ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

WIDE-RANGE TUNING METHODS AND TECHNIQUES

APPLICABLE TO SEARCH RECEIVERS

QUARTERLY PROGRESS REPORT NO. 14, TASK ORDER EDG-4
Period Covering October 1, 1954 to December 31, 1954

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Project 2262

CONTRACT NO. DA-36-039 sc-63203
SIGNAL CORPS, DEPARTMENT OF THE ARMY
DEPARTMENT OF ARMY PROJECT NO. 3-99-04-042
SIGNAL CORPS PROJECT 194B

January, 1955

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Abstract

The progress of the Electronic Defense Group on Task EDG-4 is reviewed for the fourth quarter of 1954. A spot-check measurement technique has been developed for ferrite cores. A twin coaxial inductor has been designed for VHF measurements. The method has been greatly improved for the preparation of subminiature ferroelectric capacitors for PANDU units, high frequency electric tuned oscillators, and special measurements. High frequency Q measurements have begun on ferroelectric capacitors with variable dc field and preliminary data are reported in the form of a QEF surface. The BLARE unit is completed and preliminary results are reported. The Panoramic Display Unit (PANDU) has been revised, and two new front end assemblies of electric tuned receivers covering the range 28 to 110 mc, have been constructed and tested. Electric tuned oscillators for 150-230 mc and 250-385 mc ranges have been constructed and tested. Noise measurements on the Michigan Voltage-Tunable Magnetron have been started. The objectives for the quarter have been accomplished.

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1. PURPOSE

This report reviews the progress made by the Electronic Defense Group in the study of wide-range tuning methods and techniques applicable to search receivers during the fourth quarter of 1954.

2. PUBLICATIONS AND REPORTS

Mr. H. Diamond attended the Symposium on Ferroelectricity at Rutgers University on October 14, 1954.

Dr. L. W. Orr visited the Centralab Division of Globe-Union Inc., Milwaukee, Wisconsin on November 12, 1954 to discuss barium titanate ceramics suitable for electric tuning.

3. FACTUAL DATA

3.1 Use of Ferromagnetic and Ferroelectric Materials in the Tuning of RF Componen

3.1.1 Ferromagnetic Materials. (L. W. Orr)

3.1.1.1 SCF Measurements on Ferrite Cores. Spot check with field (SCF) measure-ments are required on a large backlog of ferrite cores produced by Task 6 in ad-dition to cores currently being produced. Adequate facilities have not been avai able to get data with variable bias field on this large number of cores. There-fore, all data taken on these cores to date have been for zero field.

For a general survey of these cores, the amount of data per core must b restricted. Thus, each core is to be spot checked for Q and inductance at one or two frequencies in the range 0.3 to 1.0 mc, at a small number of values of bias field. This procedure is followed in the SCF tests.

What is desired is a knowledge of the relative variation of μ and Q as the bias field is varied. Therefore, absolute accuracy is not required of these tests. The results of the tests, when correlated with the production parameters, should indicate a desired trend towards a core having ideal properties for magnetic tuning.

In addition to restricting the amount of data per core, facility for tl SCF measurements must have some simple means of preparing the core for the test. One of the chief difficulties was the problem of winding and unwinding some 50 turns of wire per core. Several attempts to produce a demountable, capsule type of multi-turn coil were not successful because of the difficulties of constructic plus the large number of contacts involved (two for each turn).

A method now being developed uses a seven wire, flexible cable which may be quickly wound and unwound from a core. Eight wraps of this cable will giv give a 56 turn coil if the ends are properly connected. To simplify the connecting process, each end of the cable is furnished with a subminiature plug (Fig. 1) which is small enough to enter the core even when partly wound with the cable.

After the cable is applied to the core, the plugs are inserted into two subminiature sockets (Fig. 2). These sockets are mounted in turn on an adapter plate and the sockets are wired so that the cable wires are all placed in series. This gives a coil of 56 turns on the core.

One disadvantage of this type of winding is the inherently large stray capacitance, but since this stays constant from one core to the next, a Q-correction chart may be prepared to correct the readings.

The SCF equipment will mount on the top of the Q meter as shown in Fig. 3. The core to be tested, with its cable winding, L, plugs into an adapter plate which carries the subminiature sockets and in turn is connected through banana pins to the coil terminals of the Q meter. Provision is made for inserting a capacitor (A, Fig. 3) if required. An isolating inductance, L, furnishes a path for the dc bias current.

A capacitor box, C, has been designed to permit addition of external capacity to the Q meter. The circuit is shown in Fig. 4. Any value of capacity between 400 μμf and 44,000 μμf in incremental steps of 400 μμf may be selected by appropriate settings of deck switches S_1 and S_2. Banana pins permit the box to be plugged directly into the Q meter, thus keeping external lead lengths as short as possible.

Construction of these units is now proceeding satisfactorily.

3.1.1.2 Twin Coaxial Inductor. VHF impedance bridge measurements on ferrite cores have been made only with zero bias field as there has been no facility for applying bias field. This problem is more difficult than that described in 3.1.1.1 for two reasons. The first is that only a single turn, or coaxial

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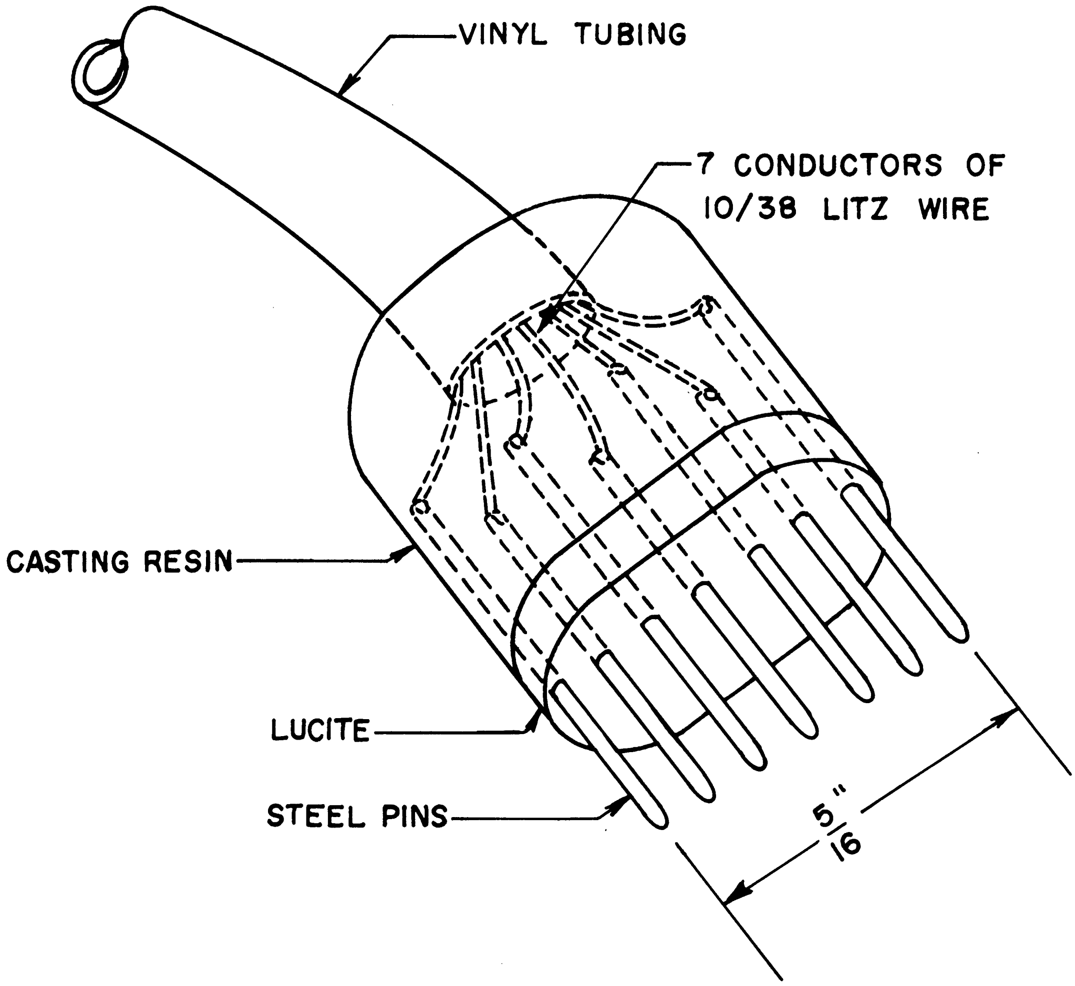

FIG. 1

SUBMINIATURE PLUG AND CABLE

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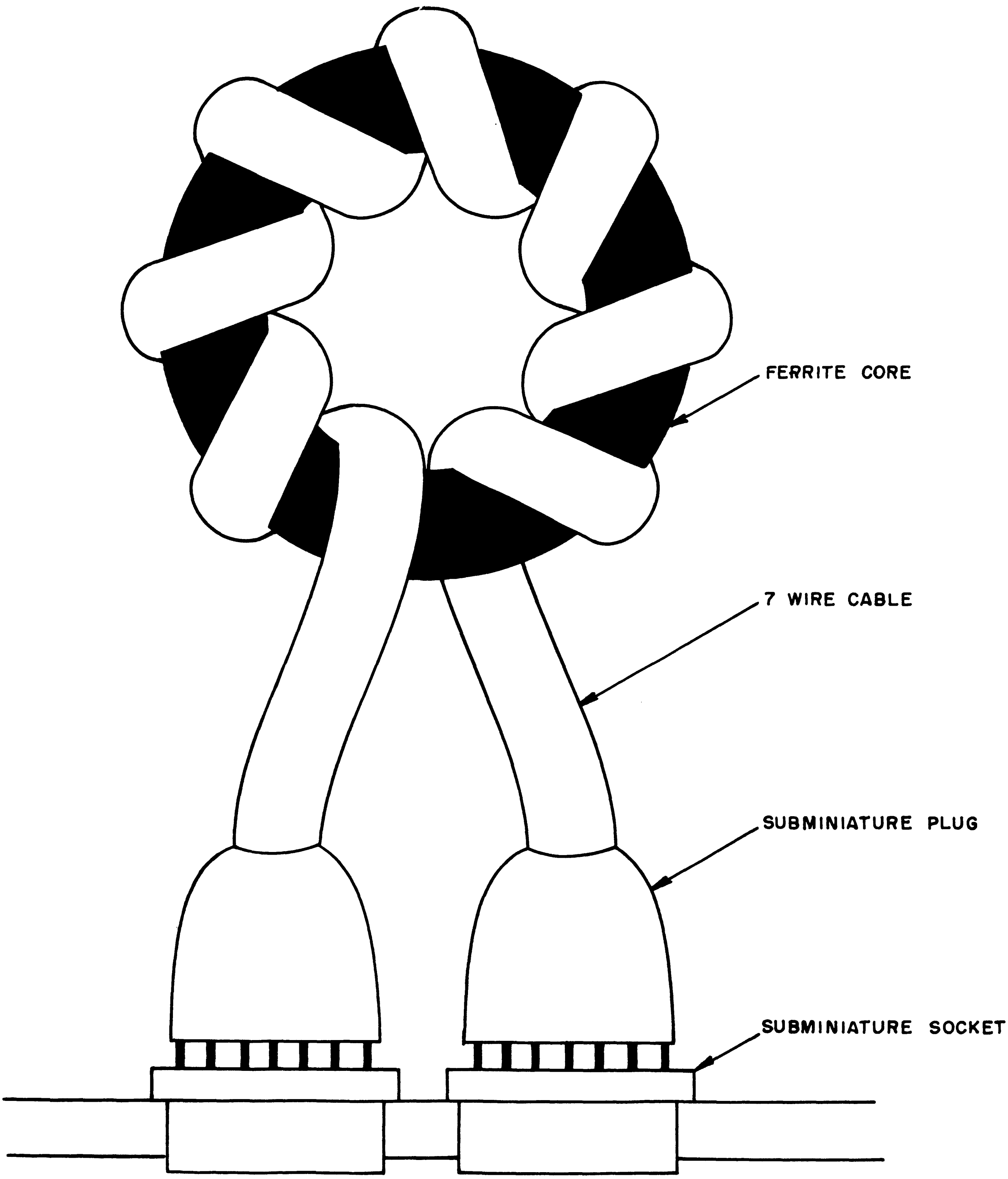


FIG. 2. CORE WITH CABLE APPLIED.

