PB 151404

NBS

Technical Note No. 45

Boulder Laboratories

OPERATING INSTRUCTIONS FOR ARN-2 AUXILIARY LOG-LINEAR NOISE RECORDER

BY R. T. DISNEY AND C. A. SAMSON

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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January, 1960

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Price $ .50

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Operating Instructions for the ARN-2 Auxiliary Log-Linear Noise Recorder

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1. Purpose

1.1 General

The auxiliary equipment for the ARN-2 recorder[1] installed in the C rack is for the purpose of measuring the deviation of the average voltage and the average logarithm of the voltage with respect to the average power. The reason for measuring these additional parameters of the noise is to determine to a much greater extent the interference value of the recorded noise to a number of types of communication systems. By measuring the average value of the three parameters, it is possible to reconstruct the average amplitude-probability distribution required to give the values recorded[2]. From this distribution, considerable information can be derived as to the performance of a particular communication system in the presence of noise[3].

1.2 Choice of Parameters

The average voltage and average logarithm of the voltage were chosen as the parameters to be measured for a number of reasons. First, it was thought highly desirable to use a parameter of the noise envelope that could be described easily and simply mathematically. The power (V^2), the voltage (V), and the log of the voltage (log V) fell nicely into this classification, and discarded such parameters as peak or quasi-peak values. The next consideration was to use three parameters that could be represented by fairly well separated points on the amplitude-probability plot. The power is influenced most by the high voltage, low-probability values, while the log is influenced most by the low voltage, high-probability values[2]. The voltage value falls approximately midway between the other two values. The third factor considered was the ease of obtaining the values from a circuitry standpoint. The voltage required only an averaging and metering circuit while the log required a logarithmic amplifier, averaging and metering circuit. All of this is rather straightforward circuitwise.

1.3 The Measured Values

The actual measurements made are deviations of the average voltage and average log in db below the power. The reason for making the deviation measurement was twofold. First, the deviation could be measured directly more accurately than measuring, for instance, the power and voltage independently and comparing the two. Second, the dynamic range of any system used to measure any characteristic of radio noise must necessarily be large. The ARN-2 power recorder was already in successful operation providing a constant power level take off point in the servo loop. Therefore, the required dynamic range of the voltage and log measuring circuitry could be reduced so the average values would fall within a 20 to 30 db range.

2. General Operation

2.1 Block Diagram

The signal is taken through an isolation resistor just prior to the input to the parabolic amplifier in the servo loop of the power recorder. This signal voltage is fed into the input of another 51 kc I. F. amplifier (see block diagram, Fig. 1). The output is connected to the input of a 51 kc amplifier-detector. The output of the detector is connected to the inputs of the log and linear amplifiers, integrators, and metering circuits. These outputs are connected to recording meters through the log-gate timer to record directly in db below the power.

2.2 Function of Units

The I. F. amplifier and detector are quite similar to the corresponding units in the power recorder. The log-linear amplifier-integrator is a two channel integrator with separate inputs for each channel from the detector. The log input is at the detector output level and the linear input is 30 db below the log input. The log signal is connected to a logarithmic amplifier. The output of this amplifier is averaged by an R-C integrating network with a time constant of about thirty seconds and recorded. The linear signal is averaged using an R-C integrating circuit with a time constant of approximately fifty seconds. The averaged signal is fed into a d. c. amplifier, then into a logarithmic amplifier, and then into another d. c. amplifier which drives the recorder. The function of the log-gate timer is to prevent the log and linear recorders from recording a nonvalid reading with respect to the power reading. If the average power at the output of the detector is one db from the reference point, the integrator-control unit will require 200 to 240 seconds to step the attenuator. Therefore, if a period of four minutes elapses from the time of the last attenuator step, the power reading must be within 1 db of the true power reading, and valid log and linear readings may be obtained with respect to the power reading. The log-gate timer insures that this necessary four-minute interval has passed from the time of the last attenuator step before the log and linear readings are displayed on the recording meters. The log-gate timer also drives the recorder pens to the right-hand side of the charts during the three-minute period when the attenuator forward drive is connected just after a frequency change.

3. Operational Procedures

3.1 General

By means of the daily checks and adjustments, the correct operation of the C rack independent of the power recorder is assured and the calibration insures the correct operation in conjunction with the power recorder.

3.2 Checks and Adjustments

The following steps should be taken to insure the proper functioning of the C rack itself.

3.2.1 Power Supplies - Check the panel meters indicating the output voltage of the power supplies to insure the proper supply voltages. If the output meter for the 75 volt supply does not indicate 75 volts $\pm$ 1 volt, open the drawer and adjust VOLT ADJ on the 75 volt power supply chassis (see Fig. 2) so that the meter reads exactly 75 volts. Next check the output meter for the 300 volt supply, and if it does not read 300 volts $\pm$ 5 volts, adjust VDC ADJ on the top of the 300 volt supply chassis so that the 300 volt reading is obtained.

3.2.2 Detector Meter - All checks on the equipment are made in reference to the detector meter reference point (0 db on the meter with the meter selector switch in the 0 db position). Therefore, the first step in checking the operation of the equipment is to adjust the meter controls to give the proper meter reading. To accomplish this, turn the meter selector switch to the ZERO position. The meter should now read at meter ZERO, the last line on the left-hand side of the meter scale. If the meter does not read meter ZERO, open the drawer and adjust the ZERO ADJUST (R 39) located on the detector chassis (see Fig. 3). Next turn the meter selector switch to REF. The detector meter should now read 0 db. If it does not, adjust the RANGE ADJUST (R 44) located on the detector chassis. Recheck the meter ZERO, and if this requires readjustment recheck the REF adjustment, since there is some interaction between the two controls.

3.2.3 I.F. Amplifier - (A word of caution is advisable at this time. The detector reference voltage is 300 volts. During the switching operation of the power recorder, a relay (Re 1) on the detector chassis is energized by the muting voltage from the power recorder. This relay switches the detector output to the 300 volt supply giving and maintaining the reference reading for the period (90 to 180 seconds) that the cam operated switch in the E-A power recorder is closed. No adjustments utilizing the detector meter or the log-linear recording meters should be made during this period). With minimum output on 51 kc, connect the output of the alignment oscillator directly to the input, I1, on the I. F. amplifier chassis. The gain control (R8) of the I. F. amplifier should be set so that an input from the alignment oscillator of approximately 65 db will give the detector reference output (0 db on the 0 scale). This adjustment is not critical at this time. The exact setting is explained in paragraph 3.2.7. Now tune C1 for maximum reading on the detector meter. When the tuning of any capacitor on the ARN-2 is found to give a peak reading with the adjustment screwdriver slot either parallel or perpendicular to the control mounting screws, a check should be made to be sure a double peak is obtained since in one position or the other, the capacitor will be at maximum or minimum capacitance position.

3.2.4 Detector - With the output of the alignment oscillator still connected to the input of the I. F. amplifier, adjust C2 on the detector chassis for maximum detector meter reading. Next adjust the detector bias. To do this, disconnect the input to the I. F. amplifier. Turn the detector meter switch to the 60 db position. Adjust the BIAS (R 14) control on the detector chassis to obtain approximately 0 db reading on the detector meter. This adjustment affects the detector linearity and it may be necessary to readjust later to improve the linearity at low detector output. Turn the detector meter switch back to the 0 db position and reconnect the alignment oscillator to the I. F. amplifier input. Adjust the output of the alignment oscillator so that detector 0db reference is read on the detector meter. The detector should be linear, within ± 1 db, over a range of 60 db, (from 10 db above reference to 50 db below reference). To check the linearity, increase the alignment oscillator output by 10 db. The detector meter should now read + 10 db. Decrease the alignment oscillator by 20 db, and change the detector meter selector switch to the 20 db position. The reading at this point should be -10 db (20 db below reference on the switch position +10 db meter reading = -10 db). Continue to decrease the alignment oscillator in 10 db steps and check the detector meter reading (with the detector meter switch in the appropriate position) until a reading of -50 db has been obtained (60 db below reference on the switch position +10 db meter reading = -50 db). The detector meter reading should be within ± 1 db at each of these steps. If it is not within this limit at the lower input end (-30, -40, or -50 db points) readjust the bias control to bring the reading within the acceptable limits. If it is not within limits at the + 10 db point, try replacing the 3A2 diode or checking the other tubes on the detector chassis.

3.2.5 Log Linear Amplifier Integrator - The d.c. amplifier balance should be checked and reset if necessary. To check the balance, turn the BAL-LONG-SHORT switch to the BAL position. Then turn the meter switch to the BAL position. The detector meter should now read at meter zero (the last line on the left-hand side of the meter scale). If the meter reads far enough below the meter zero so that the meter hand rests on the stop or if the meter reads above -6 on the meter scale, open the drawer and adjust the AMPLIFIER BALANCE (R 33) control so that the meter reads meter zero. Return the meter control to ZERO and the BAL-LONG-SHORT switch to SHORT.

If required, the d.c. amplifier linearity may be checked in the following manner, though normally it is not necessary to do so. Originally the test point, TP 1, on the detector chassis was connected to the log tap on the detector output divider network. In most cases, it has been connected to the linear tap on the output divider network. This can be checked with the VTVM. With the input to the I. F. amplifier from the alignment oscillator adjusted to give reference detector meter reading, the voltage at TP 1 on the detector chassis should be 300 volts if TP 1 is connected to the log output tap or 10 volts if connected to the linear tap. If with the detector meter indicating reference, the voltage at TP 1 is approximately 10 volts this point may be used to check the d.c. amplifier linearity. If the voltage at this point varies more than two volts from the 10 volt value, the detector unit should be replaced. Set the alignment oscillator output so that exactly 10 volts is measured at TP 1 on the detector chassis. Now check the voltage at TP 1 on the amplifier-integrator chassis. There should be a 10:1 gain through the d.c. amplifier so that a reading of 100 volts should be obtained at TP 1 on the amplifier-integrator chassis. The output of the alignment oscillator should now be decreased so that the input to the d.c. amplifier (measured at TP 1 on the detector chassis) is decreased in 1 volt steps down to 1 volt. The corresponding values of the output of the d.c. amplifier should be ten times the input, that is 100, 90, 80, etc. to 10 volts as measured at TP 1 on the amplifier-integrator chassis. If this varies by more than 10% of the correct value, the d.c. amplifier tubes should be checked and replaced if necessary or if this does not correct the linearity, the amplifier-integrator unit should be replaced.

3.2.6 Recording Meters - First set the mechanical zero of both recorders. To do this, disconnect the input to the recorders by disconnecting the Cannon connector on the back of the recorder.

