



# The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

## Techniques of Signal Generator Inspection

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A signal generator provides a test signal of controllable frequency, voltage, and modulation and may be judged in terms of various characteristics, such as frequency stability, accuracy of frequency calibration, lack of spurious frequencies, lack of incidental amplitude modulation or incidental frequency modulation, low distortion, etc. The relative importance of the individual characteristics depends greatly, of course, on the specific application in which the generator is to be used.

Table 1 lists various signal generator characteristics of interest. Some items are primarily a fundamental characteristic of the design and need not be tested on an individual basis after the prototype run has been developed. Examples of these are RF output frequency stability, RF output impedance, residual FM, and frequency response of the FM system. Such items need to be tested on only one instrument in many and fall logically within the scope of a Quality Control program.

Other items require inspection on each unit, with corrective adjustments often being needed. Examples are RF output frequency accuracy, RF output voltage accuracy, modulation accuracy and harmonic distortion. These items are included, furthermore, in a Quality Control program calling for "spot checks".

We now propose to discuss some of the testing and calibrating procedures used in making certain that the desired characteristics are obtained in the generators produced. These are procedures generally applicable to the types of



Figure 1. Adjustment of Basic Voltage Standardization Equipment by the Author. Normalized Atmospheric Conditions (Temperature and Relative Humidity) for Improved Stability are Maintained by Air-conditioning Equipment in Background.

generators discussed and, in most instances, are applicable to each unit of a given type. Our aim is to produce units which will meet and maintain closer tolerances than those advertised.

TABLE 1

1. *RF Output Frequency Characteristics:* Range • Dial Calibration Accuracy • Accuracy, crystal standardized (internal) • Stability • Crystal Controlled • Vernier Dial • Incremental Frequency Switch • Fine Tuning Control • Spurious Output Frequencies.
2. *RF Output Voltage Characteristics:* Range • Accuracy • Impedance.
3. *Frequency Modulation Characteristics:* Deviation Range • Accuracy • Distortion, harmonic • Frequency Response • Residual • Microphonism • AM on FM, spurious.
4. *Amplitude Modulation Characteristics:* Range • Accuracy • Distortion, harmonic • Frequency Response • Phase Shift • FM on AM, spurious • Pulse • Square Wave.

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5. *Internal Modulating Oscillator Characteristics:* Frequencies available • Frequency accuracy • Voltage available externally.
6. *Modulation Characteristics, miscellaneous:* External Modulation Input, AM • External Modulation Input, FM • Simultaneous AM and FM.
7. *Swept RF Characteristics:* Range of Sweep Widths • Linearity of Swept Frequency • Sweep Repetition Rate • Flatness of Swept RF Output Voltage Level.

**RF Range and Accuracy**

Frequency indicating dials, tuning coils, and tuning capacitors are usually fabricated to prescribed physical layouts and dimensions. When these uniform components are installed the assembled instruments will lie "within calibration range" of the manufacturing adjustments provided.

For calibration purposes the generator output frequency is usually referred to a commercially available crystal type calibrator, accuracy rating  $\pm 0.002\%$ . "Zero beats" are obtained at a sufficient number of generator dial points (usually 6 or 8 per frequency range) to insure accurate calibration. (Individually marked dials must, on the other hand, be calibrated and marked at each division line.)

In instances where the frequency interval between "zero beat" points is very small in comparison to the frequency being checked, a "single response" type of frequency indicator must be used to determine that the correct "zero beat" point has been located. A simple frequency-calibrated tuned circuit and diode voltmeter (or "Megacycle Meter") which may be coupled to the generator output and resonated at any one of the "zero beat" points is usually satisfactory for this purpose.

The crystal-type calibrator, with its accuracy rating of  $\pm 0.002\%$ , offers accuracy entirely adequate for checking signal generators having published ratings of  $\pm 0.5\%$  or  $\pm 0.1\%$ . This type of calibrator may be checked against

WWV if desired.

Signal generators having crystal controlled output frequencies are checked for accuracy against specially built crystal calibrators which are adjusted against WWV.

**RF Output Voltage Range and Accuracy**

In instrument production assurance of the proper voltage range and accuracy usually involves a measurement of output voltage at a high voltage level, and assurance of attenuator linearity or dial tracking accuracy.

Output voltage measuring equipment has an input impedance of 50 ohms, thus providing a normal load and duplicating the input impedance of the accessory 501-B Cable at the signal generator panel connector.

**RF Output Calibration — Method 1** . . . A three stage process is involved in our standardization of RF output voltages (see Figure 2).

- a. *Basic Standardization* (performed in a temperature-controlled and humidity-controlled room). The current from a DC supply is passed through a thermocouple ammeter and resistor series connected. The DC voltage developed across the resistor is measured on a basic standard consisting of a Weston Model 4 Standard Cell (unsaturated cadmium type) and Leeds and Northrup Type K-2 Potentiometer. Over-all accuracy is 0.1%.
- b. *DC to AF Transfer.* Current from a low distortion AF oscillator is substituted for DC and adjusted for the same thermocouple ammeter reading as with DC. The AF signal voltage now developed across the resistor and applied to the electronic voltmeter is equal in magnitude to the previous DC voltage (the electronic voltmeter loading is negligible). The AF voltage accuracy is 0.5%.
- c. *RF Standardization.* The specially-built bolometer bridge responds equally to an internally generated low distortion AF voltage, or to RF voltage from the signal generator being calibrated which is substituted for the former. The electronic voltmeter from (b) is used to standardize the AF voltage and, hence, to calibrate the signal generator, usually at 50 K $\mu$ V RF and at several output frequencies. The bolometer bridge input impedance is equal to the signal generator output impedance, 50 ohms.

