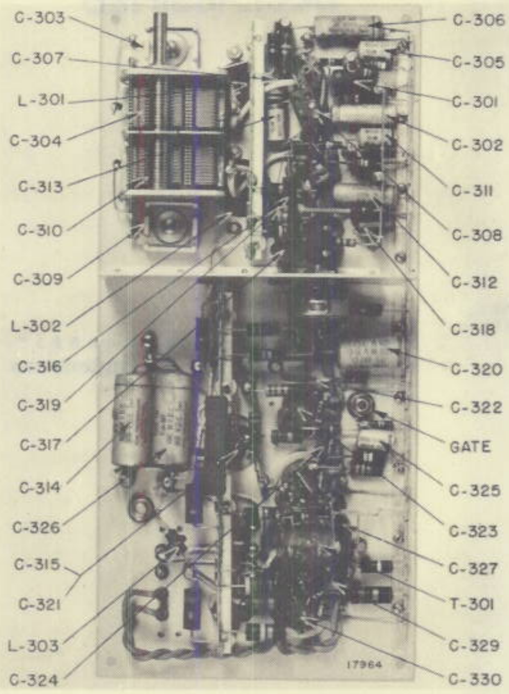


Figure 7.10. Receiver chassis, viewed from outside (condensers identified)

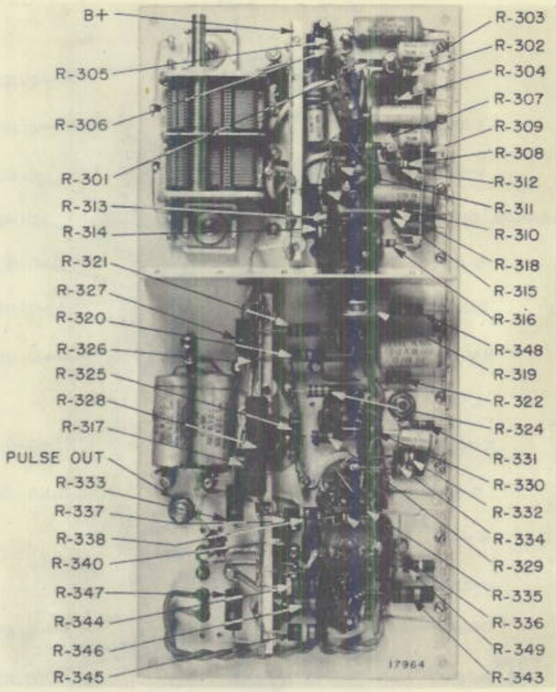


Figure 7.11. Receiver chassis, viewed from outside (resistors identified)

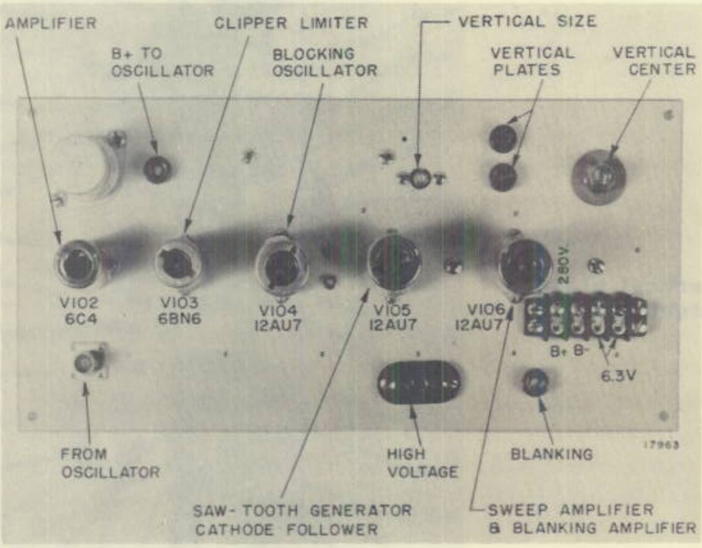


Figure 7.12. Vertical chassis, viewed from inside

DECLASSIFIED

[redacted]

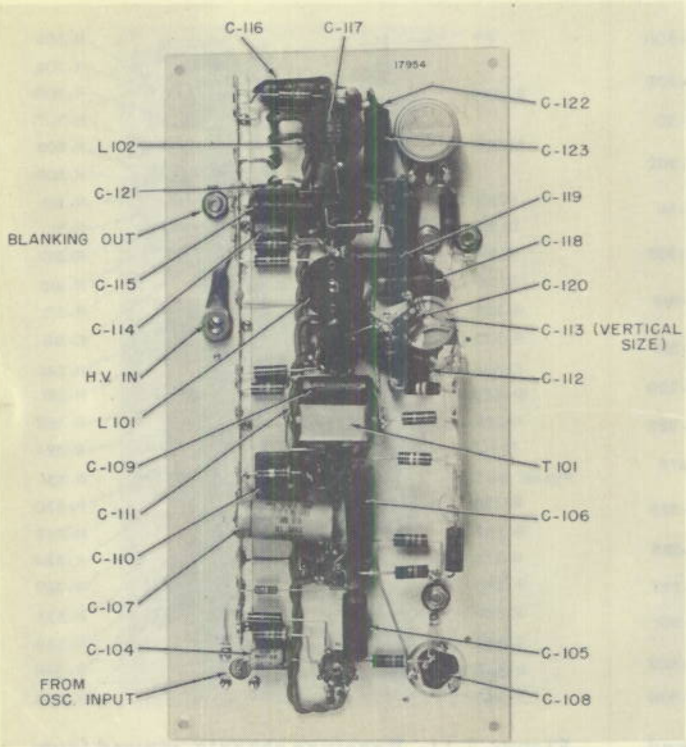


Figure 7.13. Vertical chassis, viewed from outside (condensers identified)

