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INSTRUMENTS

MICROBAROGRAPH EVALUATION REPORT

Division 5231

September 18, 1953

Reprinted: September 3, 1959

Sandia Corporation
CONTRACTOR FOR U.S. ATOMIC ENERGY COMMISSION

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INTRODUCTION

This report describes the procedures used and the results obtained in evaluating the Wiancko type 3-PBM-2 microbarograph system.

Requirements for this unit are somewhat rigid because it must be suitable for field use, it must be able to withstand salt spray, and because good accuracy is imperative.

Briefly, the manufacturing specifications of Sandia Corporation stated that:

1. The amplifier shall have a bandpass filter with low-frequency, half-amplitude points at 0.01, 0.03, 0.1, and 0.3 cps; and with high-frequency, half-amplitude points at 1, 3, 10, and 30 cps.

2. Ranges of sensitivity (for a full-scale deflection of 0 to +20 mm or 0 to -20 mm on the Brush record) shall be in the following steps: 4, 12, 40, 120, 400, 1200, 4000, 12,000 microbars.

3. The system shall drive a Brush BL-202 recorder with the two pen-motors being driven in a 1 to 1/4 sensitivity ratio. Amplitude limiters shall be provided to protect the Brush pens.

4. Over-all deviations from linearity shall not exceed ±5 percent of full-scale range within the limits of the bandpass characteristic.

5. Calibration controls shall be provided to give a calibration step when a known current is passed through the sensing element. The calibration step shall be applied with a push-button switch and shall give a deflection of 15 mm on the most sensitive pen motor.

6. Internal system noise and drift shall not exceed 1 percent of full scale of any range selected following a warm-up period of five minutes.

7. The system shall be constructed and mounted so that it can be transported over rough terrain.

8. All units shall be capable of operation at ambient temperatures ranging from $-10^{o}F$ to $+120^{o}F$, and at relative humidity ranging from 0 to 90 percent.

9. Maximum weight for amplifier and power supply combination, including metal transport case, shall not exceed 100 pounds.

10. This system is to operate on 50 to 60 cps, 105-120 v AC power, maintaining drift characteristics over this range as noted in item No. 7.

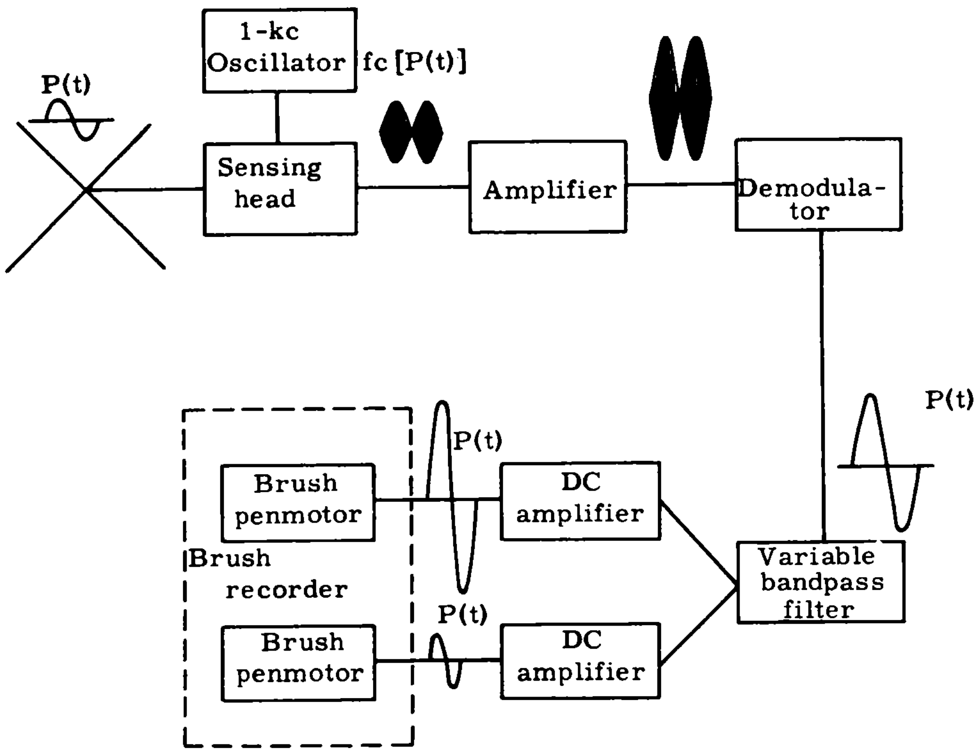
11. The sensing head shall be designed to operate at distances as great as one mile from the recorder and amplifier (using Belden No. 8424 shielded cable or equivalent). It shall be mounted in a weatherproof, light-reflecting case.

System drifts caused by the sensing head shall not exceed 5 percent of full scale when the sensing element, in its case, is subjected to a temperature rise of $10^{o}F$ to 30 seconds using a radiant source of energy.

12. Standard 19-in relay rack panel mountings of amplifier and oscillator-power supply are required.

13. The system shall include hose array complete with hardware and removable leaks.

GENERAL THEORY OF OPERATION



General operation of the microbarograph may be easily explained by referring to the block diagram shown above.

The first requisite is that there be a changing function of pressure which is designated as P(t). This P(t), plus some undesirable high and low frequency noise, arrives at the hose array which has an upper half-amplitude cutoff frequency of approximately 48 cps.

The partially filtered signal is then impressed on the Wiancko sensing head which has a back-volume bleed giving it a lower half-power cutoff frequency of 0.0078 cps. The sensing head is of the variable reluctance type and is fed with a carrier of 975 cps. Output of the sensing head, therefore, consists of 975 cps modulated with the signal P(t).

The modulated signal from the sensing head is impressed across a range attenuator which has been calibrated with the system to give the following ranges: 4, 12, 40, 120, 400, 1200, 4000, and 12,000 microbars ±.

From the range attenuator switch, the signal passes through a conventional 4-stage resistance coupled amplifier with a dynamic output range of about 50 volts. At this point the modulated signal is demodulated by a phase-sensitive demodulator circuit having a dynamic range also of 50 volts.

The demodulated signal is then impressed on an adjustable bandpass filter which, when acting with the two previous filters, may be set to have lower half-amplitude frequencies of 0.01, 0.03, 0.1, or 0.3 cps and upper half-amplitude frequencies of 1.0, 3.0, 10.0, or 30 cps. With this filtering it is possible to attenuate most of the noise, keeping the signal, P(t), at full amplitude, assuming that its frequency is near the mid-frequency of the bandpass filter.

The filtered signal is now impressed on two DC amplifiers in parallel, one having a gain of four times the other. The DC amplifiers drive the two channels of a Brush type BL-202 recorder having a side marking pen which records 1-sec timing pips. Peak clipping circuits in the DC amplifiers prevent the recorder pens from being driven off scale with high amplitude signals.

The desired signal is now recorded; and by knowing the range setting and timing, the record may be interpreted for amplitude in microbars and period in seconds.

HOSE ARRAY

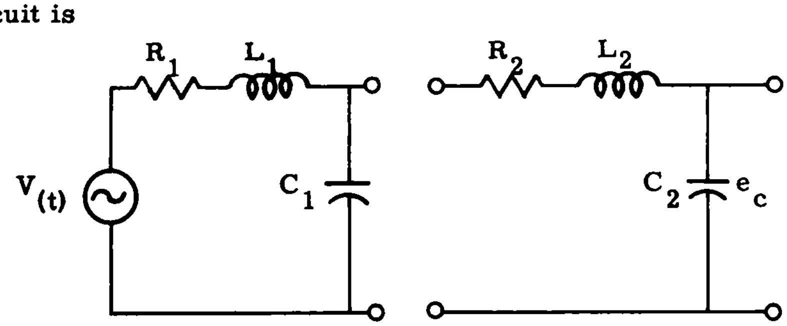
The hose array is the part of the sensing unit that is actually open to the atmosphere and essentially has two important functions: (1) It acts as a low-pass filter to prevent the system from being overdriven by high-frequency noise. (2) Because of its large area, it serves to cancel the effects of small local disturbances such as whirlwinds.

The array is arranged in the form of a plus sign with the Wiancko sensing head at the center. Each leg is 20 feet in length and has 5 orifices spaced at 4-ft intervals.

The size of the orifice is critical in determining the frequency characteristic of the array. Determination of the orifice dimensions was made experimentally in the following manner:

> An M-B vibrator was used to drive a bellows working into a large closed volume.* An elementary section of the hose array, consisting of one 4-ft section with one orifice in the center, was attached to the closed volume; and the microbarograph sensing head was attached to the elementary section. This arrangement provides a variable-frequency pressure generator which very nearly produces a sine wave.

The system used may be compared to an electrical circuit in which R is analogous to flow resistance, L is analogous to mass, and C is analogous to volume. Using this analogy, the electrical circuit is



*M-B Manufacturing Company, New Haven, Connecticut.

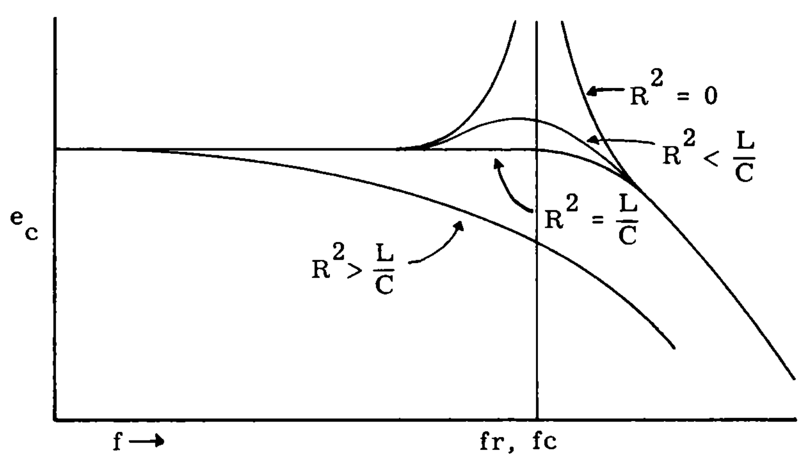
In the driver section, $V_{(t)}$ represents the driving force applied by the vibrator; R_1 represents the flow resistance of the bellows; L_1 represents the mass of air moved; and C_1 represents the large closed volume.

Because it was desired that only the frequency characteristic of the hose array be measured, it was necessary to eliminate completely all effects of the driver and the measuring equipment. The microbarograph system in conjunction with a cathode ray oscillograph was used because this combination provided the best available means for measuring the small pressures.

It is essential that in the determination of the frequency characteristic of the array the pressure appearing across C_1 be constant for all frequencies. To accomplish this the microbarograph was attached to the large volume, C_1, and the system was driven with the microbarograph vibrator through the frequency range, 5 to 70 cps. The amplitude of the microbarograph output was observed on the cathode ray oscillograph and the driving force was adjusted to keep this output constant for all frequencies. Driving settings recorded every 5 cps gave the settings by which a flat response from 5 to 70 cps was obtained. This procedure included the nonlinearities of response of the microbarograph system so that it was now possible to add the hose array to the large volume, C_1; and with the settings already determined, be able to find the frequency response of only the hose array.

Figure 1 shows a plot of amplitude vs frequency, using an orifice 0.052 inch in diameter and 0.75 inch long.

From Fig. 1 it is noted that the frequency response has a slight peak at about 20 cps. This peak might be expected in a filter of this design provided the circuit elements are in the proper relationship; namely, if $R^2 < \frac{L}{C}$. The figure below shows the relationship between the circuit elements and the frequency response of this type filter. A rigorous mathematical derivation may be found in Appendix C.



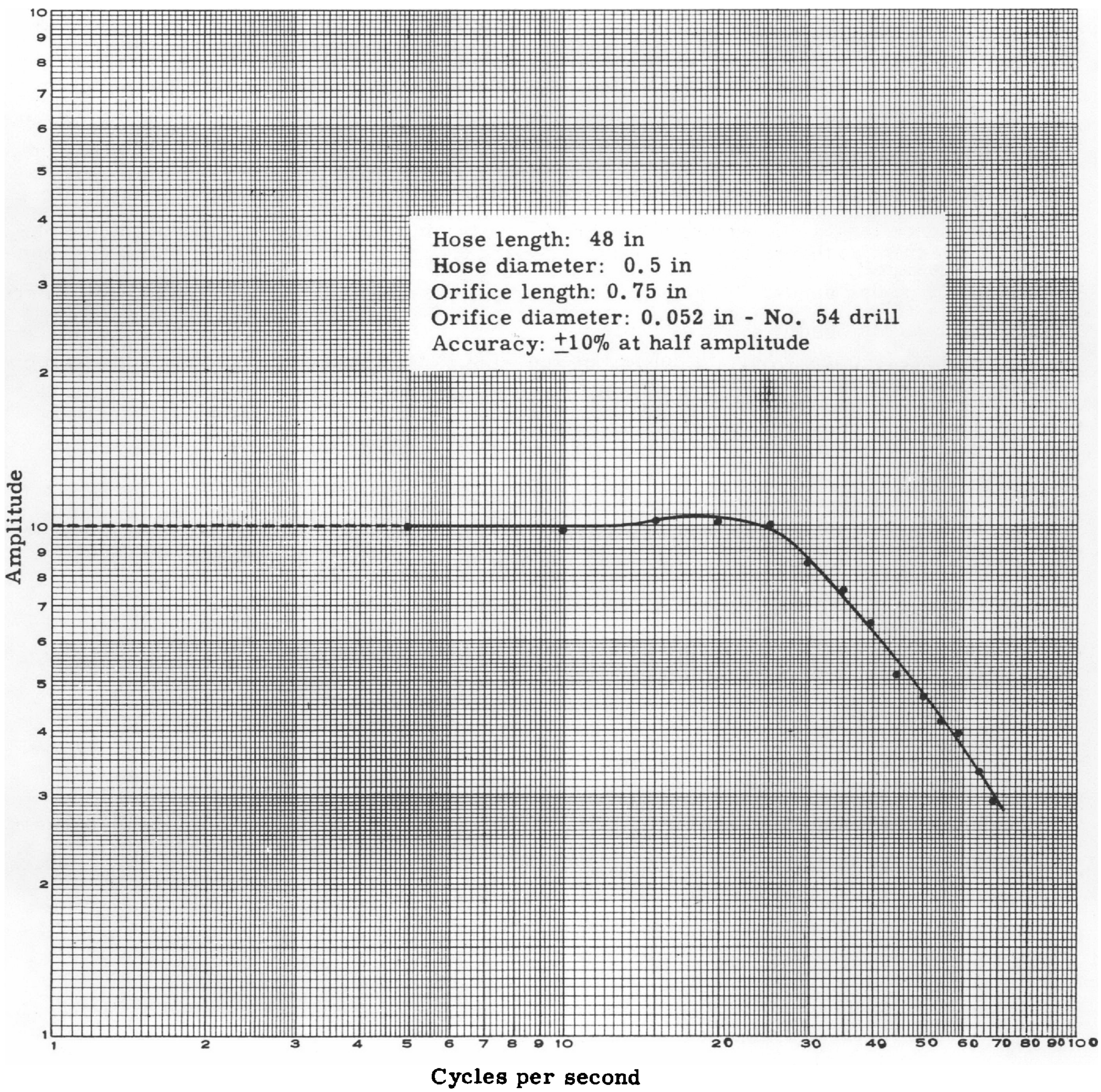


Fig. 1 -- Response of an elementary section of hose array

The condition where $R^2 = \frac{L}{C}$ gives a flat frequency response from 0 to cutoff frequency*
and is commonly known as a constant-k type filter. Ordinarily the constant-k type filter is preferred because of its flat response. In the case of the hose array a small resonant peak is desirable because it tends to hold the composite frequency response of the microbarograph at a higher value and gives it a sharper cutoff. (Fig. 9).

Since the orifice dimensions determine the resistance of the analogous electrical circuit, it is not possible to raise the cutoff frequency by increasing the orifice diameter. The cutoff frequency may be lowered, however, by decreasing the orifice diameter or by increasing the orifice length. Lowering the cutoff frequency in this manner will decrease the sharpness of the cutoff.

