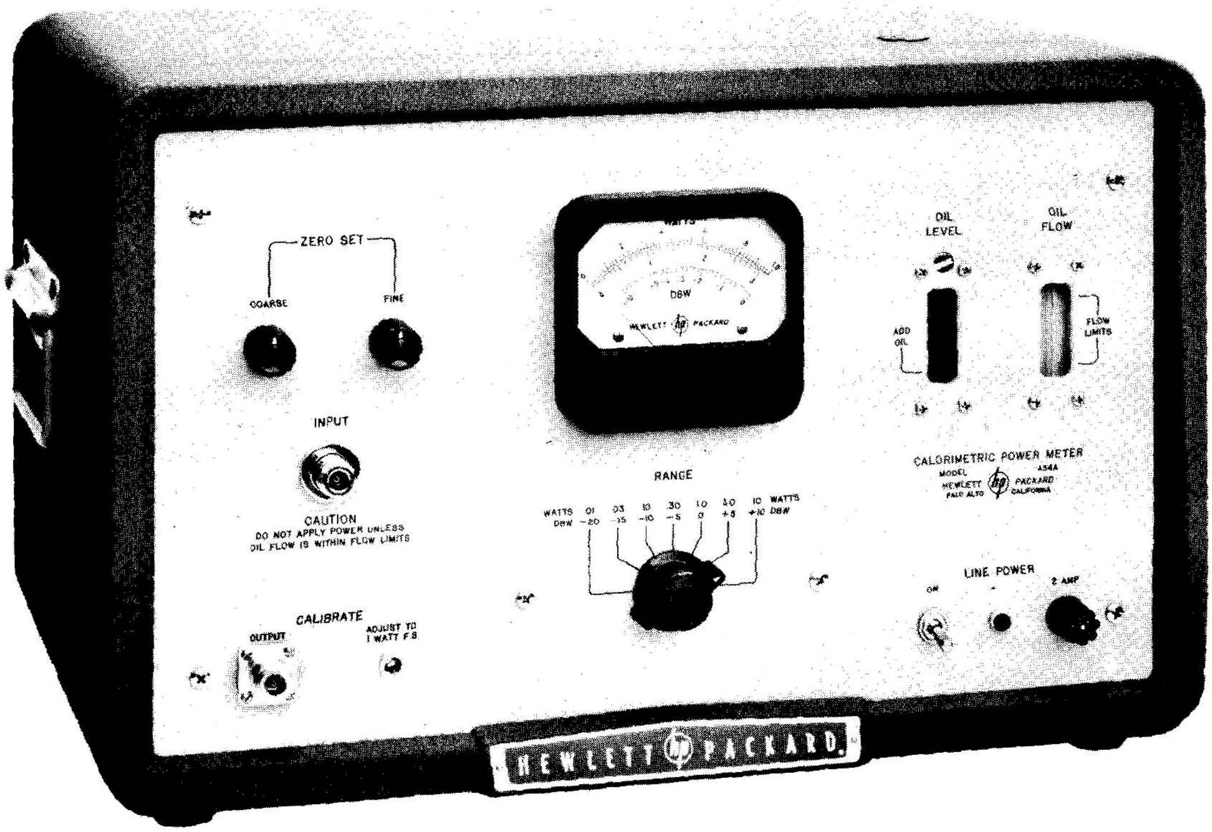
OPERATING AND SERVICING MANUAL

MODEL 434A
CALORIMETRIC POWER METER

SERIAL 151 AND ABOVE



275 PAGE MILL ROAD, PALC ALTO, CALIFORNIA, U.S.A.

434A001-1/9-59

SECTION I
GENERAL DESCRIPTION

1-1 INTRODUCTION

Model 434A is a power meter which bridges the gap between bolometric methods and conventional calorimetric methods while retaining the advantages of both. Bolometric methods of power measurement using the self-balancing principle are fast, but the upper limit of power measurement is quite low (10 to 100 mw). On the other hand, conventional calorimetric methods are slow, and are not suitable at powers less than about 1 watt.

By combining the self-balancing principle with a calorimetric device, fast response has been obtained over the range from 1 milliwatt to 10 watts.

1-2 SPECIFICATIONS

INPUT POWER RANGE:
Seven meter ranges. Full-scale readings of .01, .03, .1, .3, 1.0, 3.0 and 10 watts. Meter scale also calibrated from -10 to 0 DBW, providing continuous readings from -30 to +10 DBW. Power range can be extended upward with attenuators or directional couplers.

PEAK INPUT POWER: 1 kilowatt, maximum.

FREQUENCY RANGE: DC to 12.4 kmc.

DC INPUT IMPEDANCE:
50 ohms ±5 ohms at type N input jack.

INPUT SWR:

DC to 5 kmc:	less than 1.3:1
5 to 10 kmc:	less than 1.5:1
10 to 12.4 kmc:	less than 1.7:1

METER RESPONSE TIME:
Less than 5 seconds for full scale deflection.

ACCURACY:
Within ±5% of full scale. Includes dc calibration and rf loss. Greater accuracy can be achieved through appropriate techniques.

ESTIMATED ATTAINABLE ACCURACY:

	Upper	Two Lowest
DC	Ranges 1/2%	Ranges 2%
0 to 1 kmc	" 1%	" 3%
1 to 4 kmc	" 2%	" 4%
4 to 10 kmc	" 3%	" 5%
10 to 12.4 kmc	" 4%	" 5%

POWER SUPPLY:
115/230 volts ±10%, 50/60 cycles, approximately 155 watts with no input, 175 watts with 10 watts input.

DIMENSIONS:

Cabinet Mount:	20-3/4" wide, 12-3/4" high, 14" deep.
Rack Mount:	19" wide, 10-1/2" high, 13-3/8" deep behind panel.