Adjust the mechanical zero adjustment (see Fig. 4) so that the recording pens are marking on the first line on the left-hand side of the chart paper. Reconnect the Cannon connector. To make the scale adjustments, adjust the signal input to the I. F. amplifier from the alignment oscillator so as to give detector reference reading on the detector meter. Both recording pens should now be on the 0 db lines (the first line on the left-hand side of the chart paper). The chart paper used should be E-A No. 4304 (sixty divisions with every fifth line accentuated) on the log (left-hand) recorder, and 4303 (forty divisions with every fifth line accentuated) on the linear (right-hand) recorder. If either pen is not recording on the 0 db line, appropriate adjustment should be made. To correct the log recorder, adjust RECORDER ZERO (R 15) on the amplifier-integrator chassis. To correct the linear recorder, adjust the RECORDER ZERO (R 47) on the amplifier-integrator chassis. Next set the recorder range. Decrease the I. F. amplifier input by 20 db by means of the alignment oscillator output attenuator. This should give a reading of 20 db on the linear chart (the last line on the right-hand side of the chart paper. If it does not, correction should be made by adjusting the RECORDER RANGE (R 45) on the amplifier-integrator chassis until the linear recorder indicates 20 db. Decrease the output of the alignment oscillator another 10 db (total of 30 db below detector reference). The log recorder should now read 30 db (the last line on the right-hand side of the log chart). If it does not, correct the reading by adjusting RECORDER RANGE (R 11) on the amplifier-integrator chassis. Return the alignment oscillator to the output required to give detector reference and again check the 0 db point on the two recording meters readjusting as above if necessary. If readjustment is necessary due to the interaction of the ZERO and RANGE adjustments, the full range (20 db for the linear and 30 db for the log) should be rechecked and readjusted if necessary. If the 0 db indication is correct on both recording meters, the intermediate points should now be checked. Decrease the alignment output by 10 db. Both recording meters should now read within 0. 5 db (one small chart division) of the 10 db line (this is the fifth accented line from the left on each chart, the accented lines being 0, 2. 5, 5, 7. 5, and 10 db). Decrease the alignment oscillator by another 10 db and the log and linear recorders should indicate 20 db on the charts. If these intermediate points are not recording correctly, appropriate remedial steps should be taken. First recheck the 0 db and full range settings of the recording meters. If these are set properly, and both recorders indicate nonlinearity, recheck the linearity of the detector (paragraph 3. 2. 4). If the detector meter indicates detector linearity within the prescribed limits but the meter itself is suspect, the meter can be checked by measuring the output voltage at TP 1 with the VTVM. If the detector meter and the

VTVM agree, it can be assumed that the detector meter is correct. However, if they disagree, it is highly recommended that a second VTVM be used to obtain readings verifying the error in either the first VTVM or the detector meter. If only the linear recorder is incorrect at the intermediate points, linearity of the d.c. amplifier may be checked (paragraph 3.2.5). If after proper adjustment either the detector or d.c. amplifier is found to be nonlinear, check and replace bad tubes or if this does not correct the trouble, replace the unit.

3.2.7 Calibration with Respect to the Power Recorder - After the completion of the checks and adjustments indicated in paragraph 3.2.1 through 3.2.6, the log and linear recorders within themselves are functioning properly. At this point, it is necessary to adjust the gain of the I.F. amplifier so that the proper relationship between the log and linear recorders and the power recorder is established. The log-linear recorder can be used in conjunction with either the A rack (four lower frequencies) or the B rack (four higher frequencies) of the power recorder. The selector switches on the front panel of the log-gate timer and the I.F. amplifier-detector-amplifier integrator drawer must both be in the appropriate position to record with the low (A rack) or high (B rack) power recorder (see paragraph 5.1 for correct connection). The A or B rack must be completely adjusted and in proper operation prior to the time the following calibration procedure is accomplished. The same procedure will be followed regardless of which section of the power recorder is connected to the C rack. For illustration purposes in this discussion, the assumption will be made that the log-linear recorders are to be operated in conjunction with the low (A rack) power recorder. Corresponding referenced units or controls in the high (B rack) should be substituted when the connection is changed to the B rack. Make sure that both the log-gate timer and C rack input HIGH-LOW switches are in the LOW position. Make sure the output of the C rack HIGH-LOW switch is connected to the input terminal of the I.F. amplifier. Turn the BAL-LONG-SHORT switch to the SHORT position and the log-gate timer IN-OUT switch to the OUT position. On the A rack, connect the output of the alignment oscillator to the dummy input terminal. Make sure the dummy antenna, channel frequency, and alignment oscillator frequency are all on the same frequency (it may be any one of the four low-frequency channels). Place the STEP-MAN-AUTO channel switch in the MAN position and the integrator switch in the REFERENCE LONG or SHORT position. Set the A rack attenuator at 50 db and the detector meter switch (A rack) at 0 db. Adjust the alignment oscillator output so that the A rack detector meter indicates detector reference (0 db on the 0 db scale).

Turn the C rack detector meter switch to the 0 db scale position. The C rack detector meter should now read reference (0 db on the 0 db scale). If it does not read detector reference, open the drawer and adjust the I. F. amplifier gain control (R 8) so that the 0 db reading is obtained. Check the log and linear recording meters to determine that they are reading on the 0 db lines (if they are not, repeat the steps for setting the recorder zero and range given in paragraph 3. 2. 6). If both recording meters are indicating 0 db, mark this point as 0 (see Figs. 13 and 14). Decrease the input to the C rack by 10 db by increasing the A rack attenuator setting to 60 db. Both the log and linear recording meters should now indicate 10 db. If they do, mark this line 10 (if not, check zero and range adjustments as given in paragraph 3. 2. 6). Again decrease the input to the C rack by 10 db by increasing the A rack attenuator to 70 db. If both the log and linear recording meters read 20 db within 0. 5 db (one small chart division) mark the point indicated 20. Increase the A rack attenuator setting in steps of 2 db (72, 74, ---80) and mark the indicated point at each step on the log chart as 22, 24, ---30. If the indicated value is more than 0. 5 db below the 20 db chart line, i. e. 18 or 19, and the chart zero and range adjustments are properly set, return the A rack attenuator to the 60 db point (10 db reading on the log and linear recording meters) and mark each 2 db step on both charts from this point (the chart deflection corresponding to the 62 db setting of the A rack attenuator should be marked 12, etc.). This crowding of the scale at the higher end is due to the effect of noise from the I. F. in the A or B rack. Normally distortion of the scale will take place between 20 and 30 db when the C rack is connected to the A rack and between 10 and 20 db when the C rack is connected to the B rack (the I. F. gain is approximately 12 db higher in the B rack).

3.3 Recording

The C rack is now calibrated and ready to record data. To record, turn the BAL-LONG-SHORT switch to LONG, turn the detector meter switch to ZERO, turn the log-gate timer IN-OUT switch to IN and make sure the timer clock red hand is set at four minutes. Return all switches on the A (and/or B) rack to normal operating position.

4. Daily Operational Checks and Calibration

4.1 General

In order to insure good, usuable data, it is necessary to perform certain daily checks and a daily calibration. These checks and calibration should be made in the order given, especially with respect to resetting the I. F. gain of the A or B rack (whichever the

C rack is connected to) and the I. F. gain or recorder scale adjustments in the C rack.

4.2 Power Supplies

Read and record on the daily log sheet (see Fig. 15) the output voltage of the 75 v. and 300 v. C rack power supplies. If the output of the 75 v. supply varies by more than $\pm$ 1 volt, reset the output voltage (paragraph 3.2.1). If the 300 volt supply varies more than $\pm$ 5 volts, reset the output voltage (paragraph 3.2.1).

4.3 Detector Meter

Note and record the reading of the detector meter with the meter switch in the ZERO and REF positions. Since it is impossible in most instances to actually "read" the needle position on the ZERO, give some indication of relative position. For instance if the "reading" is between meter zero and -6 db, indicate it by >ZERO. If it is -6 or above, the reading can be given. If it is between meter zero and the stop at the end of the pointer travel, it can be indicated as <ZERO. If the pointer is resting on the stop, it can be noted as PEG or STOP. If the ZERO or REF reading is incorrect, readjust as indicated in Paragraph 3.2.2.

4.4 First Daily Calibration

This step should be completed before any I. F. gain adjustments are made on the power recorder rack connected to the log-linear recorder and before any further adjustments or readings are taken on the C rack. Mark the recorder scale calibration on both the log and linear charts as indicated in paragraph 3.2.7 but ignoring the parts dealing with the adjustment of the I. F. gain and readjustment of the recorder ZERO and RANGE controls.

4.5 Completion of Daily Log Sheet

Next record (in the same way meter ZERO is recorded) the d.c. amplifier balance reading. If it falls outside the <ZERO or -6 reading, readjust (see paragraph 3.2.5). Check the detector linearity over the +10 to -50 db range. If the reading is outside the $\pm$ 1 db tolerance at any 10 db point, correction should be made (see paragraph 3.2.4). Check and record the log recorder chart reading at the 0 and 30 db points and the linear recorder chart reading at the 0 and 20 db points as indicated in paragraph 3.2.6. If any of these four readings are off more than 1/2 db (one small chart division) the appropriate corrections should be made. Next, turn the detector

meter switch to the REF position. Read and record the I. F. amplifier, detector, and amplifier integrator unit currents (No. 1, 2, and 3 respectively) from the panel meter.

4.6 Second Daily Calibration

If any adjustments were made to the ZERO ADJUST or RANGE ADJUST recording meter controls under 4.4, or if 0 db reference on the A (or B) rack detector meter did not correspond to 0 db reference on the C rack detector meter or if any adjustment of the A (or B) rack I. F. amplifier was necessary to correct the diode factors, a second chart calibration should be made. All I. F. amplifier adjustments on the A (or B) rack or C rack should be made prior to the second calibration and then the calibration made (paragraph 3.2.7).

4.7 Recording

All switches should now be put back in the record position (see paragraph 3.2.8).

5. Miscellaneous Information

5.1 Connection to A or B Rack

Since the log-linear recorder will operate with either the A or B rack but not both simultaneously, it is necessary to change back and forth from one to the other to obtain distribution information on all eight frequencies. So that all stations will record on the same frequencies simultaneously, the log-linear recorder should be connected to the A rack on the first Monday after January 1 and then switched to the opposite rack each Monday thereafter throughout the year. Thus, on the first, third, fifth, etc. Monday of the year, the C rack will be connected to the A rack while on the second, fourth, sixth, etc. Mondays of the year, the C rack will be switched over to operate with the B rack. In this way, at least fourteen days of operation should be obtained on each frequency each month. In changing the operation of the C rack from the A to B rack or the B to A rack, the daily calibration of the power recorder should first be completed (except for resetting the I. F. gain of the rack connected to the C rack). The first daily C rack calibration should be completed (paragraph 4.4) and the log sheet completed (paragraph 4.5). At this point, the C rack input switch and the log-gate timer HIGH-LOW switch should both be turned to correct position for the following week's recording. When this is done, the diode factors on the control frequencies (51 kc for the A rack and 2.5 for the B rack) should be rechecked. Even though the output of the A and B racks are connected to the C rack by an isolating resistor, connecting or disconnecting the C rack can cause a change of 0.3 to 0.7 db in the A and B racks. The I. F. gain of the A and B racks should now be adjusted so that the same diode factor is obtained as obtained previously during the daily calibration of the A and B racks. Since this is merely restoring the earlier diode reading, it is not necessary to show any changes on the chart stamp or the calibration summary sheet. The C rack I. F. gain adjustment and chart calibration should be performed as given in paragraph 3.2.7.