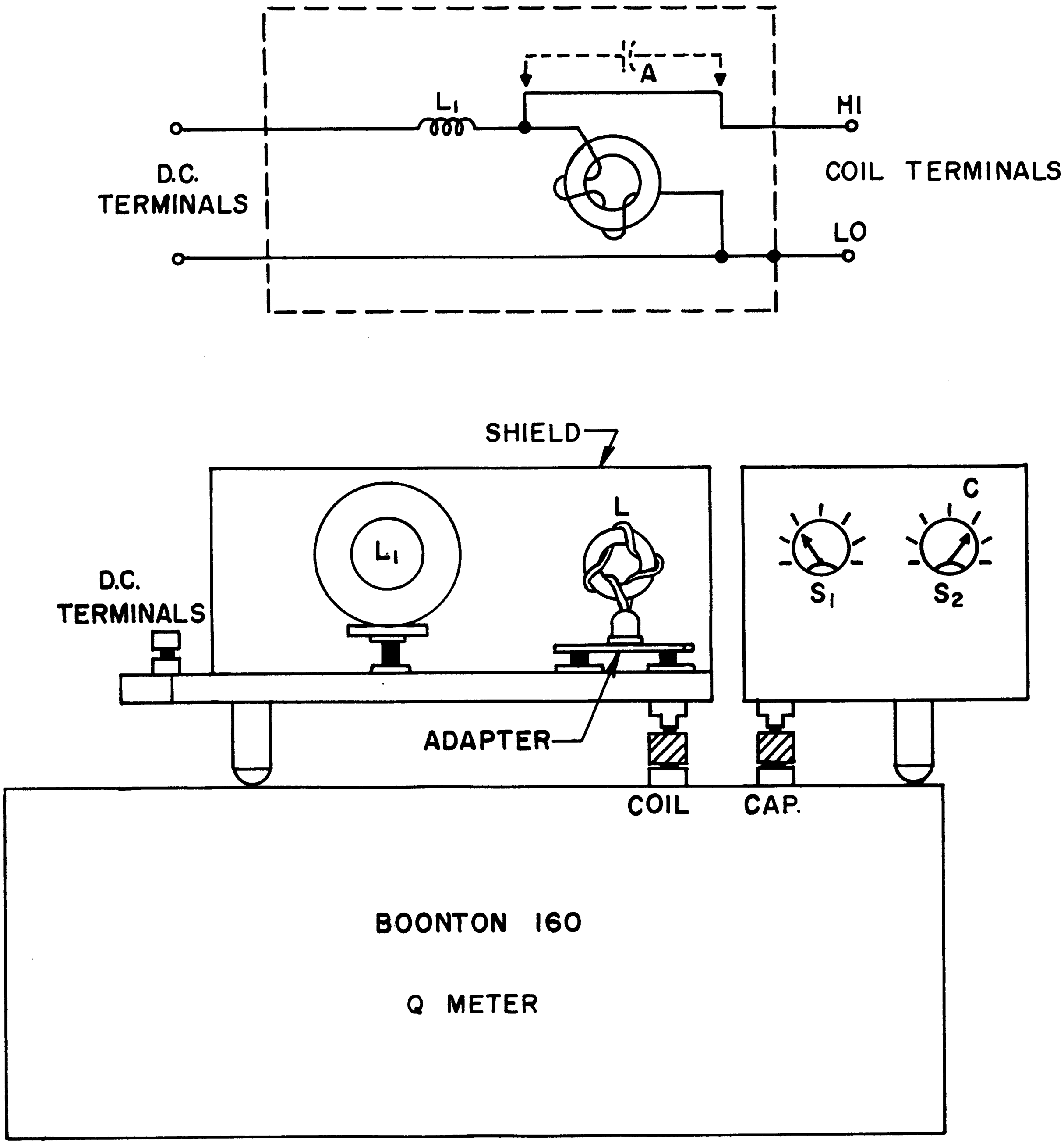


FIG. 3

SCF EQUIPMENT

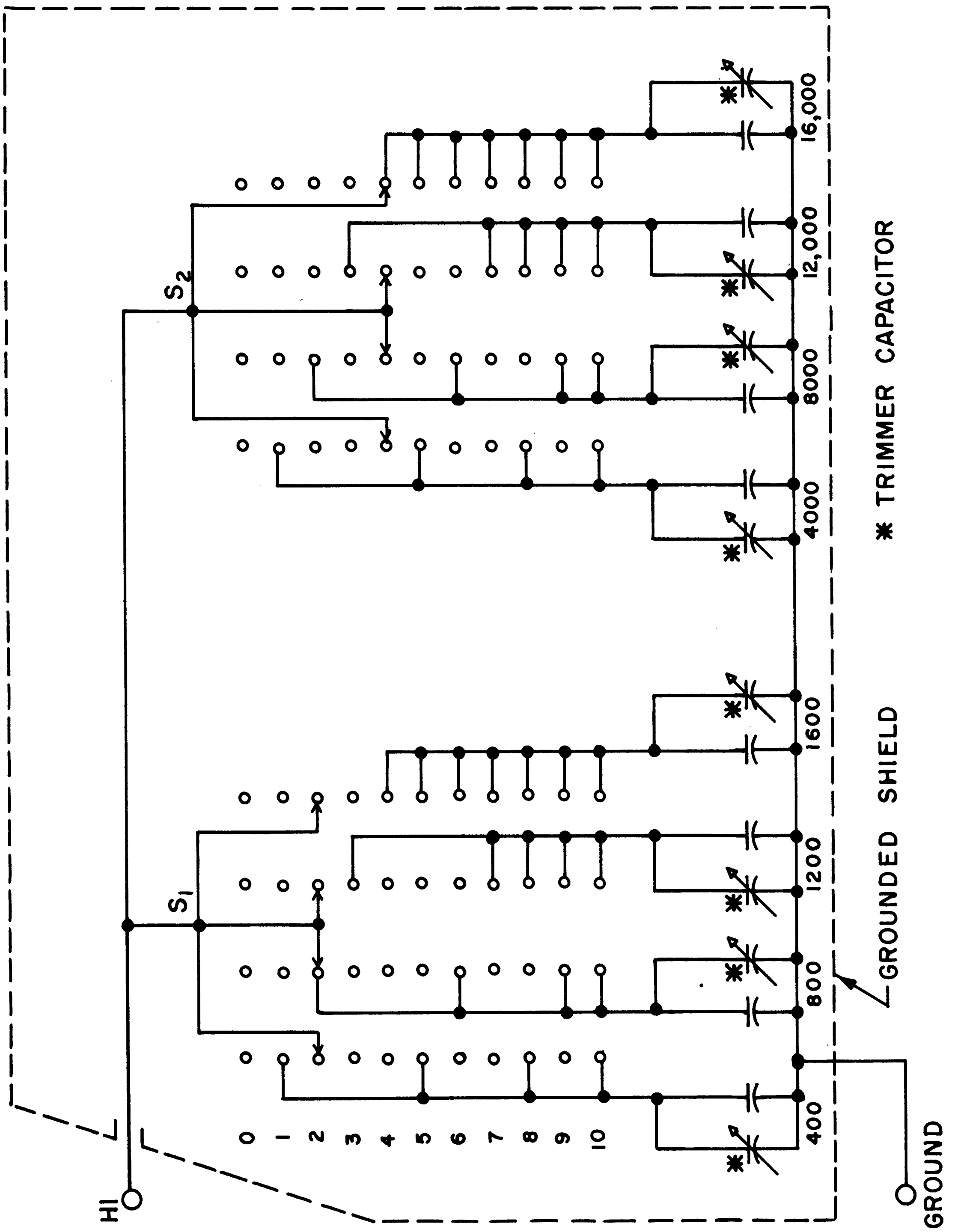


FIG. 4
CAPACITOR BOX

cavity type of "winding" must be used on the core, so that the center conductor must carry the large dc current which furnishes the magnetic bias. The second reason is that low loss cores at VHF have inherently low permeabilities and therefore require much stronger fields to drive them into saturation.

To solve this problem, the twin coaxial inductor, Fig. 5, was designed. The large center conductor will permit the passage of several hundred amperes for short periods which will furnish bias fields up to 100 oersteds to the two cores. Two cores are required for the measurement so that the upper and lower sections of the cavity will have approximately equal VHF impedances when measured from the shell to the mid point of the center conductor. To connect this point to the impedance bridge, a removable center pin is used which forms a part of the side coaxial connector.

The pin is removed, and is then replaced after inserting the lower core. The upper core is inserted and the nuts and washers replaced on the center conductor. The pressure nut is drawn down tight enough to establish low loss contacts between the silver washer and the relieved lips of the washer seats.

To prevent dc from flowing in the outer case, a mica insulator is located between the bottom plate and the rest of the case. This serves as a low capacitive reactance path to the VHF currents, and completes the RF path in the lower section of the cavity.

The design of the removable center pin may require some modification before construction is begun, since it is the one asymmetric feature of the present design. This feature is now being considered.

3.1.2 Ferroelectric Materials.

3.1.2.1 Preparation of Subminiature Ceramic Capacitors. (H. Diamond) For high frequency measurements and applications (such as PANDU) special ferroelectric capacitors are required. These capacitors must have a dielectric thickness of

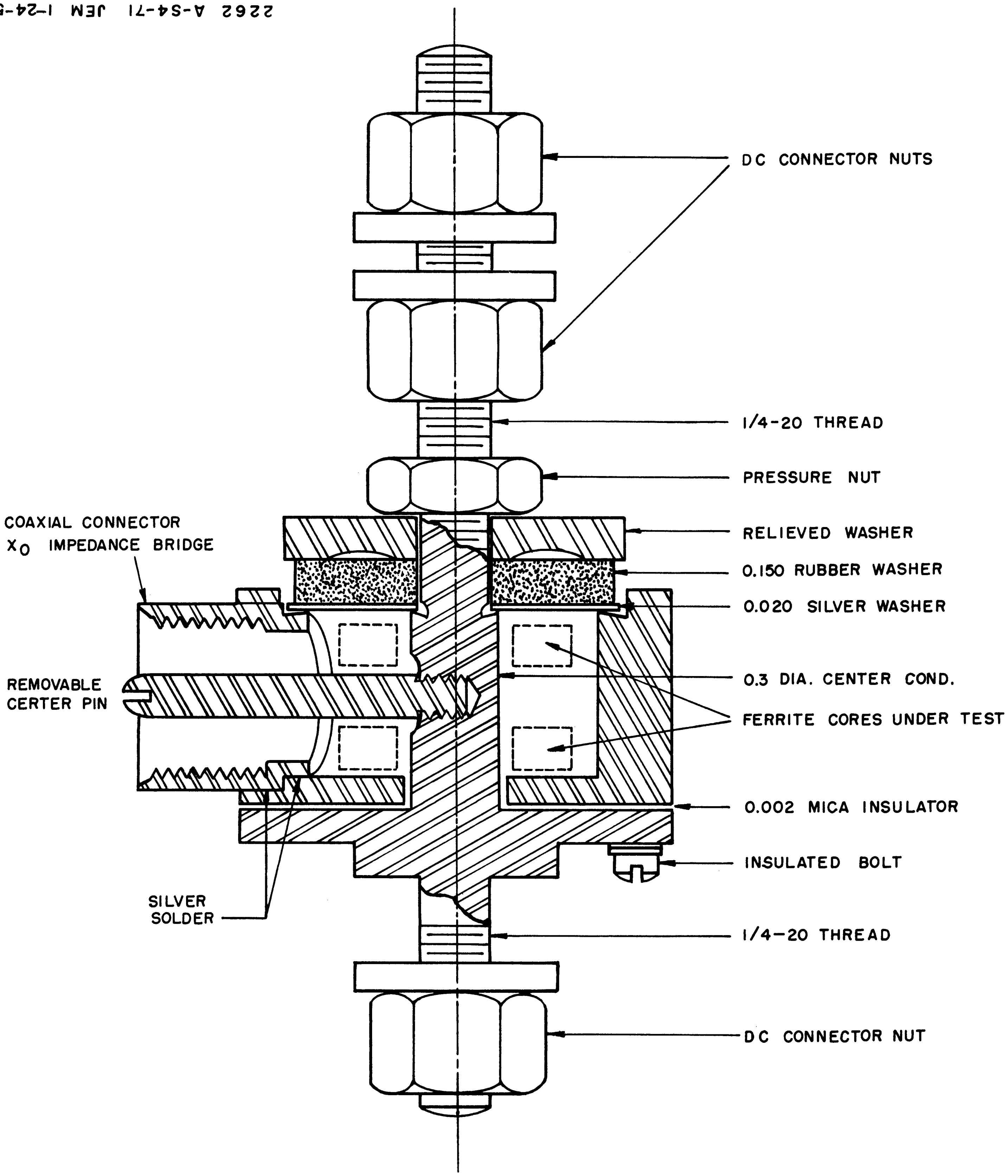


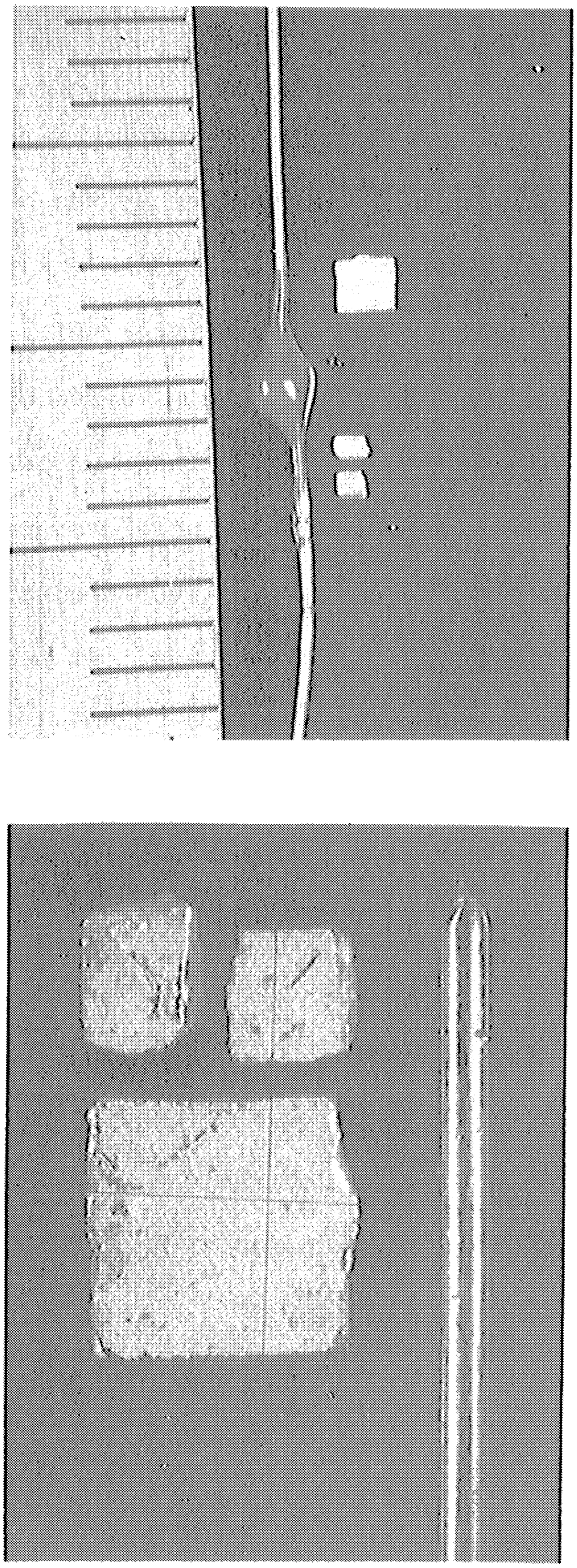
FIG. 5. TWIN COAXIAL INDUCTOR .

of 10 to 20 mils, a relatively large K value to give wide range electric tuning, and a starting capacitance of 20 to 60 μμf. This results in a capacitor of very small dimensions to give the low starting capacitance (the value for zero bias field). In addition, it has been found by experiment that, to produce the best results, the electrode plating must extend to the edges of the dielectric without "spilling over".

No manufacturer has been found who will furnish such units in capacities lower than about 150 μμf. The capacitors are therefore being manufactured by Task 4, using as raw material silvered slips of ceramic 10-20 mils in thickness and 1/2 inch in diameter. The ceramic material has been obtained largely from the Aerovox Corporation to date. These samples are coated with a one mil silver coating. By careful fracturing, small squares of ceramic less than one mm on each side, may be made. Each of these squares is inspected under a microscope to see that it is not badly chipped at the edges, and is free from voids or overhangs in the silver coatings.

Wire leads are carefully soldered to the plated surfaces of a small square, and the ceramic is then thoroughly cleaned, and baked at 100°C to remove all traces of moisture. It is then potted in a plastic bead as shown in the microphotograph (Fig. 6). To the left in this figure is a millimeter scale, and to the right are squares of ceramic broken from a larger wafer. In Fig. 6(b) these same squares are shown enlarged 24 diameters. The rod to the right is a piece of No. 30 wire, 10 mils in diameter.

The technique for making these subminiature capacitors has advanced considerably during the quarter. A batch of 50 may be run off in about 3 hours. Previously we obtained a large number of rejects, but at present only 2 or 3 rejects are found in a batch of 50. The great reduction in the number of rejects



A.
ENLARGED
5 DIAMETERS

B.
ENLARGED
24 DIAMETERS

FIG. 6

SUBMINIATURE FERROELECTRIC CAPACITOR, AND CERAMIC SQUARES was obtained by baking the units before potting, and coating with Q-dope immediately after baking to prevent moisture absorption by the dielectric.

Each unit is tested by observing its P-E loop while a 60 cycle electric field of 100 volts per mil is applied. If the unit stands this field without breakdown, and shows a thin, steady P-E loop, it is considered satisfactory. Since this test was instituted, capacitor failure in PANDU units has been eliminated, including those tests in which the capacitors were over-rated.

All of the plated commercial stock has a silver conducting paint applied to the ceramic surfaces by a silk screen process. It has been noted in our work that some of the dielectric properties are improved when vacuum plated, pure silver electrodes are used. At the present time vacuum plating equipment is on order, and upon installation of the vacuum system further experiments will be made.

3.1.2.2 High Frequency P-E Loop Data. (H. Diamond and L. W. Orr) To date, most of the applications (e.g., to PANDU) and high field measurements on ferroelectric materials have made use of a high voltage 60 cps sine wave source. If rapid sweep techniques are to be used, it is desirable to gather data on the P-E loops of these materials for higher frequencies.

It is noted by Merz[1] that the P-E loop of a barium titanate crystal should degenerate as the frequency of the driving field is increased. This is du to the finite time of nucleation of new domains, plus the propagation rate of the domain boundaries (about 10^4 cm/sec for a field of 4 kv/cm).

The time required for the electric field to switch a crystal from negative saturation polarization, $-P_s$, to positive saturation polarization, $+P_s$,

[1] W. J. Merz, "Domain Formation and Domain Wall Motions in Ferroelectric $BaTiO_3$ Single Crystals," Phys Rev., 95, p 390, Aug. 1, 1954.

thus depends upon the crystal thickness and strength of the applied field. For a crystal 10 mils thick, this time is about 2.5 microseconds at 4 kv/cm.

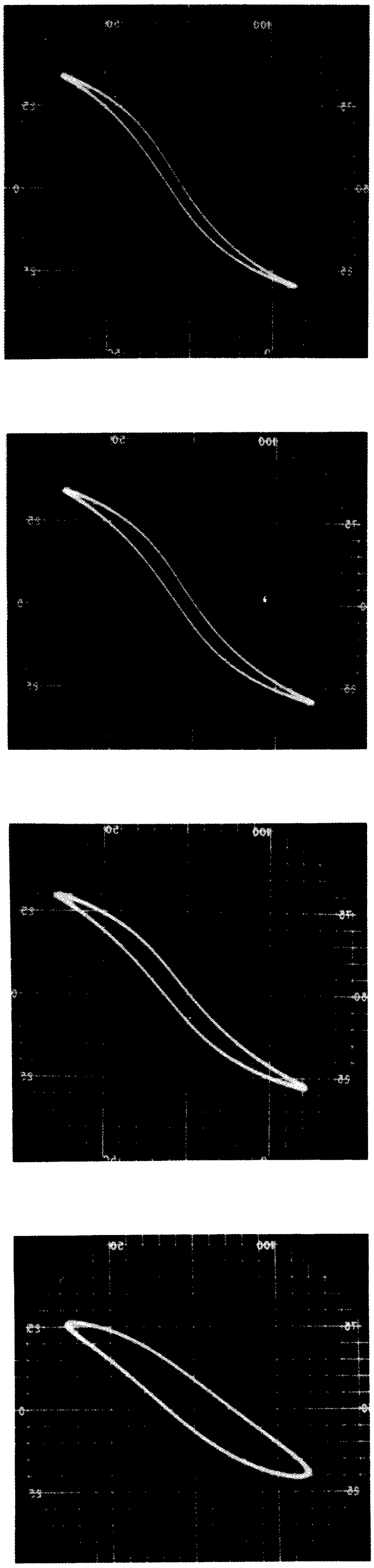
If the applied field is sinusoidal, the polarization will cycle between $+P_s$ and $-P_s$, lagging slightly behind the field. As the driving frequency is raised, a point is reached where these extreme values of polarization are not attained because of insufficient time, and the maximum cyclic polarization in the crystal thus falls below P_s.