WEIGHT:

Cabinet Mount:	Net 49 lbs, Shipping 71 lbs.
Rack Mount:	Net 44 lbs, Shipping 66 lbs.

1-3 DAMAGE IN TRANSIT

This instrument has been thoroughly tested and is ready for use when received. If any damage is apparent, please refer to the Warranty sheet.

1-4 INSTALLATION

To connect for operation from 230 volts, 50-60 cps, see paragraph 4-4.

Before using this instrument, check the oil level. Add silicone oil as described in paragraph 2-4. Also, since inverting the instrument may wash the oil from the lower motor bearing, lubricate it with several drops of light machine oil.

To assure adequate cooling do not obstruct the ventilating holes in the bottom of the cabinet or the air outlet at the rear of the cabinet.

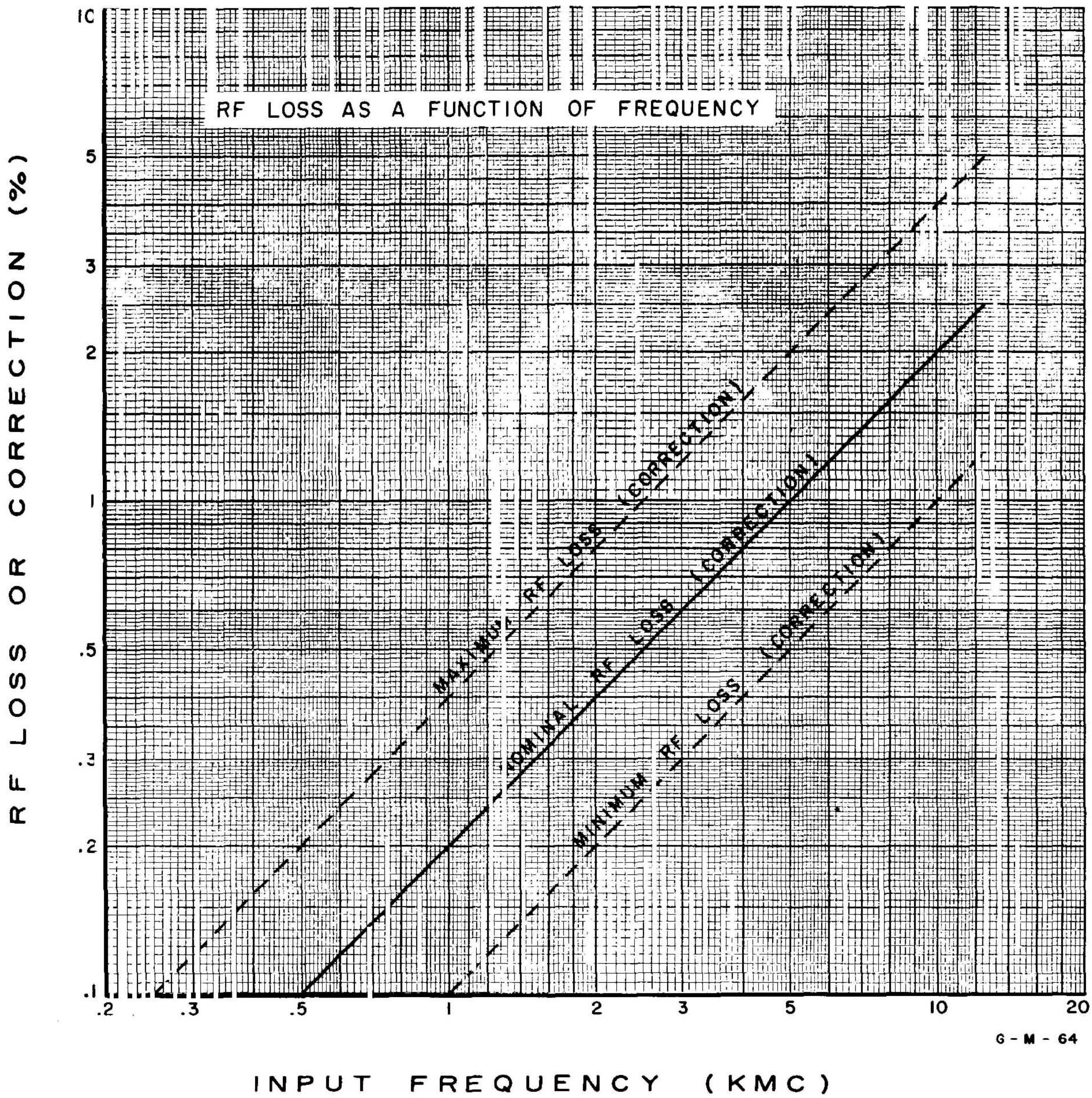


Figure 2-1. RF Loss Showing Probable Limits of Error

ADDITIONAL OPERATING INSTRUCTIONS

ELIMINATING EXCESSIVE NOISE

Air in the oil system may cause excessive noise on the most sensitive range (0. 01 watts). This problem can be eliminated by allowing the instrument to operate for approximately 30 minutes before making measurements on the most sensitive range. If the instrument has been shipped or subjected to vibration, it may take as long as 10 hours of operation to remove the air from the oil system.

INTERNAL CALIBRATOR

A stable transistorized calibrator is included in the instrument. The calibrator produces a fixed dc voltage which develops 100 milliwatts (±1%) into a nominal 50 ohm load. The calibrator is useful for checking the dc calibration of the Power Meter.

Operating Procedure:

1. Turn instrument ON. For maximum stability, allow approximately 30 minutes to warm up.
2. Set RANGE switch to . 10 watt.
3. Adjust ZERO SET controls to zero meter.
4. Connect the INPUT to the CALIBRATE OUTPUT. Meter should indicate . 10 watt.
5. If necessary, adjust the CALIBRATE control (R79) on the panel for an indication of . 10 watt.