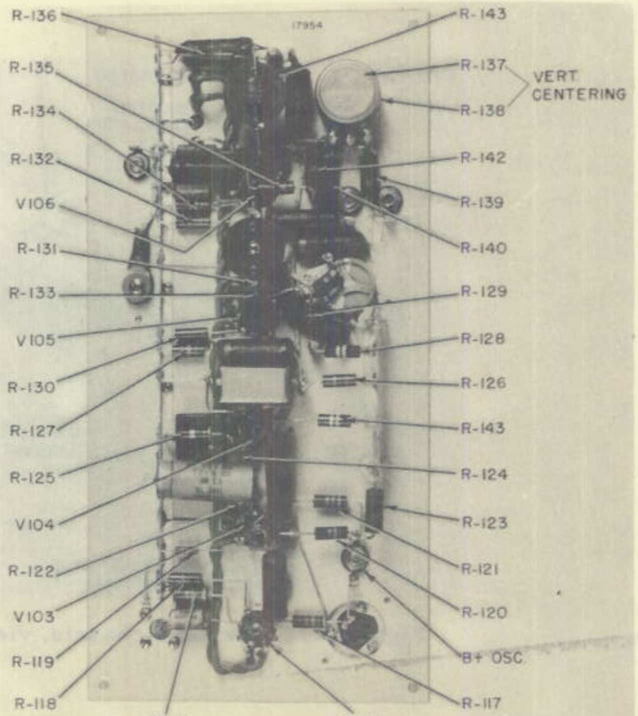


Figure 7.14. Vertical chassis, viewed from outside (resistors identified)

DECLASSIFIED

[redacted]

UNCLASSIFIED

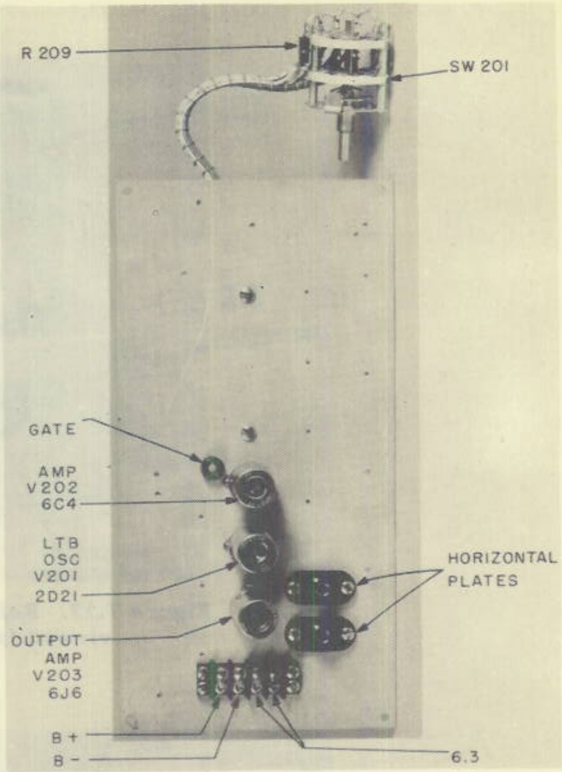


Figure 7.15. Horizontal chassis, viewed from inside (resistors identified)

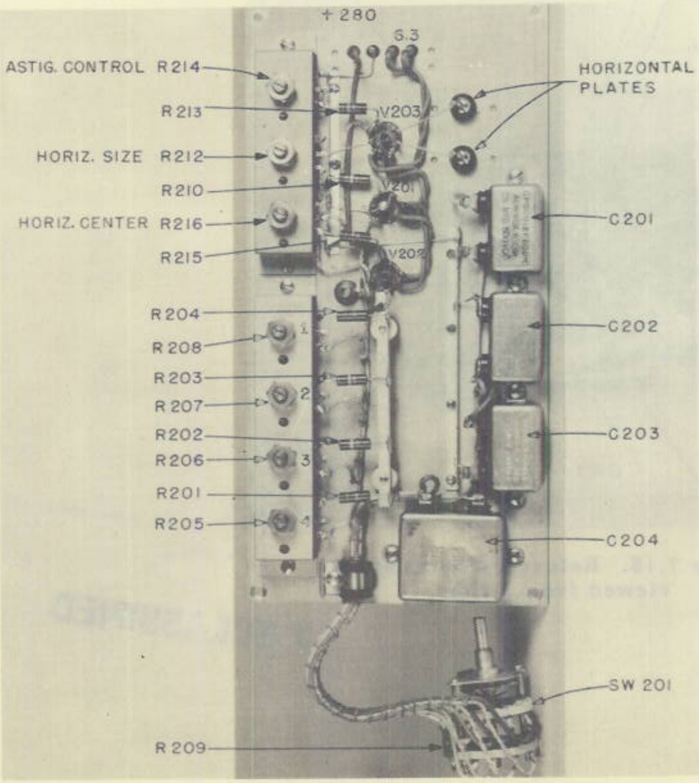


Figure 7.16. Horizontal chassis, viewed from outside

DECLASSIFIED

[redacted]