This effect is illustrated by the P-E loops (Fig. 7) for a 10 mil sample of Glenco K3300 titanate ceramic. In each case the maximum driving field is about 25 volts per mil. Little reduction in height is noted going from 1 to 10 kc, but a greater reduction is obtained in going from 10 to 100 kc, indicating the effect described in the preceeding paragraph. The 100 kc loop is also considerably broader in the middle, caused by lag in the domain wall motion.

Height reduction and some broadening is also produced at all frequencies when the specimen becomes heated to a temperature approaching the Curie point. At rapid cycling rates, the dielectric heating of the specimen may be sufficient to produce these effects unless precautions are taken to prevent it. However, it is usually possible to reduce the dielectric heating by choosing a small, thin specimen so that dielectric volume is sufficiently small.

Figure 8 shows the circuit of the recently completed P-E loop plotter for this work. The specimen capacitor, C_x, is driven by the 807 voltage amplifier. This amplifier gives a $\pm$ 250 volt peak swing at all frequencies from 10 cycles to 100 kc.

It can be shown that the polarization of the sample is related to the voltage appearing at the Y terminals of the oscilloscope by:



100 CPS

1 KC

10 KC

100 KC

FIG. 7

P-E LOOPS FOR GLENCO K3300 CERAMIC

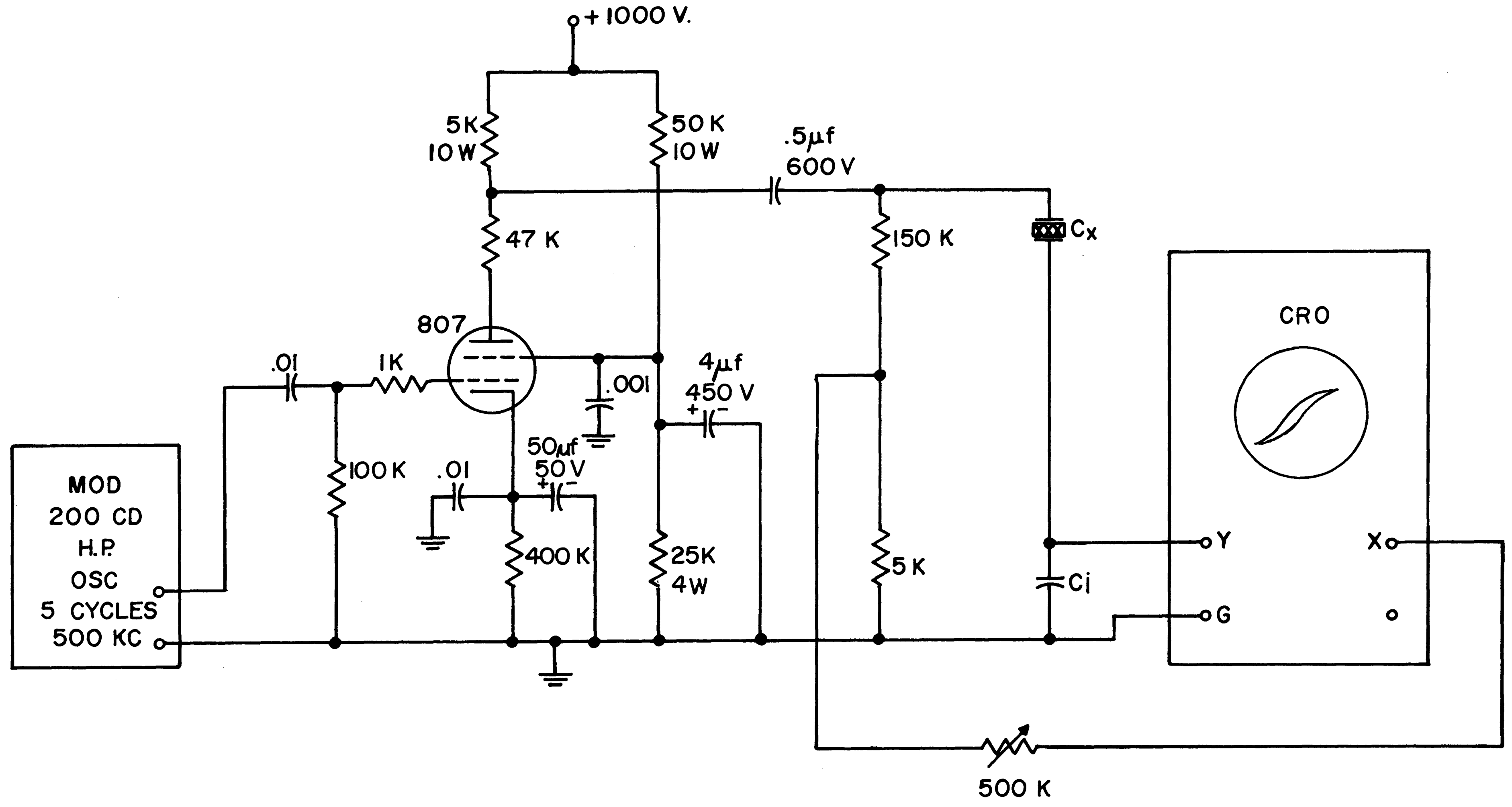


FIG. 8

VARIABLE FREQUENCY P-E LOOP PLOTTER

$$P_x = \frac{C_i E_i}{A_x}$$

where E_i is the voltage at the scope terminals,

P_x is the polarization of the sample,

C_i is the capacity of the integrating capacitor, and

A_x is the electrode area of the sample.

Therefore, the P-E loop obtained from the oscilloscope can easily be calibrated.

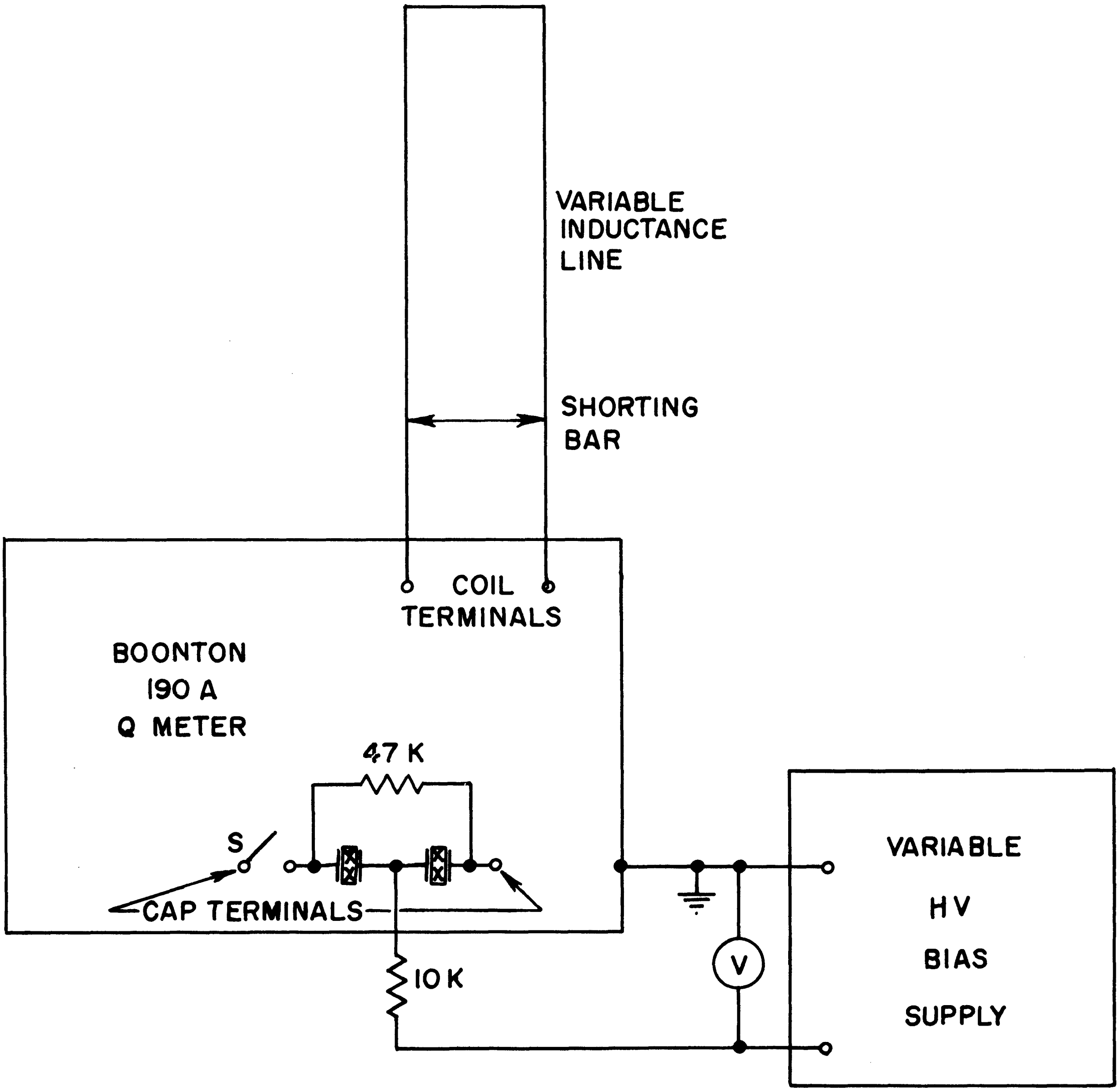
3.1.2.3 High Frequency Q-measurements with Applied Electric Field. (H. Diamond) To obtain high frequency Q data with varying bias field, the Boonton Model 190-A Q-meter was equipped with a variable length shorted line as the inductive branch. The capacitor units to be tested are placed in series as shown in Fig. 9. Two units in series are required for isolating the dc bias voltage from the Q-meter circuit. The dc bias is applied to the common junction through a 10 K resistor. The switch, S, is required for capacity measurements by the substitution method. It consists of a small metal plate upon which the knurled nut makes contact. To open the switch, the nut is loosened or removed entirely, as in Fig. 10, which shows the inductive line and shorting bar.

The test capacitors must have very small values for the 50-300 mc range Special low value subminiature capacitors were therefore constructed for these measurements, using technique described above (Section 3.1.2.1). Because of the inductance of the capacitor leads, the apparent (indicated) capacitance, C_A, differs from the true capacitance, C_T, according to the relation

$$C_T = C_A(1-\omega^2 C_T L_\ell)$$

where L_ℓ is the inductance of the leads.

To minimize this correction, capacitor leads were made extremely short. This was facilitated by mounting the test capacitors on a lucite test plate