Calibrator Maintenance:

The calibrator consists of a stable transistorized regulated dc power supply. Each calibrator is factory adjusted for optimum calibration with the particular instrument. No maintenance should be required.

Do not attempt to change any parts or values unless you have laboratory standards for establishing the output voltage to an accuracy of better than ±0. 1%.

If precision tests indicate the calibrator needs adjustment, we recommend you return the instrument to the factory.

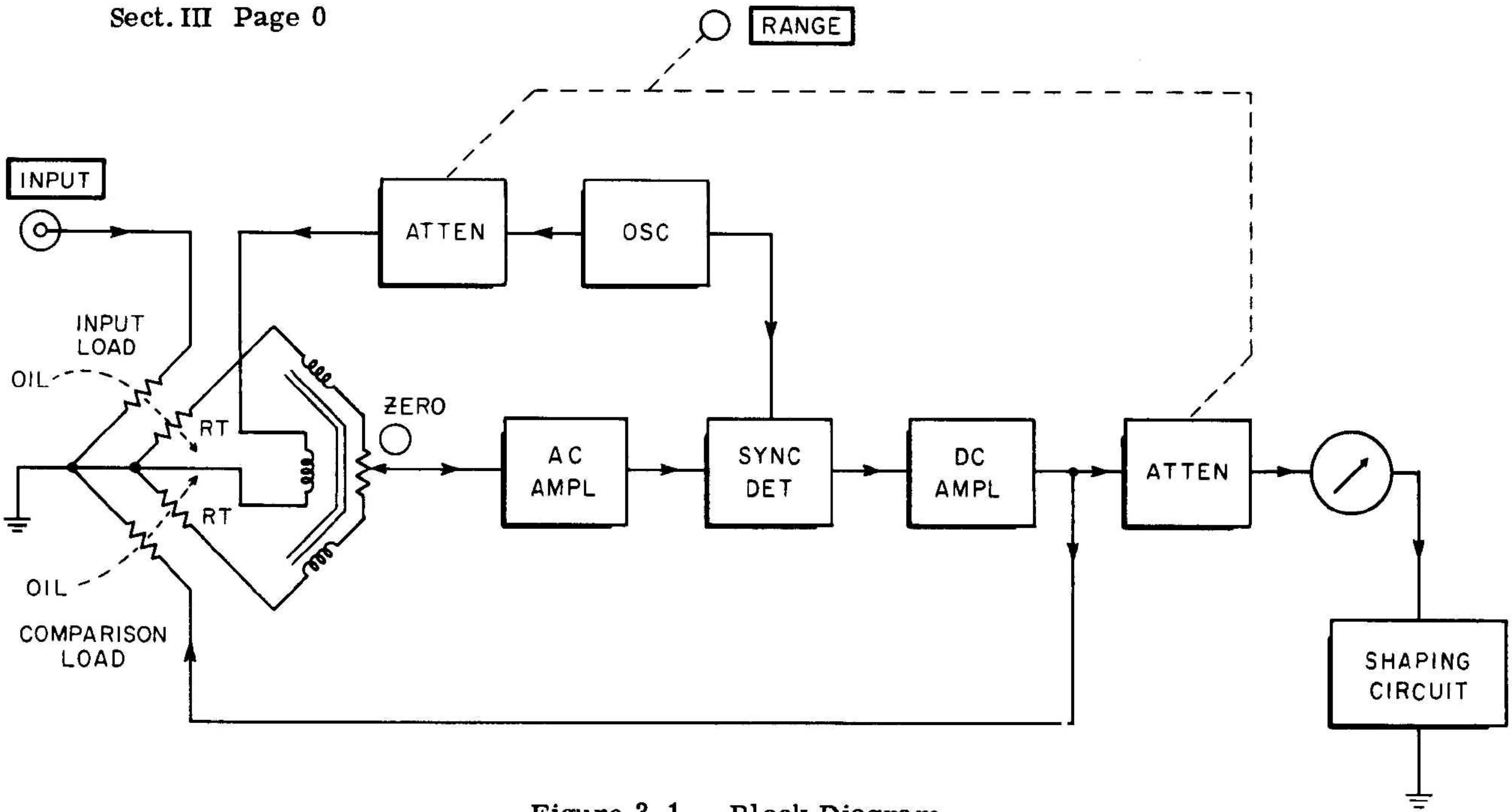


Figure 3-1. Block Diagram

BD-L-122AB

SECTION III
THEORY OF OPERATION

3-1 INTRODUCTION

This section describes the circuit operation of the 434A Calorimetric Power Meter through the use of the Block Diagram, Figure 3-1, and the Schematic Diagram, Figure 4-2. Each major circuit is taken in turn and discussed.

3-2 OVER-ALL OPERATION

Power connected to the INPUT of the ⓗⓟ Model 434A is dissipated as heat in the input load resistor, R1. Silicone oil flows over R1, is heated, and flows downstream to a temperature-sensitive resistance-wire gage which is one leg of the bridge. This load, oil stream, and gage form the input head of the bridge. A similar comparison head contains another load resistor, R2, and a gage which is a second leg of the bridge. The other two legs of the bridge are the secondary windings of transformer T1 driven by an oscillator. With no power to the input head the bridge is balanced with the ZERO SET controls. When power is applied to the input head, the oil stream transfers the heat from the input load to the gage, increasing its resistance and developing a signal at the output of the bridge. This signal is amplified and fed back to the comparison load resistor, heating its oil stream and gage and bringing the bridge back towards balance. The meter monitors feedback voltage and is calibrated directly in input power.

The signal output of each gage in volts is proportional to the power input in watts, so that each head constitutes a square-law element. This does not matter in the case of the input head, but the comparison head is located inside the feedback loop. As a result, the loop gain varies with power level and the ratio of feedback power to input power also varies with level. In changing ranges, the loop gain is adjusted by means of switch S1A so that the gain is the same for each range at any point on the meter scale. Thus, gain is always such that on any range the difference between input and feedback powers is, for example, 2% at full scale, 6% at one-tenth scale, etc. The actual difference between input and feedback power is calibrated out in the meter circuit so that the meter indication is in terms of the input power.