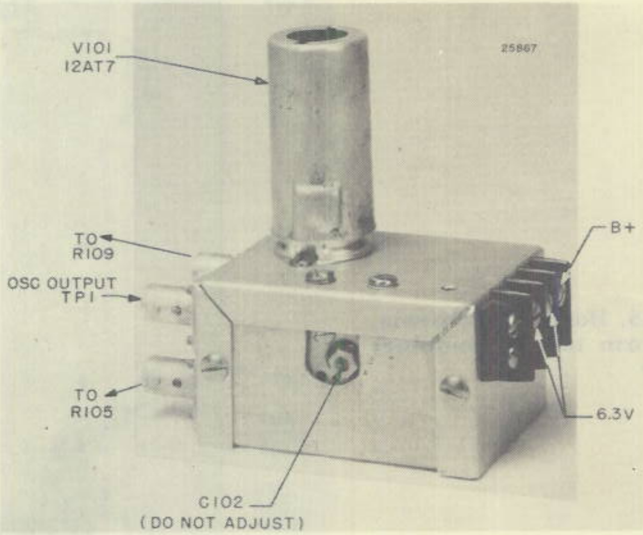


Figure 7.17. Reference oscillator, viewed from above

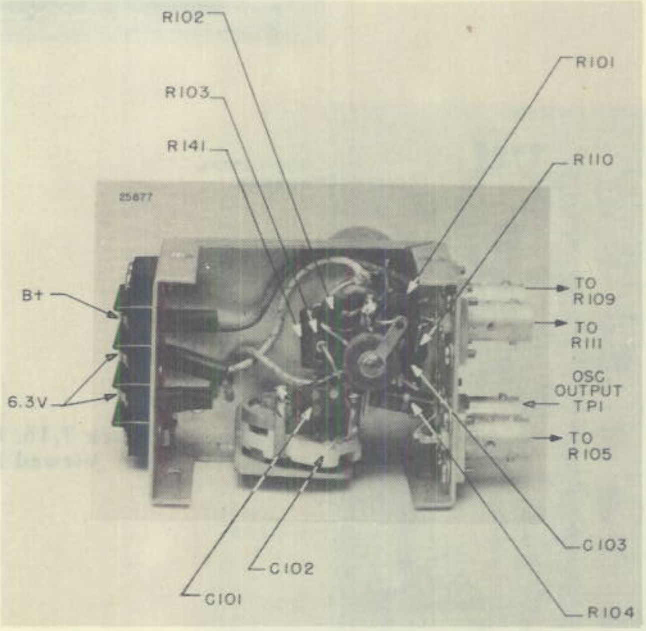


Figure 7.18. Reference oscillator, viewed from below

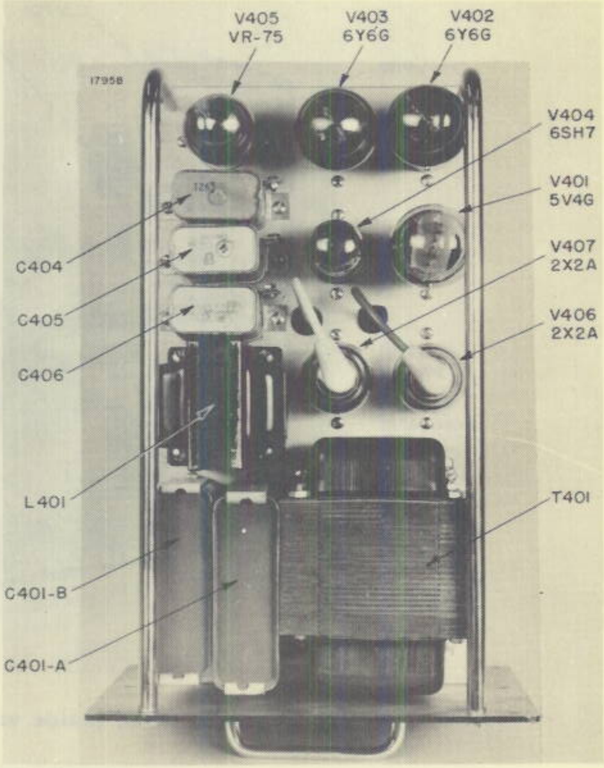


Figure 7.19. Power supply, top view

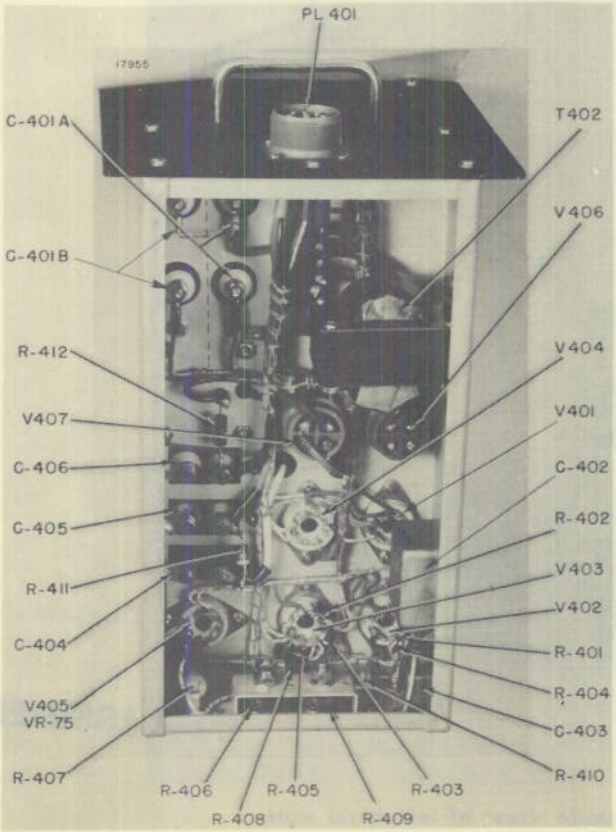


Figure 7.20. Power supply, bottom view

[redacted]

[redacted]