NOTE: FERROELECTRIC CAPACITOR IS DENOTED THUS

FIG. 9

SCHEMATIC FOR HIGH FREQUENCY Q MEASUREMENTS

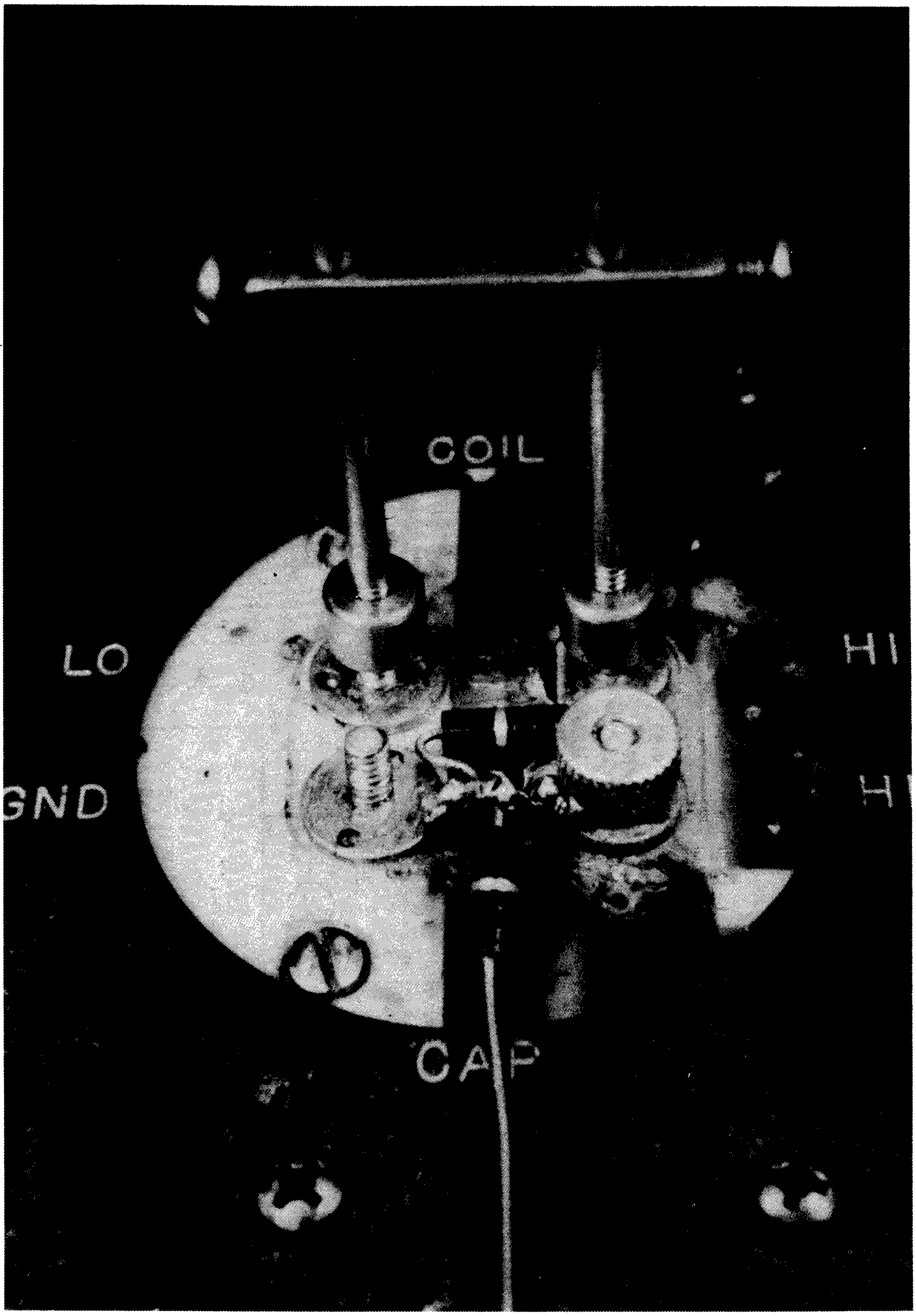


FIG. 10

SET-UP FOR HIGH FREQUENCY Q MEASUREMENTS

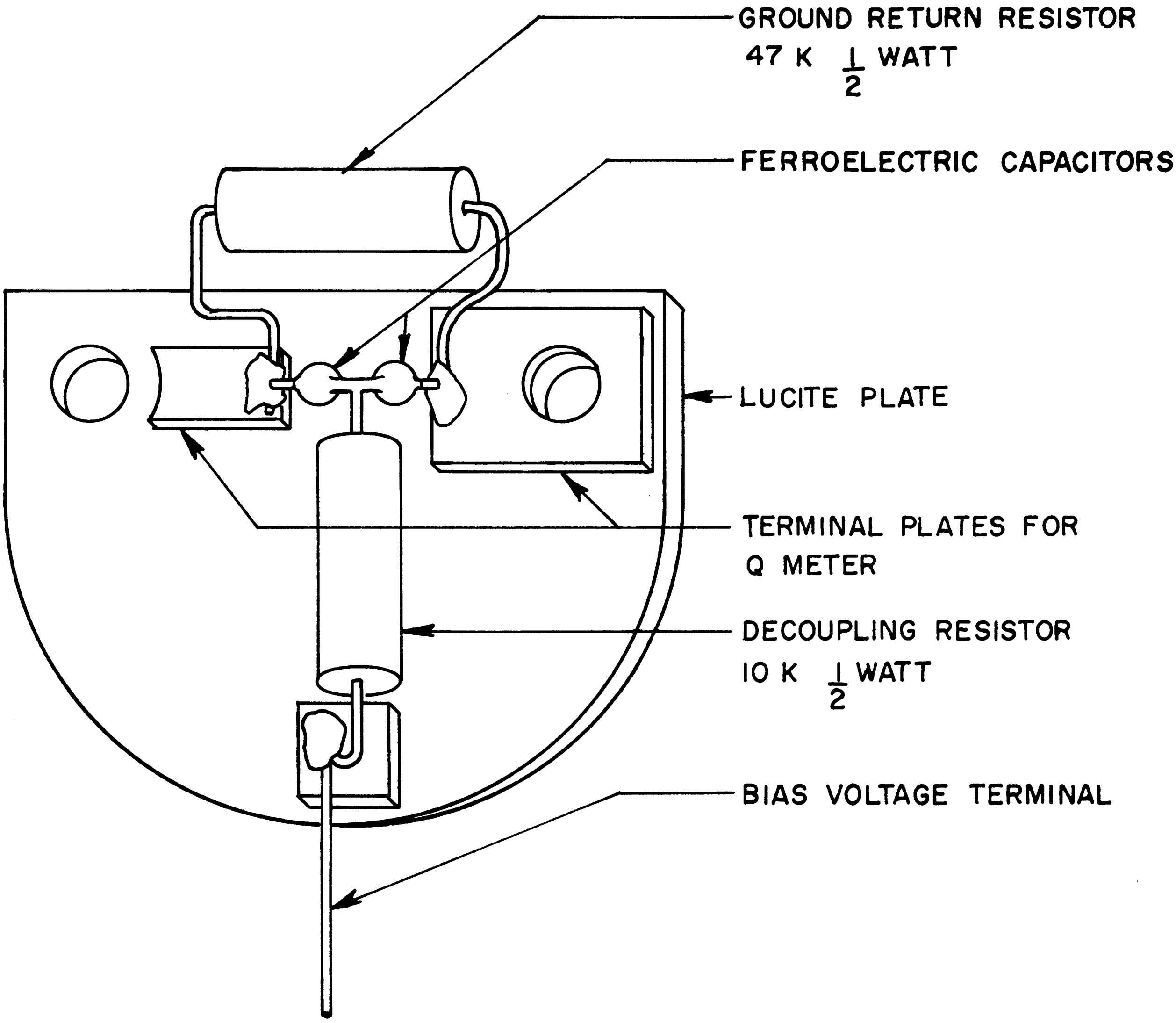


FIG. 11

TEST PLATE FOR HIGH FREQUENCY Q MEASUREMENT

(Fig. 11) which also carries the resistors. This plate mounts directly on the capacity terminals of the Q meter.

3.1.2.4 QEF Surface for Ferroelectric Capacitors. (H. Diamond and L. W. Orr)
A convenient method of portraying the variations of Q as both frequency and field are varied, is a 3 dimension plot, or QEF surface. The results of preliminary measurements on a pair of subminiature capacitors (made from Aerovox B2K45 ceramic) are shown in Fig. 12. It is seen that at 250 mc, the Q is extremely low for zero dc bias field, but increases as the field is increased. It also increases as the frequency is reduced.

The data given in Fig. 12 is of low accuracy at certain frequencies because the Q of the capacitors is obtained by differential measurements. Details of measuring technique are being worked out to improve accuracy.

3.1.3 BLARE- Butterfly Loop Automatic Recorder. (M. Winsnes and L. W. Orr)

3.1.3.1 Circuits and Operation. The BLARE unit reported in Quarterly Progress Report No. 13, EDG Task-4 has been completed, and is now operating satisfactorily.

The motor-driven dc supply circuit is shown in Fig. 13, and consists of the following: (1) the motor which drives the second variable transformer, with its associated switching network and (2) the rectifier and filter section.

The cam system and powerstat shaft are driven by the motor with a V-belt on pulleys. Two speed reductions are available. The cams marked R, 1/2, and F are staggered axially, and each one engages only the follower on the micro-switch which is marked in the same manner. The cam disk is directly connected to the variac shaft. With the switch, S3, open, the cam disc will oscillate between position R and F engaging the micro-switches, which are mounted in a line. When S3 is closed, the system will oscillate between cam positions 1/2 and R. The push buttons marked FB and RB can be used to manually control the

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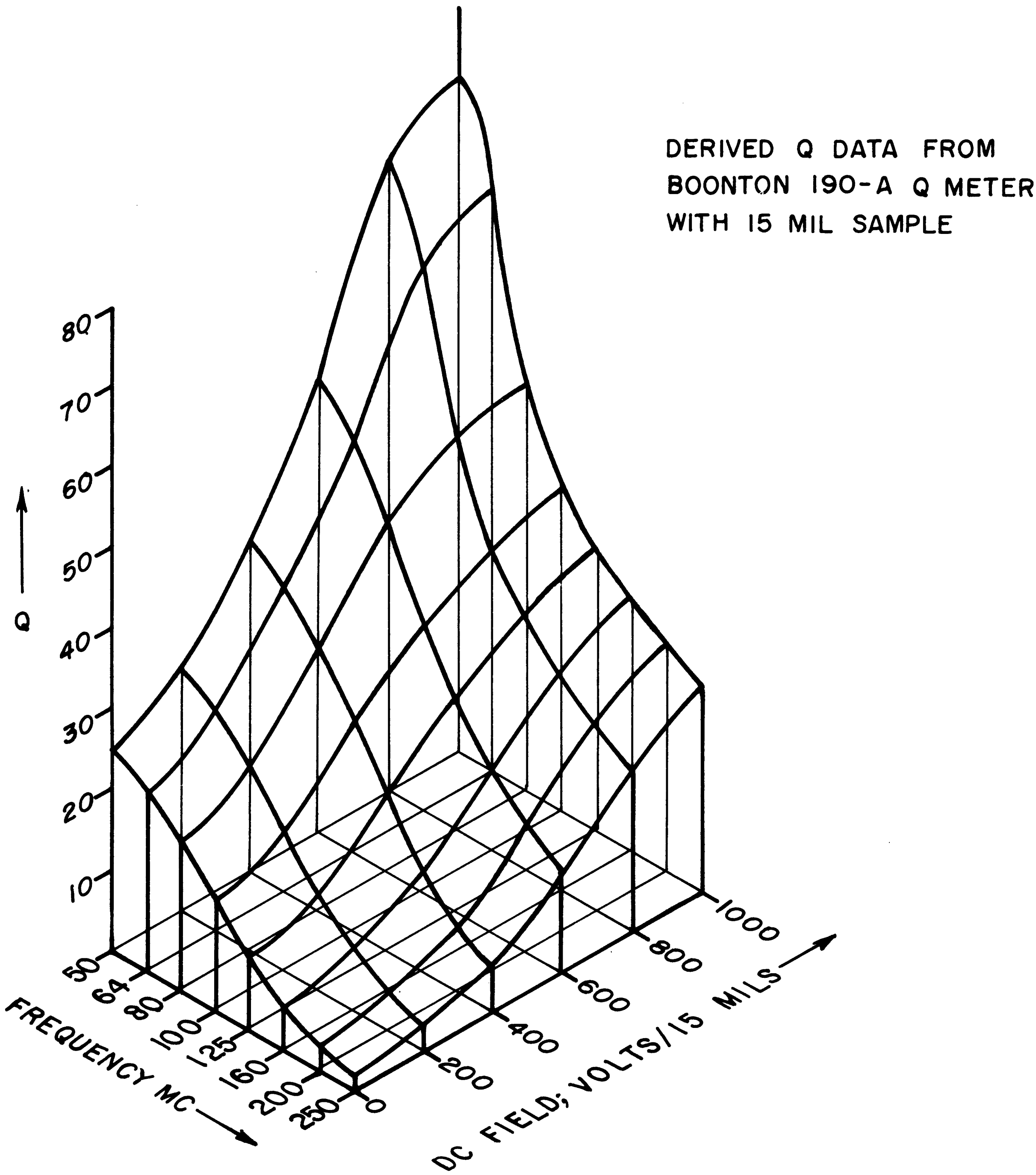

FIG. 12

QEF SURFACE
FOR AEROVOX B2K45 CERAMIC

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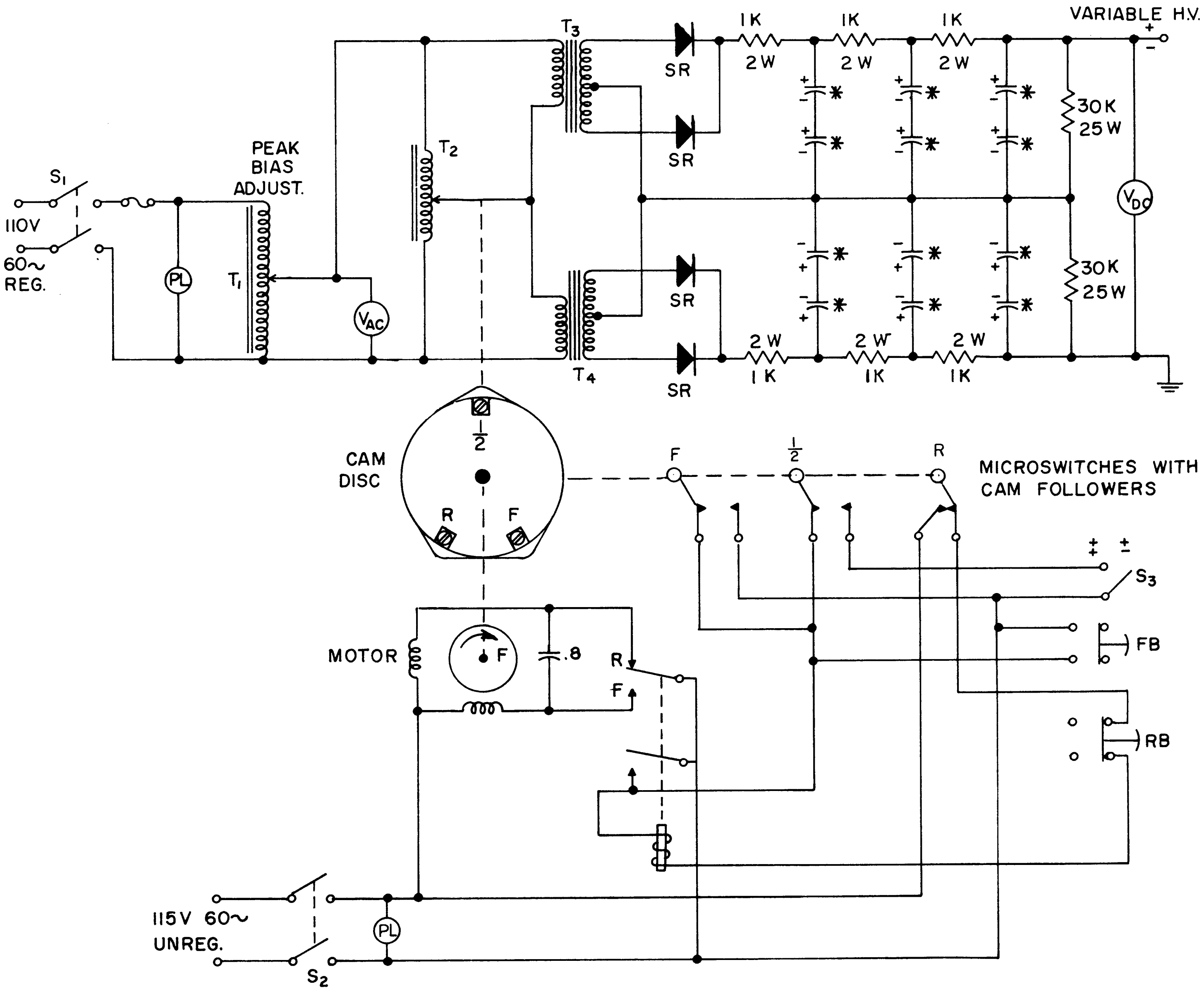


SR - SELENIUM RECTIFIER 2KV PEAK INVERSE (SARKES-TARZIAN)

* - 450V 40μf ELECTROLYTIC

FIG. 13

MOTOR DRIVEN D.C. HIGH VOLTAGE SUPPLY UNIT FOR BLARE direction of rotation. All three cams can be moved on the rim of the cam disc to give any desired reversing positions. The variable dc output of this network, can be swept at a choice of two rates – from +1000 v to -1000 v or any intermediate voltage. When S3 is closed, the voltage can be swept from 0 to plus 1000 v or to any intermediate voltage.

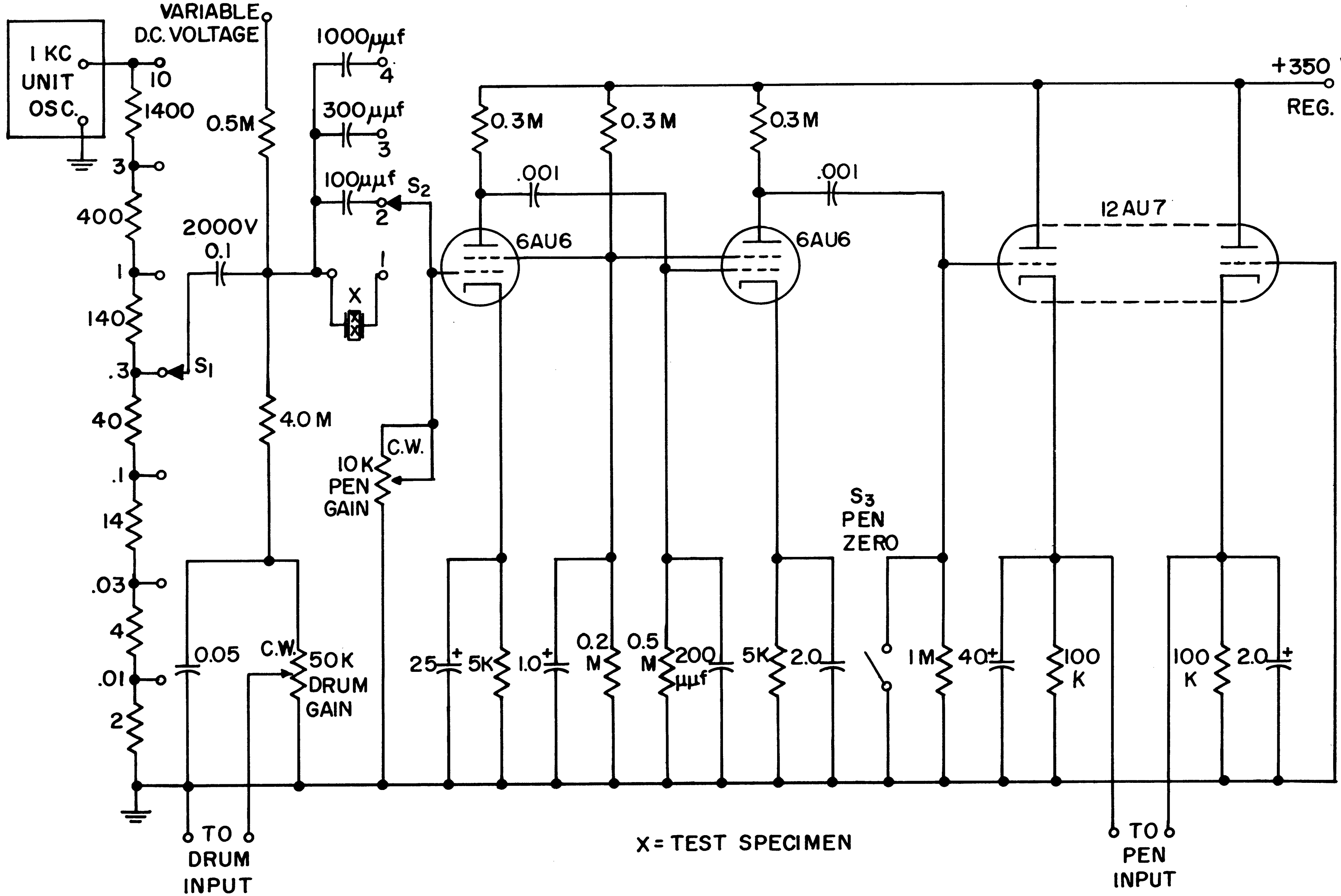
The detector amplifier circuit is shown in Fig. 14. A 1 kc signal may be applied to the sample in steps from 10 mv to 10 v rms by switch S_1. S_2 is a selector switch, permitting any one of three standard mica capacitors, as well as an unknown capacitor, to be selected, so that a direct calibration in capacitance value can be obtained. The drum and the pen deflection sensitivities can be controlled continuously by the two variable resistors marked drum gain and pen gain. The closing of switch S_3 gives a zero reference output to permit the setting of the pen zero on the recorder.