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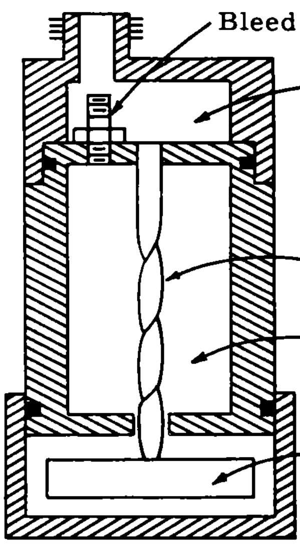
*Cutoff frequency here is defined as the point in the frequency response where attenuation starts.

SENSING HEAD



The sensing head incorporates the Wiancko twisted bourdon tube as the pressure-sensitive element driving a rotating armature in the field of a four active-arm-reluctance bridge.

The sketch shows that the sensing head is designed to have a front and back volume; therefore, the pressure measured is the difference between the front-volume pressure and the back-volume pressure. The bleed plug which connects the front and back volume has a time constant* of between 20 and 21 seconds; the decay for the pressures used being nearly exponential, as shown in Fig. 2.

The bleed rate of the back-volume bleed plug is adjustable with an Allen head setscrew and may be reached through the pressure intake of the sensing head. The purpose of this bleed plug is to provide a means of compensating for long period changes in atmospheric pressure and also to provide a high-pass filter with a cutoff frequency of the desired value. When adjusted to a time constant of 20.3 seconds, the half-power cutoff frequency is given by $fc = \frac{1}{2\pi T}$ where T is the time constant in seconds:

$$fc = \frac{1}{2\pi 20.3} = 0.0078 \text{ cps.}$$

An additional feature incorporated into this unit is a calibrating circuit which may be used for making secondary calibrations and placing calibrating steps on the records. The

*The time constant is defined as the time required for the pressure to decay to 1/e of its initial value.

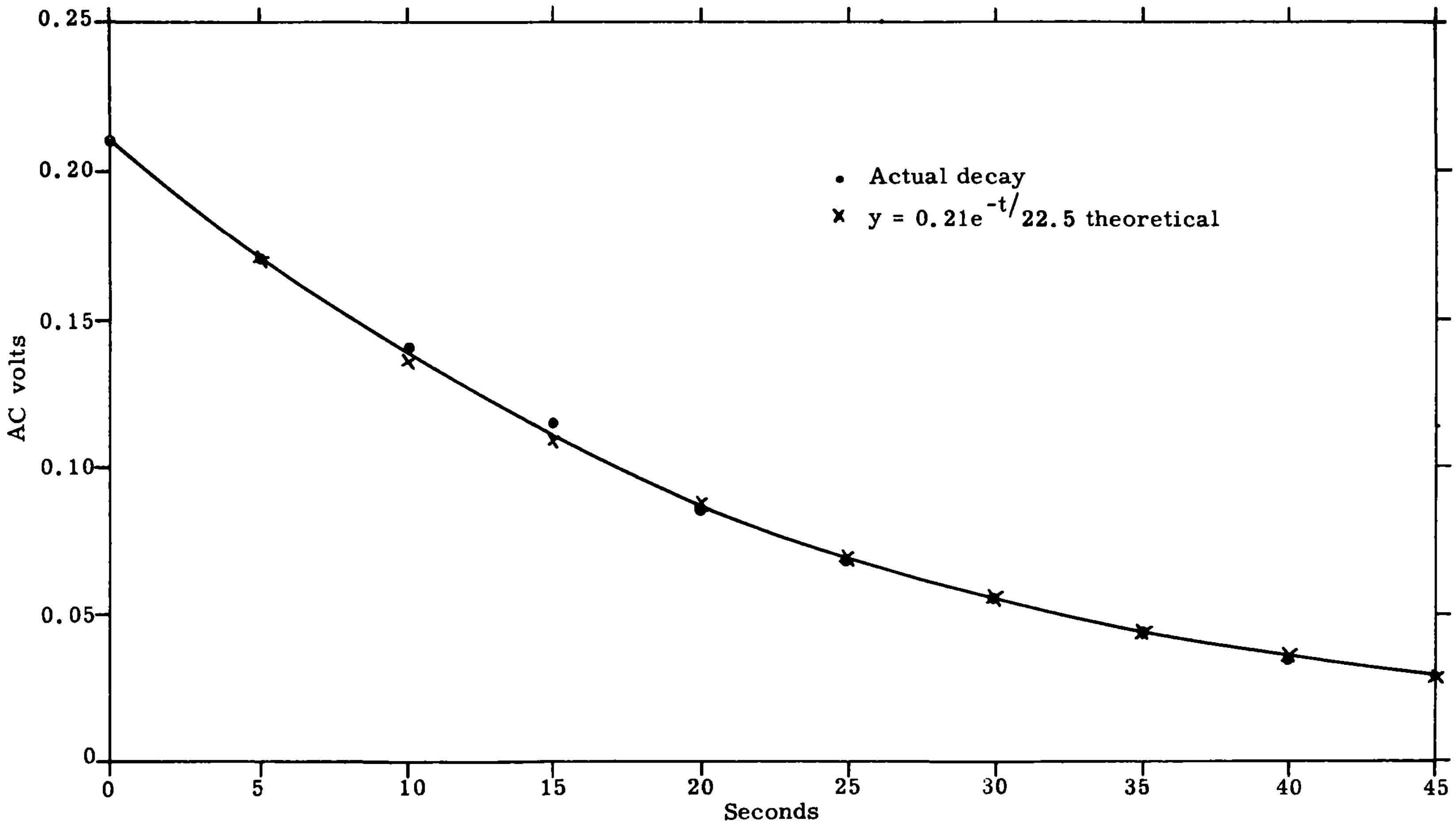
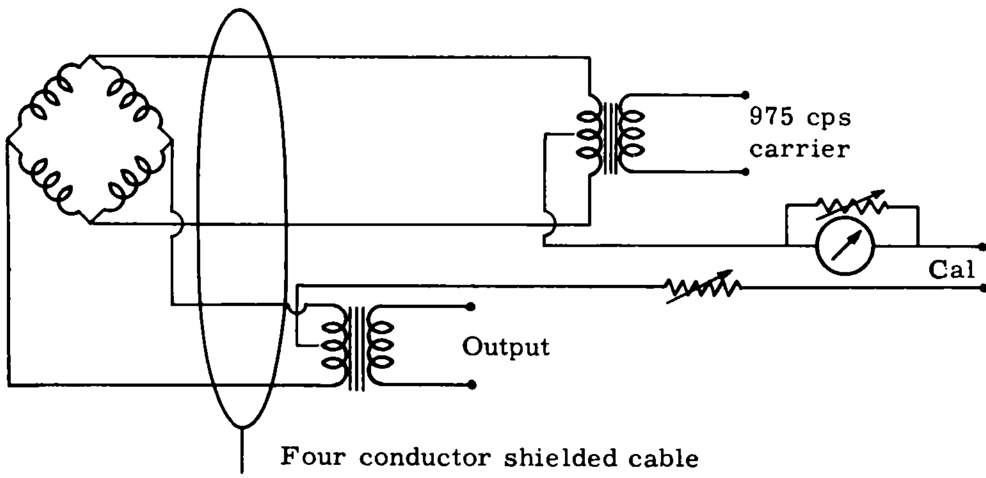


Fig. 2 -- Back-volume bleed characteristic of the Wiancko sensing head, serial No. 9848

essential element for making the calibration circuit function is an alnico permanent magnet which is placed so as to polarize the armature. With the armature polarized, a direct current may be passed through the bridge windings in either direction, giving a deflection to the armature and unbalancing the bridge, thus giving a simulated signal.



Bridge circuit showing calibration arrangement

This sensing head has a natural rotational frequency* of about 215 cps which is far above the highest signal frequency of 30 cps that it is designed to measure; therefore, the dynamic response is flat over the desired frequency range.

Figures 3 and 4 show the linearity and sensitivity of the sensing head; the deviation from linearity over the operating range of ±12,000 microbars is less than 2 percent.

The voltage output of the sensing head was measured at the input to the range attenuator which is located on the secondary side of a coupling transformer having a step-up ratio of 16.7 to 1. Under these circumstances, the sensing-head sensitivity is not given directly in Figs. 3 and 4; however, it can be determined by the following equation:

$$\text{Sensitivity} = \frac{1}{16.7} \frac{4.8 \text{ volts}}{(12,000 \text{ microbars})} = 0.000024 \text{ volts/microbar} =$$

$$0.024 \text{ millivolts/microbar}$$

The full range output of the sensing head is therefore 0.024 x 12,000 = 288 millivolts.

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*Natural rotational frequency is defined as the frequency where maximum rotational amplitude exists when a sinusoidal driving force of constant amplitude is applied.

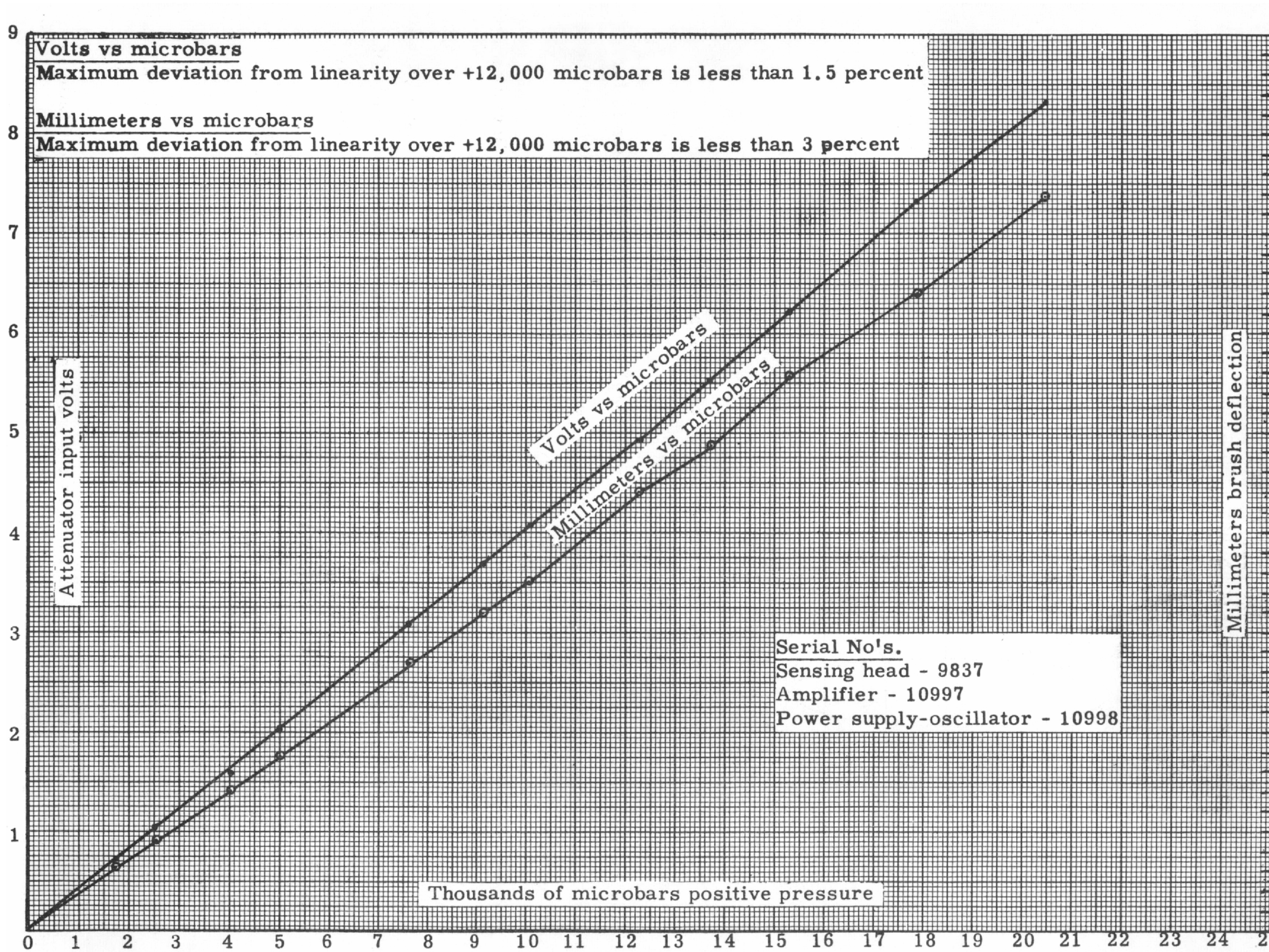

Fig. 3 -- Linearity of the Wiancko microbarograph sensing head, serial No. 9837, and linearity of the total system

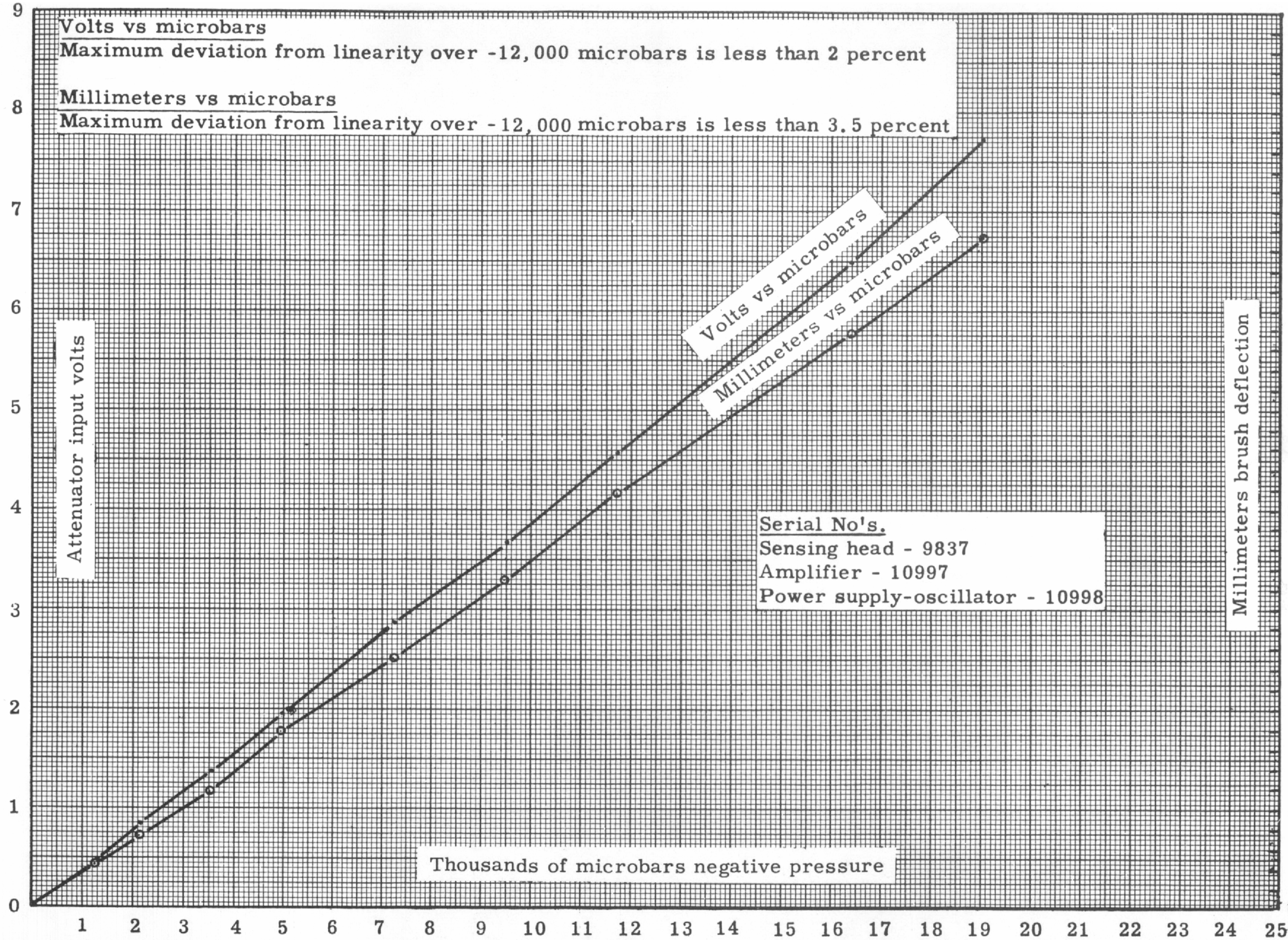

Fig. 4 -- Linearity of the Wiancko microbarograph sensing head, serial No. 9837, and linearity of the total system

AMPLIFIERS AND DEMODULATOR

The unbalanced output of the sensing head is impressed across the attenuator as shown in the circuit diagram (Fig. 5). It will be noted that there are also two more gangs on this switch which adjust the calibration current to the proper magnitude for each range switch position. The 500 ohm resistors on SW6 and SW7 provide a path for the calibration current so that the total current drawn from the supply is constant regardless of the position of SW6 and SW7. The calibration current is adjustable with a potentiometer on the power-supply panel, and when this calibration current is properly adjusted and calibrated the meter on the power-supply panel will read 10 when the push-button switch is depressed.