Since the comparison head is a square-law element ($R \propto E^2$), the resistance change of the gage is independent of the phase of the feedback voltage. Consequently, reversing the phase of the bridge output causes positive feedback, and the system runs away. This condition obtains when the ZERO SET controls move the meter pointer below zero. A small amount of positive feedback is necessary so the meter pointer can be brought below zero. Otherwise, zero setting the pointer would be difficult. The synchronous detector restores phase sensitivity to the system so the positive feedback can be controlled.

DC output polarity of the synchronous detector depends on the relative phase of the two ac voltages applied. Output is positive for the normal phase signal from the bridge; negative if the phase reverses. The dc output of the Synchronous Detector is applied through a two-stage amplifier to a tube biased near cut-off, whose cathode resistor is the comparison load. Thus, only positive voltages from the synchronous detector result in feedback.

3-3 INPUT BRIDGE

The Input Bridge circuit includes the input and comparison load resistors, their gages, the bridge transformer, a Phase Balance control and the zero-set circuit. The Phase Balance control is used to balance out the stray lead inductance and the transformer leakage inductance. The Bridge Balance control is a very coarse zero-set used to adjust for gross unbalance in the bridge so that the COARSE and FINE controls can be set to midpoint in normal operation.

3-4 AC AMPLIFIER, SYNCHRONOUS DETECTOR, AND FILTER

The signal from the bridge is amplified by a conventional ac-coupled amplifier and supplied to the Synchronous Detector. Output of the Synchronous Detector is positive when power is applied to the INPUT, and negative when the bridge is unbalanced in the wrong direction. The Filter is an rc network which shapes the gain characteristic of the feedback loop and smooths out the detector output, so that nearly pure dc is applied to the DC Amplifier. The time constant of the network is 5 seconds, giving a very low cutoff frequency to the loop. This is necessary because of the transit time of the oil between the comparison load and its gage. The transit time introduces into the feedback loop a phase shift which increases linearly with frequency.

When the meter pointer is moved below zero, a negative voltage is developed by the Synchronous Detector. Capacitor C9 (see schematic) tends to charge in the reverse direction. Since there is no feedback when meter pointer is set below zero, the feedback loop is open. In this case the discharge of C9 would cause a long delay between motion of the zero set controls and corresponding movement of the meter pointer upscale. Hence, the diode CR5 shunts C9 limiting its charge and speeding its discharge to assure fast response of the meter.

3-5 DC AMPLIFIER AND CLAMP

The DC Amplifier is composed of V3 and cathode follower V4 and has considerable negative feedback to make it linear. V4 is biased near cutoff when there is no signal from the Synchronous Detector. Thus, V4 supplies power to the comparison load when there is a positive output from the detector, but is driven into cutoff by a negative signal. When the meter is zeroed, a small current flows through V4 and through R35, R36, and R37, but the cathode is at ground potential and no power is dissipated in the comparison load (R2). When V4 is cutoff, its cathode goes below ground and a small current flows in reverse direction from ground through R2, R35, R36, and R37 to the negative supply. This current causes the meter pointer to move below zero. Without this movement there would be no way of telling when the zero-set controls had been moved too far. This is a condition of positive feedback, but the amount of "run-away" is limited by the clamping action of V5. Positive feedback power is never more than a few percent of full scale. The DC Zero control is used to set the meter to zero with no signal from the Synchronous Detector. Following the DC Amplifier is duodiode V5 which performs two clamping functions.

1) One section, (see schematic diagram) in conjunction with an attenuator operated by the range switch, limits the drive to the output cathode follower V4. This clamp prevents damage to the meter circuit if the RANGE switch is set to a sensitive range and applied power is large compared to full scale.

2) The other section of the clamp limits the reverse current in R2 when V4 is cutoff. Hence, the power in R2 (due to the reverse current) is kept to a small percentage of full scale power for each range, simplifying the zero set operation. The clamping action is reduced and then removed on the higher ranges.

3-6 RANGE SWITCH

The RANGE switch, S1, determines the sensitivity of the input bridge, attenuates the signal to the Meter Circuit, and sets the clamping levels of V5. S1A attenuates the drive to the bridge as the range is increased so that the loop gain varies in the same manner on each range as described in paragraph 3-2. S1B and S1C attenuate the signal to the meter so that the input to the Meter Circuit for full-scale deflection can be kept constant. S1D limits the output of V4 to prevent Meter Circuit damage should high power (compared to full scale) be applied to the INPUT. S1E controls the meter swing below zero.

3-7 METER CIRCUIT

Of major importance in the Meter Circuit is the Shaping Circuit. This network reduces the resistance in series with the meter as the voltage to the meter circuit increases to permit a meter scale that is nearly linear in power. The circuit contains four diodes which are biased by a voltage divider from a well-regulated source. As the voltage to the meter circuit increases, the diodes conduct in turn to reduce the resistance of the meter circuit. The difference between an exactly linear characteristic and the approximation actually obtained is calibrated out on the meter face. The calibration also includes the effect of variation in the difference between input and feedback power, as described in paragraph 3-2.

3-8 OSCILLATOR

The Oscillator is a conventional rc oscillator which operates at a fixed frequency of about 1200 cps. Amplitude is stabilized by a nonlinear resistance, RT1. Output voltages from the Oscillator are supplied to the Synchronous Detector and through a section of range switch to the Input Bridge.

3-9 POWER SUPPLY AND VOLTAGE REGULATOR

The Power Supply is a conventional full-wave rectifier and the Voltage Regulator is a series type which regulates for both line and load variations. There is also a half-wave rectifier which supplies -150 v, regulated by a glow discharge tube.