<u>3.1.3.2 Modification for P-E Loop Plotting.</u> An integrating circuit and electrometer have been added to the BLARE unit for obtaining very slow P-E loops. These are shown in the block diagram in Fig. 15. The same motor-driven dc supply is used. A high input impedance Kiethley Electrometer measures the potential across the integrating capacitor. The electrometer delivers an amplified signal which drives the pen of the recorder. In this way, a slow P-E hysteresis loop can be recorded.

<u>3.1.3.3 Results of Preliminary Tests on BLARE.</u> Figure 16 shows a family of butterfly loops for different samples of commercially available ceramic a capacitors.

Figure 17 shows the butterfly loop and the P-E hysteresis loop with the same E axis.

When the dc applied to the sample cycles between zero and a positive value, the tuning capability of the capacitor can be determined. If only the



X = TEST SPECIMEN

FIG. 14

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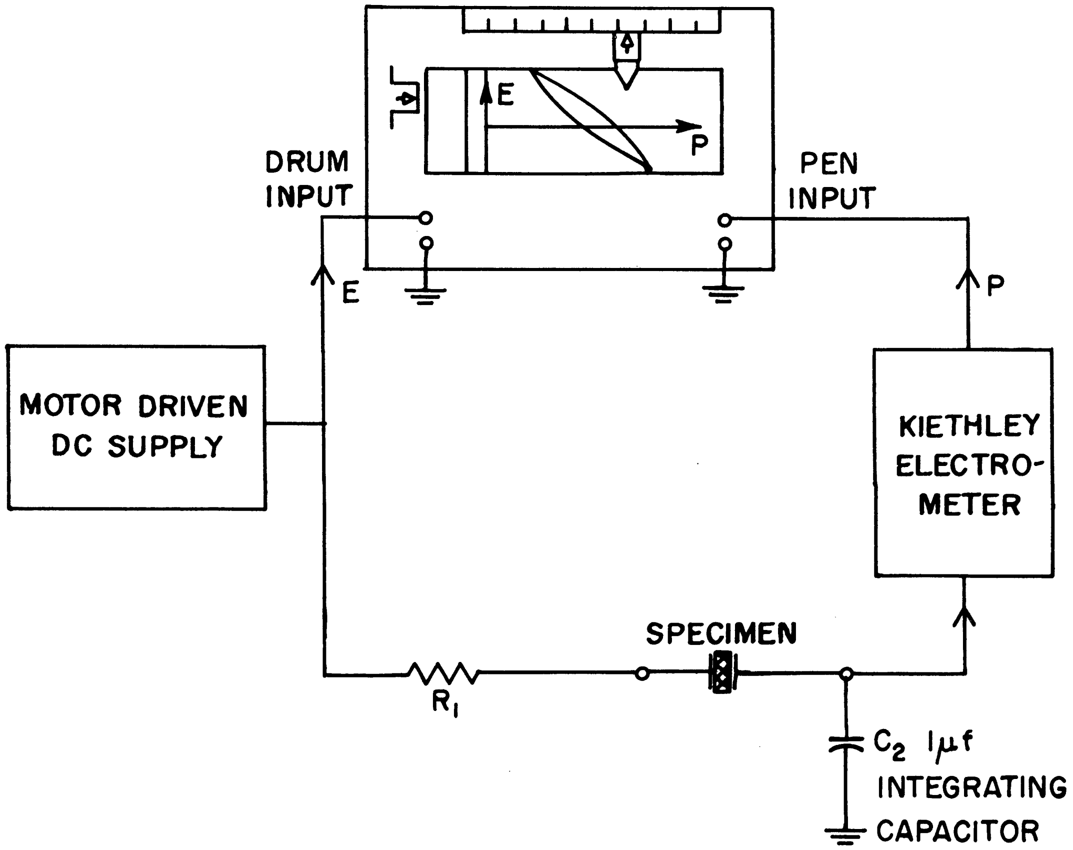

FIG. 15

BLARE UNIT MODIFIED
FOR SLOW PE LOOP PLOTTING

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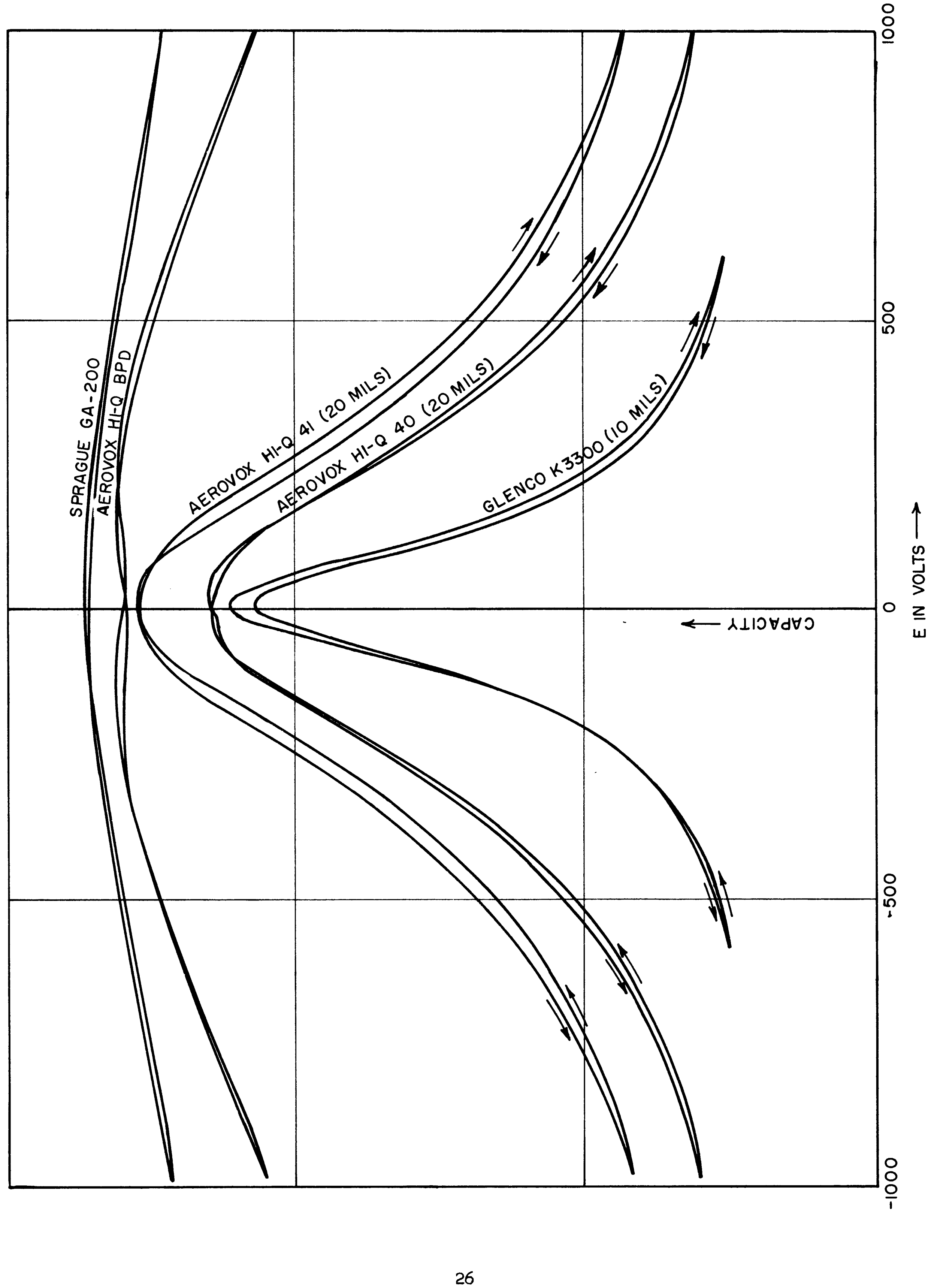

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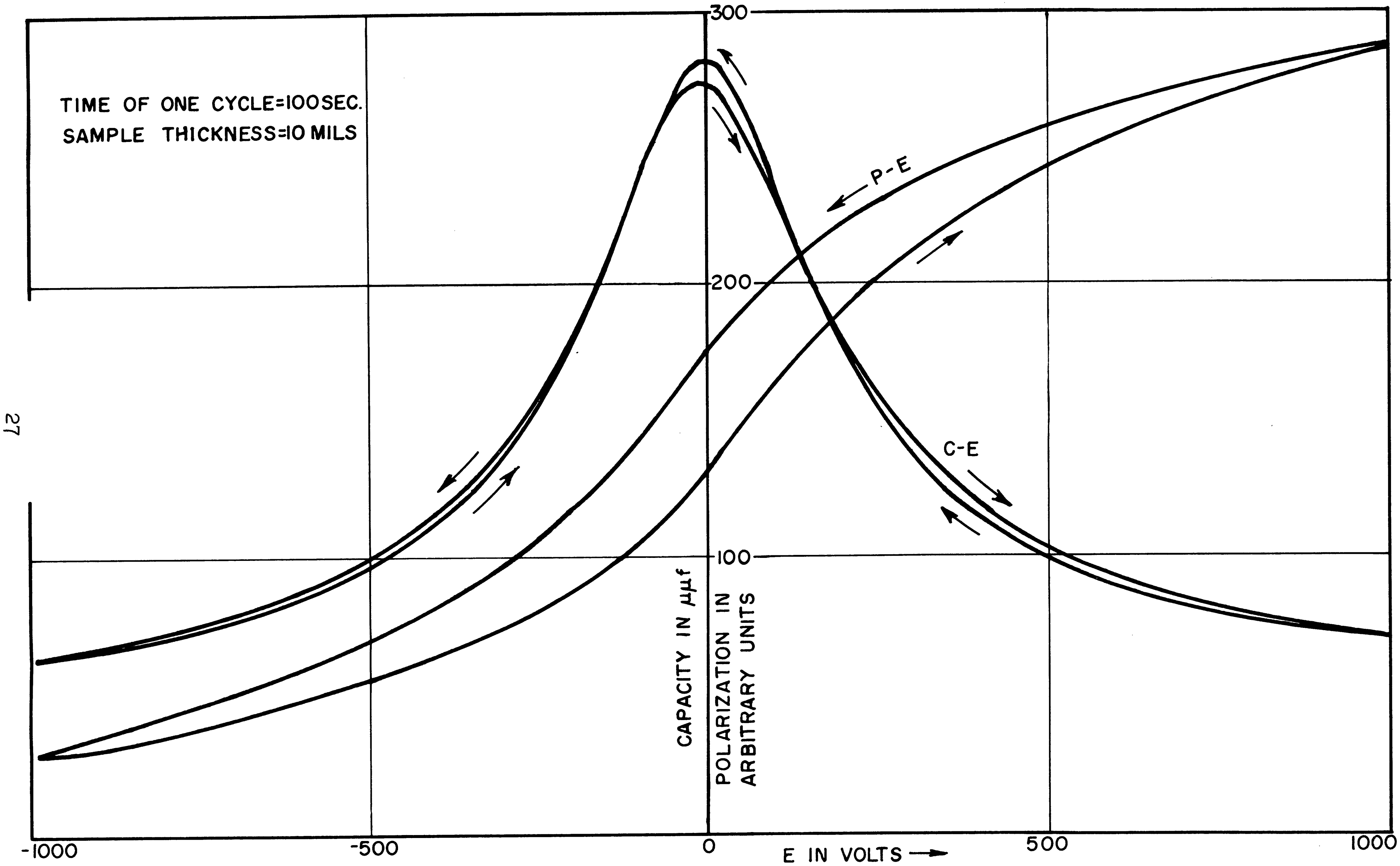

FIG. 17

BUTTERFLY C-E AND P-E LOOPS FOR GLENCO K3300 increasing trace is recorded for a number of different temperatures, and the capacity plotted versus both temperature and field on a three dimension plot, a so-called Epsilon-Temperature surface is obtained. Figure 18 and Figure 19 show two such surfaces, which demonstrate clearly the tuning capability of these capacitors over a range of temperatures. Centralab D13 is a 96 percent $BaTiO_3$, 4 percent $PbTiO_3$ ceramic, whereas Aerovox "Hi-Q" 40 is a Barium-Strontium titanate ceramic. Data for these surfaces were obtained from the BLARE unit.

The character of the surface for D13 (Fig. 18) shows that this material has an almost invariant dielectric constant from 20°C to 90°C and in this temperature range, the change with applied electric field is very slight. Hence this material is unsuitable for electric tuning, but may be very useful for other purposes. In particular the sharp rise in dielectric constant at about 120°C might be used to advantage in temperature control devices.

The character of the surface for Hi-Q 40 shows that this material is quite suitable for electric tuning, and at 28°C has a very low temperature coefficient, which is desirable.

3.1.4 PANDU - Panoramic Display Unit. (W. J. Lindsay)

3.1.4.1 Changes in PANDU. Since the last progress report was issued, a number of significant changes have been made in the PANDU unit. The photograph in Fig. 20 shows the changes that were made. Nothing was changed below the test shelf, so the photograph shows only the section of the rack above that point. The top panel, containing the 60 cycle sweep and the high voltage bias supplies, was redesigned to shorten its height. The voltmeters and controls for the various voltage supplies are arranged in a single row across the panel. The next panel is a rack mounted DuMont Model 304-AR oscilloscope.