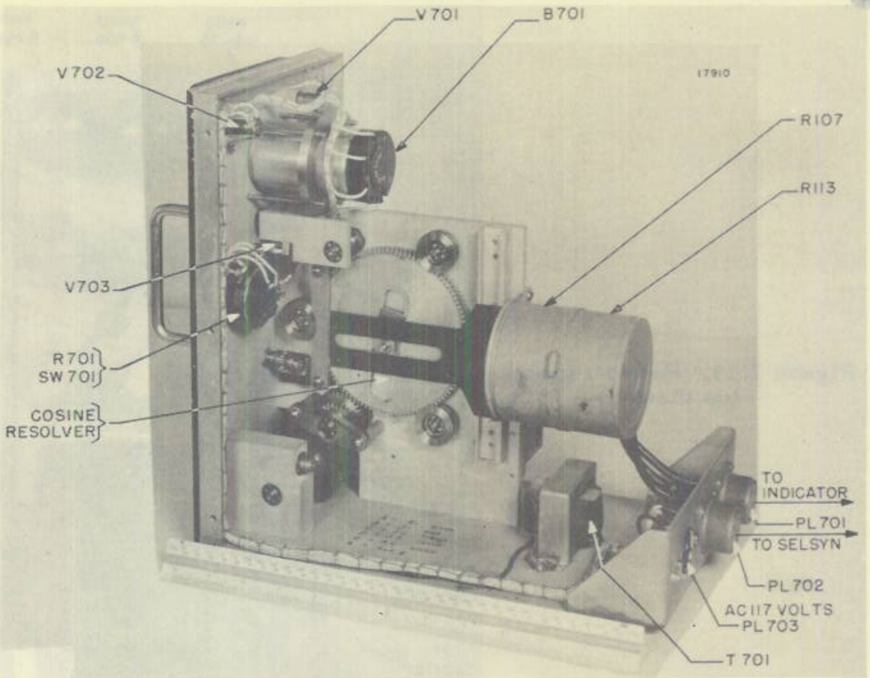


Figure 7.21. ODC, inside view of right-hand side

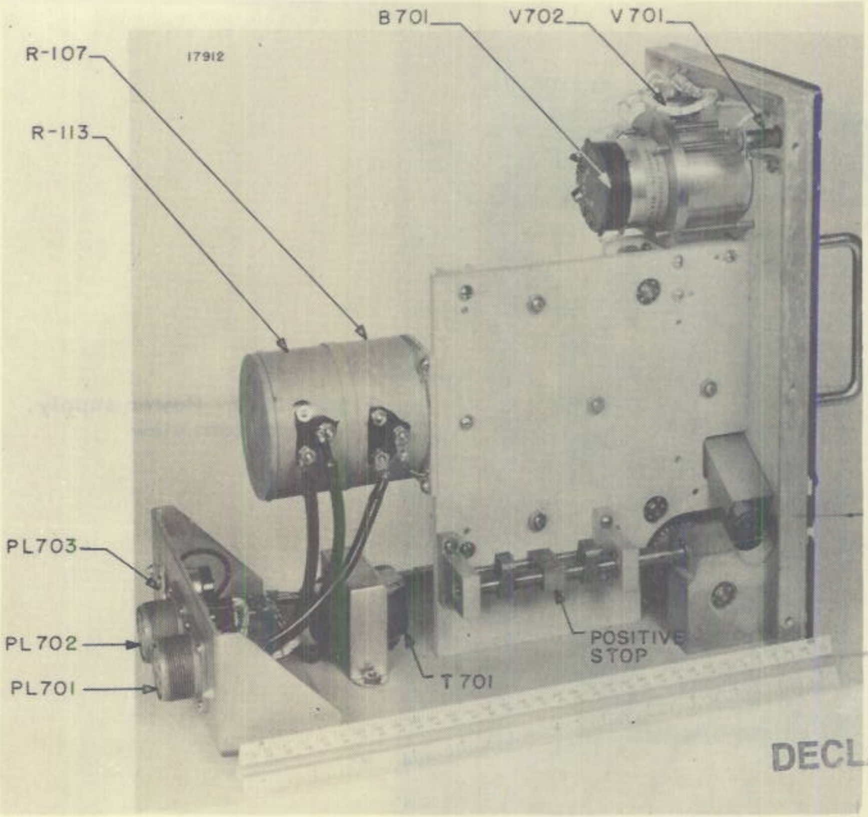


Figure 7.22. ODC, inside view of left-hand side

* * *

[redacted]

[redacted]

Appendix - Voltage Regulator

PARTS LIST FOR LINE VOLTAGE REGULATOR
SORENSON MODEL 250 SF

RESISTORS

R1			Voltage Compensator
R2	10 Ω	1/2w	
R3	10K	2w	
R4	35K	10w	Tapped at 10k
R5	25K	10w	Tapped at 10k
R6			Omitted
R7	1.8m	1w	
R8			Diode adjust
R9	1Ω	3w	Variable resistance
R10			Temperature Compensator
R11			NTC Resistor
R12	27K	2w	
R13	150K	2w	

CONDENSERS

C1	4μf	600v	
C2	0.1 μf	1000v	
C3	4μf	600v	
C4	0-1μf	600v	Valve selected as necessary
C5	2μf	600v	

TRANSFORMERS

T1		1589 Power Transformer
T2		904 Comp. Transformer
T3	1175AC 1174DC	Saturable Core Reactor
T4		205 Auto Transformer

INDUCTANCES

L1	1093	3rd Harmonic Choke
L2	744	Loading Choke
L3	278	5th Harmonic Choke

[redacted]

INSTRUCTION MANUAL
FOR
SORENSEN AC REGULATORS

GENERAL INFORMATION

Before you begin to use your new Sorensen instrument, please read this instruction book very carefully.

The Sorensen Regulator is a precision instrument. This does not mean that your Sorensen instrument will not stand rough handling - it will. How much, will, of course, depend on your own experience and good judgement. You have chosen the Sorensen unit over all other similar types of equipment for any of the reasons listed-

- Wide Input Range
- Precise regulation accuracy
- Excellent wave form
- Insensitivity to line frequency fluctuations
- Adjustable output voltage
- Fast recovery time

The experience and "know-how" which have made Sorensen the first line of STANDARD electronic voltage regulators, stand behind this instrument. If, for any reason, difficulties are encountered, notify the factory at once. . . DO NOT ATTEMPT ADJUSTMENTS OR REPAIRS WITHOUT FIRST NOTIFYING THE FACTORY. DO NOT TAMPER WITH ANY OF THE COMPONENTS. UNINSTRUCTED TAMPERING WITH ANY OF THE COMPONENTS WILL VOID YOUR GUARANTEE FOR THAT PARTICULAR PART.

REQUESTS FOR INFORMATION AND SERVICE

All questions concerning the operation or malfunctioning of this instrument should be directed to the Service Department, Sorensen & Company, 375 Fairfield Avenue, Stamford, Connecticut.