3-10 OIL SYSTEM

The oil-flow system is an important part of the 434A. It transfers the heat from the input load, R1, to its gage and from the comparison load, R2, to its gage. The complete oil flow system is shown in Figure 3-2. Since the flow rate through the heads must be equal, the oil flows in a series path. The pump has more capacity than is required and an oil-flow regulator consisting of a spring-loaded by-pass valve maintains steady flow. Adjusting the valve sets the flow rate to any desired value. The flow indicator is a simple uncalibrated flow meter, used only to show that flow rate is within a range of about 30 to 50 cc per minute. If the flow rate gets too low, the system may oscillate because of excessive phase shift in the feedback loop as discussed in paragraph 3-4 while if flow rate is too high, the noise level of the system increases.

The parallel-flow heat exchanger decreases random variations of temperature along the streams and brings the streams to nearly the same temperature. Reducing temperature variations reduces noise in the system while bringing the stream temperatures together reduces the required zero-set range.

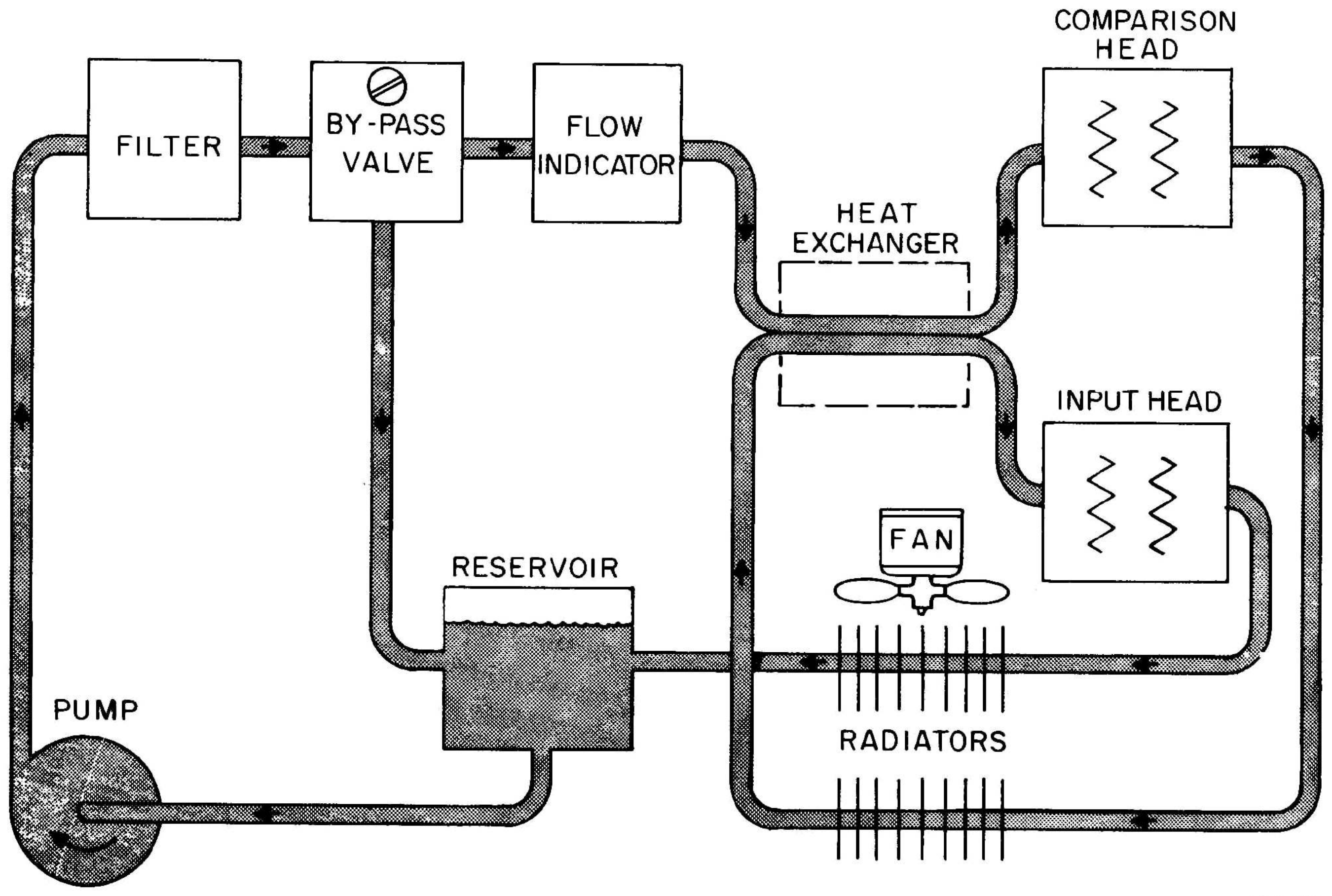
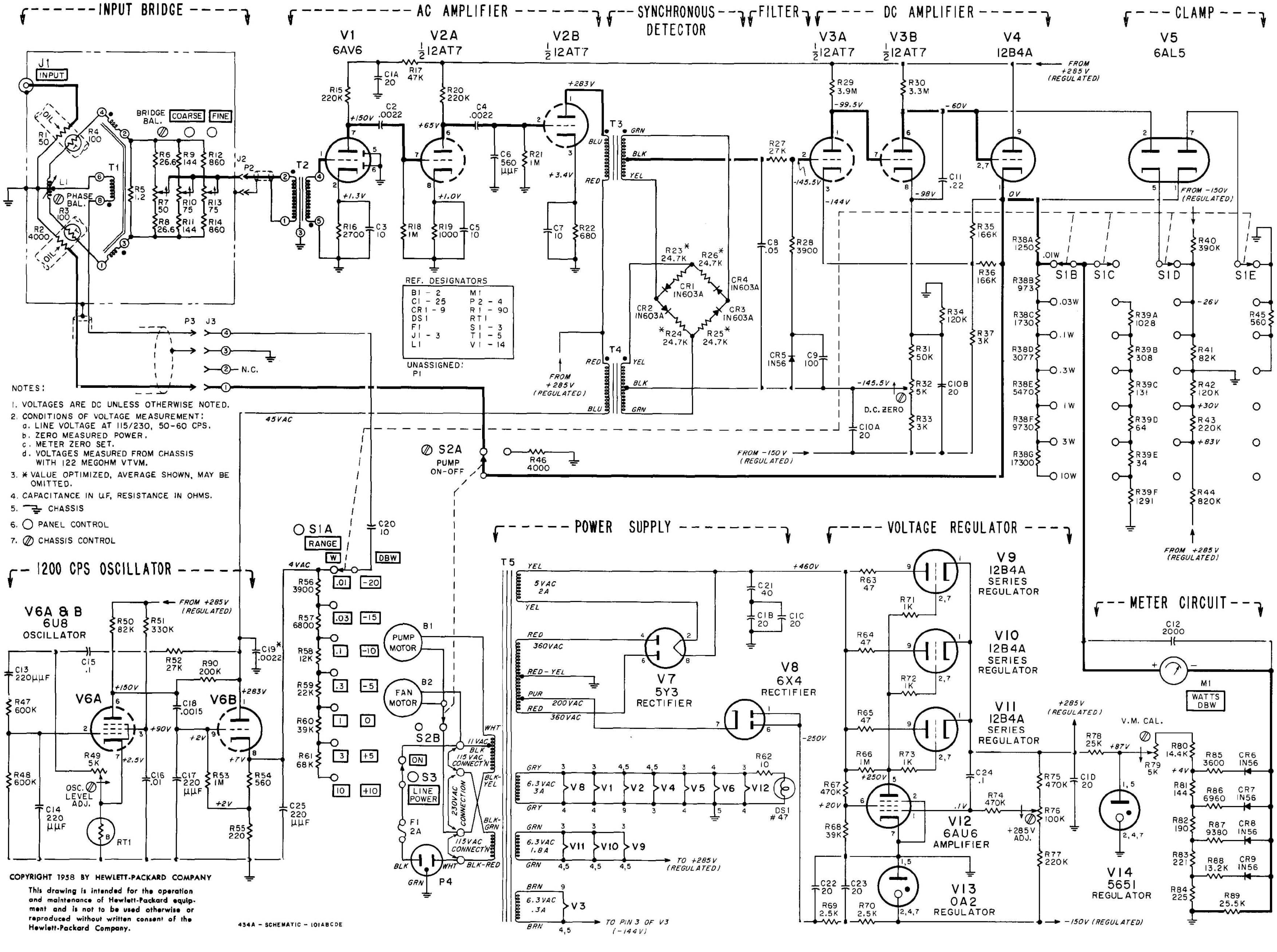