The panel directly below the oscilloscope is divided into right and left hand sections. The right hand section is an accessory panel containing

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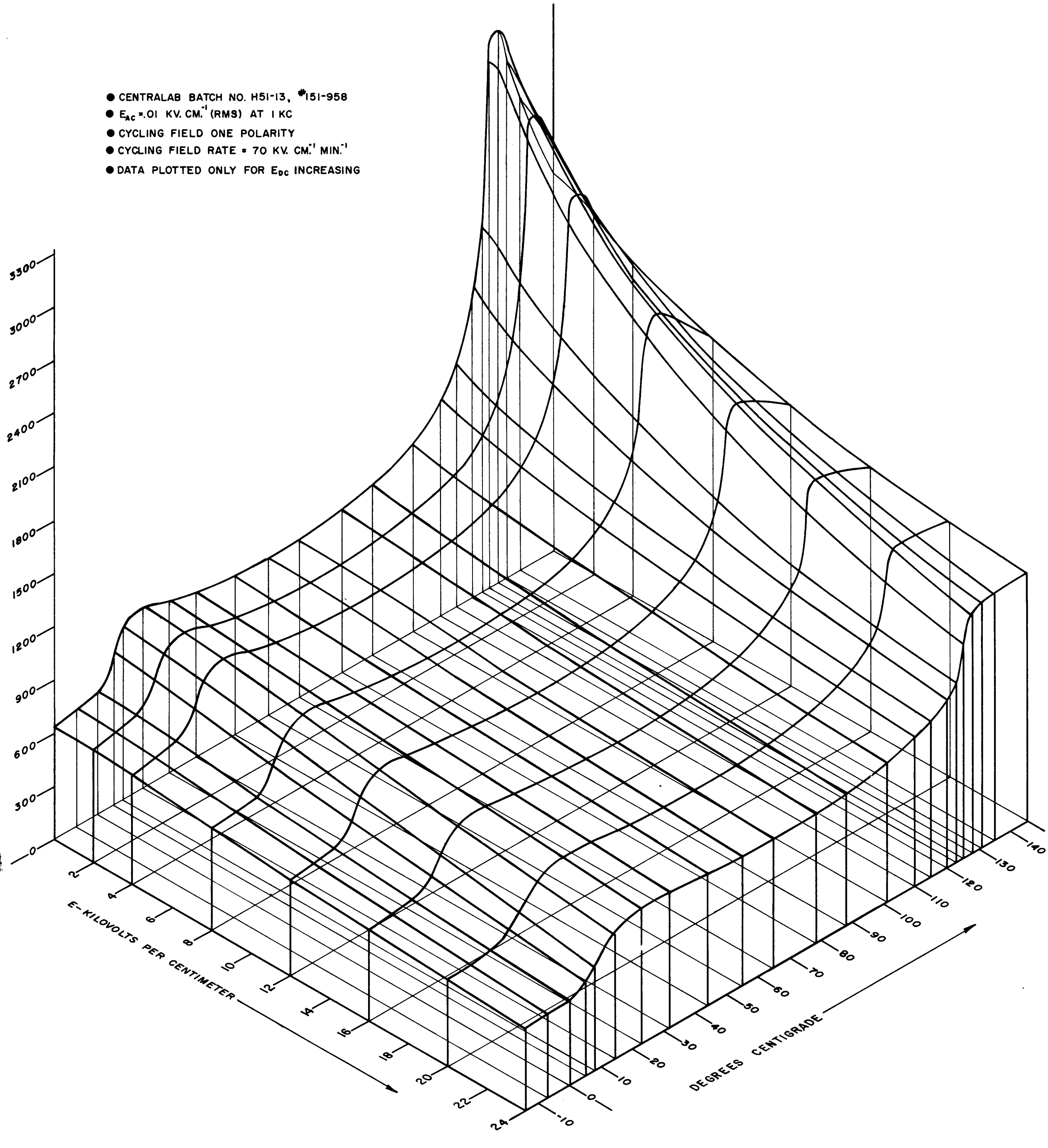

FIG. 18

EPSILON-TEMPERATURE SURFACE
FOR CENTRALAB D-13

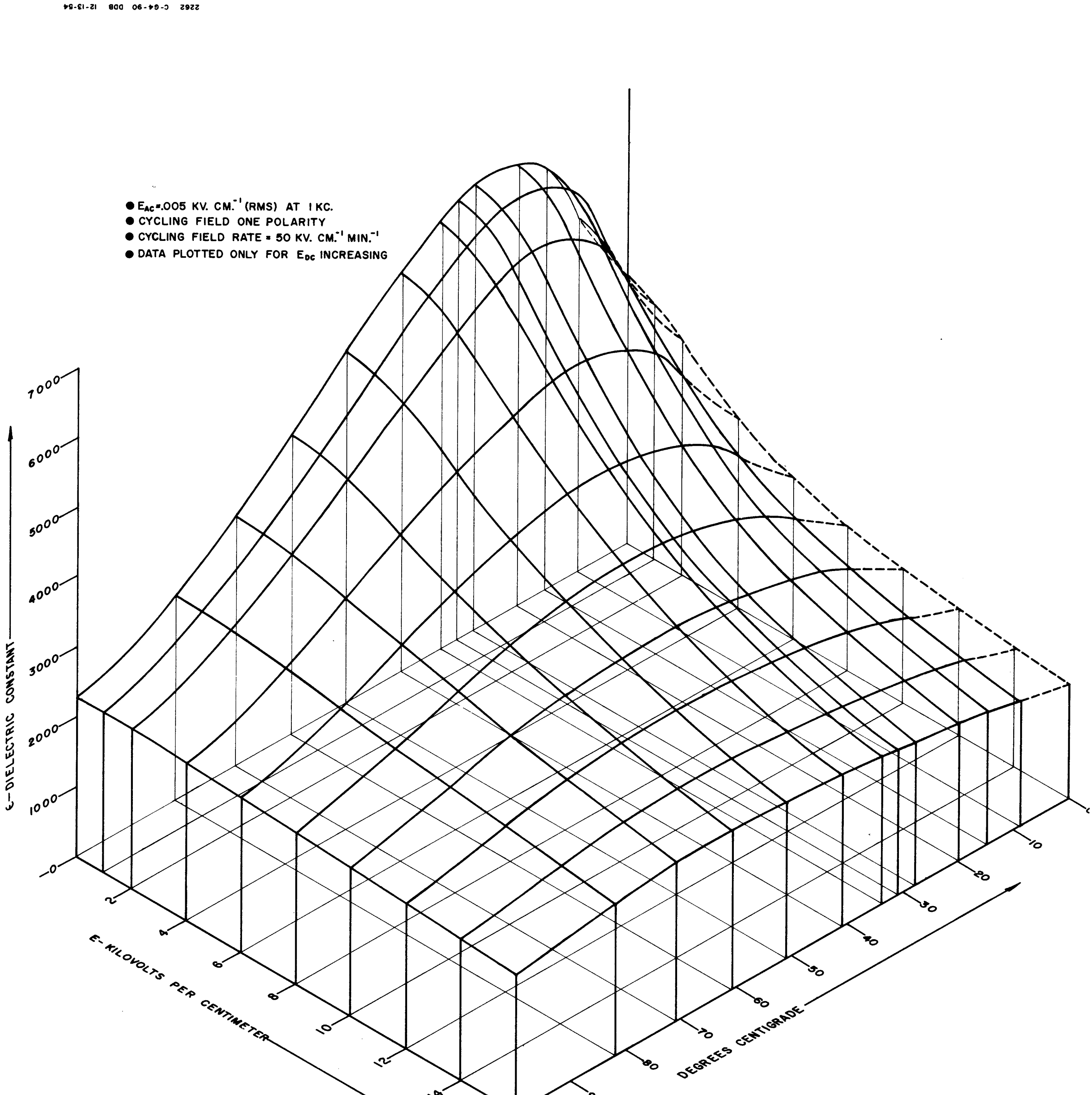

FIG. 19

EPSILON TEMPERATURE SURFACE
FOR AEROVOX "HI-Q" 40

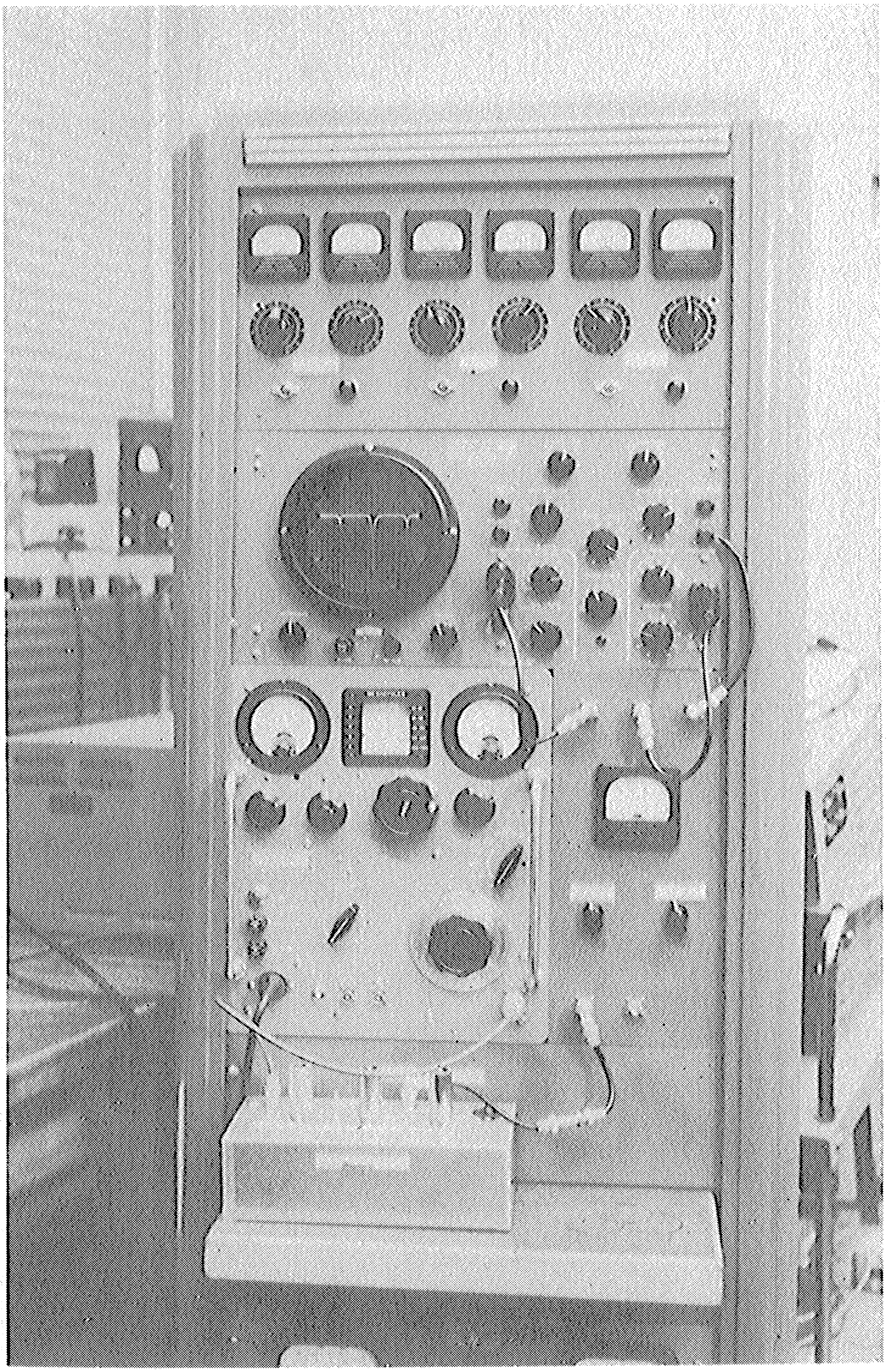

FIG. 20

PANDU -REVISED

BNC plugs for the IF strip and the blanking circuit, as well as the control for an auxiliary B+ controller. There is also an indicating meter and selector switch to read either the RF head or IF strip B+ voltage. The IF strip, blankin circuit chassis, and auxiliary B+ controller are all located behind this panel. There is an extra set of plugs for an additional IF strip. One of these is presently being used for the sweep voltage connection to the x-axis of the scope The left hand section of this panel consists of a Hewlett-Packard Model 608-C signal generator, which has proved to be highly superior to the previous equipment. The Type 608-C signal generator shown in the photograph is substituting for a type 608-D, which is being repaired. The 608-D has a crystal oscillator giving 10 mc check points on calibration throughout its range. The output level indicator and the "microvolter" are very convenient for our purposes. This change alone solved a number of the equipment problems mentioned in the previous report.

It was found, after some operating time was spent on the Front End units, that to optimize the operating conditions of the entire unit, separate B+ controls were needed for the Front End unit and the IF strip. An auxiliary B controller and monitor meter have been installed, as indicated above, to furnish this requirement. A schematic of the B+ controller and power distribution box is shown in Fig. 21.

3.1.4.2 Front End Assemblies. (W. J. Lindsay) Since the last report, two working model electric-tuned Front Ends (FE) assemblies, FE-2 and FE-3 have been built and tested on the revised PANDU. FE-2 tunes from 28 to 60 mc, and FE-3 tunes from 55-110 mc. The "sensitivity" of the receivers may be defined as that input signal which produces a "pip" on the scope that is twice the height of the residual noise.[1] While being swept over the tuning ranges listed, the

[1] J. B. L. Foot, "Wide Band VHF Panoramic Receiver," Wireless World, Sept. 1953 pp 392-395.

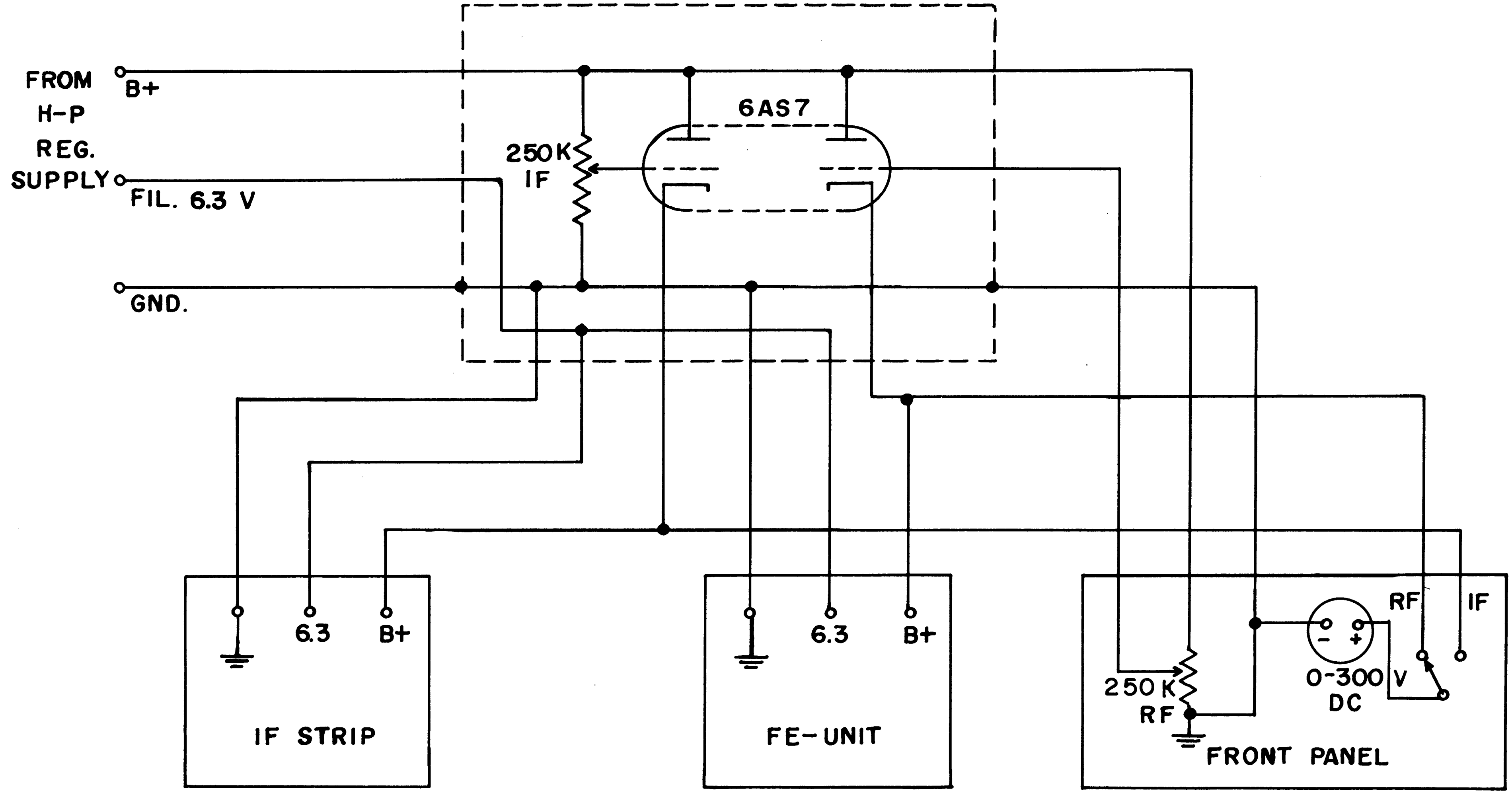

FIG. 21

AUXILIARY B+ CONTROL FOR PANDU

2262 A-CT-160 DDB 1-29-55

sensitivity of each unit is 5.0 ± 1.0 microvolts. Under statically tuned conditions, the sensitivity goes up to an average of 1.5 microvolts. The reason for this change appears to be that the noise generated in the front end assemblies is some function of the sweep-width and tracking.

It was found that by operating the capacitors in the tuned circuits at higher dc voltage levels, the tracking problems were helped considerably. This is because of greater linearity of the inverse root curve of the capacitance versus bias voltage at the higher dc voltage levels. This was tried initially, and the results proved so good that no further reduction of the circuit Q was considered for tracking purposes. The tuned circuits are designed for as high Q as possible under the circumstances.

The schematic for FE-2 is shown in Fig. 22. Both the RF and mixer stages employ the 6CB6 pentode. This tube has a good quality factor and low noise. A common disadvantage in using a high gain pentode mixer is that the oscillator may be "pulled" by the tuning of the mixer circuit. This is usually caused by too close coupling of the oscillator to the mixer stage. There is no evidence of "pulling" using the link-coupling method shown, but good injectic is obtained. This method performed the best of about six that were tried.