Sorensen & Company, Inc. has adopted a sales and service policy which is meant to be a protection to you as purchaser and Sorensen & Company, Inc. as supplier.

INSPECT INSTRUMENTS AT ONCE FOR SHIPPING DAMAGE

All shipments should be inspected by the buyer upon delivery and in the event of damage in transit, a claim should be filed against the carrier at once.

WARRANTY

Defective instruments or defective components found in the instruments will be considered for adjustment only if Sorensen & Company, Inc. is notified within the Warranty period specified. The period of Warranty (with the exception of the tubes) for this instrument is one year from date of your acceptance.

THE THERMOSEN DIODE IS UNCONDITIONALLY GUARANTEED FOR 2500 HOURS OR ONE YEAR, WHICHEVER EXPIRES FIRST.

The instrument and materials are warranted against defective workmanship and construction, and no other warranty may be implied.

The warranty only covers equipment that is maintained in proper condition and is used by you in skillful and proper manner. No other warranties may be implied.

PROCEDURE FOR RETURNING DAMAGED OR DEFECTIVE MATERIAL

When claiming adjustment for defective materials, the following procedure should be followed:

A. A request should be made directly to the Service Department of Sorensen & Company, Inc. for authorization to return the defective instrument. In order that your request can be serviced as quickly as possible, it is necessary to list the following information:

1. The order number on which the instrument was shipped.
2. Model number and serial number of the instrument.
3. A brief description of the reason for rejection.

B. It will be determined by the Service Department of Sorensen & Company, Inc. whether a repair will be attempted at your plant by one of our Field Engineers or Representatives. If this is to be done we will notify you immediately and make arrangements for a visit to your plant. If we indicate that the material is to be returned to our Plant for repair or replacement, a RETURN MATERIAL TAG, which outlines a shipping procedure, will be sent to you.

I. SPECIFICATIONS

A. Nominal Ratings

1. Input Voltage Range - 95 to 130 volts AC (or 190 to 260 in "-2S" models).
2. Output Voltage - Rated at 115 V, or 230 in "-2S" models, but adjustable between 110 and 120 volts, or 220 to 240 in "-2S" models.
3. Regulation Accuracy - plus or minus .1% against line or load with a 25°C. ambient.
4. Recovery time -.05 seconds for 150, 250, 500 VA; 0.1 seconds for 1000, 2000 VA; 0.15 seconds for 3000 and 5000; 0.2 seconds for 10,000 and 15,000 VA units. When an abrupt change occurs in the input voltage or in the load an instantaneous change in output Voltage occurs. The magnitude of the instantaneous output-voltage-change is dependent upon the magnitude of the change in load or input voltage. A finite time is necessary for the regulator to restore the output voltage from its maximum deviated value to the normal value. The recovery time is defined as the time necessary to effect at least a 63% complete recovery from its maximum deviated value.
5. Input frequency range - 50 to 60 cycles. Centered at 50 cycles in "C" units, at 60 cycles in standard units.
6. Power Factor Range - 1.0 to .7 power factor lagging. See Graph A, page 7 for complete details.
7. Load Range - 0 to full load. Model number indicates full load rating in VA.
8. Harmonic Distortion - 3% maximum. The rating applies to a nominal input frequency of 60 cycles. See Graph B, page 8. The harmonic distortion rating applies only under conditions of a sinusoidal input voltage, since input distortion can cause appreciable output distortion. Normal distortion 5% in hermetically sealed units.
9. The rated ambient for the unit is -20°C. to +60°C. although the unit will operate at higher ambients with lighter loads and at lower ambients with some change in operating characteristics.
10. Temperature compensation is employed to reduce the output voltage change that would be present when the ambient is changed over this wide range. The output voltage may shift plus or minus ½ of 1% over this wide ambient range, but the regulation against line or load will be maintained.

Most units are fully protected against overload by automatic thermal breakers. Circuitry arrangement and the special diode employed protects the units against over voltage resulting from tube failure.

11. The unit is rated to withstand normal humidity conditions in a sheltered location. The wound components are varnish impregnated in a good commercial manner.

    NOTE: Dangerous voltages exist in the control circuits. Observe appropriate precautions.

12. The controls are located on the front panel. A main power switch is provided for all models except the 5, 10, and 15 KVA units. A fuse for the control circuit only is provided. This fuse does not disconnect the power circuit but merely disconnects the control circuit. A pilot light is also provided to indicate that the control circuit is working. The voltage adjustment control is provided to permit ample voltage adjustment, as rated.

    It must be noted that to completely disconnect all possible voltages from the load or from the internal portions of the unit, the power switch should be off, or the line cord or other connection to the main power opened. Removing a fuse will not completely remove all voltages from the unit or the load. See the schematic for details.

13. The standard finish is grey wrinkle although black wrinkle is also available.

INSTALLATION NOTES

The input power is supplied by using the flexible line cord or terminals.

The output is available at the rear of the unit by inserting a suitable plug into the dual receptacle or using the terminals provided.

The chassis is isolated from the input and output terminals and it is recommended that the chassis and case be grounded. The input is not isolated from the output as is evident by referring to the attached schematic.

The fuse on the front panel is provided as a protection for the control components in the event of an internal failure. The unit is protected against overload by the internal automatic type over-current protector in most models.

Principle of Operation

The operation of the unit can best be understood by referring to the schematic diagrams included.

The basic power circuit includes an autotransformer T4 and a saturable core reactor T3. The reactor is in series with the primary of the autotransformer across the input terminals. Variation of the impedance of the saturable core reactor will vary the voltage impressed on the primary of the autotransformer and consequently will vary the output voltage.

A decrease in reactor impedance, for instance, will increase the portion of the input voltage impressed on the autotransformer primary and will result in an increase in output voltage.

Conversely, an increase in reactor impedance will result in a decrease in output voltage.