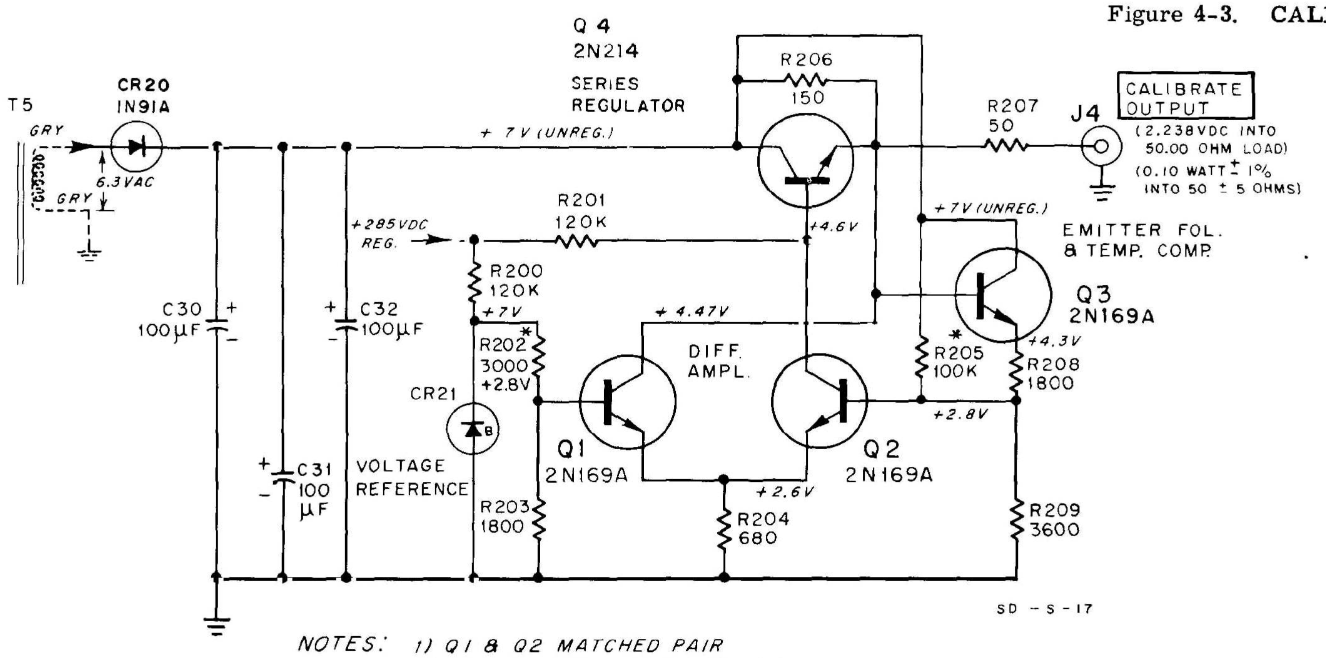
Figure 3-2. Oil Flow Diagram



NOTES:

1. VOLTAGES ARE DC UNLESS OTHERWISE NOTED.
2. CONDITIONS OF VOLTAGE MEASUREMENT:
   a. LINE VOLTAGE AT 115/230, 50-60 CPS.
   b. ZERO MEASURED POWER.
   c. METER ZERO SET.
   d. VOLTAGES MEASURED FROM CHASSIS WITH 122 MEGOHM VTVM.
3. * VALUE OPTIMIZED, AVERAGE SHOWN, MAY BE OMITTED.
4. CAPACITANCE IN μF, RESISTANCE IN OHMS.
5. ⏚ CHASSIS
6. ○ PANEL CONTROL
7. ⊘ CHASSIS CONTROL

Figure 4-3. CALIBRATOR



NOTES: *1) Q1 & Q2 MATCHED PAIR*
2) R202 FACTORY ADJUSTED FOR CORRECT OUTPUT VOLTAGE.
3) R205 FACTORY ADJUSTED FOR BEST REGULATION WITH CHANGE IN LINE VOLTAGE.
4) VOLTAGES MEASURED ON A TYPICAL INSTRUMENT WITH LINE VOLTAGE ADJUSTED TO 115VAC.

Calibrator Parts List

C30 thru C32:	Capacitor: fixed, electrolytic, 100 μf, 12 vdcw; ⓗⓟ Stock No. 18-60, Mfr., CC
CR20:	Rectifier, silicon: 100 v PIV, 500 ma; ⓗⓟ Stock No. 212-148, Mfr. BV
CR21:	Diode, silicon; ⓗⓟ Stock No. G-29C-74, Mfr. HP
R200, 201:	Resistor: fixed, composition, 120,000 ohms ±10%, 1 W; ⓗⓟ Stock No. 24-120K, Mfr. B
R202:	Resistor: fixed, deposited carbon, 3000 ohms ±1%, 1/2 W; ⓗⓟ Stock No. 33-3000, Mfr. NN Electrical value adjusted at the factory.
R203:	Resistor: fixed, deposited carbon, 1800 ohms ±1%, 1/2 W; ⓗⓟ Stock No. 33-1800, Mfr. NN
R204:	Resistor: fixed, composition, 680 ohms ±10%, 1/2 W; ⓗⓟ Stock No. 23-680, Mfr. B
R205:	Resistor: fixed, composition, 100,000 ohms ±5%, 1/2 W; ⓗⓟ Stock No. 23-100K-5, Mfr. B Electrical value adjusted at the factory.
R206:	Resistor: fixed, composition, 150 ohms ±10%, 1/2 W; ⓗⓟ Stock No. 23-150, Mfr. B
R207:	Resistor: fixed, deposited carbon, 50 ohms ±1%, 1/2 W; ⓗⓟ Stock No. 33-50, Mfr. NN
R208:	Resistor: fixed, deposited carbon, 1800 ohms ±1%, 1/2 W; ⓗⓟ Stock No. 33-1800, Mfr. NN
R209:	Resistor: fixed, deposited carbon, 3600 ohms ±1%, 1/2 W; ⓗⓟ Stock No. 33-3600, Mfr. NN
Q1, 2:	Matched pair of 2N169A transistors, ⓗⓟ Stock No. 213-34, Mfr. HP
Q3:	Transistor, type 2N169A, ⓗⓟ Stock No. 213-33, Mfr. ZZ
Q4:	Transistor, type 2N214, ⓗⓟ Stock No. 213-35, Mfr. ZZ

MANUAL CHANGES

MODEL 434A

CALORIMETRIC POWER METER

Serial 251 and above:

(See attached schematic diagram of 434A Calibrator)

C33: Add capacitor, fixed, paper, .01uf ±20%, 400 vdcw; -hp- Stock No. 16-109, Mfr., CC

CR21: Change to diode, silicon; -hp- Stock No. G-29A-25, Mfr., HP

CR22: Add diode, silicon; -hp- Stock No. G-172J, Mfr, HP

Q5: Add transistor, 2N169A; -hp- Stock No. 213-34, Mfr., HP

R200: Change to resistor, fixed, composition, 18,000 ohms ±10%, 2 W; -hp- Stock No. 25-18K, Mfr., B

R201: Change to resistor, fixed, deposited carbon, 9,380 ohms ±1%, ½ W; -hp- Stock No. 33-9.38K, Mfr., NN

R202: Change to resistor, fixed, deposited carbon, 2,900 ohms ±1%, ½ W; -hp- Stock No. 33-2.9K, Mfr., NN

R203: Change to resistor, fixed, deposited carbon, 2,510 ohms ±1%, ½ W; -hp- Stock No. 33-2.51KR, Mfr., NN

R204: Change to resistor, fixed, deposited carbon, 1,800 ohms ±1%, ½ W; -hp- Stock No. 33-1.8K, Mfr., NN

R205: Delete

R208: Delete

R209: Change to resistor, fixed, deposited carbon, 3,300 ohms ±10%, ½ W; -hp- Stock No. 23-3.3K, Mfr., B

R210: Add resistor, fixed, composition, 18,000 ohms ±10%, 2 W; -hp- Stock No. 25-18K, Mfr., B

R211: Add resistor, fixed, composition, 2,400 ohms ±5%, ½ W; -hp- Stock No. 23-2.4K-5, Mfr., B

R212: Add resistor, fixed, deposited carbon, 20,000 ohms ±1%, ½ W; -hp- Stock No. 33-20K, Mfr., NN Optimum value selected at factory. Average value shown.