The oscillator was changed from the push-pull circuit to the Hartley circuit, which performed as well on the lower frequency range and a little better on the higher range. Using the Hartley circuit, there are fewer componer to cause stray capacitance, and the construction is somewhat simplified. The 6AH6 (triode-connected) performs well here. A 6J4 may be used in its place.

It became apparent some time ago that there was little difference in the operation of the FE units whether the blower was on or off. This caused concern because this had not been previously the case at all. As the work on FE-2 and FE-3 progressed, it became evident that there definitely was an effect

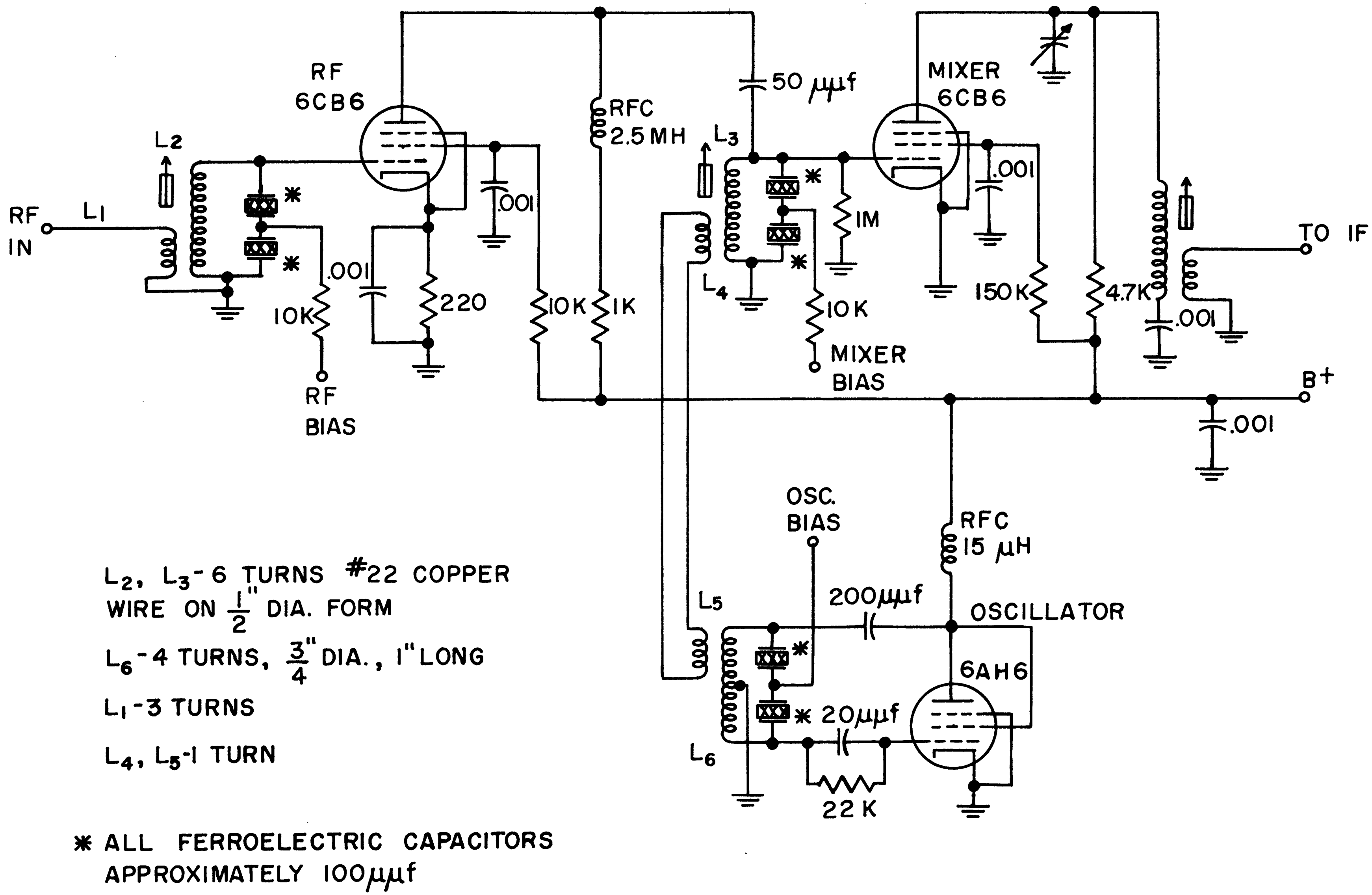

FIG. 22

SCHEMATIC OF FE-2

on the tuning range of the FE unit caused by varying the oscillator drive. When the B+ voltage is raised, increasing the drive on the oscillator, the tuning range shrinks. This effect may come from two causes, one through rf heating of the capacitors; the other through the movement of the point of operation on the epsilon surface[1]. However, evidence was obtained that the majo cause of the shrinking in tuning range was rf heating of the oscillator capacitors.

It was then found that the reason the ventilating system was no longer effective in stabilizing the FE unit capacitors was that the new potting methods used in making the capacitors created such a good insulated coating on the body that the gentle movement of air did not transfer the heat away fast enough. Whe a small jet of air at room temperature was directed on the oscillator capacitors adequate cooling and stable operation was obtained. However, the problem of better heat dissipation from the oscillator capacitors requires further attentio

Figure 23 shows two oscillograms of the response of the FE-2 unit. The upper picture shows 20 μ-volt markers at frequencies of 28, 30, 40, 50 and 60 mc. The lower photo was made with a short piece of wire connected to the antenna post, indicating the local strong signal spectrum.

Figure 24 shows a similar display for FE-3. The upper picture shows a series of 20 μ-volt markers at 55, 65, 75, 85, 95, 105 and 110 mc. In the lower photo, a high gain discone antenna, oriented in the direction of two Detroit television stations was connected to the receiver. The sound and video carriers for the TV stations show up strongly at the low frequency end, and quit a number of FM radio stations are in evidence on the higher portion of the band.

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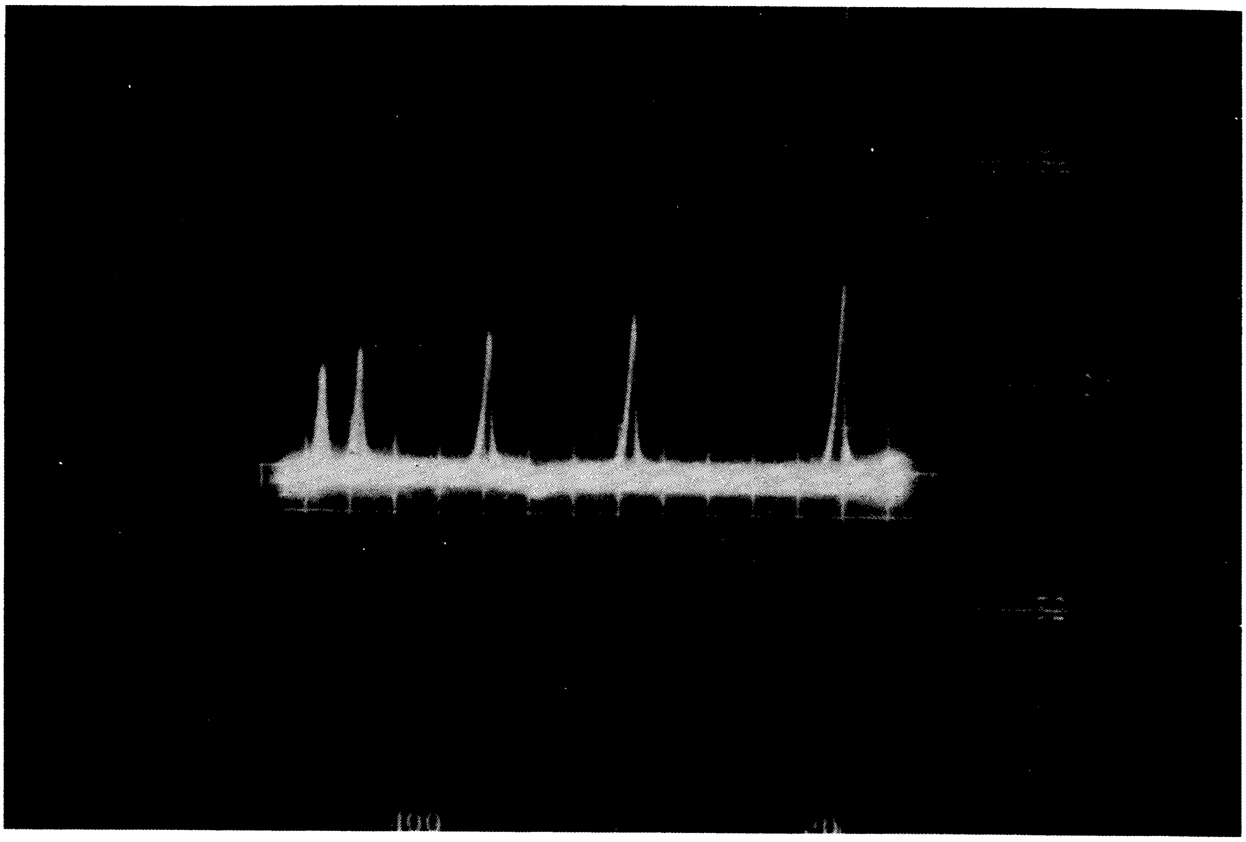
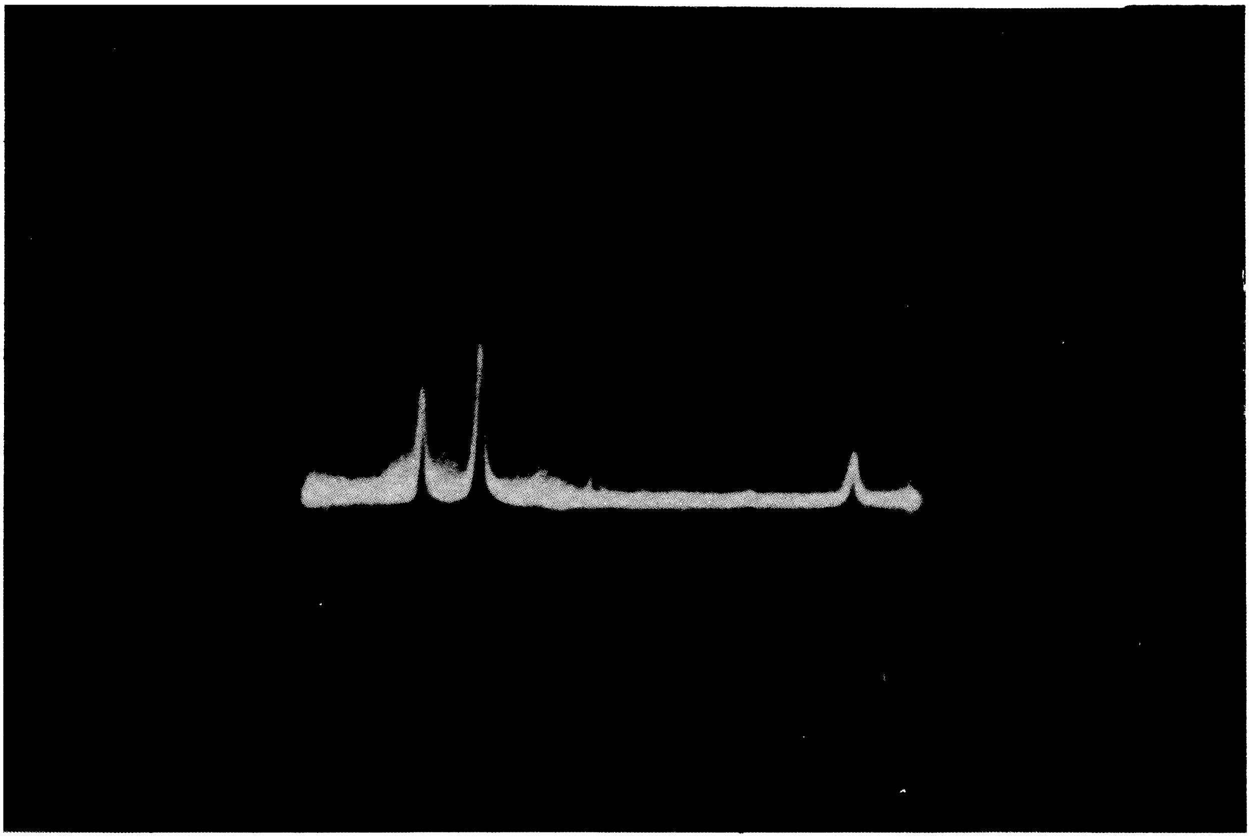
[1] L. W. Orr, "Ferromagnetic and Ferroelectric Tuning" Technical Report No. 32, Electronic Defense Group, University of Michigan, July, 1954.



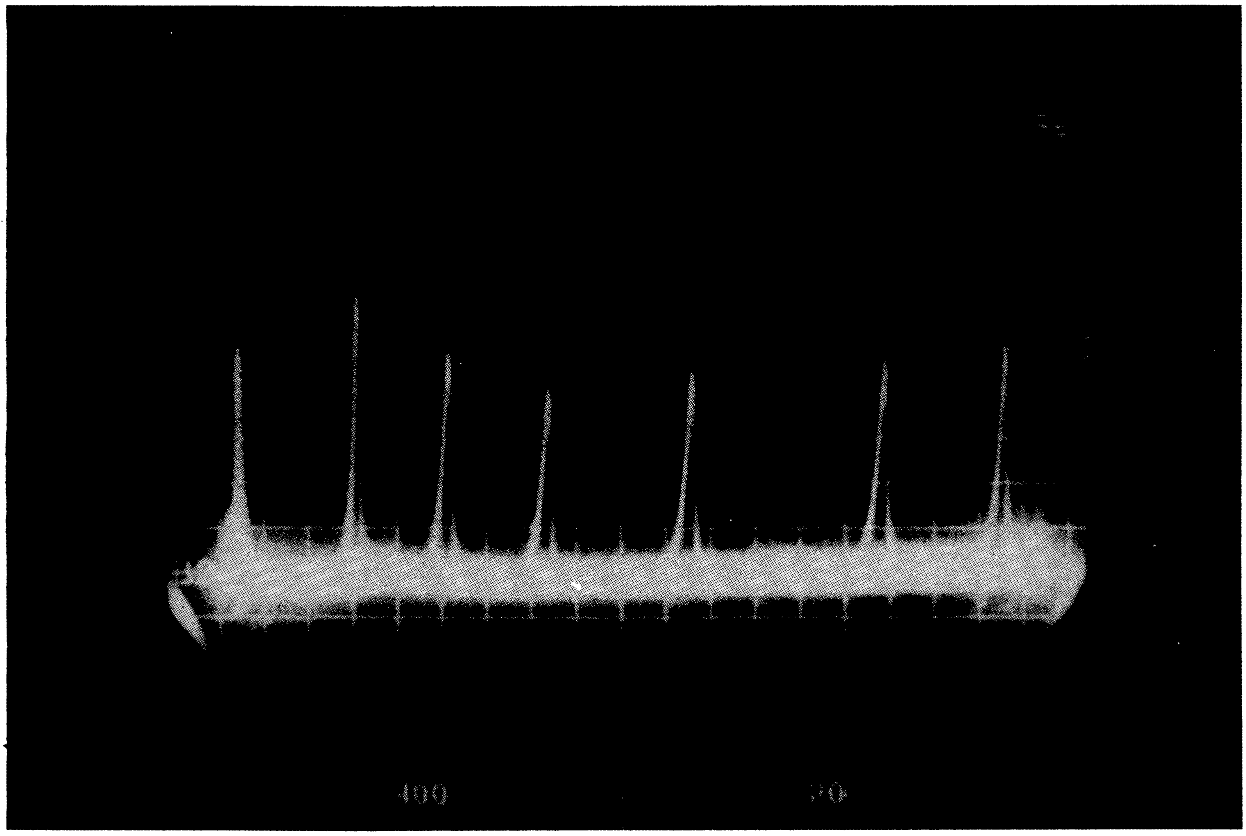
MARKER SIGNALS AT 28, 30, 40, 50, AND 60 MC.