5.2 Stamping the Record

After the daily checks and calibration have been completed, the log and linear charts should both be stamped with the station stamp provided for this purpose. The stamp should be placed on the chart in a position as free from data as possible in order to facilitate the reading of both the data and the information recorded on the stamp. After stamping, place a check in the appropriate boxes following L_d (log deviation), V_d (voltage deviation), HF (high frequency, B rack connection), and LF (low frequency, A rack connection). Record the date and approximate time the calibration was made and initial in the space after operator. On Mondays, the chart should be stamped twice. Once when the calibration for the previous week's frequencies has been completed and again after the final calibration of the day for the frequencies to be used during the following week. In this way, the time recorded on the stamp will indicate which stamp refers to which part of the record. When cutting the record over the weekend or holidays, be sure to stamp the day's record on which no calibration was made and fill in the check marks indicating the type of record and whether it was connected to the HF or LF rack. Also, the date the recording was made. If this information is not recorded as the record is cut, the danger of misplacing it in time sequence and losing the type and time information is too great.

5.3 Chart Drive Time Setting

The chart drive STOP-HOUR-MINUTE feed lever is placed in the HOUR position for normal operation. The chart paper can be set to the proper time by advancing the paper or moving it back through the chart drive. The time should be set to correspond with the time on the power recorder charts. Since the chart drives on the power and log-linear recorders are independent spring drive clocks, the chart drive speed may vary between the two. Therefore, it is necessary to check the indicated time on both sets of recorders daily and reset the chart to the correct time if necessary. If one chart drive and/or the other gains or loses each day, the FAST-SLOW adjustment setting should be corrected as indicated in the Esterline-Angus recorder handbook.

5.4 Tube Checks

As with the ARN-2 power recorder, all of the tubes in the C rack should be checked at least once every three months. If the tube has been checked and the G_m noted or if the tube is a replacement during the three-month period with its G_m recorded at the time of replacement, it is not necessary to recheck during the regular tube check. Any tube whose G_m value has dropped to 85% of the design value or less must be replaced in order to achieve proper operation of the equipment.

5.5 Detector Meter Scales

Some confusion has been encountered in reading the value obtained from the combination of the detector meter reading and the scale factor indicated by the detector meter switch. The divisions on the detector meter are indicated as db above reference, while the scale factors indicated by the detector meter switch are in db below reference. For this reason, it is necessary to subtract the scale factor from the meter reading to obtain the correct reading in db's from reference. The following examples illustrate this. If the meter reading is +8 and the scale factor is 0, then the reading is +8 -0 = +8 db or 8 db above reference. If the meter reading is +8 and the scale factor is 40, then the reading is +8 -40 = -32 or 32 db below reference. If the meter reading is -4 and the scale factor is 0, then the reading is -4 -0 = -4 or 4 db below reference. If the meter reading is -4 and the scale factor is 20, the reading is -4 -20 = -24 or 24 db below reference. Unfortunately, because of a combination of meter scale limitations, it is impossible to read any value between 6 and 10 db below reference, 26 and 30 db below reference, and 46 and 50 db below reference.

5.6 Log-Gate Timer Setting

The red hand on the timer should always be set for a four-minute delay. The timer settings are indicated for 60 cycle operation. Therefore, if the line voltage supply is 60 cycle, set the red hand at the four-minute mark. If the line voltage supply is 50 cycle, the red hand should be set at three minutes forty seconds. This four-minute delay in some cases may prevent a reading from being taken that could have been obtained with a 2-1/2 or three-minute setting of the log-gate timer. However, if the power recorder is recording atmospheric noise, the following time sequence should take place. The attenuator will step up for as long as three minutes after a frequency change (usually a shorter period of time is required for the attenuator to reach the proper level if the noise is atmospheric in origin). At the end of the three minutes, the attenuator programer will step up an additional

6 or 8 db (depending on whether it is the B or A rack attenuator). If the attenuator was at the correct level before the attenuator programer stepped up the attenuator, it will have to step down a maximum of 8 db, or possibly during sunrise periods 10 db. The time required for this including the possible four minutes for the last step should not be more than seven minutes. This then under extreme conditions leaves five minutes from the last step to the end of the recording period, which is ample time to get a valid log and linear reading. During periods of sunrise and sunset when the average power is changing at the greatest rate, a change of more than 10 to 12 db per hour would not be expected on any frequency. On the basis of a linear change with time,

$\frac{10}{15}$ or $\frac{12}{15}$ of a db change would be the maximum change expected in atmospheric noise power in a four-minute period. This is not enough to ordinarily step the attenuator again in the four minutes if it is within 1 db at the beginning of the four-minute period. On the other hand, if the noise is man-made in origin or signal, it can and very probably will change more than the 1 db in a four-minute period, thus causing the attenuator to step and preventing an erroneous reading from being taken. While it is true, especially during periods of local thunderstorm activity, that some valid readings will be lost, it is felt that this will be a small percentage of the nonvalid readings that will be eliminated. Thus, the method of operation is felt to be worthwhile.

6. Records Processing of Log and Voltage

6.1 General

General instructions relating to mailing, tabulating, and frequency identification of the noise power records (ARN-2 manual, pages 100-101) should be followed in processing log and voltage records. Tabulation sheets should carry the designation "Log" or "Voltage" under "TYPE OF MEASUREMENT."

6.2 Editing before Scaling

Before scaling log or voltage charts, check them against the power record, and mark sections of the recording made during periods when the power equipment is not operating normally. These sections should not be scaled.

6.3 Scaling

Operating with the four-minute timer setting, the record is likely to show a single spike, in which case read (to the nearest half db) the point of greatest deviation from chart zero. This is actually a negative value (db below the power level), but the sign of the deviation should not be recorded on the tabulation sheet. If there is more than one spike, use the average of the point readings. When a point reading is not obtained, but rather a trace of varying amplitude, record the average value of the varying portion. The greatest deviation (20 or 30 db) side of both the log and voltage charts may be distorted by noise generated in the first I. F. amplifier. It is, therefore, necessary to check the values placed on the chart at the daily calibration, both at the beginning and end of the period, before scaling any values. Observe the point at which the calibration values depart from the scale values by more than one-half db. Any values read at deviations greater than this must be scaled using the calibration scale instead of the chart lines. Ordinarily there will be only a few readings falling in this category. If successive calibrations show differences of more than 1 db for corresponding points on the chart scale, the data between these calibrations should be discarded. When using the calibration scale, use the day's calibration for the record from the preceding midnight to the following midnight. For days when no calibration is made, use the previous calibration approximately half way through the period of no calibration and the following calibration for the balance of the period. When two calibrations are made for one day, use the first up to the time it was made and the second from the time it was made.

6.4 Editing after Scaling

After tabulating the hourly values, check the log and voltage tabulation sheets against each other, eliminating data from either log or voltage tabulation if there is not a reading of the other parameter for the same hour and day. For example, if there is a reading of the log at a certain hour but none for the voltage, the log value should be discarded; or if there is a voltage reading but none for the log, discard the voltage reading. The recommended procedure is to place a single red pencil mark through the discarded value. In all cases, the log deviation should be equal to or greater than the voltage deviation for the corresponding interval; if it is not, both values (log and voltage) should be discarded, since an operational fault is indicated.

6.5 Analysis of the Records

After making the checks outlined above, determine a median value of the deviations for the month at each hour (see instructions for determining the median value, ARN-2 Handbook, page 107). These values are then recorded in the "V_{dm}" and "L_{dm}" columns on Form RN-13. The V_{dm} and L_{dm} value recorded should be rounded off to the nearest half db. For example, if the median is found to be 12.2 db, record it as 12.0 db or if the median is 8.4 db, record it as 8.5 db. If the median is 10.25, record this as 10.0 db, and if the median is 10.75, record this as 11.0 db.

6.6 Disposition of Data

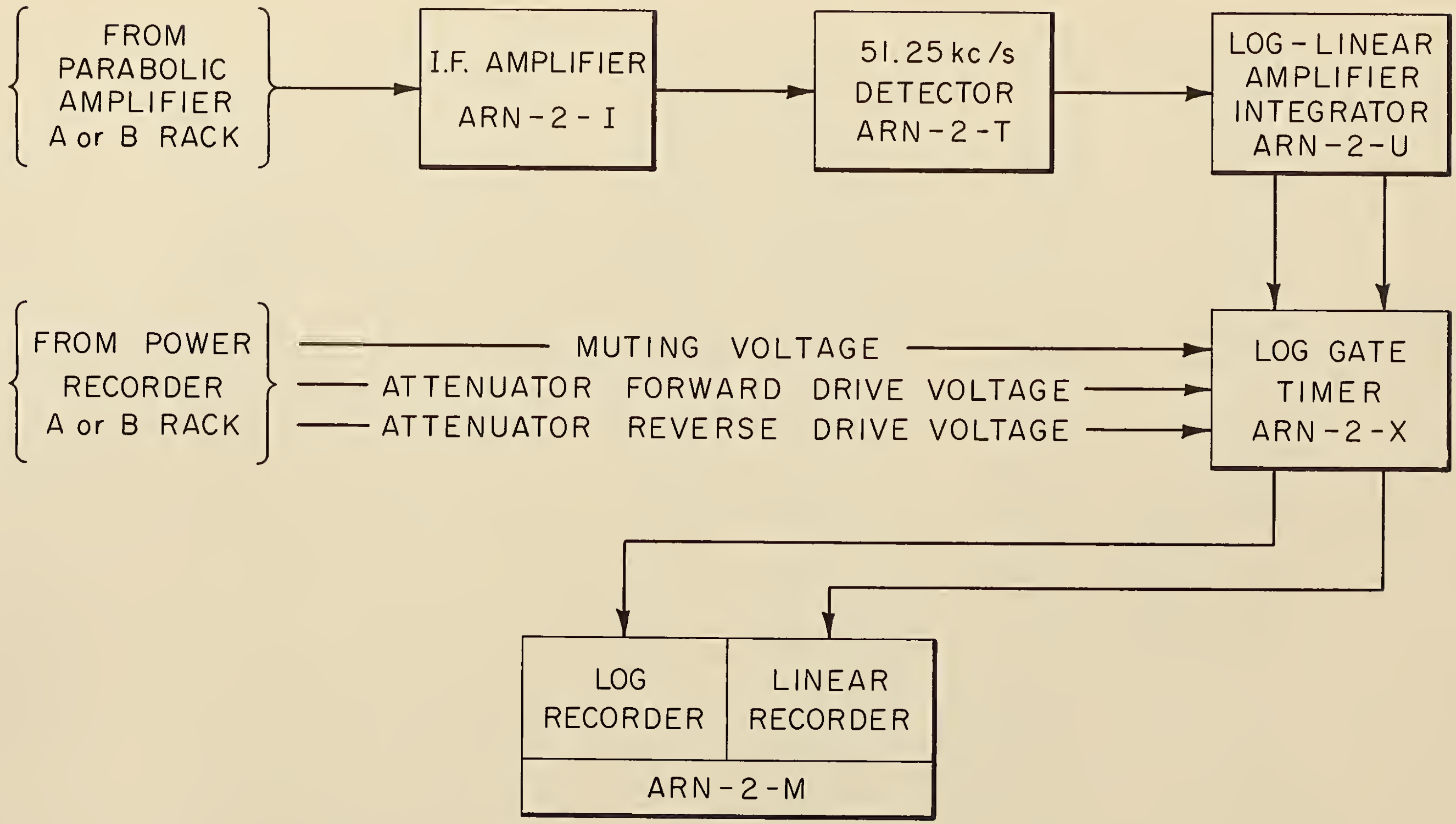
The E-A records and the original copy of the tabulation sheets should be sent to Boulder each month with the power recorder data.