The modulated signal from the attenuator switch is impressed on a 4-stage conventional amplifier consisting of VT1, VT4 and VT2 (Fig. 6). The two series-tuned circuits in the cathode circuits of VT1 and VT2 are tuned to the carrier frequency of 975 cps. At 975 cps the feedback is essentially determined by R38 and R40 of VT1 and R52 and R55 of VT2. At frequencies where the impedance of the filter is high compared to R39 of VT1 or R54 of VT2, the feedback is essentially determined by the resistors R38 and R39 of VT1 and R52 and R54 of VT2.* The bandpass characteristics of these two stages can therefore be determined by adjusting R40 and R55. This means is used in the gain-compensating circuit which merely utilizes the proper value of resistance in shunt with R40 to give equal amplitude of all center frequencies at all bandpass settings except 1-1.

The resistive balance control is a 2000-ohm helipot voltage divider across the carrier supply which may be adjusted to cancel the 'in-phase' component of the carrier from the sensing head.

The reactive balance control is a variable-phase shift network which can be adjusted to balance exactly the out-of-phase carrier component from the sensing head.

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*Wiancko Microbarograph Instruction Book

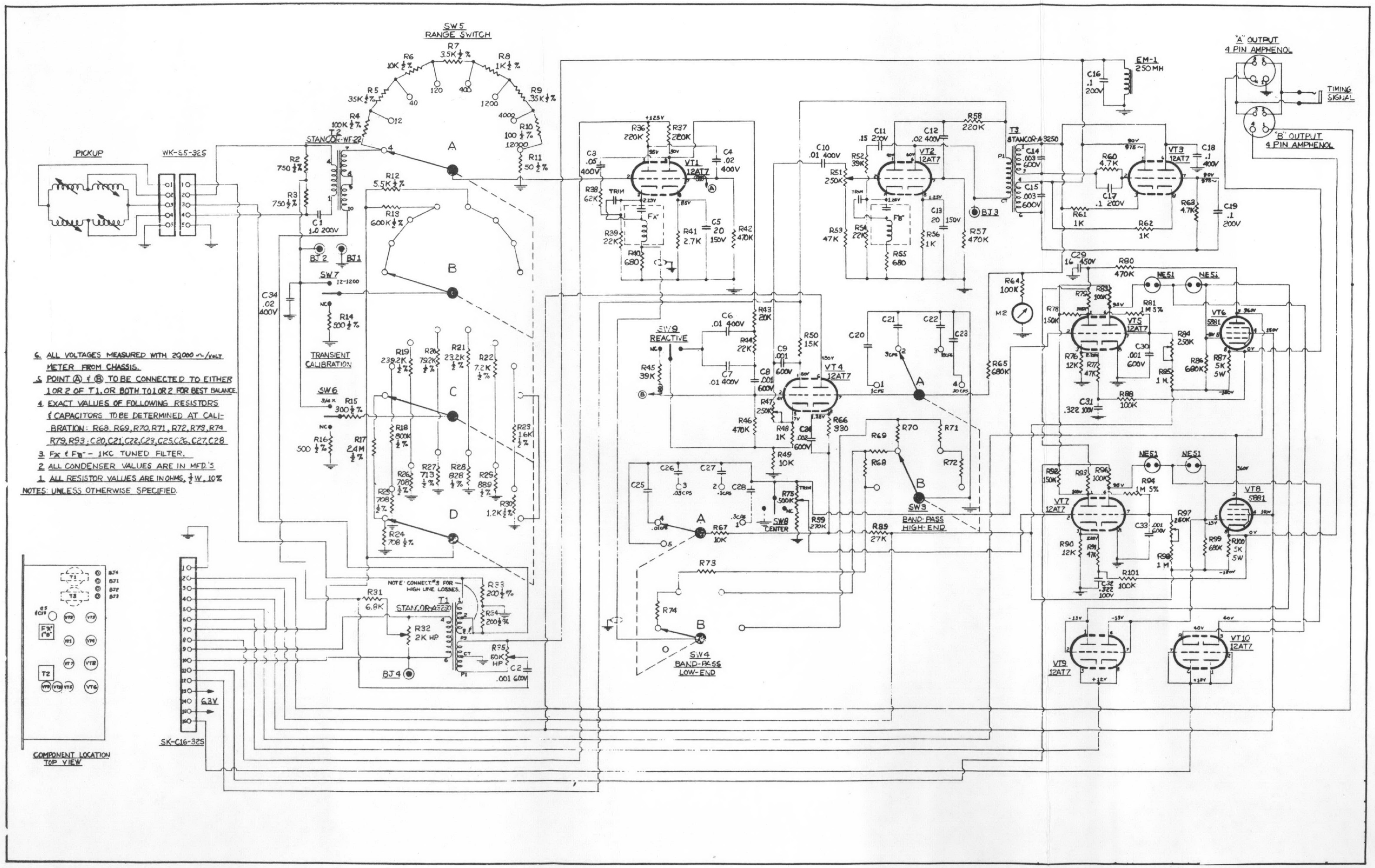

Fig. 5 -- Schematic-Wiancko microbarograph amplifier

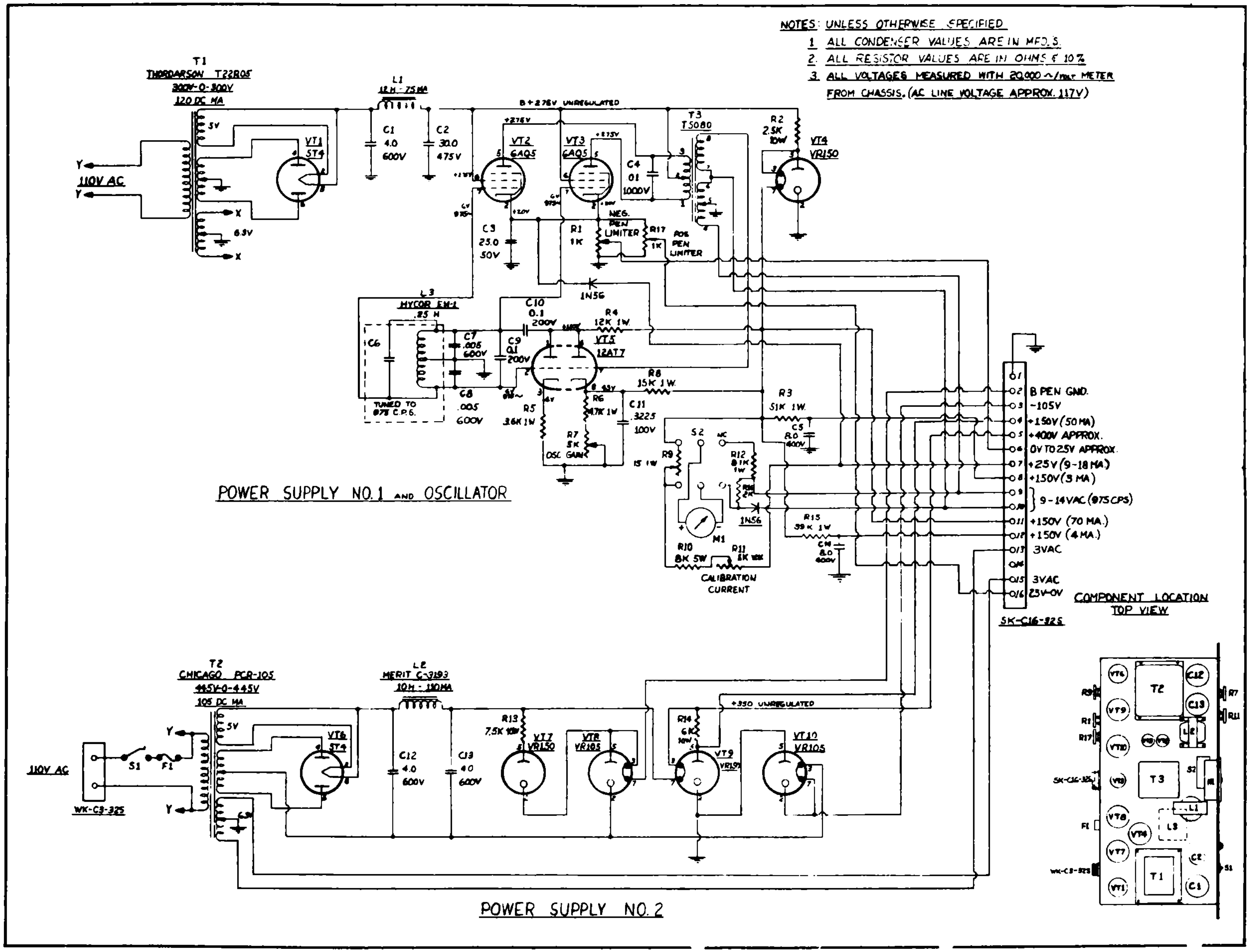

Fig. 6 -- Schematic-Wiancko microbarograph power supply and oscillator

Resistive balance is indicated when M2 reads zero. Reactive balance is indicated when M2 reads zero with SW-9 (button marked reactive) depressed.

Depressing SW-9 shifts the phase of the gauge voltage 90^{o}, causing the reactive component to be in phase with the reference voltage that is supplied to the demodulator. To obtain good balance it may be necessary to alternately adjust the reactive and resistive balance controls several times.

The demodulator is of the half-wave phase sensitive type employing both triode sections of a 12AT7. The operating points are set such that the linear dynamic range of the demodulator is a maximum of 50-v positive and negative. The balance meter, M2, is calibrated to read 50 volts each side of center and indicates that the instrument is operating within its dynamic range whenever the meter is on scale.

The parallel DC output amplifiers have their gains set in a ratio of four to one. The most sensitive amplifier (that with the highest gain) is designated as amplifier 'A' and the least sensitive is designated as amplifier 'B'.

Two 12AT7's connected as duodiodes are used as peak limiters to provide protection for the recorder. In one case, VT9 is connected to the control grids of VT6 and VT8 and biased to the proper point to give positive peak limiting. In the other case, VT10 is also connected to the control grids of VT6 and VT8 through the NE51 glow tubes and biased to the proper point to give negative peak limiting.

These peak limiters are essential for reliable operation of the instrument because relatively small pressure transients can break or dislocate the recorder pens.

Linearity of the total system is checked by applying known pressures to the sensing head, suddenly removing the pressure, and reading the amplitude of the resulting response on the Brush recorder. Figures 3 and 4 show the linearity as measured in this manner over a range greater than the rated operating range with the bandpass in the 4-4 position. It is seen from Figs. 3 and 4 that the deviation from linearity is less than 3.5 percent over the maximum designed range of ±12,000 microbars. Although the least sensitive pen motor may read up to ±48,000 microbars, there is no assurance that the system will be linear above ±12,000 microbars.

Figure 7 shows the combined linearity of the sensing head and AC amplifier, and was obtained by applying pressure to the head with a water manometer and measuring the voltage input to the demodulator with a vacuum-tube voltmeter.

This plot shows that the deviation from linearity over the maximum operating range is not more than 1.5 percent.

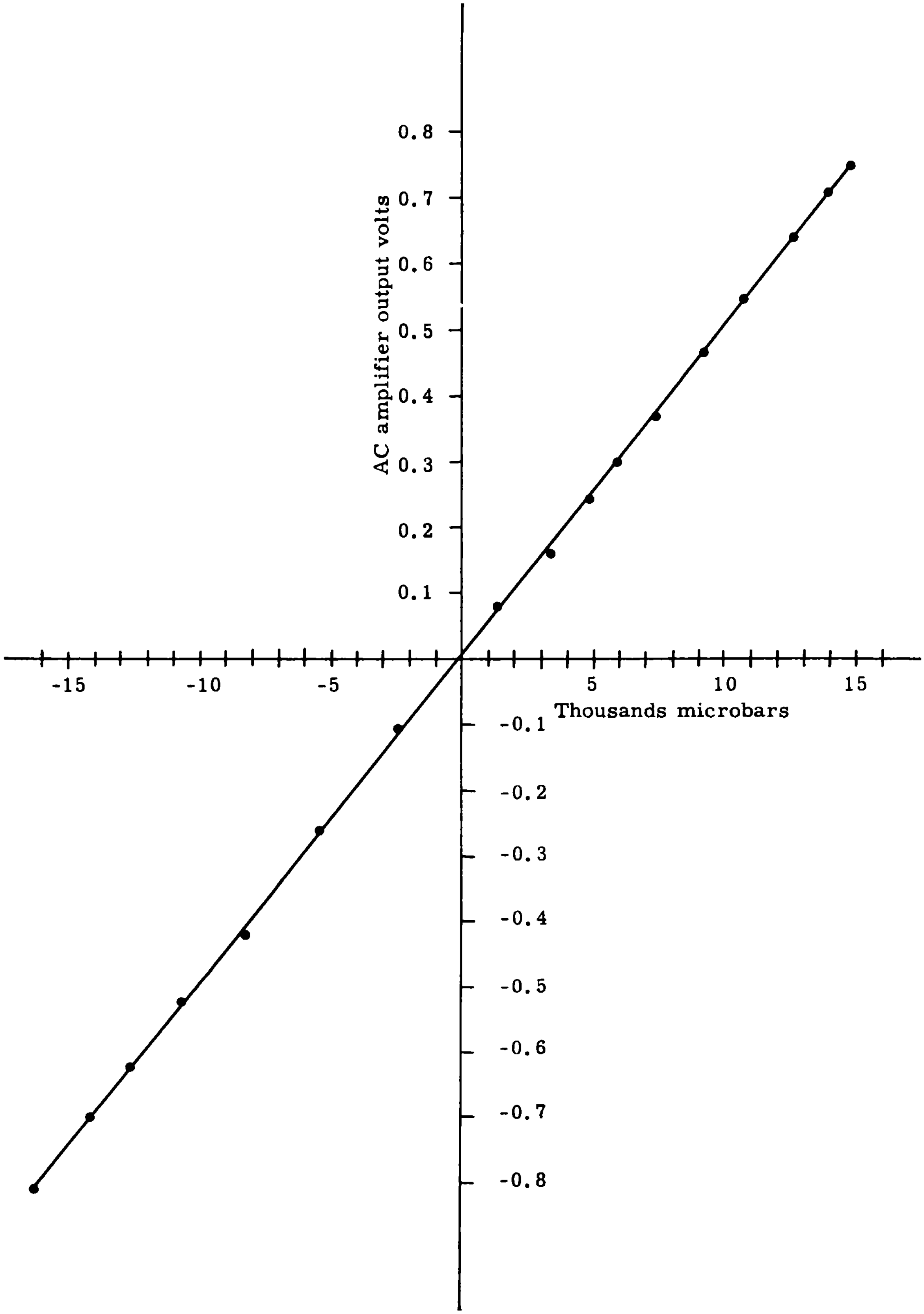

Fig. 7 -- Combined linearity of the Wiancko microbarograph sensing head, serial No. 9837, and AC amplifier, serial No. 10997

BANDPASS FILTER

The bandpass filter consists of two RC filters: a high pass and a low pass. Each filter has four positions which are numbered 1, 2, 3, 4, with number 1 on the inside and the numbers progressing to the right for the low-pass filter and progressing to the left for the high-pass filter.