All that is necessary to achieve voltage regulation is some automatic method of varying the reactor impedance by the right amount to restore the output voltage to its original value at such times as it may vary due to changes in load or input voltage. This action is accomplished by the electronic control circuit.

The basic voltage sensitive element is the Wheatstone Bridge. One arm of the bridge consists of the diode V1, the filament of which is lighted by the output voltage. In some low capacity models only two arms of the bridge show on the schematic diagram. The power supply has the missing two arms by virtue of its arrangement.

The diode is operated at a temperature limited condition. With this arrangement,

DECLASSIFIED

UNCLASSIFIED

a small increment of output voltage results in a change in cathode emission and a large change of plate resistance in the diode. The signal voltage of the bridge is applied to the grid of beam power tube V2 which controls the DC saturating current of the reactor.

A typical sequence of operations is as follows: Assume a rise in output voltage as a result of reduced load or a rise in input voltage. Increased output voltage results in increased voltage and heating of the diode filament. With increased heating, the diode cathode emission increases reducing the plate resistance of the tube. Since the diode forms an arm of the bridge, a change in plate resistance will change the balance condition of the bridge; in this instance the change results in a more negative potential applied to the grid of V2. The more negative grid signal results in a sharp drop in the plate current of V2 and consequently, reduced saturation of the reactor. Reduced DC saturation of the reactor results in an increase in AC impedance which, as pointed out before, lowers the output voltage.

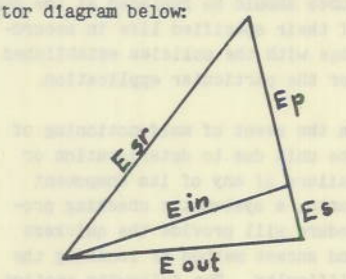
The above action will continue until an equilibrium is reached wherein the net change in output voltage is sufficient to compensate for the changed circuit conditions in the control circuit. The gain of the control system is of such magnitude that the unit will maintain output voltage within tolerance rated, while compensating for the rated range of input voltage and load variations.

The tube V3 is a rectifier tube for the saturating circuit, and S1 a selenium rectifier for the diode bridge circuit. Adjustment of the output voltage is accomplished by the potentiometer in the circuit supplying the diode filament voltage. Variation of the resistance in this circuit varies the value of output voltage required to obtain a given diode filament temperature, and consequently will control the output voltage.

The resistor shown connected between the plate and the screen of tube V2 (across terminals 9 and 10 in high capacity models) is a swamping resistor to absorb inductive surges originating in the DC reactor winding. The winding has a very high inductance.

When the regulator is first turned on, electronic circuit elements are cold and a period of approximately 60 seconds is required for the unit to reach operating temperature. During this period, the output voltage will be low; however, as the tubes begin to conduct, the output voltage rapidly rises to its proper adjusted value. This is a normal condition and in no way indicates any malfunctioning of the regulator.

The phase relationships of the voltages in the power circuit are illustrated by the Vector diagram below:



E_s = voltage of auto trans. sec.

E_p = voltage of auto trans. primary.

E_{sr} = voltage across saturable core reactor.

E in = input voltage

E out = output voltage.

The magnitude of the Vectors are indicative of operation of the regulator at full load and nominal input and nominal output.

II. MAINTENANCE AND TROUBLE SHOOTING

It was stated in the opening paragraphs of this Instruction Booklet that no tampering or adjustments should be attempted if the unit is within the warranty period without first contacting the Service Department, Sorensen & Co., Inc., or your local Sorensen representative. If the unit is outside of the warranty period it should be remembered that damage can be done to various components even when the unit is being checked. It is

DECLASSIFIED

[redacted]ION

most necessary that the user of this equipment be familiar enough with the circuit to avoid such damage. If the simple checks outlined in this section do not point out immediately the source of trouble, the Service Department of Sorensen & Co., Inc., or the local representative of Sorensen, should be contacted immediately.

A. Maintenance

1. During normal life, the unit requires no maintenance or servicing other than the care usually afforded this type of equipment. Vacuum tubes should be replaced at the end of their specified life in accordance with the policies established for the particular application.

2. In the event of malfunctioning of the unit due to deterioration or failure of any of its component parts, a systematic checking procedure will provide the quickest and surest method of locating the difficulty. The following section gives systematic checking procedures which should be followed in locating sources of trouble.

3. The schematic shows the voltages which should exist in various parts of the circuit during normal operation. These voltages should be measured with an electronic type voltmeter.

   NOTE: DANGEROUS VOLTAGES EXIST IN THE CONTROL CIRCUITS. OBSERVE APPROPRIATE PRECAUTIONS.

COMPENSATION PROCEDURE

Definition of compensation: Compensation in Isotronic terms means a reduction of the amount of voltage deviations caused by line or load changes.

The regulator has several components that are factory adjusted to the optimum value and readjustment in the field is not recommended. However, a brief description of the procedure is given to be used in an emergency. As noted on the schematic, R1 is a resistor consisting of a suitable length of nichrome wire. This value is preset at the factory. In general, increasing the value of this resistance will produce an effect of causing the output voltage rise to be less than normal and even decrease when the line voltage is increased. Several trials should produce the optimum value. Although load compensation is primarily determined by the "load line", adjustment of R1 also has some effect on load compensation. Load compensation is obtained by inserting the optimum value of resistance of the conducting lead between the output terminal or point where R1 is connected and the point where the other primary terminal of T2 connects to the output line. This is designated as the "load line" on the schematic. One terminal of the primary of T2 connected to R1. For special conditions under or over compensation can be achieved to cause the same effect for load changes. This latter characteristic is handy when voltage drop in long leads must be accounted for.

Another adjustment involves the resistor designated R8. Adjustment of the resistor may be necessary when a new diode is installed and the voltage adjustment potentiometer does not permit setting the output voltage between 110 and 120V or 220 and 240 in "-2S" models.

Adjustment of R12 is made to secure optimum temperature compensation. This should not be adjusted since the optimum value cannot readily be determined in the field. However, in an emergency the value of this should be such that the output voltage drops 6 to 8 volts when the trial value of R12 is shorted out under full load.