7. References

1. W. H. Ahlbeck, W. Q. Crichlow, R. T. Disney, F. F. Fulton, Jr., and C. A. Samson, "Instruction book for ARN-2 radio noise recorder, serial numbers 1 to 10," January 3, 1958, available from the authors.

2. W. Q. Crichlow, C. J. Roubique, A. D. Spaulding, and W. M. Beery, "Determination of the amplitude-probability distribution of atmospheric radio noise from statistical moments," J. Research NBS, 64-D (Radio Propagation), 49 (1960).

3. A. D. Watt, R. M. Coon, E. L. Maxwell, and R. W. Plush, "Performance of some radio systems in the presence of thermal and atmospheric noise," Proc. IRE, 46, (12), 1914 (1958).



BLOCK DIAGRAM, C RACK
ATMOSPHERIC RADIO NOISE RECORDER
ARN-2 DWG. Nº 83449

Figure 1

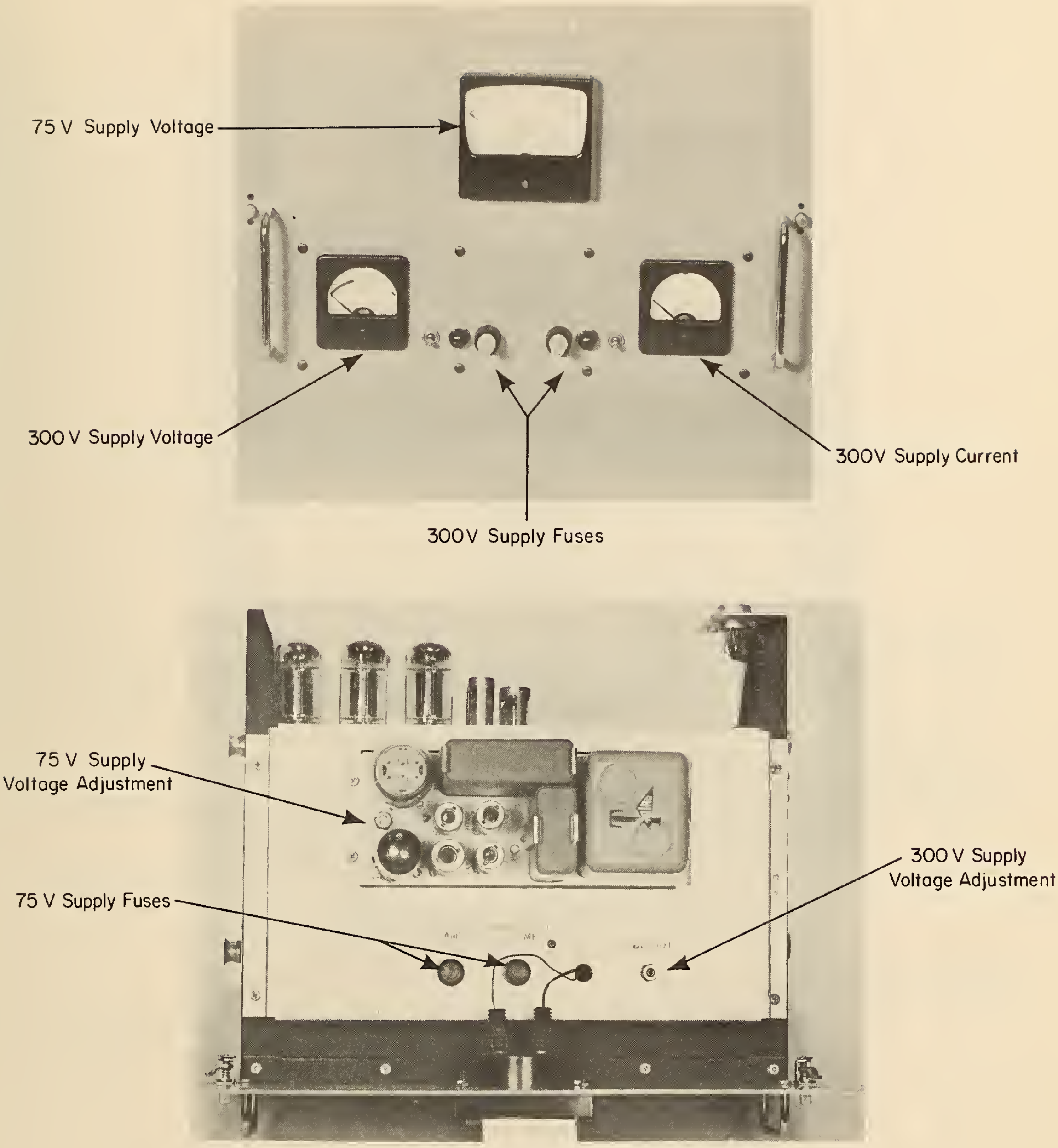


FIG. 2 POWER SUPPLY

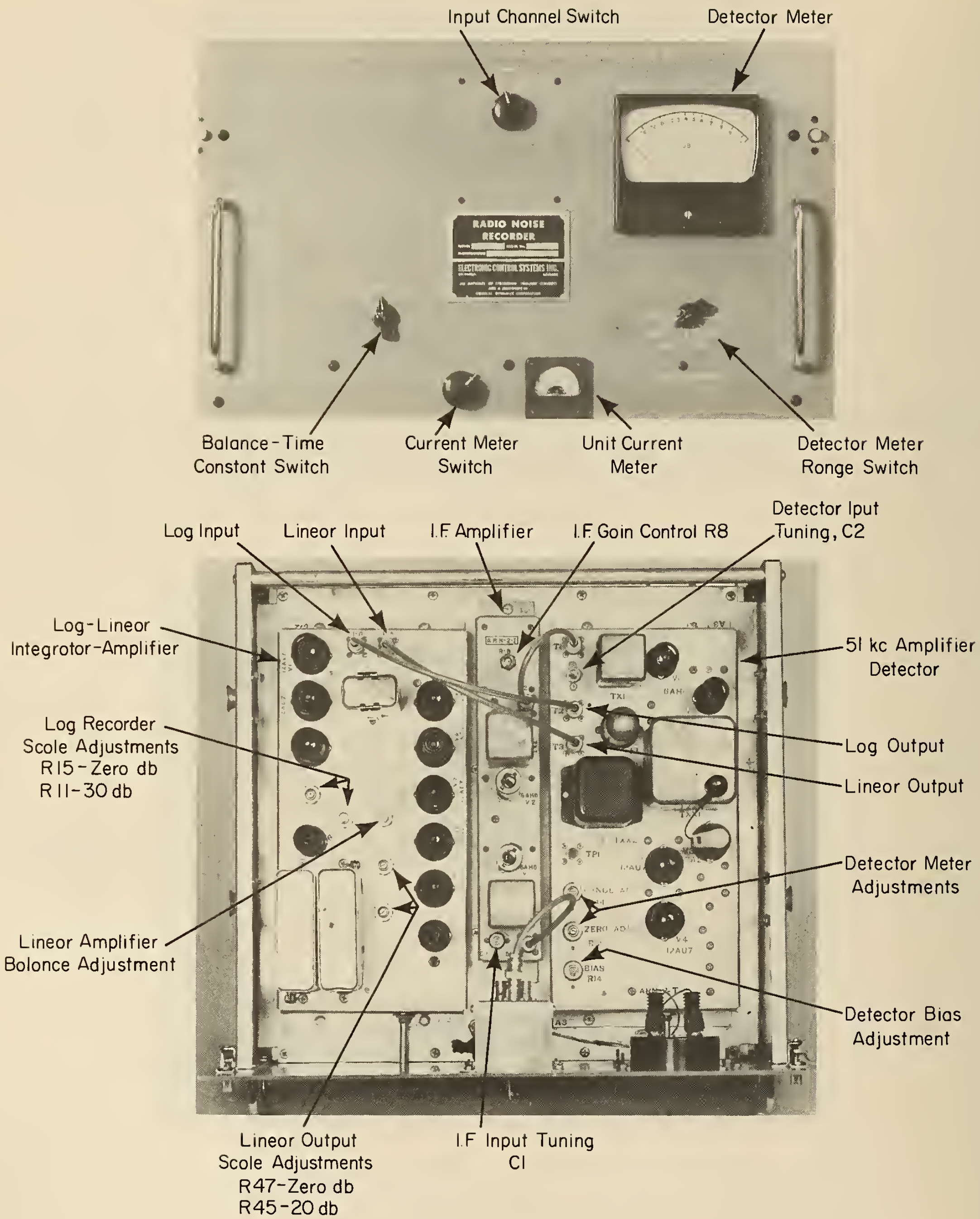


FIG. 3 I.F. AMPLIFIER, DETECTOR, INTEGRATOR