Compensation to adjust the midfrequency amplitude for each bandpass setting except 1-1 has been incorporated by adjusting the feedback in the first amplifier stage so that the center frequency of each band has the same amplitude.*

The system should never be set up with the bandpass in position 1-1 because this position is not compensated.

The bandpass characteristics of the system, including the sensing head and recorder but not the acoustic effects of the bleed plug and hose array, may be determined by connecting an audio oscillator between BJ2 and BJ1 and driving the sensing head electrically. The characteristics found in this manner are shown in the following bandpass plots (Figs. 8 and 9) as dashed curves labeled 'electrical'.

The acoustic filter characteristics of the bleed plug and hose array are also shown as dashed curves labeled 'bleed' and 'hose array', respectively.

The resultant frequency characteristic curves are shown as solid lines and are found by multiplying the dashed curves together.

The acoustic hose-array response was found as described in the hose-array section. The acoustic bleed response may be found from the formula: $f = \frac{R}{2\pi T\sqrt{1 - R^2}}$ where f is cps, R is pressure differential at a particular time, T is the time constant in seconds, and where the initial pressure is normalized to unit. The sensing-head response may also be plotted

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*Wiancko Microbarograph Instruction Book

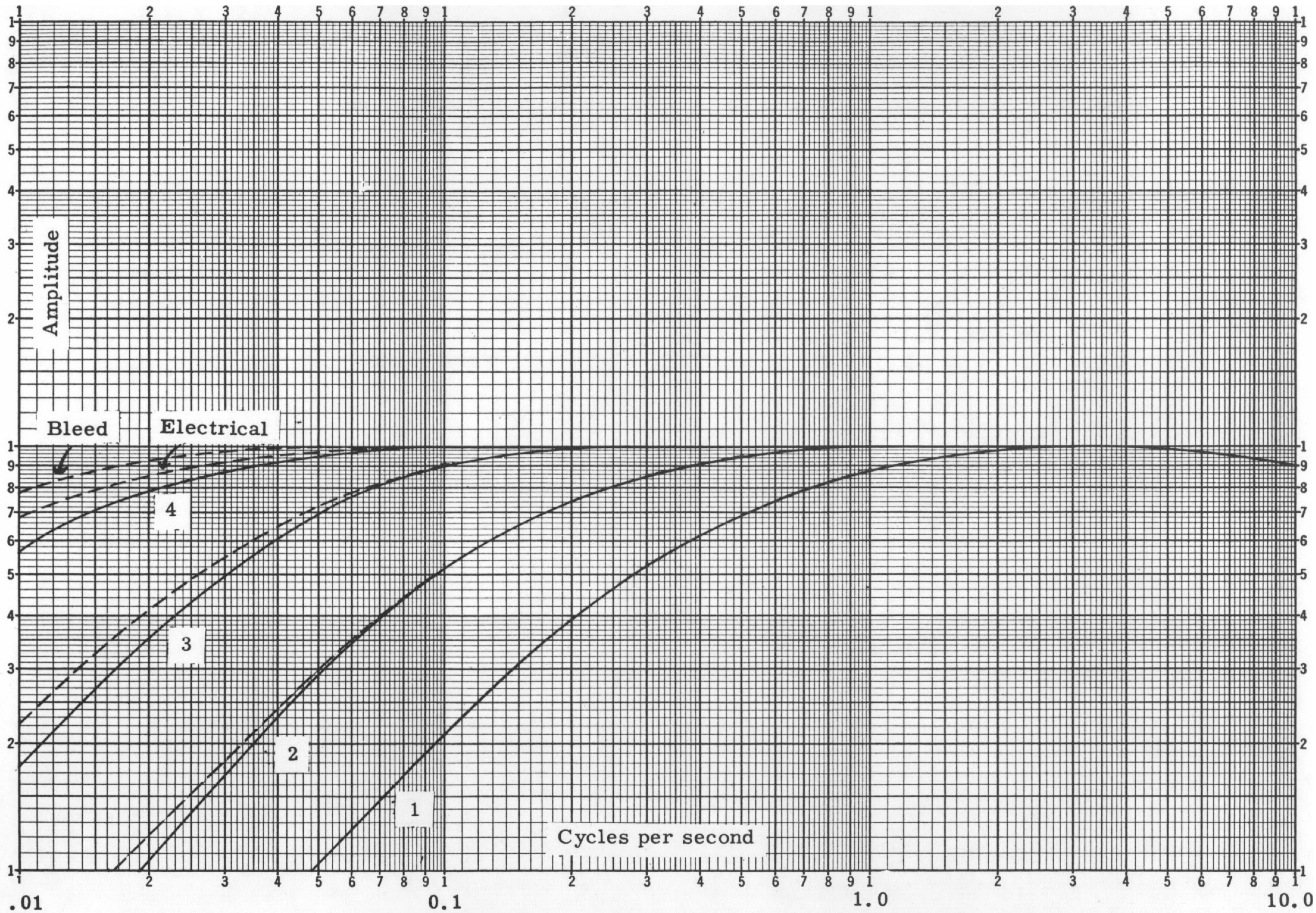


Fig. 8 -- Bandpass characteristics of the microbarograph system (Wiancko 3-PMB-2)

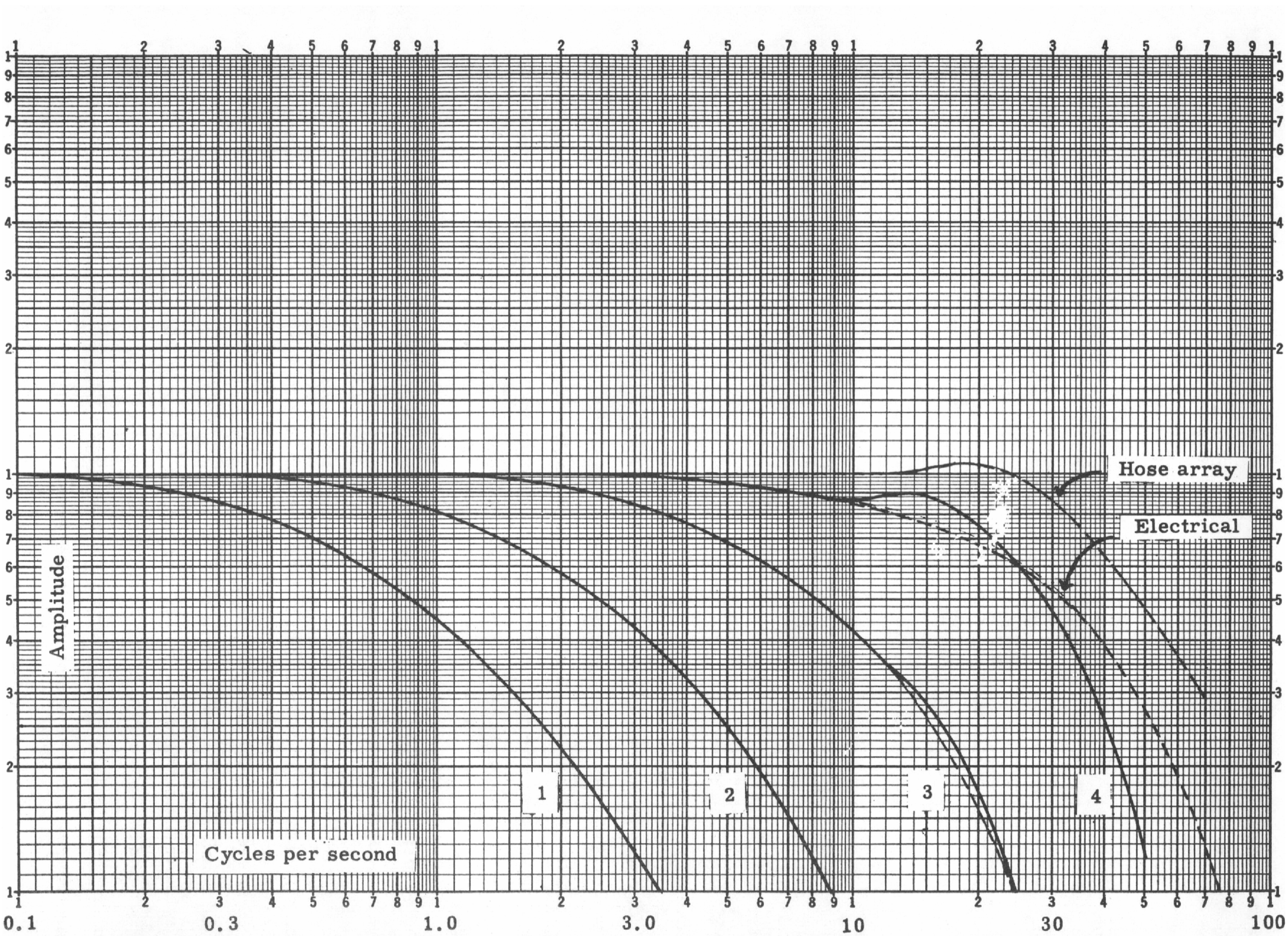


Fig. 9 -- Bandpass characteristics of the microbarograph system (Wiancko 3-PMB-2)

from the attached universal curve (Fig. 10) where the response R is plotted as a function of the frequency times the bleed time constant given as Y

$$Y = \frac{R}{2\pi\sqrt{1 - R^2}} ,$$

or solved for R

$$R = \frac{2Y}{\sqrt{1 + 4\pi^2 Y^2}} .$$

Figures 11 and 12 show the transient response of the microbarograph system to the step function applied by the calibration circuit.

Since the high-pass section of the bandpass filter is composed of series capacitance and shunt resistance, the transient response to a step function will be an exponential decay from which we can easily obtain the frequency response. The lower half-power cutoff frequency, fc_1, is given by the formula, $fc_1 = \frac{1}{2\pi T}$, where T is the time constant in seconds. The time constant may be measured by running the recorder at a relatively slow speed, applying the calibration step, and measuring the amount of time it takes for the transient to decay 63 percent.

The transient responses for the high-pass section of the filter are shown in Fig. 11 for the four lower bandpass switch positions. The half-power cutoff frequency found from the transient response is designated fc_1, and the half-power cutoff frequency found from measuring the response with an oscillator is designated fc_2. Comparing fc_1 and fc_2 in Fig. 11, it is to be noted that a good bandpass approximation can be made by analyzing the transient response.

Because the low-pass filter affects the rise time it is necessary to extrapolate the curves as shown by the dashed lines in the two lower decay curves.

Figure 12 shows the identical method used to analyze the low-pass section of the filter, with the exception that the paper is now run at a ıast speed to expand the rise time.

It is seen that the cutöff frequencies found in this manner are not in exact agreement with the cutoff frequencies given in Figs. 8 and 9. This fact indicates that the recorder does not have a flat response and that the largest errors in data may be attributable to the recorder and not to the rest of the instrument. In fact, experience with several units during the 1953 Nevada Proving Ground test bears out the deduction that the weak spot in the microbarograph instrument lies in the Brush recorder.

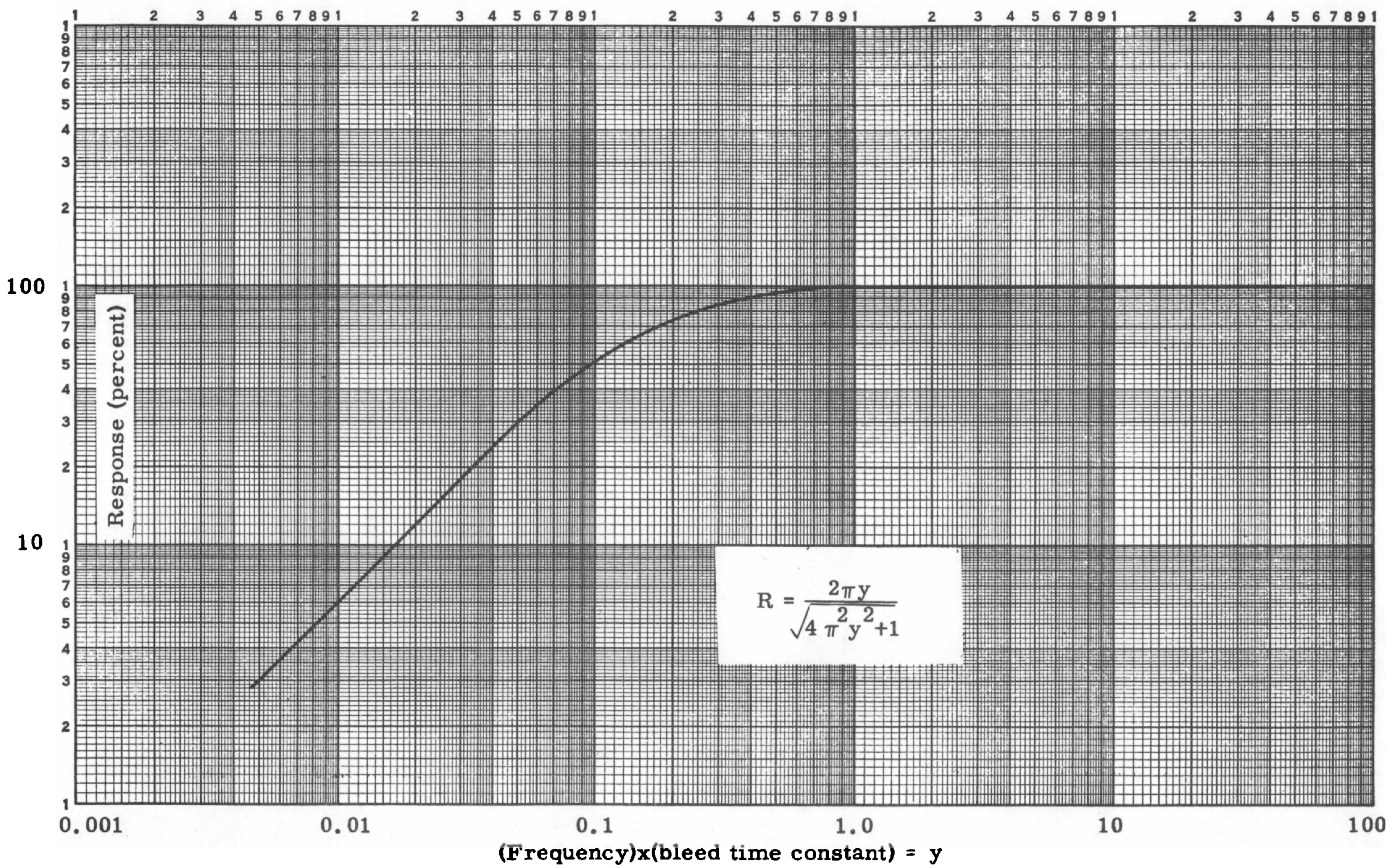


Fig. 10 -- Theoretical response of a differential pickup with a restricted back volume