R213: Add resistor, fixed, composition, 15,000 ohms ±10%, ½ W; -hp- Stock No. 23-15K, Mfr., B

R214: Add resistor, fixed, deposited carbon, 540 ohms ±1%, ½ W; -hp- Stock No. 33-540, Mfr., NN

R215: Add resistor, fixed, deposited carbon, 3,000 ohms ±1%, ½ W; -hp- Stock No. 33-3K, Mfr., NN

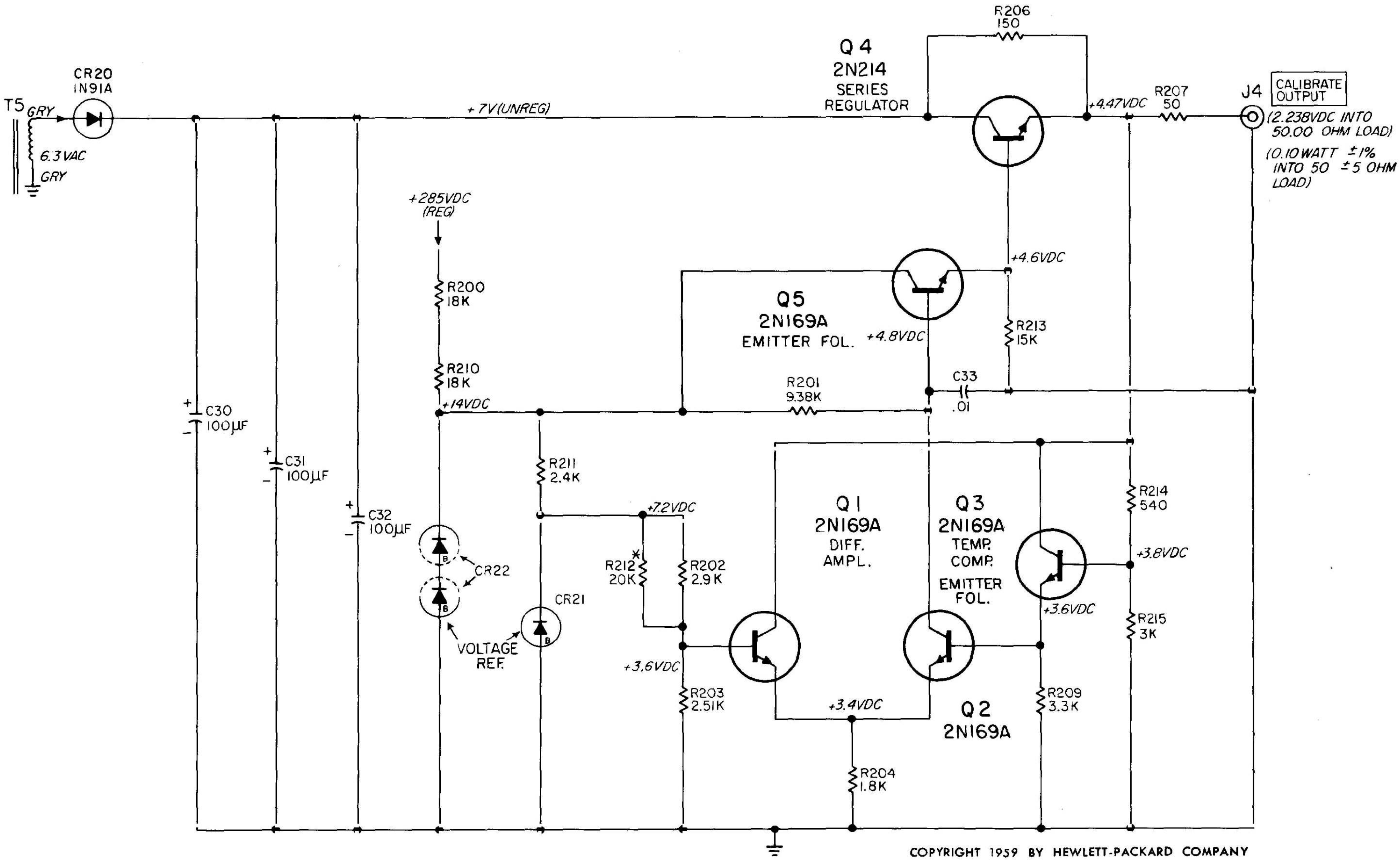
R41: Change to resistor, fixed, composition, 68,000 ohms ±10%, ½ W; -hp- Stock No. 23-68K, Mfr., B

R42: Change to resistor, fixed, composition, 150,000 ohms ±10%, ½ W; -hp- Stock No. 23-150K, Mfr., B

R91: Add resistor, fixed, composition, 15,000 ohms ±10%, ½ W; -hp- Stock No. 23-15K, Mfr., B (connected between R42 and ground)

C11: Should be connected between pin 6 of V3 and ground.

CR6 thru CR9: Change to diode, crystal; -hp- Stock No. 212-G11A, Mfr., HP


T5
GRY
6.3 VAC
GRY
CR20
IN91A
+7V(UNREG)
Q4
2N214
SERIES
REGULATOR
R206
150
+4.47VDC
R207
50
J4
CALIBRATE
OUTPUT
(2.238VDC INTO
50.00 OHM LOAD)
(0.10 WATT ±1%
INTO 50 ±5 OHM
LOAD)
+285VDC
(REG)
R200
18K
R210
18K
+14VDC
Q5
2N169A
EMITTER FOL.
+4.6VDC
+4.8VDC
R213
15K
C33
.01
R201
9.38K
C30
100µF
C31
100µF
C32
100µF
R211
2.4K
+7.2VDC
R212
20K
R202
2.9K
CR22
CR21
VOLTAGE
REF.
+3.6VDC
R203
2.51K
Q1
2N169A
DIFF.
AMPL.
Q3
2N169A
TEMP.
COMP.
EMITTER
FOL.
R214
540
+3.8VDC
+3.6VDC
R215
3K
+3.4VDC
Q2
2N169A
R209
3.3K
R204
1.8K

 434A - CAL. - 251