B. Trouble Shooting

1. THE FIRST STEP IN TROUBLE SHOOTING SHOULD BE TO REPLACE TUBES. IN MOST CASES THIS IS ENOUGH TO CURE THE TROUBLE.

2. Problem A - No Output Voltage

   This condition indicates an open in the power circuit.

   Procedure

   a. Check that the On-Off control is in the "ON" position.

   b. Check autotransformer, AC reactor coils, circuit breaker, power leads, and terminals for continuity.

3. Problem B - No Regulation and Low Output Voltage with Load.

   This condition indicates the failure of the electronic control circuit to supply saturating current.

   Procedure

   1. Check the fuse in the control circuit. Replace only with a similar type.

   2. Inspect tube filaments to see that they are lighted.

   3. Check tubes in a tube tester or by replacement with tubes known to be good.

   4. Check the DC power supply. No voltage will indicate a failure of the transformer winding or of the filter condenser. Check rectifier tube.

   5. Check the plate voltage and grid voltage of the beam power tube, V2. If the grid voltage is abnormally negative and causing cut off, check the diode bridge supply voltage and the diode filament supply voltage.

   6. Check the DC reactor winding for an open.

   7. Check the over-voltage circuit breaker if one is used in your unit.

   8. In the case of split-chassis construction, check the inter-chassis terminal boards for secure and correct connections.

Problem C - No Regulation and High Output Voltage.

Procedure:

1. Check to see that the diode filament is lighted.

2. Check tube V2 in a tube tester or replace with a spare that is known to be good.

3. Remove V2. If output voltage drops difficulty is in the control circuit.

   Check V2 grid voltage to cathode or ground.

   If this voltage is abnormally positive, or zero, check contacts, connections and resistance values of all components of the bridge. Check diode or replace with a spare known to be good. Check bridge rectifier.

4. Check the voltage adjusting potentiometer for dirty contacts.

Problem D - Drift with Age of the Range of Output Voltage.

This condition indicates a variation of tube characteristics with age.

Procedure:

1. Check tubes or replace with spares known to be good.

Problem E - Reduction of Regulation Range or Poor Regulation in General.

[redacted]

These conditions may be the result of deterioration or failure of various components of the control circuit.

Procedure:

1. Check tubes or replace with spares.

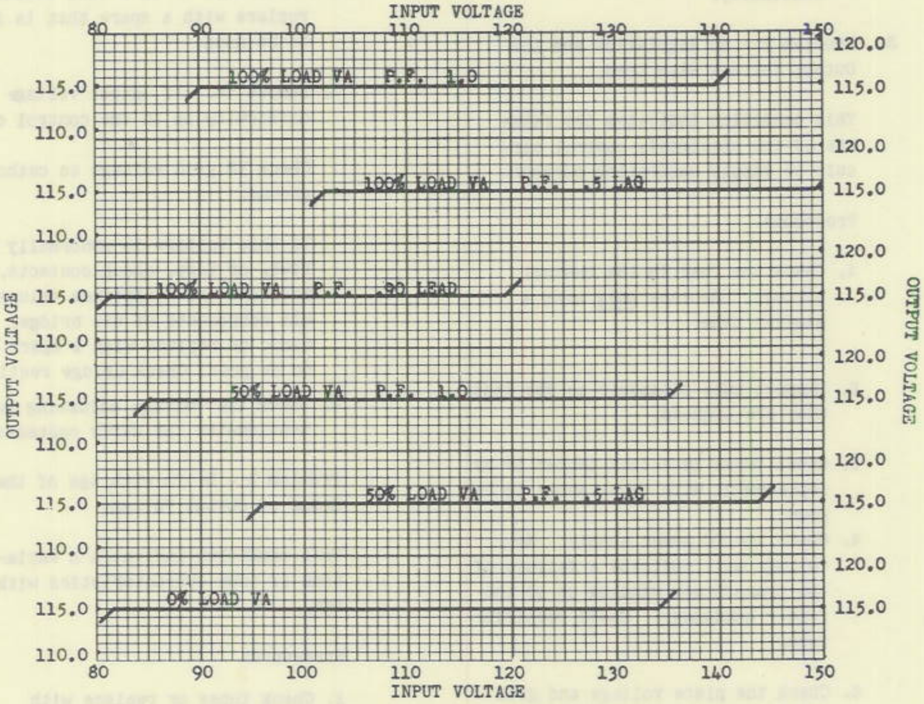
2. Check the DC Power supply voltages.

3. Check the control circuit in general for loose connections, shorts or damaged parts.

4. Check voltage and resistance values. Check condensers by replacement.

5. The output voltage adjustable potentiometer may cause irregular output adjustment. Turn the potentiometer shaft several times in both directions as far as it will go. This is a very low resistance adjustment and contacts can oxidize enough to cause uneven control.

In the event of serious trouble or damage to the unit, return it to the factory for repair and readjustment.