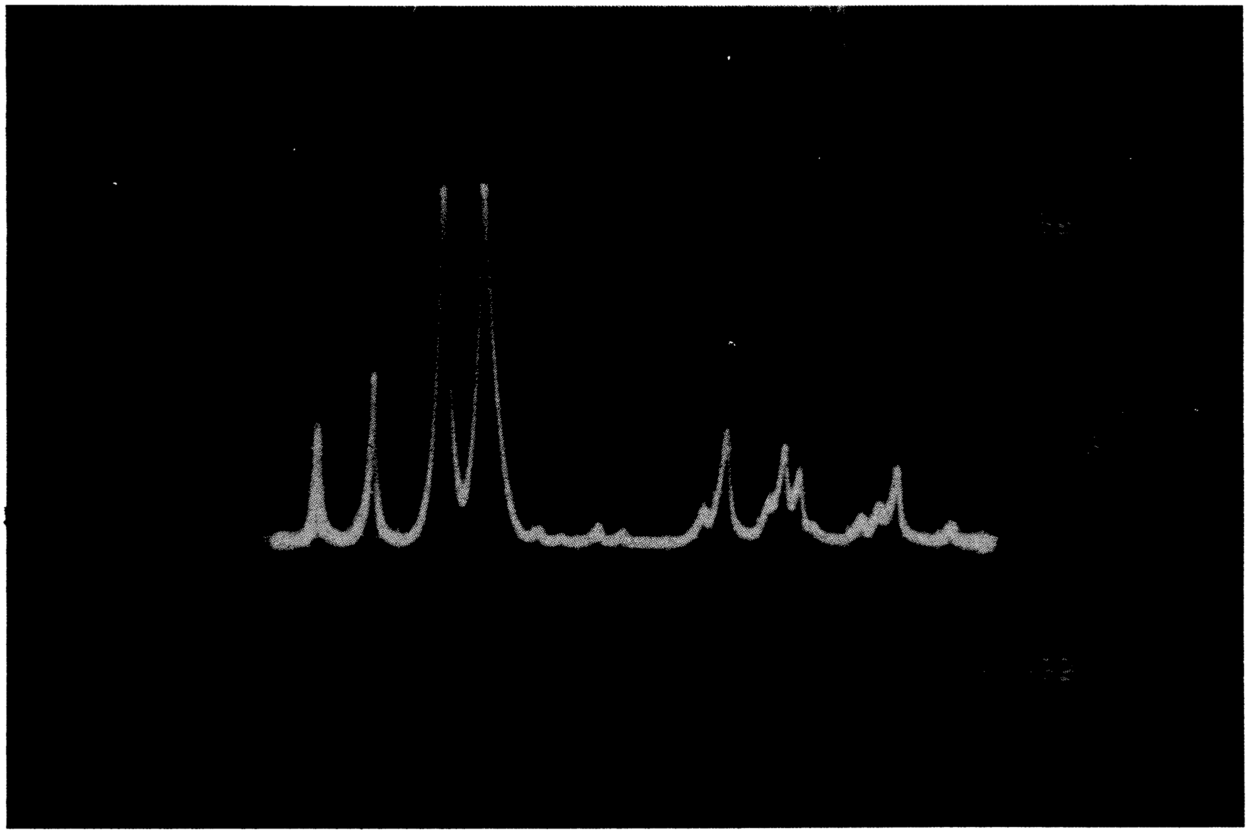
LOCAL SPECTRUM USING SHORT WIRE ANTENNA

FIG. 23

OSCILLOGRAMS SHOWING RESPONSE OF FE-2



MARKER SIGNALS AT 55, 65, 75, 85, 95, 105, AND 110 MC.



LOCAL SPECTRUM (DETROIT) WITH HIGH GAIN DISCONE ANTENNA

FIG. 24

OSCILLOGRAMS SHOWING RESPONSE OF FE-3

At present, an attempt to make noise figure measurements on these units s in progress.

3.1.5 High Frequency Electric Tuned Oscillators. (W. J. Lindsay) he maximum tuning range previously reported[1] for an electric tuned oscillator perating close to 300 mc was only 3.6 percent. This is a very difficult requency range in which to obtain electric tuning because of the reduced Q of erroelectric materials at very high frequencies.

In spite of this effect, considerable advance in the tuning ratio as been obtained at 300 mc with the advent of the new subminiature capacitors escribed above. These units have higher Q values and much larger dc breakdown oltages than previous units.

In the 150 to 300 mc range, the most satisfactory circuit appears to e the ultra-audio audion (Fig. 25) using a series tuned resonant tank circuit, nd a high g_m triode. For the tuning element, a subminiature capacitor made from erovox Hi-Q 40 ceramic gave best results.

Table I gives a comparison of oscillator performance between previously eported oscillators and recent designs.

3.1.6 Program the Next Interval. Equipment for SCF measurements (see ection 3.1.1.1) will be completed, and an appropriate schedule evolved for esting ferrite cores in quantity. More extensive P-E loop data and high frequency data will be taken on ceramic capacitors. The effect of vacuum deposited silver lectrodes on high frequency losses in ferroelectric specimens will be studied hen the vacuum system is delivered and installed. A low frequency survey of a ide variety of ceramic capacitors will be made on the BLARE unit.

[1] Howard Diamond and L. W. Orr, "Interim Report on Ferroelectric Materials and their Applications" Technical Report No. 31, Electronic Defense Group, University of Michigan, July, 1954.

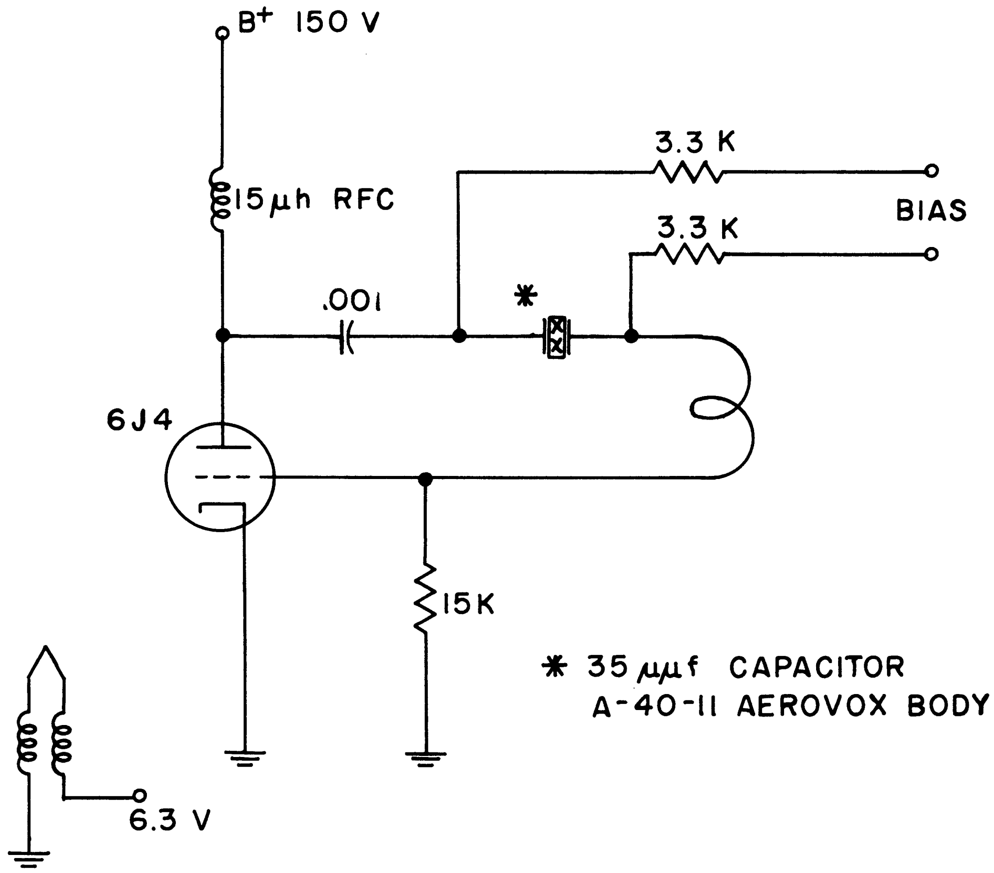


FIG. 25

CIRCUIT OF 6J4 HIGH FREQUENCY OSCILLATOR

TABLE I

	Circuit	Tube	Tuning Element Type[1]	Tuning Element Thickness mils	Bias Field volts per mil	Freq. Range mc	Tuning Ratio Percent[2]
vious illators	push-pull	6J6	A	20	10-60	135-160	18.5
	push-pull	6J6	A	20	0-50	285-295	3.6
	Ultra-Audion	6J4	A	20	0-60	365-375	2.7
ent illators	Ultra-Audion	6J4	B	20	0-100	150-230	53
	Ultra-Audion	6J4	B	20	0-150	250-385	54

HIGH FREQUENCY ELECTRIC TUNED OSCILLATORS

[1] Tuning Elements: Type A -- Stack of six 200 μμf Glenco K3300
Type B -- Single Subminiature Capacitor
Serial No. A-40-11 (Aerovox material)

[2] The Tuning Ratio is the increase in frequency as a percent of the lowest, or starting frequency, as the electric field is applied.

The PANDU program will include noise figure measurements on present front end assemblies, development of new front ends to extend the tuning range and upper frequency limit, and studies to determine the cause of increased sensitivity of front end units when the frequency sweep is stopped.

A technical report on Baukhausen noise measurements in titanate ceramics is being prepared and will be completed in the near future.

3.2 Investigation of Techniques for Signal Detection and Frequency Determination (R. W. Bradley)

3.2.1 Voltage Tunable Magnetrons. In review, an investigation is proceeding to determine the noise characteristics of the Michigan voltage-tunable magnetron, which has been called a mitron, with an eye to using it as the local oscillator in a microwave receiver or spectrum analyzer. The noise characteristi of the reflex klystron, more commonly used in these applications, have been studied and it was felt that comparative data on the magnetron would be most useful. A block diagram of the test equipment is shown in Fig. 26. The receiver is made up of a crystal mixer, the test local oscillator, and IF amplifier, and a bolometer and bridge as the detector. The noise figure of the receiver may be determined from the following equation.

$$K = \frac{\frac{N_{ns}}{KTB}}{\frac{N_{o2}}{N_{o1}} - 1}$$

where N_{ns}/KTB is the ratio of the noise power input from the microwave noise source to that from a 50 ohm matching resistor

N_{o2}/N_{o1} is the ratio of the receiver noise power output with the microwave noise source feeding the receiver input to that with the 50 ohm matching resistor across the input.

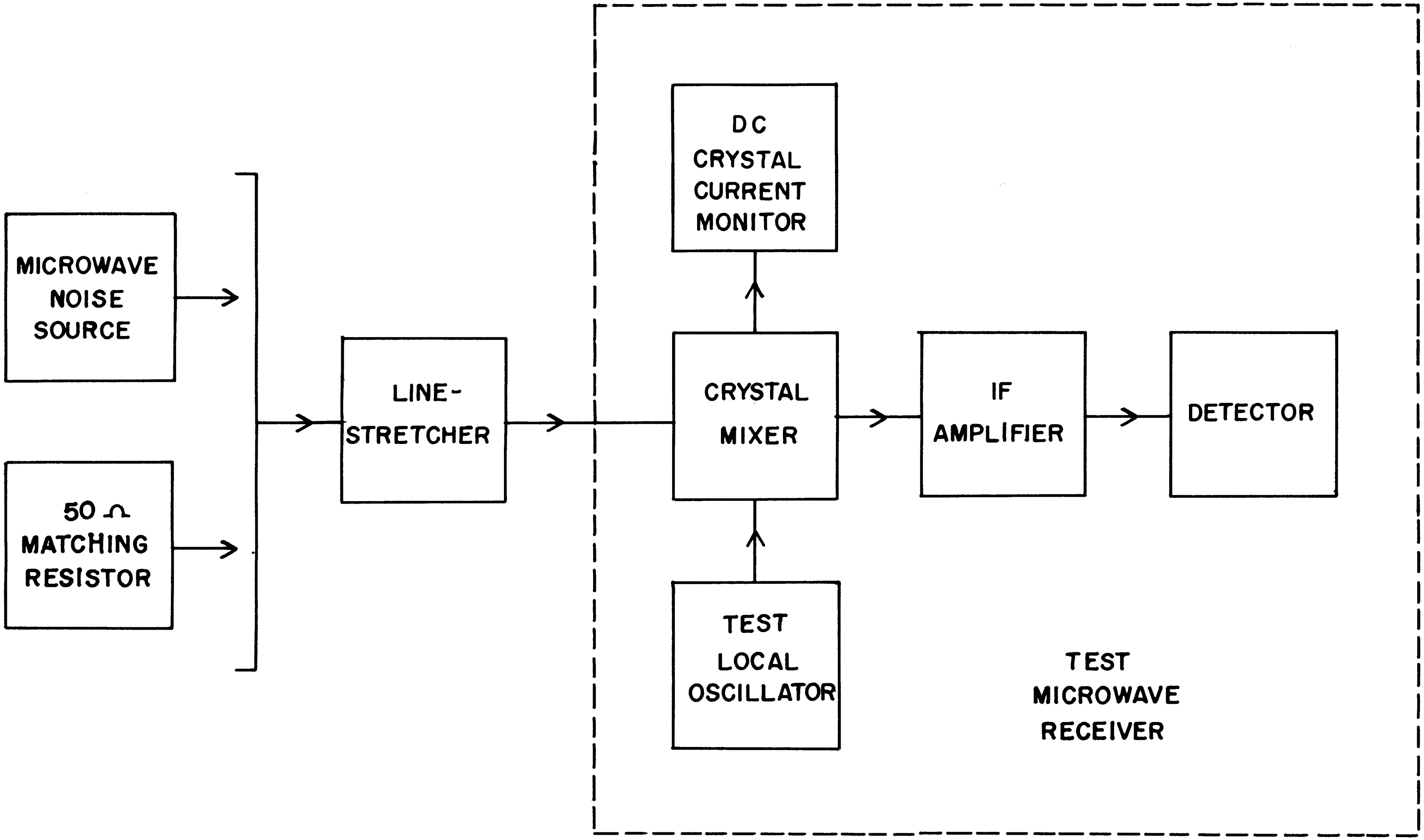


FIG. 26

EQUIPMENT FOR MICROWAVE RECEIVER NOISE FIGURE MEASUREMENTS

2262 A-S4-70 DDB 1-20-55

The standard microwave noise source provides a noise power of 38.3 KTB watts or 15.84 db above thermal noise. A line stretcher was used between the noise source, or matching resistor, and the crystal mixer, to optimize the noise power output with fixed dc crystal current. The IF amplifier has a center frequency of 30 mc with a 3 db bandwidth of 2 mc and a noise figure of 7 db. Although the magnetron may be operated at frequencies between 1500 and 3500 mc, limitations of the other test equipment permitted measurements only in the range 2600 to 3000 mc.

When a klystron was used as the local oscillator, noise figures of the order of 8.5 db were obtained. With the magnetron as a local oscillator, noise figures of 10.5 to 12.5 db were obtained. These variations in noise figures have been attributed to variations in the anode current. The noise figure obtained with the magnetron did not change appreciably with frequency. However, the noise figure varied considerably with variations in anode current. For the tube under investigation, an anode current of 8.5 ma was found to be optimum. For coherent operation it is necessary for the cathode to operate under **temp-limited** limited conditions and, since this tends to be an unstable condition, an electronic controller has been used on the filament to maintain the anode current at any desired value. For anode currents different from the optimum value, noise figures as large as 17 or 18 db were obtained. Measurements were made for anode currents ranging from 5 to 10 ma. The output from the magnetron was monitored on a spectrum analyzer during the measurements, and a marked difference in the appearance of the signals which gave noise figures of 12 and 18 db was observed. This indicates that it is quite feasible to adjust for optimum noise figure by monitoring the output on either and oscilloscope or spectrum analyzer.

3.2.2 Program for the Next Interval. In order to complete this nvestigation of the noise characteristics of the voltage-tunable magnetron it is ecessary to duplicate the measurements reported here for other IF frequencies. t is also desirable to measure the noise figure of the receiver over the complete requency range in which the magnetron can be tuned. Development of instru- entation for these tests is being carried out. These tests will complete the nvestigation of the magnetron.

4. CONCLUSIONS

The objectives for the quarter ending December 31 have been met, and all rograms are progressing satisfactorily.

5. PROGRAM FOR THE NEXT INTERVAL

The programs planned for the next quarter are outlined above in ections 3.1.6 and 3.2.2.

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