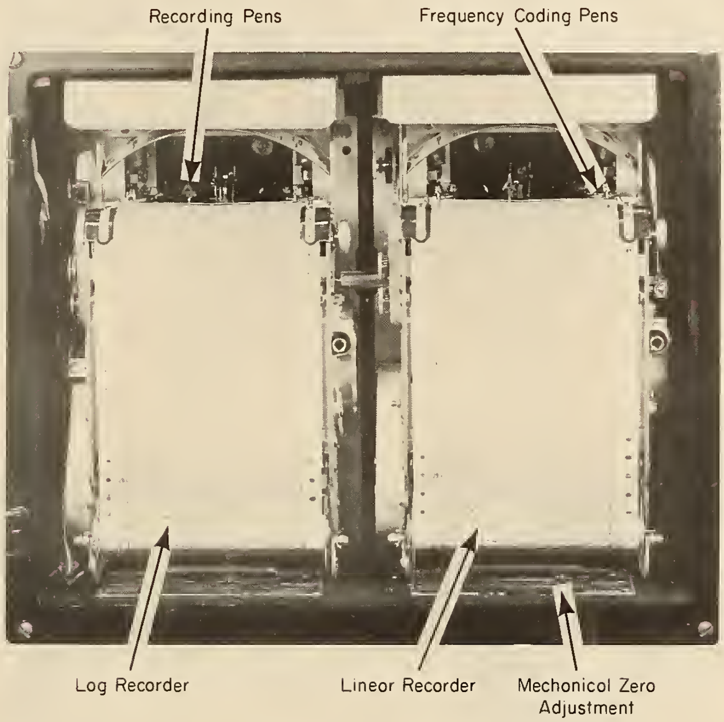


FIG. 4 GRAPHIC RECORDER

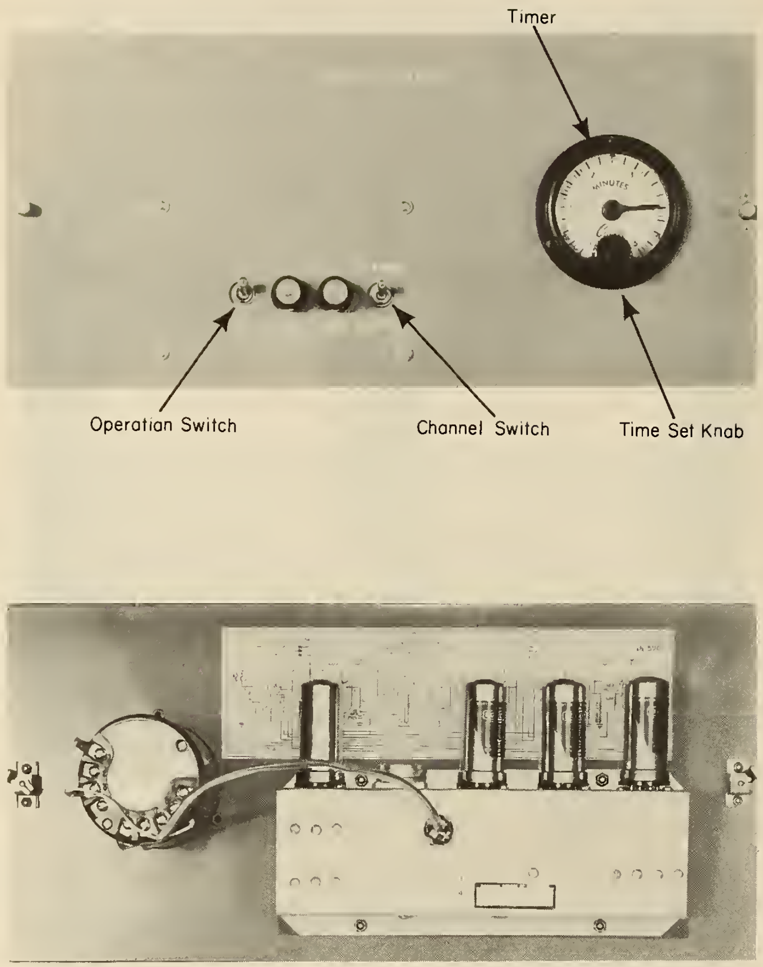


FIG. 5 LOG GATE TIMER

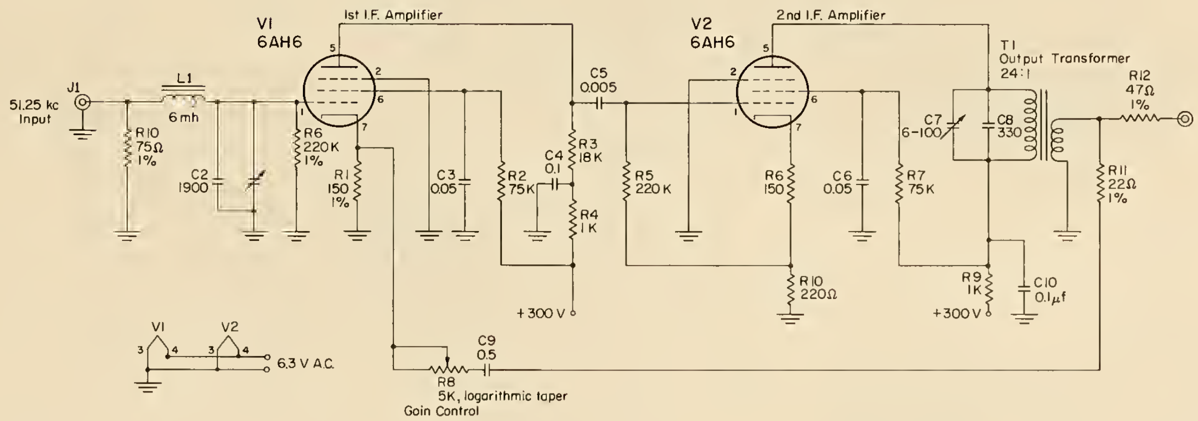


Figure 6

REVISED 10-29-57
REVISED 6-12-57
REVISED 10-16-56

ORIGINAL DATE OF DRAWING			
REVISIONS			
NO	E C N	CHANGE	DATE
1			
2			
3			
4			

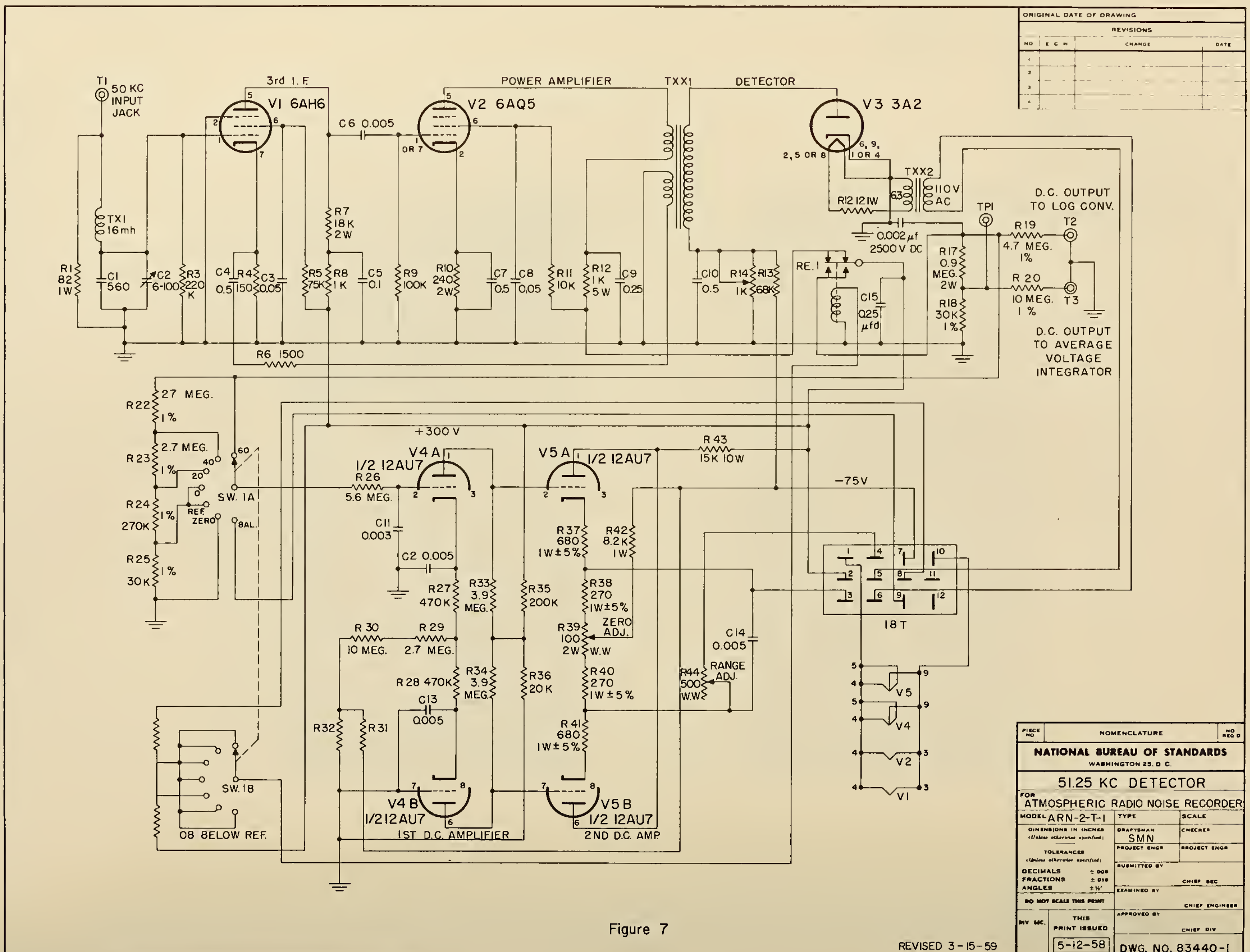
PIECE NO | NOMENCLATURE | NO REQ'D

NATIONAL BUREAU OF STANDARDS
WASHINGTON 25 D C

I.F. AMPLIFIER

FOR ATMOSPHERIC RADIO NOISE RECORDER

MODEL ARN-2-I-I	TYPE	SCALE
DIMENSIONS IN INCHES (Unless otherwise specified)	DRAFTSMAN B.G.B.	CHECKER
TOLERANCES (Unless otherwise specified)	PROJECT ENGR	PROJECT ENGR
DECIMALS ±.005, FRACTIONS ±.010, ANGLES	SUBMITTED BY	CHIEF SEC
DO NOT SCALE THIS PRINT	EXAMINED BY	CHIEF ENGINEER
DIV SEC / THIS PRINT ISSUED	APPROVED BY	CHIEF DIV
83 4 / 8-24-56	DWG. No. 83406	