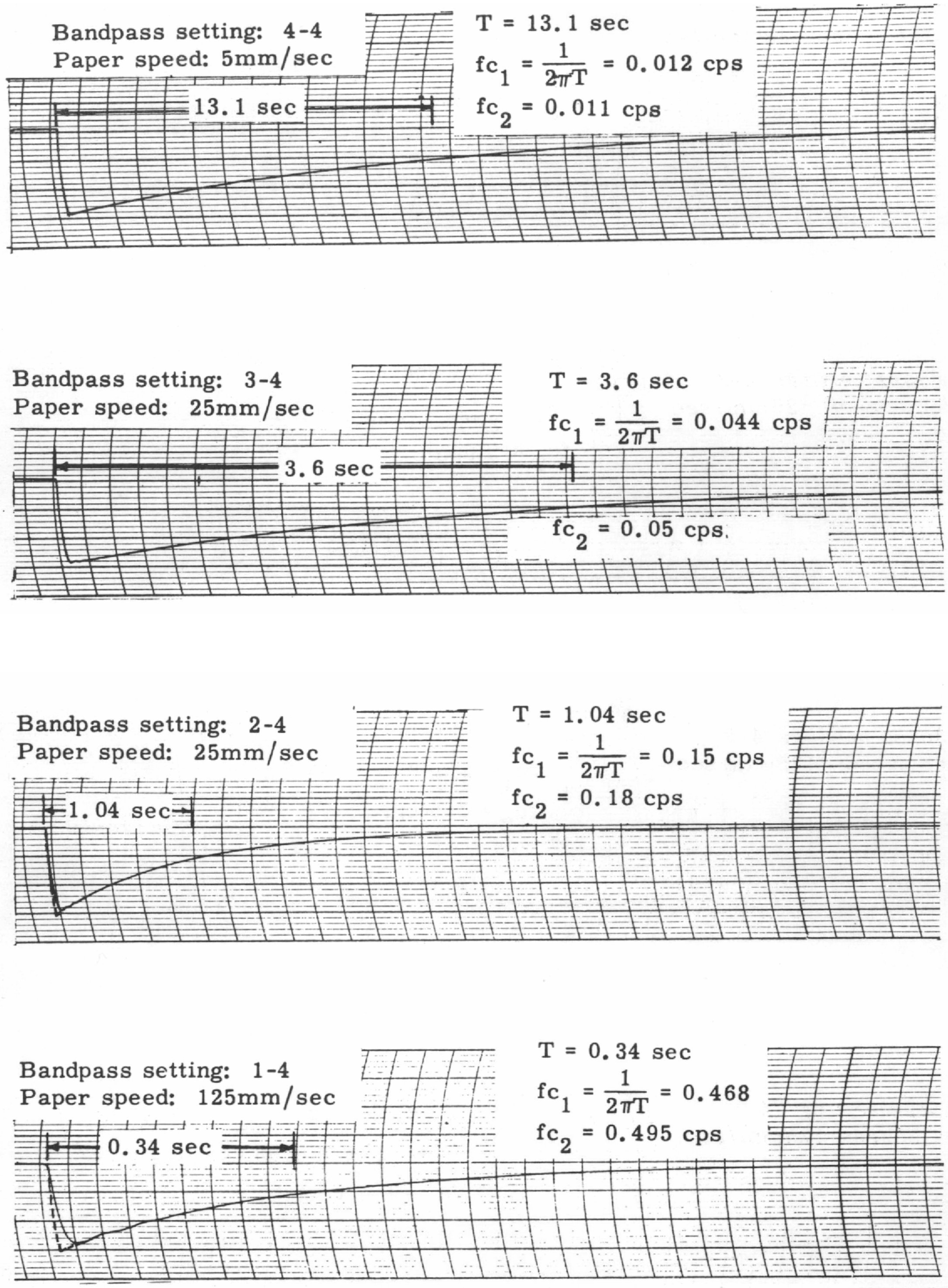


Fig. 11 -- Calibration transient response curves

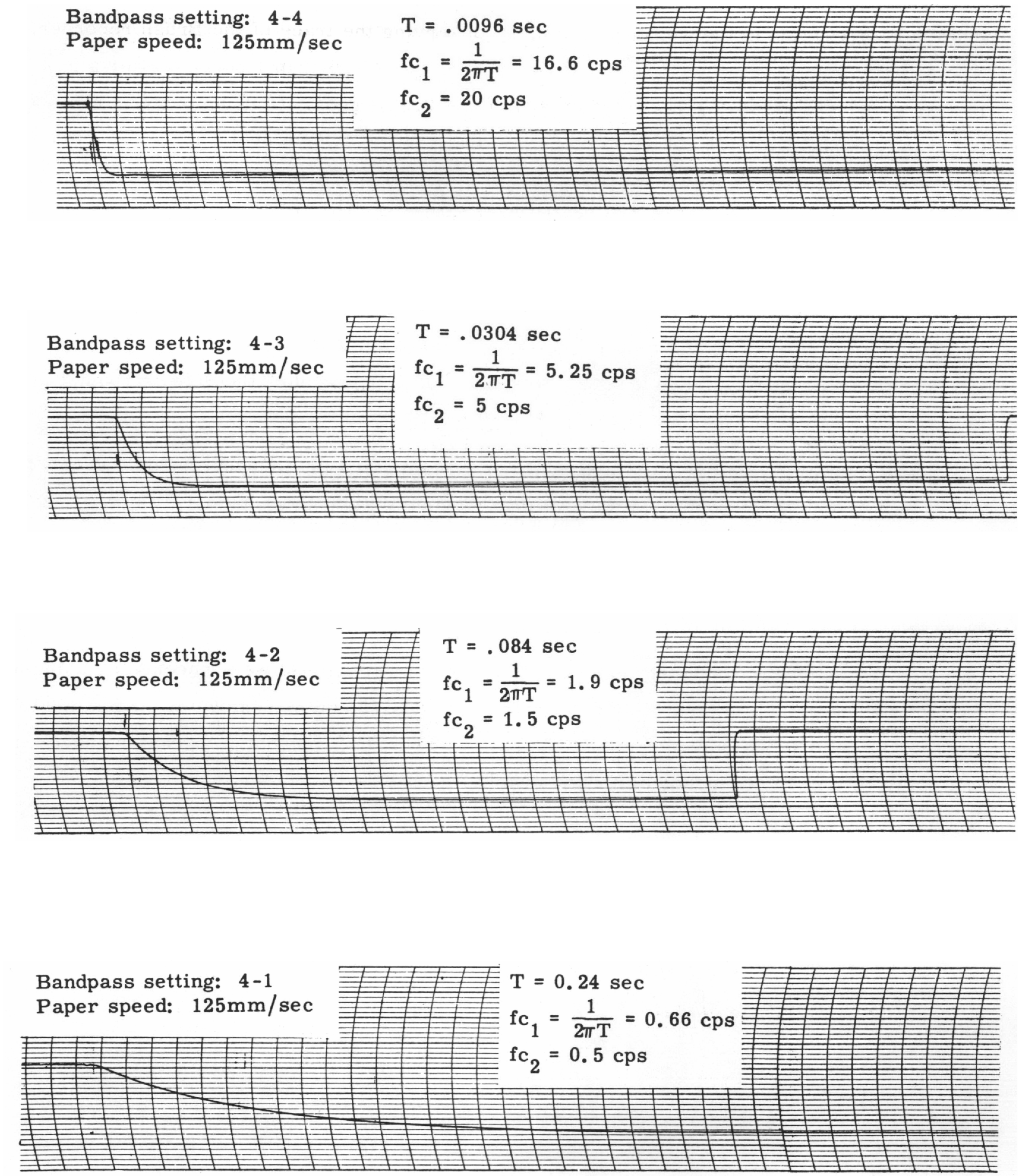


Fig. 12 -- Calibration transient response curves

Internal system noise and drift were measured, with the sensing head disconnected and the range switch in the No. 4 position, by observing the trace of the Brush recorder. The specifications state that the drift and noise should be less than 1 percent after a 5-minute warm-up period. The characteristics are not this good. Drift amounts to about 7 percent between 5 minutes and 20 minutes; however, after a 30-minute warm-up period the drift and noise was less than 1 percent.

Drift characteristics caused by input voltage variation were checked by supplying power from a Variac and changing the voltage from 105 to 120 volts and back again.

When the change of 15 volts is made very rapidly, the recorder shows a deviation of between 5 and 10 percent, but returns to the original balance within 5 seconds. When, however, the change in voltage is made over a period of 2 seconds the drift is about 1 percent.

The input transformer, T-1, is equipped with an extra tap to accommodate greater cable length; and by using this tap there should be ample gain for at least 1-1/2 miles of cable.

Experience during the 1953 Nevada Proving Ground tests indicates that the instrument works very well on 1 mile of Belden No. 8424 cable.

Drifts caused by changing temperatures on the sensing head were checked by using a radiant source of heat energy (four heat lamps). Raising the temperature of the outside of the sensing head $10^{\circ}C$ in 30 seconds caused a drift of about 2 percent. A greater change in temperature caused correspondingly greater drifts.

ENVIRONMENTAL TEST

Environmental testing of the microbarograph system to determine whether or not it is suitable for making measurements under extreme climatic conditions was carried out in three parts.

PART I: Extreme temperature test to determine if the system will operate at -10°F and +120°F.

PART II: Temperature-humidity test to determine if the system will operate under tropical conditions.

PART III: Salt-fog test to determine if the sensing head will operate when subjected to salt-spray conditions.

The tests were designed to subject the equipment to conditions much more destructive than the actual conditions under which it is expected to operate; however, in no sense of the word was this intended to be a test to destruction.

PART I - Extreme Temperature Test. -- The equipment tested was the complete microbarograph set No. 16 consisting of sensing head No. 9853, amplifier No. 11029, and power supply No. 11030.

The complete unit less recorder was placed in a temperature chamber. Recorder cables were brought outside to the Brush recorder so that the operation could be observed without opening the chamber for extended periods.

After a 1-hr warm-up period the unit was calibrated and balanced on range 40 at room temperature. The chamber was then closed and the temperature was dropped to -10°F.

After remaining at -10°F for 4 hours the unit was turned on and checked for proper operation. The meters on the panel showed no significant change in calibration current, carrier level, or resistive balance; however, the reactive unbalance reading was +1.0.

After rebalancing and peaking the reference phase, the recorder trace showed that the unit was operating; and applying a calibration step showed that the sensitivity was unaffected.

The unit was again checked 17 hours later after it had been maintained at a temperature of $+120^{\circ}F$ for a period of 8 hours.

A similar check showed the calibration current unchanged, the carrier level as 9.6 volts, the resistive unbalance as greater than -5, and the reactive unbalance as -3.0.

After rebalancing, the unit operated satisfactorily: a sensitivity check showed that the sensitivity had increased by about 20 percent. The gain control was ample to re-establish the proper sensitivity.

This part of the test indicates that the microbarograph is suitable for operation at ambient temperatures ranging from $-10^{\circ}F$ to $+120^{\circ}F$.

PART II - Temperature-Humidity Test. -- This test consisted of placing the same equipment as used in Part I in a temperature-humidity chamber which automatically went through the cycle shown in Fig. 13.

In addition to set No. 16 the amplifier-power-supply section of set No. 7 in its packing case was placed in the chamber.

The cycle is designed to duplicate tropical conditions in a ratio of 9:1; therefore, to simulate three months of tropical conditions the duration of the test was set for 10 days.

The microbarograph unit was placed in the chamber at 0900, Friday, July 10, 1953, and removed at 0900, Monday, July 20, 1953. Operation was checked at 1630, July 10, 1953; and Monday through Friday (July 13 through July 17) at 0830 every morning; and finally at 0830, Monday, July 20, when the equipment was removed and inspected.

On Monday, July 13, it was noted that the sensing head could not be balanced on range 40. The following day the same condition was noted so the sensing head was removed and inspected. Inspection showed that the sensing head was in good condition, except that the Bourdon tube had assumed a permanent set unbalancing the bridge. This condition has been observed several times previously and the cause has not been determined. Possibly the reason for the Bourdon tube taking these permanent sets is that it has been insufficiently aged.

The unbalanced condition of the sensing head was easily remedied by repositioning the E-cores about the armature.

After correcting the unbalanced sensing head it was replaced in the chamber for further testing.

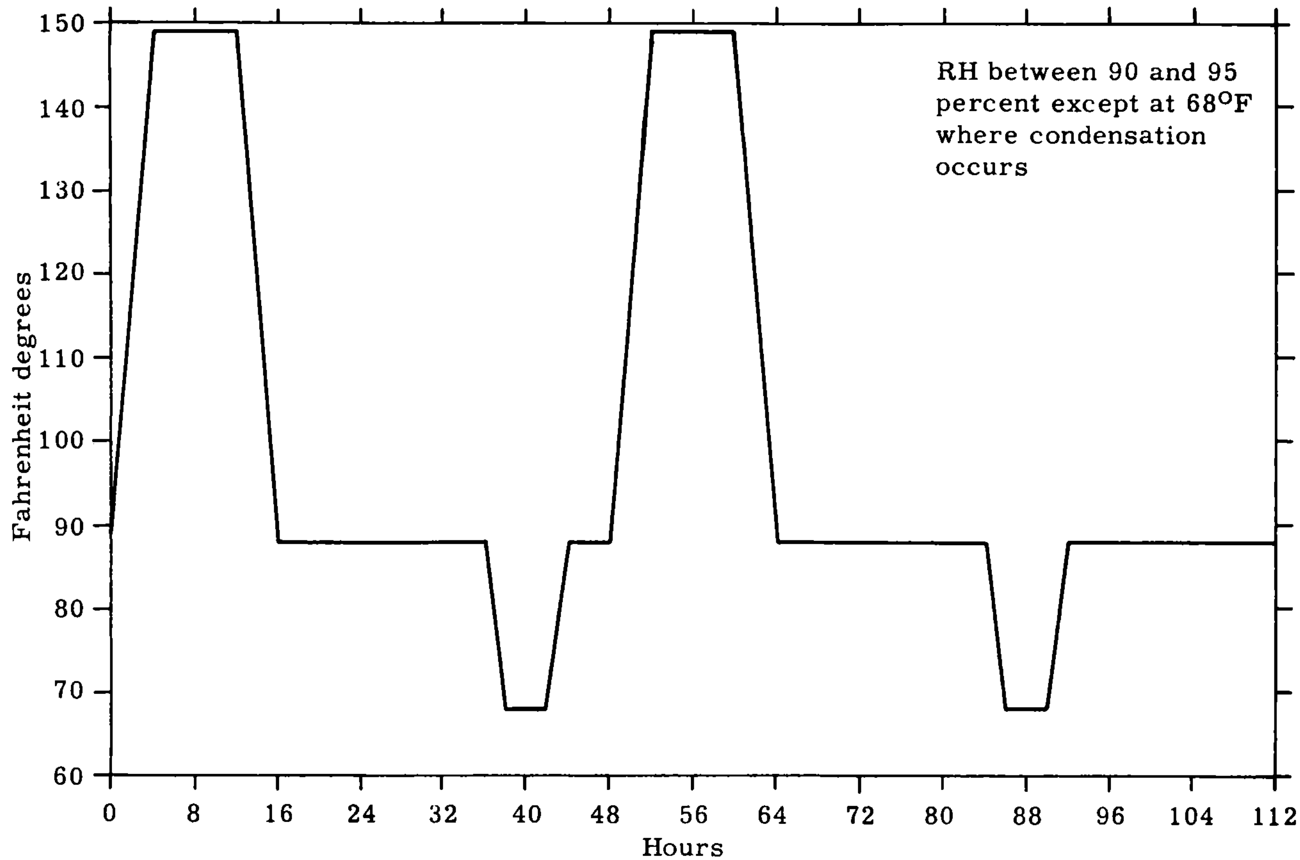


Fig. 13 -- Chamber temperature cycle

The daily operating observations indicated large variations in balance, sensitivity, and carrier level but no change in calibration current. In all cases there was ample balance control to obtain a balance; however, in three cases the carrier level could not be decreased to 10 volts. The high carrier level was not serious, however, since the gain control was ample to adjust the calibration of the instrument.

As will be noted in Fig. 13 the relative humidity reached a value of 100 percent at -68°F. This wet condition always required that the unit have at least a 10-minute warm-up period before it assumed proper operation. Evidence indicated that leakage currents were unbalancing the DC amplifiers since the recorder pens would not assume a center position until the unit had warmed up for some time.

In no instance did the warm-up time required for proper operation exceed 30 minutes.

At the conclusion of this part of the test the entire unit was still operating satisfactorily.