TYPICAL REGULATOR PERFORMANCE

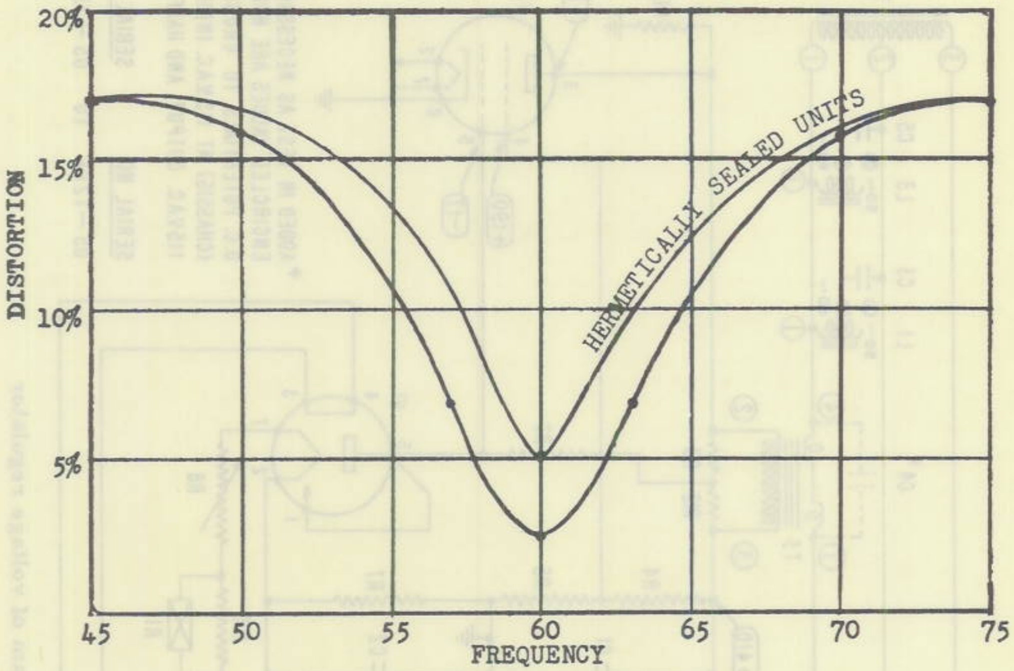
Input Range vs. Load and Power Factor Change

(In "-2S" models double the voltage)

GRAPH A

[redacted]

[redacted]



TYPICAL OUTPUT DISTORTION

VS.

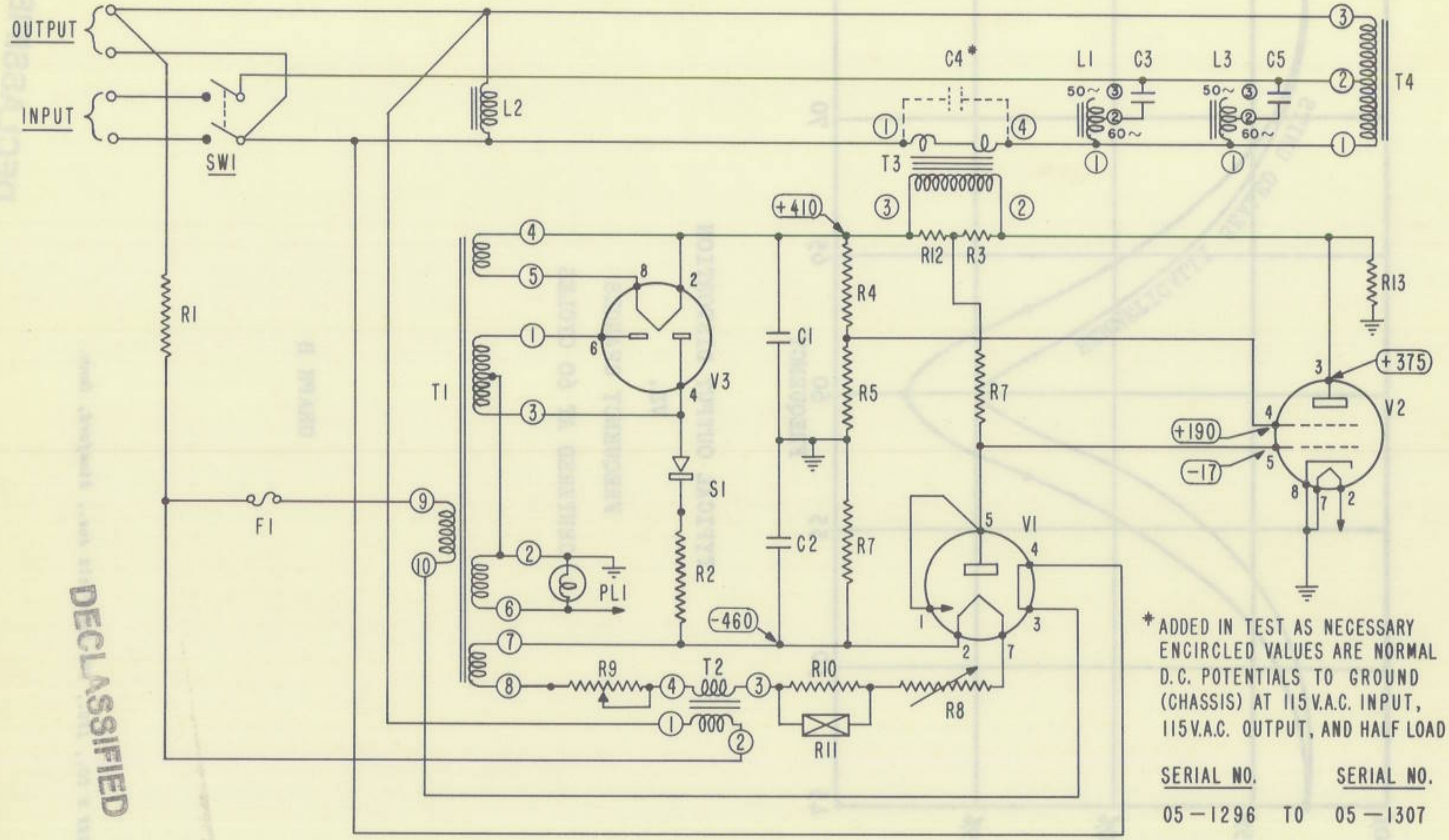
FREQUENCY CHANGES

CENTERED AT 60 CYCLES

GRAPH B

[redacted]

[redacted]



*ADDED IN TEST AS NECESSARY
ENCIRCLED VALUES ARE NORMAL
D.C. POTENTIALS TO GROUND
(CHASSIS) AT 115 V.A.C. INPUT,
115 V.A.C. OUTPUT, AND HALF LOAD

SERIAL NO.		SERIAL NO.
05 – 1296	TO	05 – 1307

Figure A.1. Schematic diagram of voltage regulator

[redacted]