ORIGINAL DATE OF DRAWING
REVISIONS
NO
E C N
CHANGE
DATE
T1
50 KC
INPUT
JACK
3rd I. F.
V1 6AH6
C6 0.005
POWER AMPLIFIER
V2 6AQ5
TXX1
DETECTOR
V3 3A2
2, 5 OR 8
6, 9, 1 OR 4
TXX2
110V
AC
63
R12 12 1W
0.002 µf
2500 V DC
TP1
D.C. OUTPUT
TO LOG CONV.
R19
4.7 MEG.
1%
T2
R 20
10 MEG.
1 %
T3
R17
0.9
MEG.
2W
R18
30K
1%
D.C. OUTPUT
TO AVERAGE
VOLTAGE
INTEGRATOR
RE. 1
C15
0.25
µfd
TX1
16mh
R1
82
1W
C1
560
C2
6-100
R3
220
K
C4
0.5
R4
150
C3
0.05
R5
75K
R7
18K
2W
R8
1 K
C5
0.1
R9
100K
R10
240
2W
C7
0.5
C8
0.05
R11
10K
R12
1K
5 W
C9
0.25
C10
0.5
R14
1K
R13
68K
R6 1500
27 MEG.
R22
1 %
2.7 MEG.
R23
1 %
R24
1 %
270K
R25
1 %
30K
40
60
20
0
SW. 1A
REF
ZERO
BAL.
+300 V
V4 A
1/2 12AU7
R 26
5.6 MEG.
C11
0.003
C2 0.005
R27
470K
R33
3.9
MEG.
R35
200K
R 30
10 MEG.
R 29
2.7 MEG.
R34
3.9
MEG.
R36
20 K
R 28 470K
C13
0.005
R32
R31
SW. 1B
08 BELOW REF.
V4 B
1/2 12AU7
1ST D.C. AMPLIFIER
V5 A
1/2 12AU7
R 43
15K 10W
-75V
R37
680
1W ± 5%
R42
8.2K
1W
R38
270
1W ± 5%
R39
100
2W
W.W
ZERO
ADJ.
R40
270
1W ± 5 %
R41
680
1W ± 5%
C14
0.005
R44
500
W.W
RANGE
ADJ.
V5 B
1/2 12AU7
2ND D.C. AMP
18 T
V5
V4
V2
V1
PIECE NO
NOMENCLATURE
NO REQ D
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D. C.
51.25 KC DETECTOR
FOR ATMOSPHERIC RADIO NOISE RECORDER
MODEL ARN-2-T-1
TYPE
SCALE
DIMENSIONS IN INCHES (Unless otherwise specified)
DRAFTSMAN
SMN
CHECKER
PROJECT ENGR
PROJECT ENGR
TOLERANCES (Unless otherwise specified)
DECIMALS ± .005
FRACTIONS ± .016
ANGLES ± ½°
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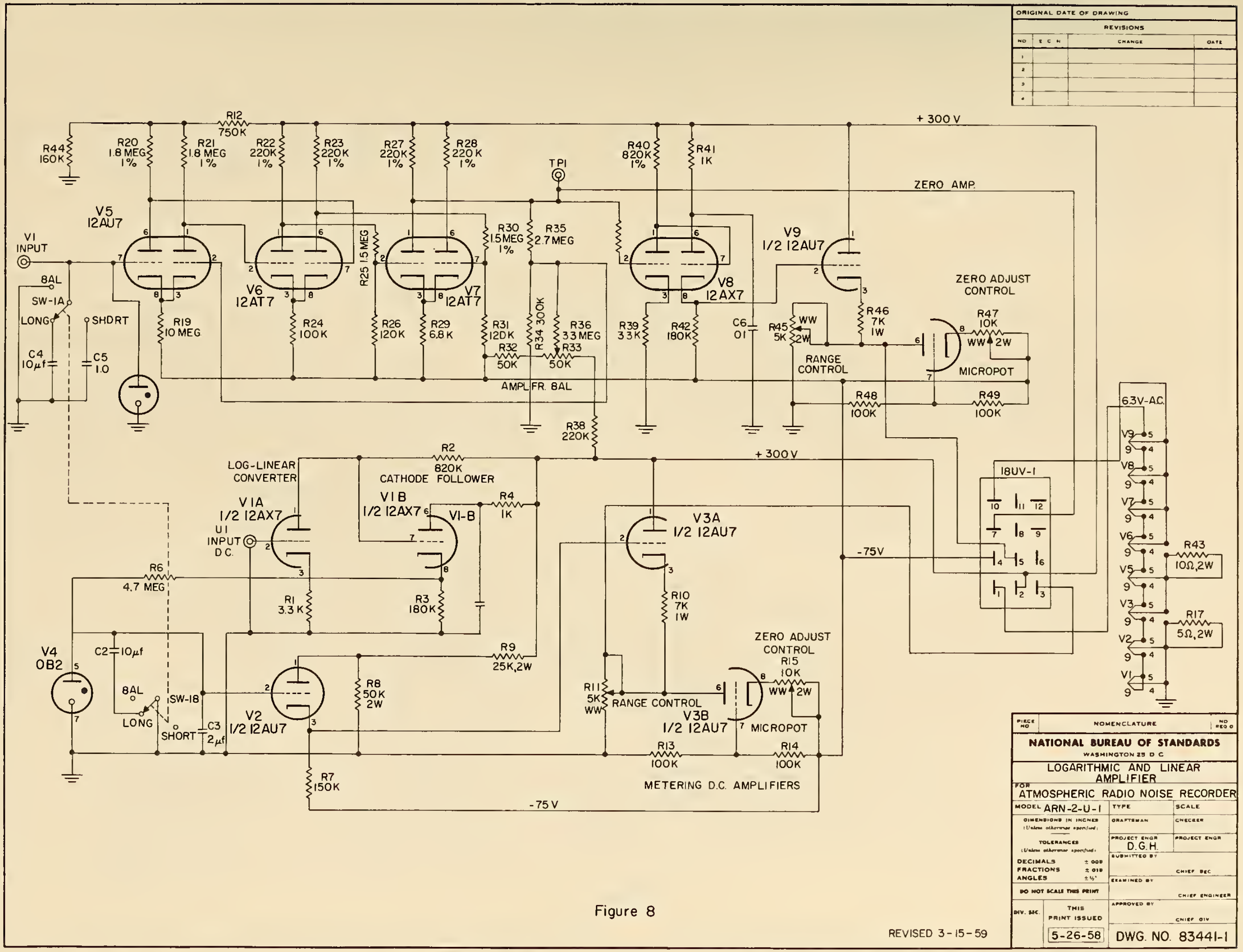
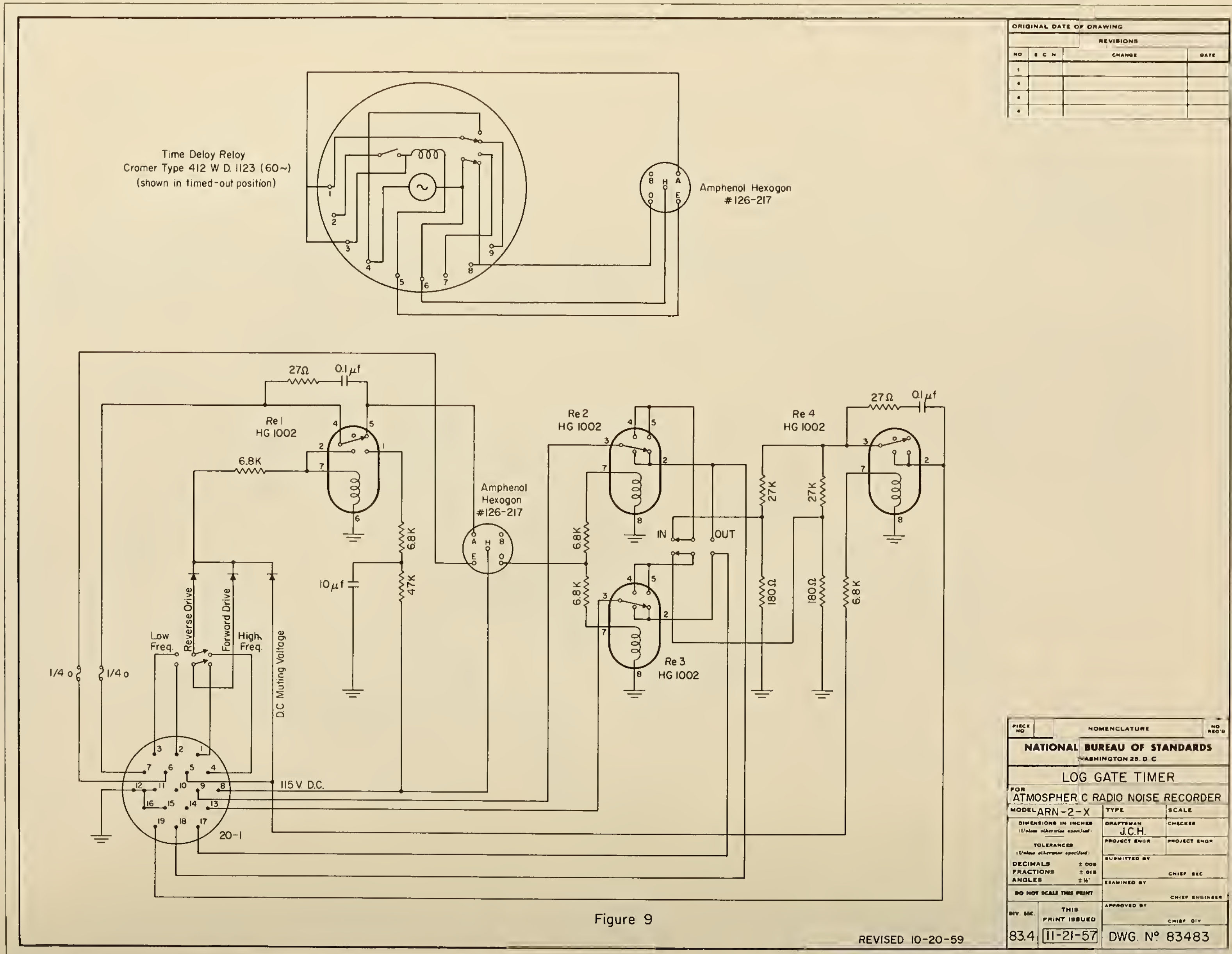
REVISED 3-15-59

Figure 7



V1 INPUT
8AL
SW-1A
LONG
SHDRT
C4 10µf
C5 1.0
R44 160K
R20 1.8 MEG 1%
R21 1.8 MEG 1%
R12 750K
R22 220K 1%
R23 220K 1%
R27 220K 1%
R28 220K 1%
R40 820K 1%
R41 1K
+ 300 V
V5 12AU7
R19 10 MEG
V6 12AT7
R24 100K
R25 1.5 MEG
R26 120K
V7 12AT7
R29 6.8K
R30 1.5MEG 1%
R31 120K
R32 50K
R34 300K
R35 2.7MEG
R36 3.3 MEG
R33 50K
TP1
AMPLFR. 8AL
ZERO AMP.
V8 12AX7
R39 3.3K
R42 180K
C6 .01
V9 1/2 12AU7
R45 5K WW 2W
R46 7K 1W
RANGE CONTROL
ZERO ADJUST CONTROL
R47 10K WW 2W
MICROPOT
R48 100K
R49 100K
6.3V-AC.
R38 220K
R2 820K
+ 300 V
LOG-LINEAR CONVERTER
CATHODE FOLLOWER
V1A 1/2 12AX7
V1B 1/2 12AX7
V1-B
R4 1K
U1 INPUT D.C.
R1 3.3K
R3 180K
R6 4.7 MEG
V3A 1/2 12AU7
-75V
18UV-1
R43 10Ω,2W
R17 5Ω,2W
R10 7K 1W
V4 OB2
C2 10µf
8AL
LONG
SW-1B
SHORT
C3 2µf
V2 1/2 12AU7
R8 50K 2W
R9 25K,2W
R7 150K
R11 5K WW
RANGE CONTROL
V3B 1/2 12AU7
ZERO ADJUST CONTROL
R15 10K WW 2W
MICROPOT
R13 100K
R14 100K
METERING D.C. AMPLIFIERS
-75 V
V9 V8 V7 V6 V5 V3 V2 V1
ORIGINAL DATE OF DRAWING
REVISIONS
NO. E C N CHANGE DATE
NOMENCLATURE
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25 D.C.
LOGARITHMIC AND LINEAR AMPLIFIER
FOR ATMOSPHERIC RADIO NOISE RECORDER
MODEL ARN-2-U-1
PROJECT ENGR D.G.H.
DO NOT SCALE THIS PRINT
THIS PRINT ISSUED 5-26-58
DWG. NO. 83441-1
REVISED 3-15-59