The visual inspection showed the following abnormal conditions:

I. Sensing head No. 9853
   - A. Externally in good condition except for spots of rust on the pressure inlet
   - B. Outside of bourdon tube housing and inside front volume speckled with rust
   - C. Volume surrounding E-cores not visibly damaged
   - D. Time constant of bleed plug unchanged

II. Amplifier No. 11029
   - A. Push button switch terminal screws corroded
   - B. NE 51 sockets corroded
   - C. Transformer cases rusty

III. Power supply No. 11030
   - A. Transformer cases rusty in spots
   - B. Capacitor C4 leaked oil impregnate
   - C. Paper covers on electrolytic capacitors came apart
   - D. Varnish peeled on 10-w resistors
   - E. Corrosion on calibration potentiometer and on filter-capacitor mounting nuts

IV. Metal rack

   A. Rusty in spots

   B. Catches corroded

V. Packing case for set No. 7

   A. Unaffected on all surfaces; rubber seal on cover not tight

VI. Amplifier-power supply for set No. 7

   A. Rubber seals in rack covers stuck slightly to rack but gave a good seal

   B. No visible signs of damage to electronics

Part III - Salt-Fog Test. -- Only the sensing head (serial No. 9853) and a portion of the hose array was exposed to the salt-fog test, since it is assumed that only these pieces will be exposed under actual operating conditions.

The salt fog was produced in a closed chamber by atomizing a sodium chloride and water solution. The solution was maintained at a specific gravity of from 1.126 to 1.157 and at a pH of between 6.2 and 7.2 when measured at a temperature between 92° and 97°F. Conditions were maintained such that a receptacle with a horizontal area of 85 cubic centimeters placed at any point in the exposure zone would collect from 0.5 to 3 milliliters of solution per hour.

Corrosion occurring on the exterior surfaces of the piece tested is indicative of corrosion that might occur during natural exposure to seashore atmosphere. The test, however, is not significant for the interior surfaces of an enclosed volume that is open to the outside through a small aperture, since with a constant temperature no breathing occurs.

The sensing head and hose array was exposed in the chamber for a total of 50 hours. Five operational checks were made and each one showed the head operating satisfactorily with a negligible change in sensitivity.

A visual examination after the test showed little more corrosion on the sensing head than existed before the test. The interior surfaces showed no corrosion; however, this was anticipated since no breathing occurred. The orifices in the hose array were coated with salt, altering the size of the orifice and consequently the frequency response of the array.

In conclusion, it appears from the environmental test that the Wiancko microbarograph is suitable for tropical use.

CALIBRATION TECHNIQUES

The static calibration is accomplished with the aid of a water manometer. With one side of the manometer open to the atmosphere and the other side connected directly to the sensing head, the pressure resulting from the difference in water height of the two columns (defined as the water head) is applied to the Bourdon tube. This pressure will be above atmospheric.

A special Wiancko calibration attachment, shown on p 46 of Appendix A, is used in this calibrating procedure. This fitting opens up the back-volume bleed to the outside atmospheric pressure. The pressure caused by the head in the manometer is led directly to the Bourdon tube entrance so that the back-volume leak can have no bleed effect upon the pressure affecting the tube.

The conversion from head of water in inches to microbars was easily made with the use of Handbook of Engineering Fundamentals by Eshbach. Table No. 41 states that 406.8 inches of water at $4^{o}C$ equals one atmosphere of pressure. Since 10^6 microbars equals one atmosphere, one inch of water equals 2458.2 microbars. The enclosed curve (Fig. 14) is constructed from these facts. Since greater accuracy can be obtained from a manometer with a scale in millimeters, a curve of millimeters versus microbars, also in Fig. 11, is given based on 1 mm equal to 96.78 microbars.

The secondary calibration is designed to give 3/4 of full scale deflection on any range setting. The water manometer can be read with greater accuracy the larger the head since the reading ability is a constant independent of amplitude. With the range set on the largest scale, $\pm$12,000 microbars, the most sensitive pen, 'Pen A', will read 9000 microbars from center to 3/4 full scale. Calibration is run for 9000 microbars.

An AC vacuum-tube voltmeter is connected into the circuit, just before the demodulator, by plugging into the jacks BJ1 and BJ3 located on the rear of the amplifier chassis. With the sensing head reading atmospheric pressure, the resistive and reactive components are balanced out

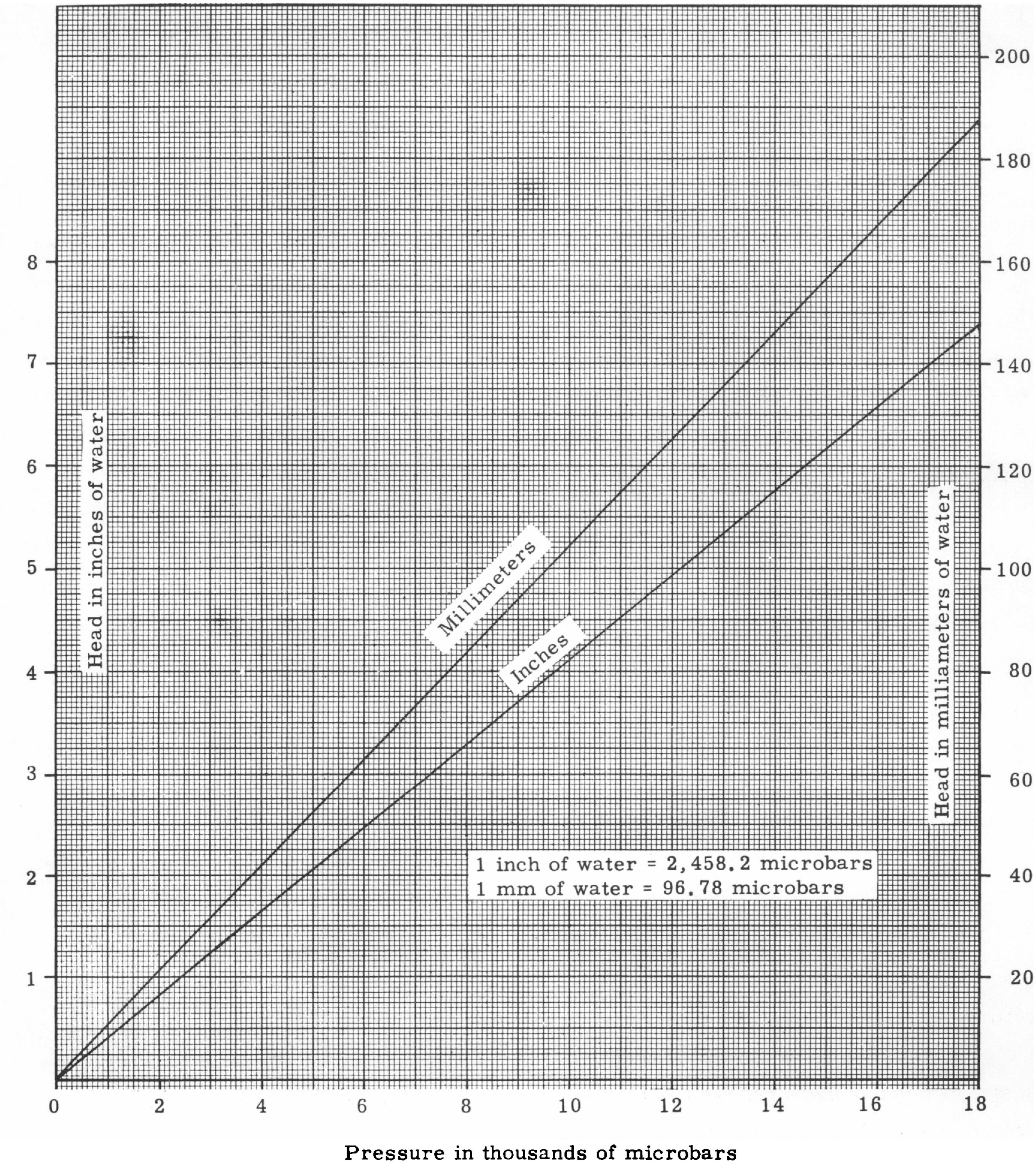


Fig. 14 -- Conversion of inches and millimeters water head to microbars

until a null is reached. A water head of 9000 microbars is then applied to the sensing head. The reading of the vacuum-tube voltmeter is taken. The pressure is released. The 3/4 transient calibration is pushed and held. The calibration current screw driver adjustment on the power supply panel is turned until the vacuum-tube voltmeter gives the same reading as when under pressure. This means that the current, read on the calibration current meter when the button below it is depressed, will cause the armature to rotate and the Bourdon tube to twist an amount equal to the twist caused by 9000 microbars pressure.

After removing the vacuum-tube voltmeter from the circuit, the output of the sensing head is balanced and the pens centered. Then the 3/4 transient calibration button is pushed and the deflection of the most sensitive pen is noted on the brush. The gain on the amplifier panel is adjusted until pushing the 3/4 calibration button gives a deflection of 15 mm on the Brush recorder. The 12-1200 Calibration Button is then depressed and the 'B Pen Gain' on the back of the amplifier chassis is adjusted until the recorder reads 3/4 full scale or 15 mm with the range switch on 400. The most accurate method of adjusting the four to one ratio between pens after secondary calibration of 'Pen A' has been made is to drive the system with an audio oscillator. The output of the audio oscillator is connected between black ground jack (BJ1) and red jack (BJ2). The 'A Pen' is driven full scale and the 'B Pen' amplitude is adjusted with 'B Pen Gain' to read 10 mm.

This calibration is a one-point calibration and is set up for 9000 microbars pressure. A plot showing linearity of the calibration circuit is shown in Fig. 15. The nonlinearity of this line illustrates the necessity for a one-point calibration.

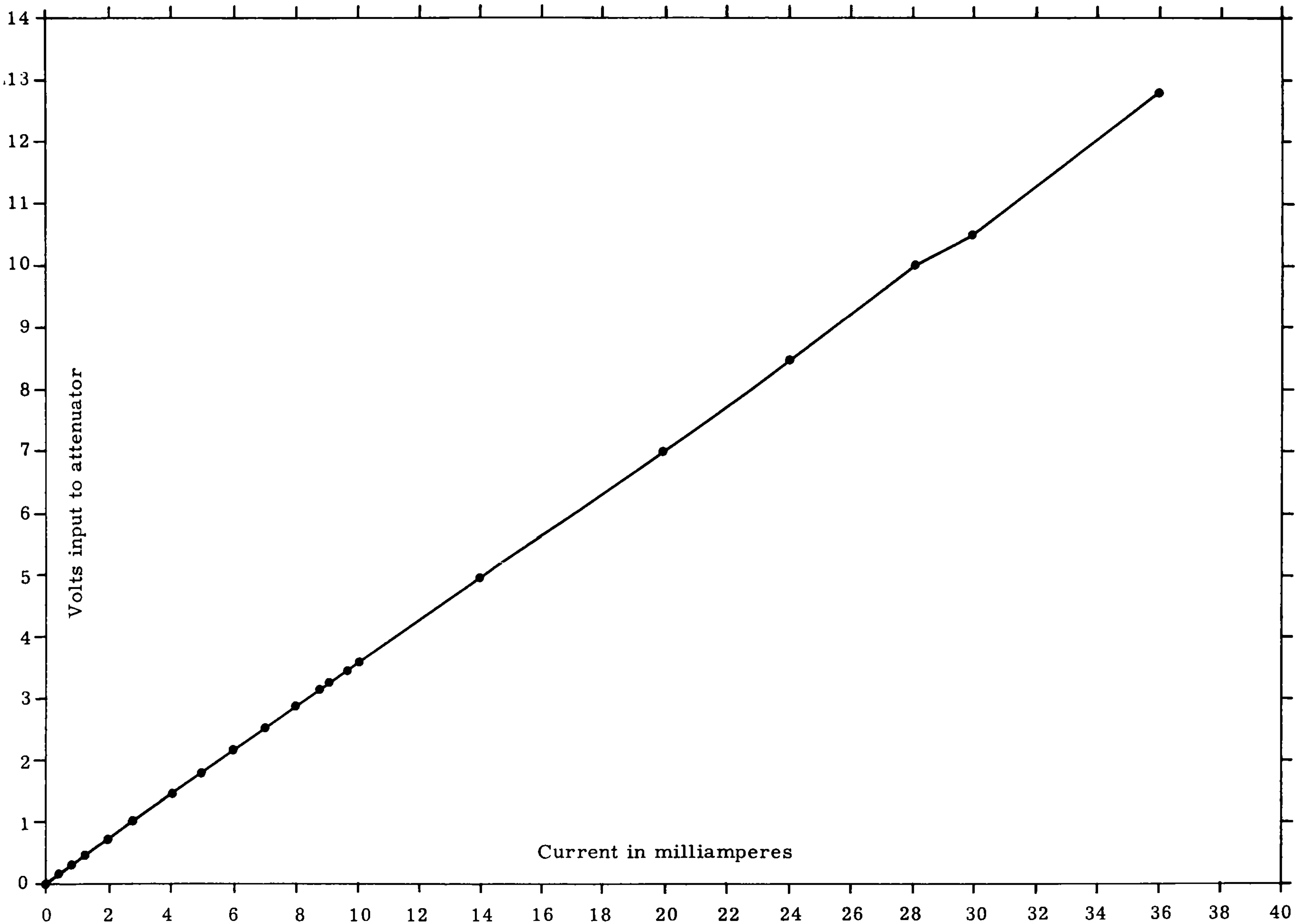


Fig. 15 -- Linearity of the calibration circuit in the Wiancko microbarograph sensing head, serial No. 9837

Appendix A to

MICROBAROGRAPH EVALUATION REPORT

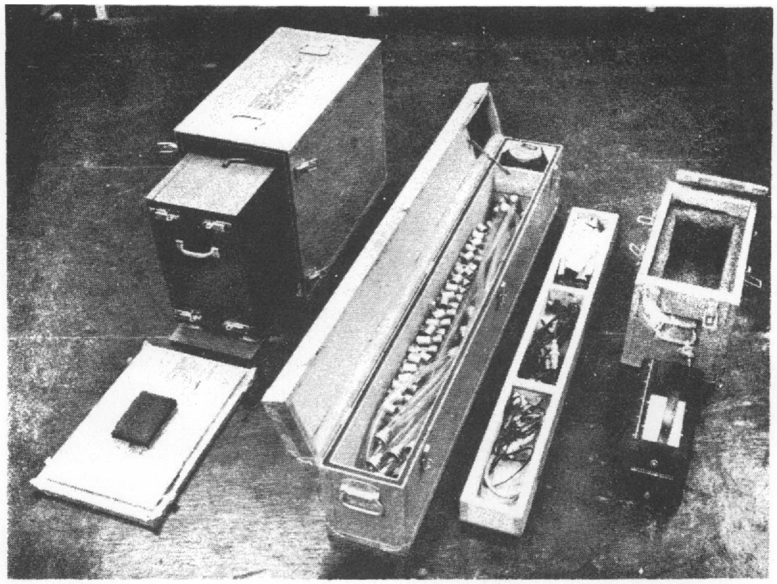


Fig. 16 -- Exploded packaging view of a complete microbarograph system

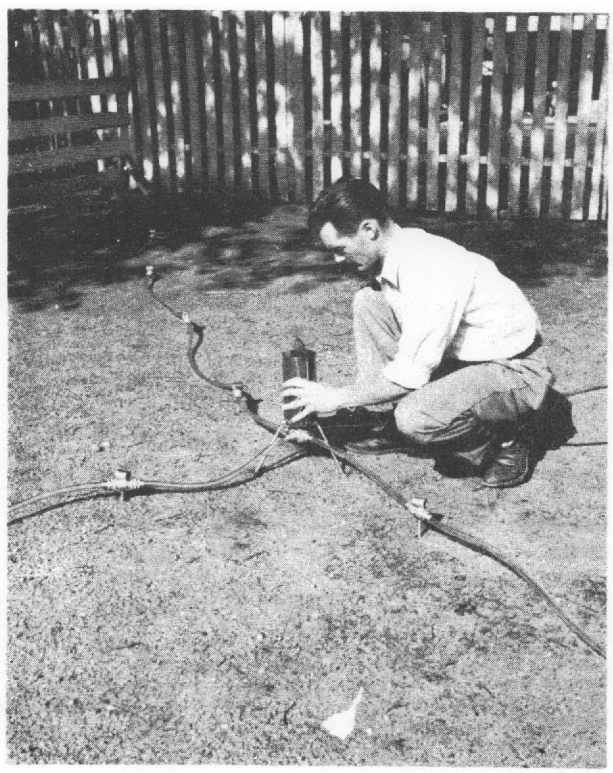


Fig. 17 -- Sensing head and hose array assembled for operation - Bishop, California

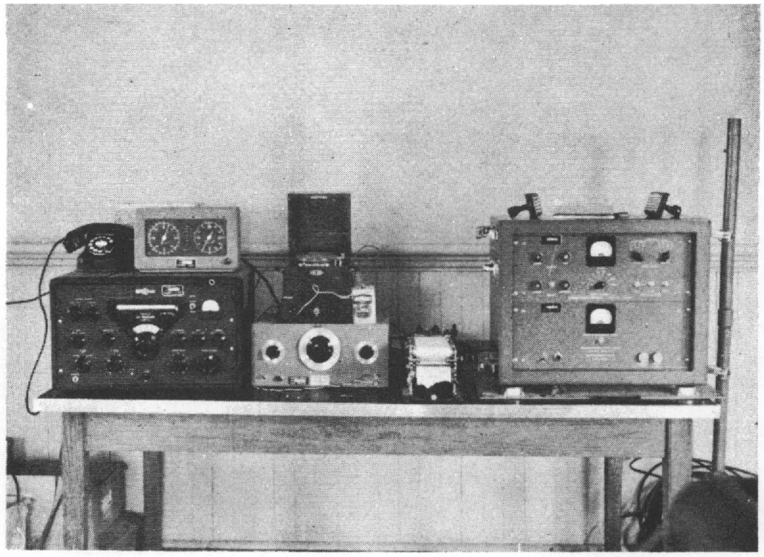


Fig. 18 -- Typical single station installation - Bishop, California

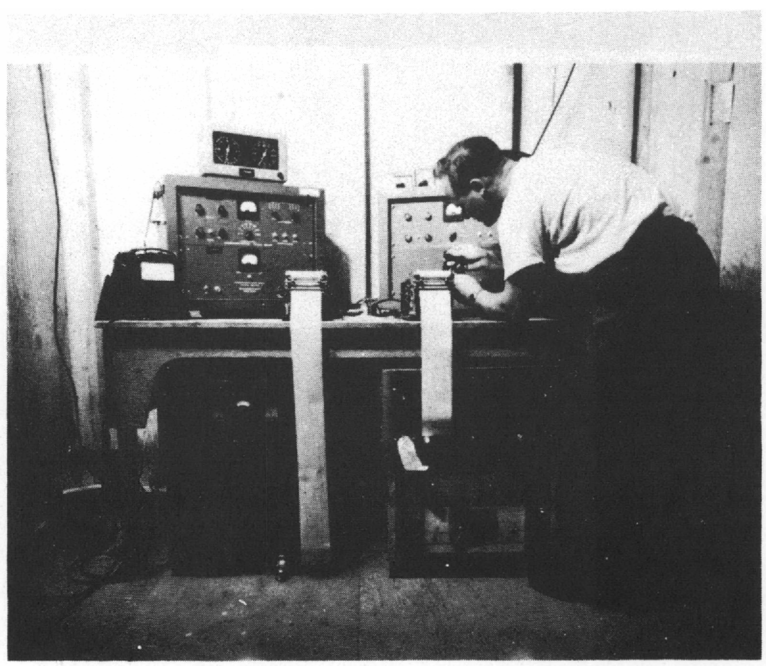


Fig. 19 -- Typical dual station installation - Indian Springs, Nevada

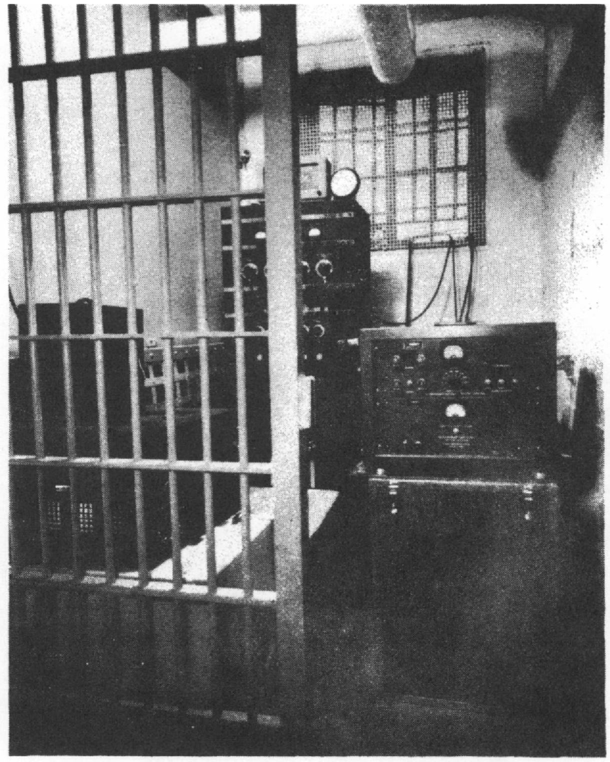


Fig. 20 -- Typical single station installation - Boulder, Nevada

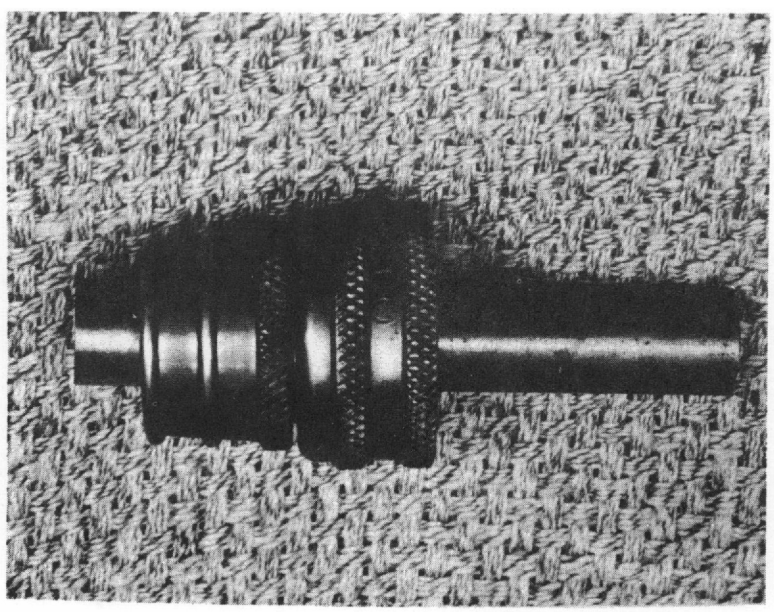


Fig. 21 -- Calibration attachment

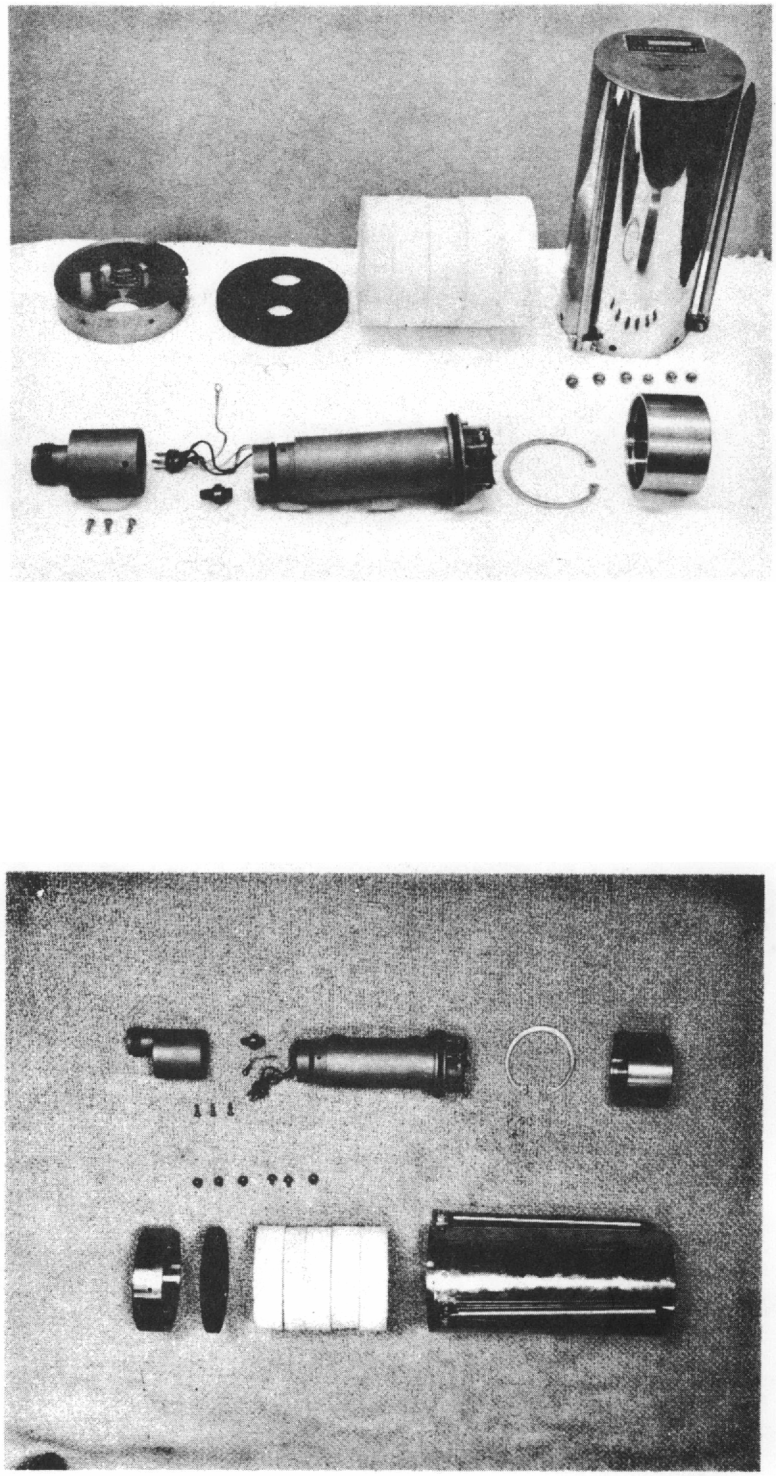


Fig. 22 -- Exploded views - microbarograph sensing head (Wiancko 3-PMB-2)

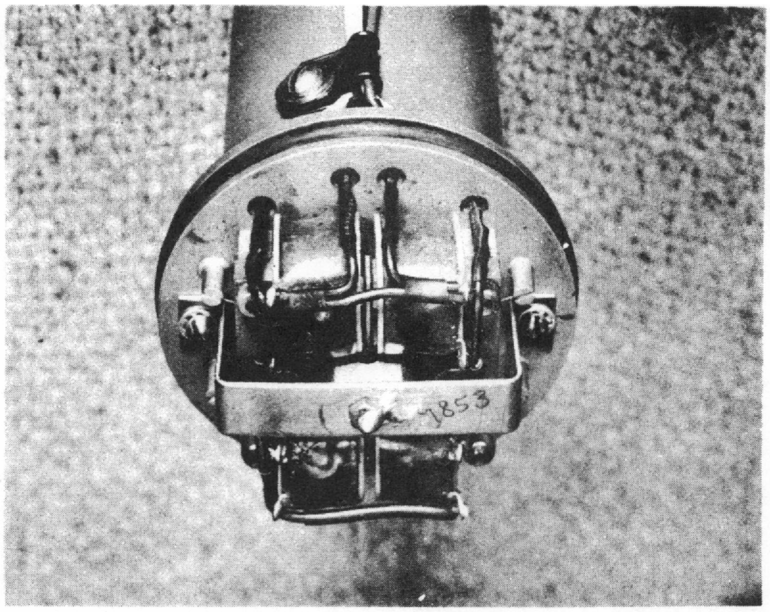


Fig. 23 -- View of sensing-head transducer showing the calibration magnet

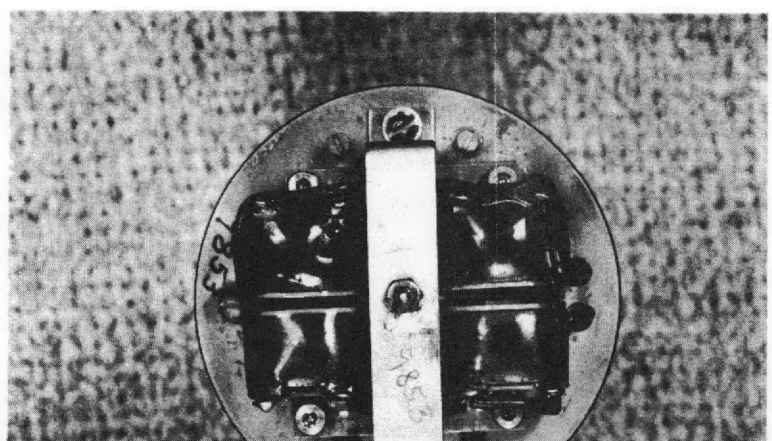


Fig. 24 -- View of sensing-head transducer showing the armature and E-coil arrangement

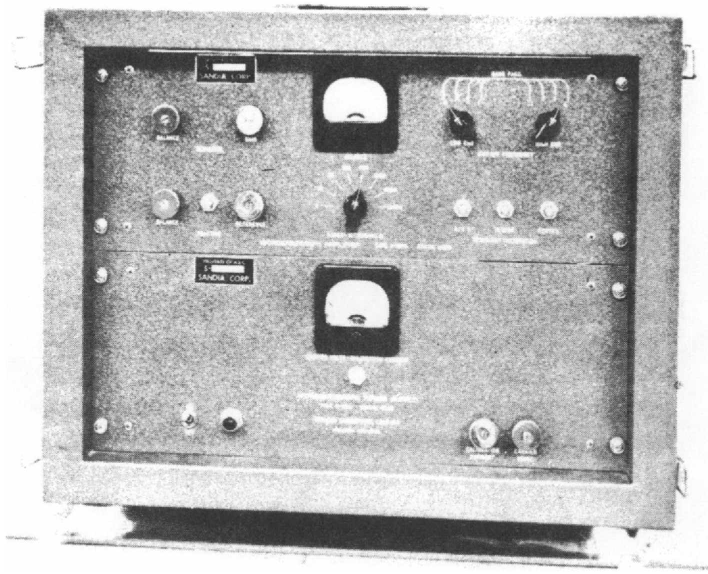


Fig. 25 -- Front panel view of the microbarograph amplifier-power-supply assembly