Figure 8



Time Deloy Reloy
Cromer Type 412 W D. 1123 (60~)
(shown in timed-out position)
Amphenol Hexogon
#126-217
Re 1
HG 1002
Re 2
HG 1002
Re 3
HG 1002
Re 4
HG 1002
27Ω
0.1 µf
6.8K
47K
10 µf
27K
180Ω
IN
OUT
Low Freq.
Reverse Drive
Forward Drive
High Freq.
D.C Muting Voltage
115 V D.C.
1/4 o
20-1
ORIGINAL DATE OF DRAWING
REVISIONS
NO
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CHANGE
DATE
PIECE NO
NOMENCLATURE
NO REQ'D
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D. C.
LOG GATE TIMER
FOR ATMOSPHER C RADIO NOISE RECORDER
MODEL ARN-2-X
TYPE
SCALE
DIMENSIONS IN INCHES
DRAFTSMAN J.C.H.
CHECKER
TOLERANCES
PROJECT ENGR
DECIMALS ±.005
FRACTIONS ±.015
ANGLES ±½°
SUBMITTED BY
CHIEF SEC
EXAMINED BY
CHIEF ENGINEER
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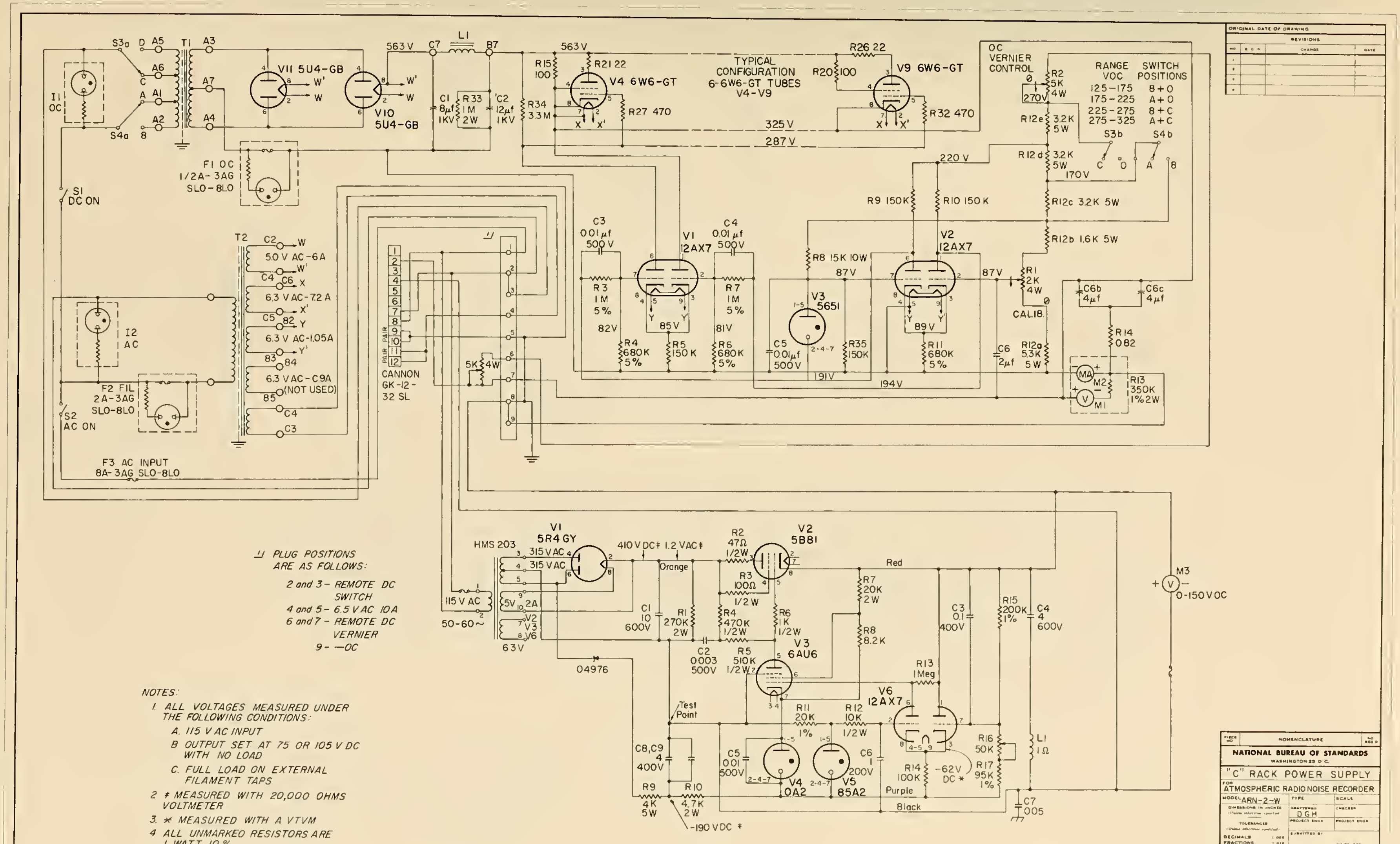
Figure 9



J1 PLUG POSITIONS ARE AS FOLLOWS:
2 and 3 - REMOTE DC SWITCH
4 and 5 - 6.5 V AC 10A
6 and 7 - REMOTE DC VERNIER
9 - —OC
NOTES:
1. ALL VOLTAGES MEASURED UNDER THE FOLLOWING CONDITIONS:
A. 115 V AC INPUT
B. OUTPUT SET AT 75 OR 105 V DC WITH NO LOAD
C. FULL LOAD ON EXTERNAL FILAMENT TAPS
2. ‡ MEASURED WITH 20,000 OHMS VOLTMETER
3. * MEASURED WITH A VTVM
4. ALL UNMARKED RESISTORS ARE 1 WATT, 10 %
5. CAPACITY IS IN MICROFARADS
TYPICAL CONFIGURATION 6-6W6-GT TUBES V4-V9
RANGE VOC / SWITCH POSITIONS
125-175 B+O
175-225 A+O
225-275 B+C
275-325 A+C
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25 D.C.
"C" RACK POWER SUPPLY
ATMOSPHERIC RADIO NOISE RECORDER
MODEL ARN-2-W
DGH
8340
11-20-59
DWG Nº 83445

Figure 10

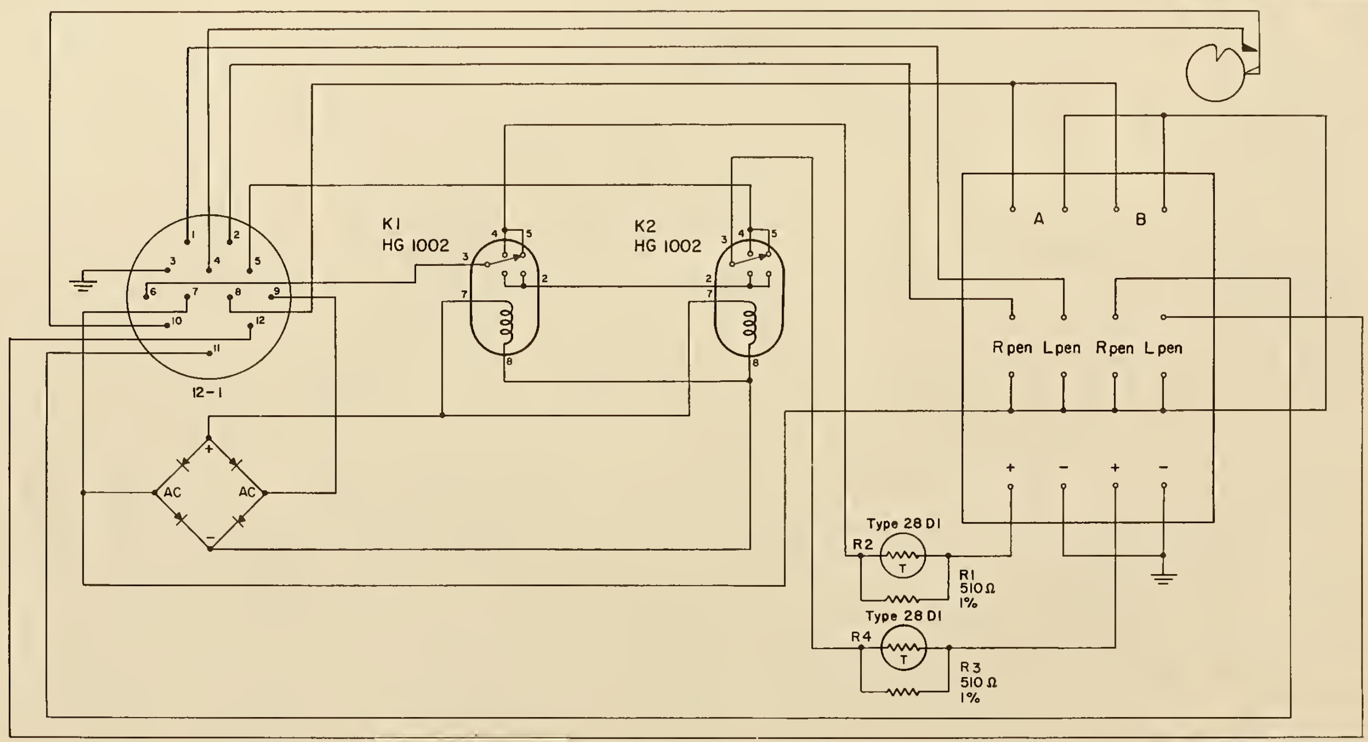


Figure 11

REVISED 11-16-59

ORIGINAL DATE OF DRAWING			
REVISIONS			
NO	E C N	CHANGE	DATE
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4			

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NATIONAL BUREAU OF STANDARDS
WASHINGTON 25 D C

RECORDER TIMER

FOR ATMOSPHERIC RADIO NOISE RECORDER

MODEL ARN-2-M-1 | TYPE | SCALE

DIMENSIONS IN INCHES (Unless otherwise specified) | DRAFTSMAN F.E.W | CHECKER

TOLERANCES (Unless otherwise specified) | PROJECT ENGR | PROJECT ENGR

DECIMALS ± .005
FRACTIONS ± .015
ANGLES ± ½°

SUBMITTED BY — CHIEF SEC

DO NOT SCALE THIS PRINT | EXAMINED BY — CHIEF ENGINEER

DIV. SEC. 83.4 | THIS PRINT ISSUED 8-31-59 | APPROVED BY — CHIEF DIV

DWG. Nº 83443-1

ARN-2 RACK C

TIMER

115 VAC	A	19-1(7)
	8	
115 VDC	O	RELAYS 2, 3
115 VAC	E	19-1(6)
115 VDC	H	19-1(8)

19-1

	1	C-1(11) 115 VDC	*
	2	C-1(13) 115 VDC	*
	3	C-1(12) 115 VOC	*
	4	C-1(10) 115 VOC	*
	5	C-1 (7) 115 VOC	*
TIMER (E)	6	C-1 (6) 115 VAC	
TIMER (A)	7	C-1 (5) 115 VAC	
TIMER (8)	8	C-1 (8) 115 VOC	
20-1(5)EA METER	9		
	10		
	11	GNO	
GNO	12	23-1(9)	
20-1(6)EA METER	13		
	14		
	15	GNO	
	16	GNO	
	17	21-1(8)EA METER	
	18	21-1(7)EA METER	
	19	23-1(2)300 VOC	

20-1

	1	20-1(11) 115 VAC	
	2	20-1(12) 115 VAC	
	3	GNO	
	4		
	5	19-1(9)	
	6	19 1(13)	
EA LIGHTS	7	23-1(7) 115 VAC	
EA LIGHTS	8	23-1(8) 115 VAC	
	9		
	10		
20-1(1)	11	21-2(6) 115 VAC	*
20-1(2)	12	21-2(5) 115 VAC	*

21-I

21-UV(11)	1	21-T(1) 6.3 VAC
	2	GNO
	3	21-SWA(1)300 VOC
	4	

21-SWA

1	21-I(3)		
2	21-T(2)		
3			
4			
5			METER +
7		6	18-1(2)
8			300 VOC
9			
10			
11	METER -		
12	21-UV(2)		

21-1

21-T(1)	1	FIL. 6.3 VAC
21-SWA	2	23-1(2) 300 VOC
	3	
21-T(7)	4	23-1(4) -75 VOC
21-T(5)	5	23-1(7) 115 VAC
21-T(6)	6	23-1(8) 115 VAC
19-1(18)	7	21-UV(5)EA METER
19-1(17)	8	21-UV(3)EAMETER
	9	
	10	GND
21-T(8)	11	C-1(7) 115 VOC
	12	

21-UV

1	21-1(1) 6.3 VAC
2	21-SWA(12)300VDC
3	21-1(8) EA METER
4	21-T(7) -75 V
5	21-T(7)EAMETER
6	
7	21-T(9) BAL.
8	
9	
10	GND
11	
12	