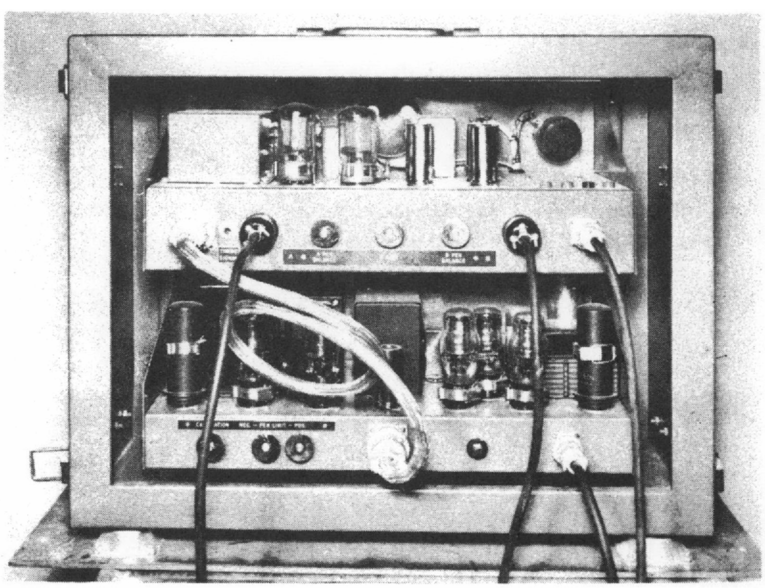


Fig. 26 -- Rear view of the microbarograph amplifier-power-supply assembly

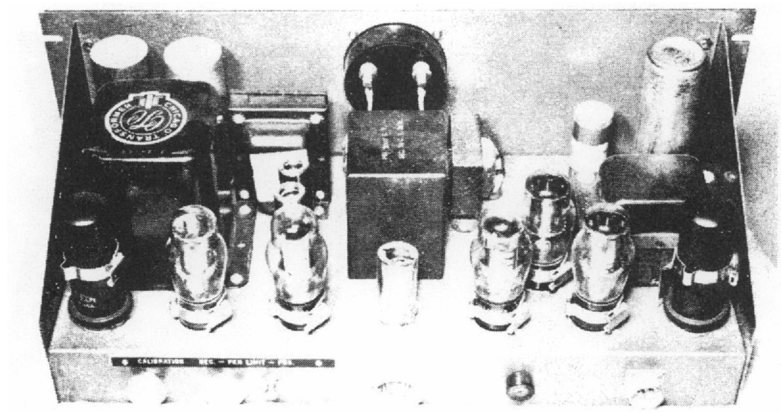


Fig. 27 -- Top view of the oscillator-power-supply chassis

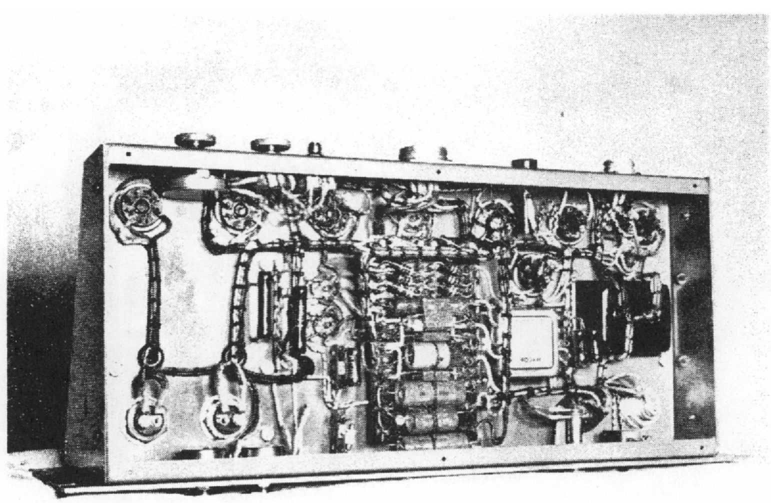


Fig. 28 -- Bottom view of the oscillator-power-supply chassis

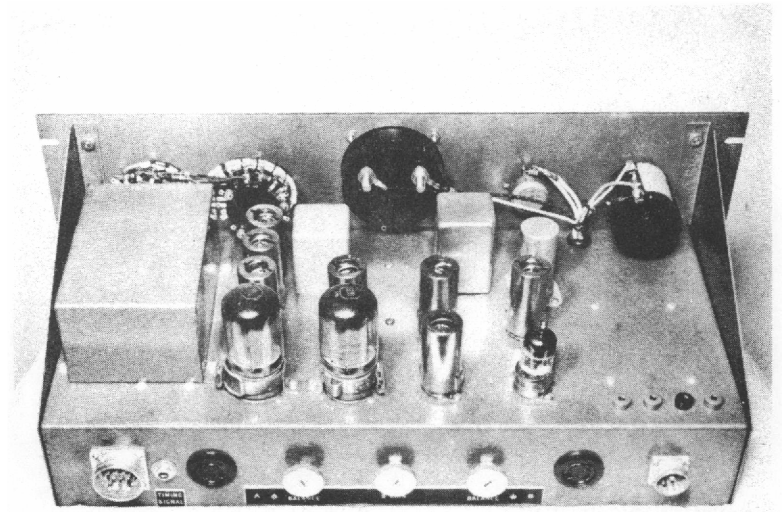


Fig. 29 -- Top view of amplifier-demodulator chassis

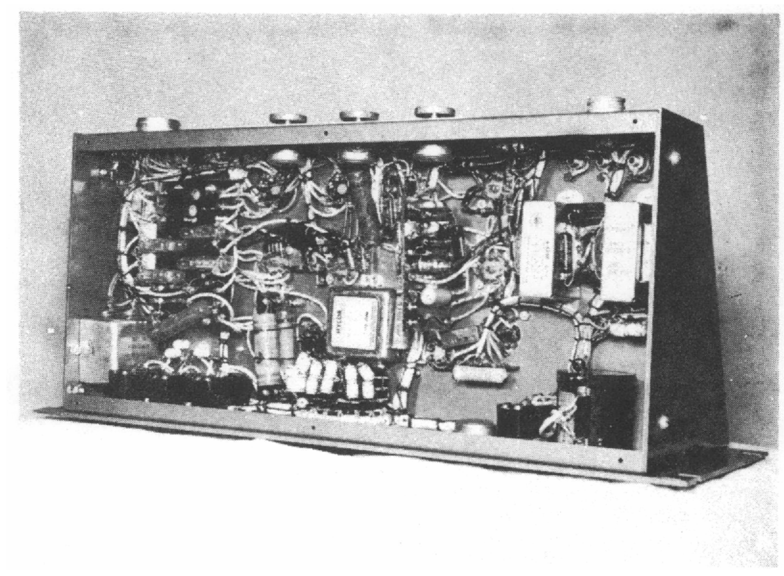


Fig. 30 -- Bottom view of amplifier-demodulator chassis

APPENDIX B

Example Records

Figure 31 shows records which were made at a distance of 5 miles from the point of detonation of two 250-pound HE blasts.

For the record made October 1, 1952, the paper was traveling at 25 mm per second; and for the record made October 22, 1952, the paper was traveling at 125 mm per second. The above speed can be verified by the event-marking pen which marked seconds on the edge of the record.

Knowing the calibration and the speed of the paper, the blast wave is easily interpreted for amplitude and period.

These examples also show the value of having a sensitivity ratio of 4 to 1 to provide backup in case the pressure amplitude prediction is in error.

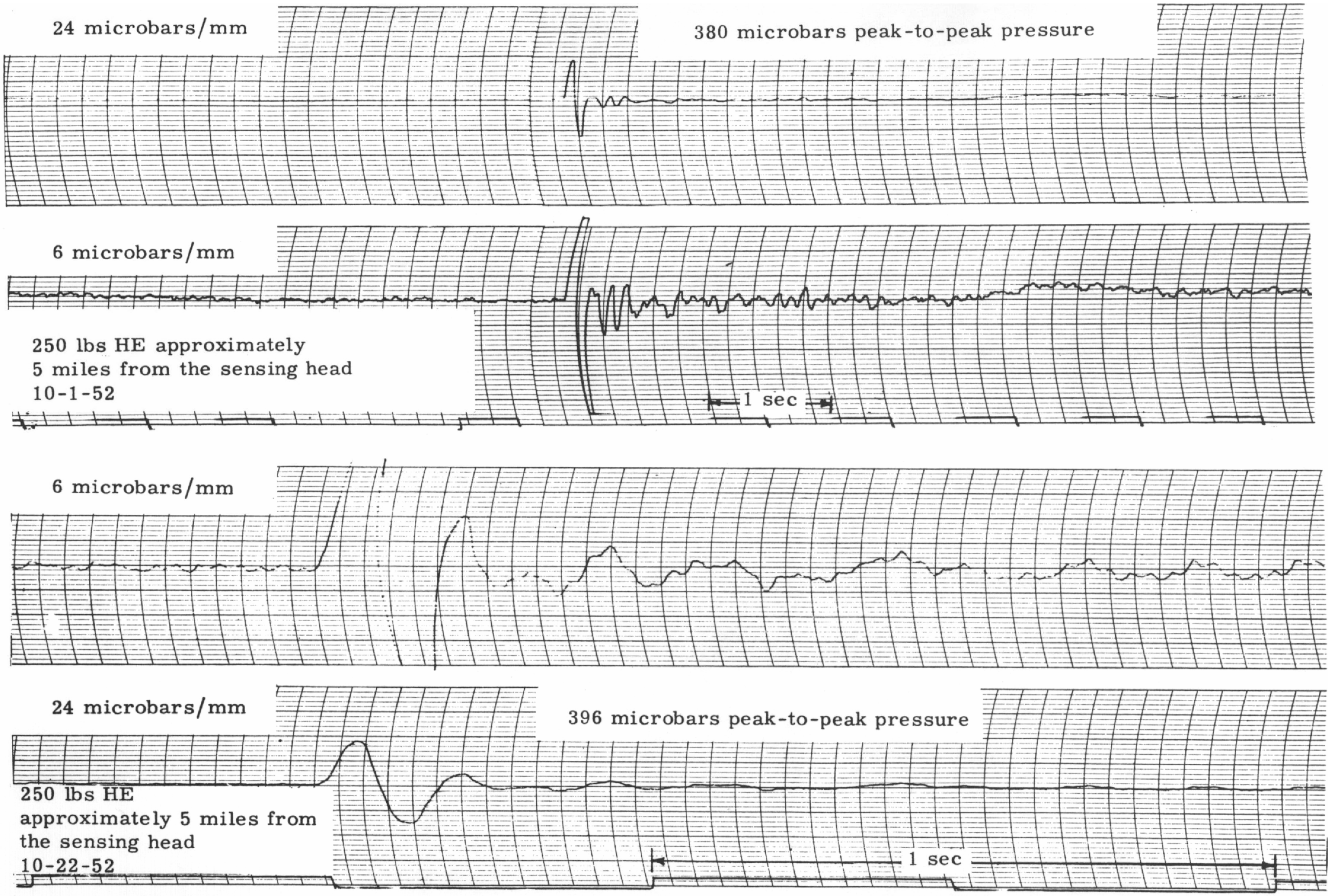
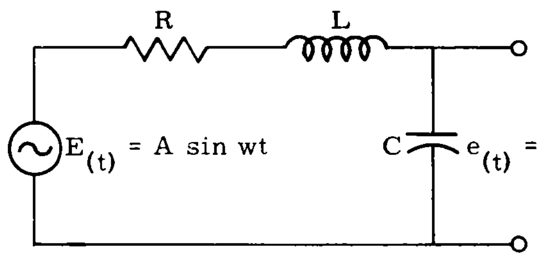


Fig. 31 -- Example of microbarograph records

APPENDIX C

Frequency Response Characteristics of an LCR Series Circuit

Given the series LCR circuit,



,

the problem is to find the steady state solution; therefore the differential equation is

$$L\ddot{q} + R\dot{q} + \frac{1}{C}q = A \sin \omega t = 1 \sin \omega t \ .$$

Transforming, where $\dot{q}(o) = q(o) = 0$, and solving the algebraic equation for q we get

$$Ls^2 q(s) + Rsq(s) + \frac{1}{C}q(s) = \frac{\omega}{s^2 + \omega^2}$$

$$q(s) = \frac{\omega}{L} \times \frac{1}{s^2 + \omega^2} \times \frac{1}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$q(s) = \frac{\omega}{L} \times \frac{1}{s^2 + \omega^2} \times \frac{1}{(s + \frac{R}{2L})^2 + (\frac{1}{LC} - \frac{R^2}{4L^2})} \ ,$$

which is best separated into partial fractions of the type,

$$q(s) = \frac{\omega}{L}\left\{\frac{As + B}{s^2 + \omega^2} + \frac{Cs + D}{(s + \alpha)^2 + \beta^2}\right\} .$$

To evaluate A and B (the coefficients of the steady state term), write the four algebraic equations for A, B, C, and D:

$$B(\alpha^2 + \beta^2) + D\omega^2 = \omega/L$$

$$\alpha^2 A + 2\alpha B + \beta^2 A + \omega^2 C = 0$$

$$2\alpha A + B + D = 0$$

$$A + C = 0 \ .$$

Let $\gamma = \alpha^2 + \beta^2$; the solutions for A and B are

$$A = \frac{\begin{vmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 2\alpha & \omega^2 & 0 \\ \frac{\omega}{L} & \gamma & 0 & \omega^2 \end{vmatrix}}{\begin{vmatrix} 1 & 0 & 1 & 0 \\ 2\alpha & 1 & 0 & 1 \\ \gamma & 2\alpha & \omega^2 & 0 \\ 0 & \gamma & 0 & \omega^2 \end{vmatrix}} = \frac{\frac{\omega}{L}(-2\alpha)}{(\omega^4 - \gamma\omega^2) + 2\alpha\,(2\alpha\omega^2) - \gamma(\omega^2 - \gamma)} \ ,$$

and

$$B = \frac{\begin{vmatrix} 1 & 0 & 1 & 0 \\ 2\alpha & 0 & 0 & 1 \\ \gamma & 0 & \omega^2 & 0 \\ 0 & \frac{\omega}{L} & 0 & \omega^2 \end{vmatrix}}{\begin{vmatrix} 1 & 0 & 1 & 0 \\ 2\alpha & 1 & 0 & 1 \\ \gamma & 2\alpha & \omega^2 & 0 \\ 0 & \gamma & 0 & \omega^2 \end{vmatrix}} = \frac{-\frac{\omega^3}{L} + \frac{\gamma\omega}{L}}{\omega^4 + \omega^2\,(4\alpha^2 - 2\gamma) + \gamma^2} \ ,$$

whence

$$q(s) = \frac{-2\alpha\frac{\omega}{L}s - \frac{\omega^3}{L} + \frac{\gamma\omega}{L}}{[\omega^4 + \omega^2\,(4\alpha^2 - 2\gamma) + \gamma^2]\,[s^2 + \omega^2]} + \text{transients}$$

$$q(s) = \frac{-\frac{R\omega s}{L^2} + \omega\left[\frac{1}{L^2C} - \frac{\omega^2}{L}\right]}{\left[\omega^4 + \omega^2\,(\frac{R^2}{L^2} - \frac{2}{LC}) + \frac{1}{L^2C^2}\right]\left[s^2 + \omega^2\right]} + \text{transients} \ .$$

The steady state solution is

$$q(t) = \frac{-\frac{R\omega}{L^2}\cos\omega t + \left[\frac{1}{L^2 C} - \frac{\omega^2}{L}\right]\sin\omega t}{\omega^4 + \omega^2\left(\frac{R^2}{L^2} - \frac{2}{LC}\right) + \frac{1}{L^2 C^2}} \quad .$$

Finding $e(t) = \frac{1}{C} q(t)$ in standard form,

$$e(t) = \frac{\left[\frac{1}{L^2 C^2} - \frac{\omega^2}{LC}\right]\sin\omega t - \frac{\omega R}{L^2 C}\cos\omega t}{\left(\frac{\omega R}{L}\right)^2 + \left(\omega^2 - \frac{1}{LC}\right)^2} \quad .$$

Expressing the voltage in the form $e = C \sin(\omega t + \phi)$,

$$e = \frac{\sqrt{\left(\frac{\omega^2}{LC} - \frac{1}{L^2 C^2}\right)^2 + \frac{\omega^2 R^2}{L^4 C^2}}}{\left(\frac{\omega R}{L}\right)^2 + \left(\omega^2 - \frac{1}{LC}\right)^2} \sin(\omega t + \phi) \quad .$$

The resonance condition is where $\omega^2 = \frac{1}{LC}$. At resonance the expression for amplitude becomes

$$e = \frac{\sqrt{\frac{\omega^2 R^2}{L^4 C^2}}}{\frac{\omega^2 R^2}{L^2}} = \frac{\frac{\omega R}{L^2 C}}{\frac{\omega^2 R^2}{L^2}} \quad ;$$

therefore the amplitude of e will be greater than unity whenever

$$\frac{\omega^2 R^2}{L^4 C^2} > \frac{\omega^4 R^4}{L^4} \quad ,$$

or

$$\omega^2 R^2 C^2 < 1 \quad ,$$

or

$$R^2 < \frac{L}{C} \quad ,$$

and will be flat to cutoff whenever $R^2 = \frac{L}{C}$. This represents a critically damped state. If $R^2 > \frac{L}{C}$, which represents the overdamped state, the amplitude will be less than unity.

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