21-T

21-I(1)	1	21-1(1) 6.3 VAC
	2	21-SWA(2)300 VOC
08 METER	3	
08 METER	4	
	5	21-1(5) 115 VAC
	6	21-1(6) 115 VAC
21-UV(4)	7	21-1(4) -75 VOC
	8	21-1(11) 115 VOC
	9	21-UV(7) BAL.
	10	GNO
	11	
	12	

21-2

21-SW8-1(1)	1	C-1(15) 115 VAC	*
21-SW8-2(1)	2	C-1(18) 115 VAC	*
21-SW8-1(2)	3	C-1(16) 115 VAC	*
21-SW8-2(2)	4	C-1(19) 115 VAC	*
21-SW8-1(3)	5	20-1(12) 115 VAC	*
21-SW8-2(6)	6	20-1(11) 115 VAC	*
	7		
	8		
	9		
	10		
	11		
	12		

CHANNEL SW 21-SWB-1

1	21-2(1) 115 VAC	3	21-2(5)
2	21-2(3) 115 VAC		

CHANNEL SW 21-SWB-2

4	21-2(2) 115 VAC	6	21-2(6)
5	21-2(4) 115 VAC		

C-1

	1	20-1(7)
	2	21-1(6)
	3	21-1(5)
	4	20-1(8)
	5	19-1(7) 23-1(7) 115 VAC
	6	19-1(6) 23-1(8) 115 VAC
*	7	19-1(5) 21-1(11) 115 VDC
	8	19-1(8) 115 VOC
	9	
*	10	19-1(4) 115 VOC
*	11	19-1(1) 115 VOC
*	12	19-1(3) 115 VDC
*	13	19-1(2) 115 VOC
	14	
*	15	21-2(1) 115 VAC
*	16	21-2(3) 115 VAC
	17	
*	18	21-2(2) 115 VAC
*	19	21-2(4) 115 VAC

23-1

	1	
19-1(19) 21-1(2)	2	300 VOC
	3	
21-1 (4)	4	-75 VOC
	5	
	6	
20-1(7) 21-1(5)	7	C-1(5) 115 VAC
20-1(8) 21-1(6)	8	C-1(6) 115 VAC
19-1(12)	9	GNO
	10	GNO
BUSS BAR	11	FIL 6.3 VAC
BUSS BAR	12	FIL 6.3 VAC

METER SWITCH CONTACTS CHECKED IN CLOCKWISE ROTATION

VOLTAGES MARKED WITH AN ASTERICK
APPEAR ONLY DURING THE SWITCHING CYCLE
OR ATTENUATOR OPERATION

Figure 12

PIECE NO	NOMENCLATURE		NO REQ'D
NATIONAL BUREAU OF STANDARDS WASHINGTON 25 D C			
CABLE DIAGRAM			
FOR ATMOSPHERIC RADIO NOISE RECORDER			
MODEL ARN-2-1	TYPE		SCALE
DIMENSIONS IN INCHES (Unless otherwise specified)	DRAFTSMAN S M N.		CHECKER
TOLERANCES (Unless otherwise specified)	PROJECT ENGR		PROJECT ENGR
DECIMALS ± .005 FRACTIONS ± .015 ANGLES ± ½°	SUBMITTED BY CHIEF SEC		
DO NOT SCALE THIS PRINT	EXAMINED BY CHIEF ENGINEER		
DIV. SEC.	THIS PRINT ISSUED 12-17-59	APPROVED BY CHIEF DIV	
		DWG. NO. 83452-C	

LOG CHART

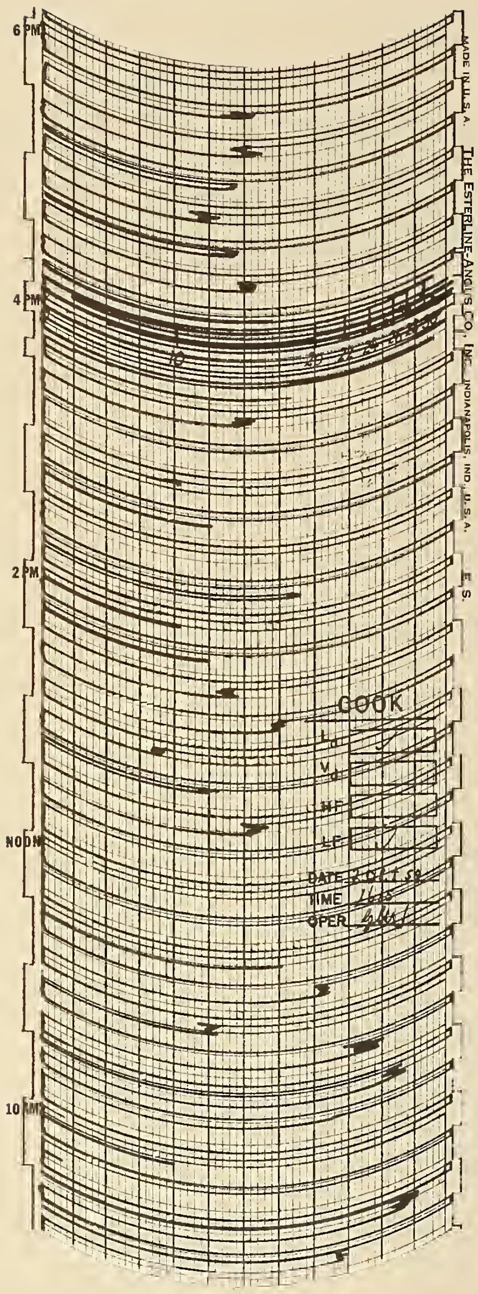


Figure 13

VOLTAGE CHART

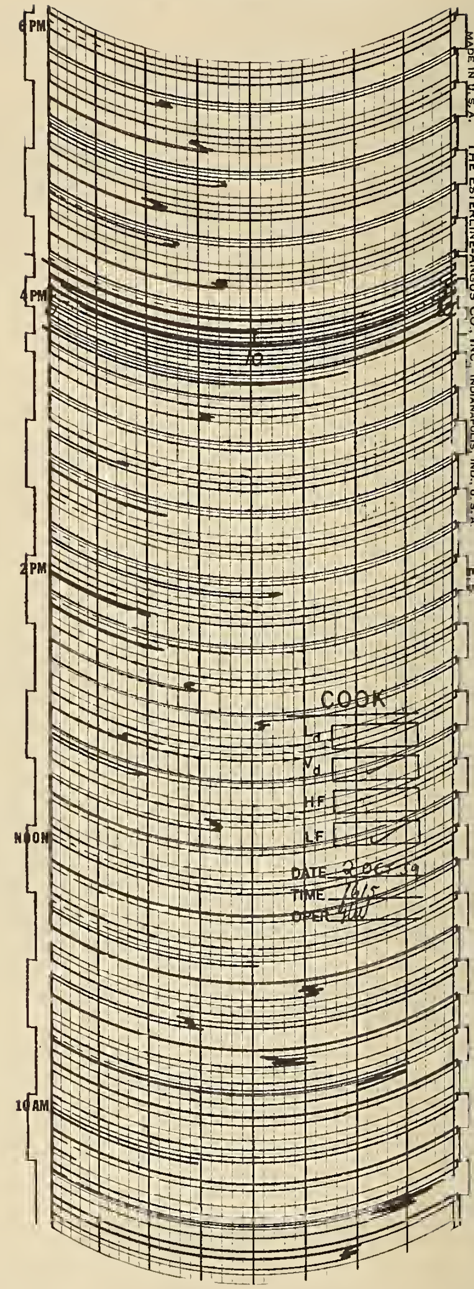
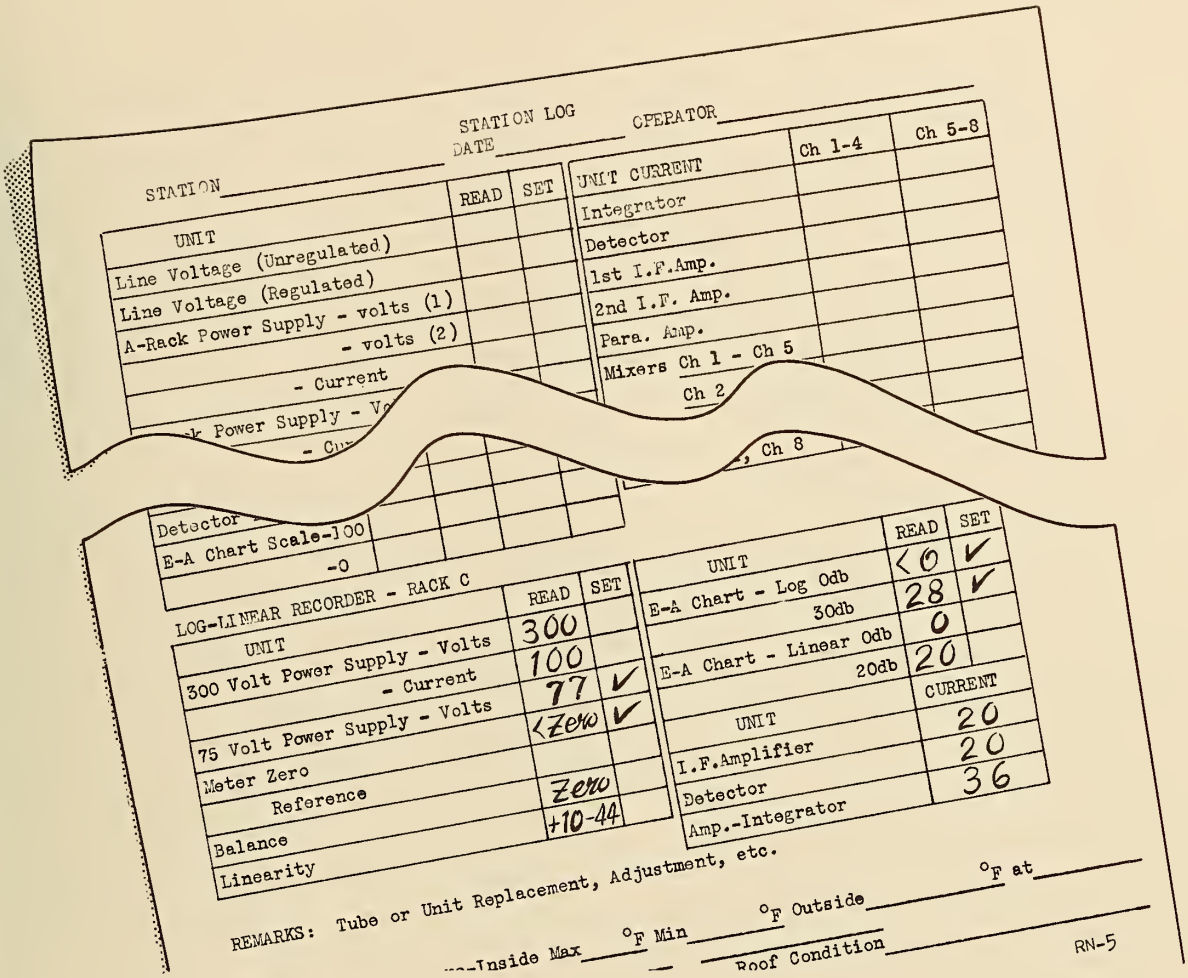


Figure 14



TYPICAL VALUES ON DAILY LOG SHEET

Figure 15

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

NBS