Accuracy of the RF voltage measurement, including reading errors, is normally 2% to 3%.

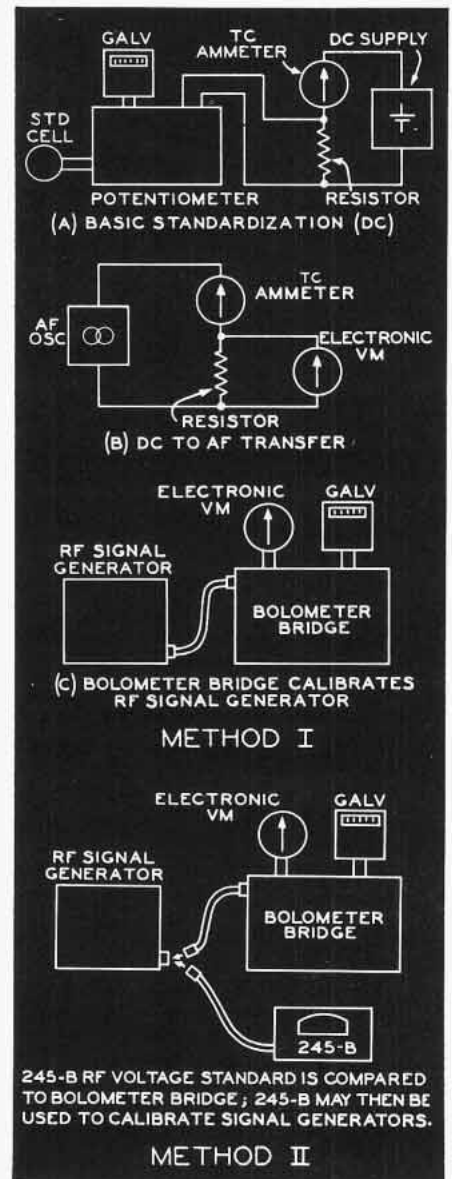


Figure 2. Standardization of RF Output Voltages.

**RF Output Calibration — Method 2** . . . RF Voltage Standard Type 245-B<sup>1, 2</sup>. This instrument may be used as a calibrated voltmeter of approximately 50 ohms input impedance, and provides a direct check on the accuracy of signal generator output voltages in the 50 K $\mu$ V region.

Our calibration procedure starts with the Standard Cell but differs somewhat in detail from that used for the bolometer bridge. The 245-B input voltage accuracy rating is  $\pm 10\%$  for frequencies of 100 kc to 300 mc; however, the units we use for signal generator calibration are additionally calibrated by direct comparison to the standardized bolometer bridge (RF comparison as in Figure 2), thus attaining accuracy approaching that of the bolometer bridge.



Figure 3. RF Comparison of 245-B RF Voltage Standard to Bolometer Bridge.

**Attenuator Linearity . . .** The linearity, or dial tracking accuracy, of piston (mutual coupling) attenuators is primarily a matter of mechanical design and control of mechanical tolerances. RF leakage must also be held to low levels.

Low-level attenuator output voltages, i.e., in the one microvolt region, may be electrically measured by means of the RF Voltage Standard Type 245-B<sup>1, 2</sup> mentioned above. The 245-B accuracy, when used in accordance with the instructions provided for this application, is:

±10%	100 kc to 100 mc
±15%	to 500 mc
±20%	to 1000 mc



Figure 4. Measurement of FM Deviation and FM Distortion of Type 202-E FM-AM Signal Generator by Use of FM Linear Detector and Associated Apparatus.

### Frequency Modulation Range, Accuracy, and Harmonic Distortion

A single "setup" of test apparatus is arranged to measure these three interdependent characteristics. (Figure 4).

The basic test apparatus is a specially built FM Linear Detector having adequate range of FM deviation and AF response. This Detector (including built-in heterodyne oscillator and mixer for signal frequency conversion) connects to the modulated RF output of the signal generator and delivers de-modulated output voltage faithful in amount and harmonic distortion to the amount of FM deviation and harmonic distortion present in the signal generator output.

Associated apparatus consists of an electronic voltmeter and distortion analyzer for reading the Detector output voltage and harmonic distortion.

For calibration of the output voltage readings vs FM deviation the Detector input is connected to the output of a signal generator calibrated by the Bessel Zero method<sup>3</sup>. The calibration thus relies basically upon audio modulating frequencies which can be measured accurately (e.g. by use of a frequency counter). An alternative calibration method employs the Weston Model 4 Standard Cell, Leeds and Northrup Type K-2 Potentiometer, and crystal-standardized signal frequencies. The Detector employs an electronically regulated power supply and has excellent long term stability.

In production testing each generator is checked and adjusted (within the RF unit) at several output frequencies for the correct value of FM deviation. Adjustment for acceptable distortion is also made within the RF unit.

### Amplitude Modulation Range, Accuracy, and Harmonic Distortion

For the measurement of the *depth of amplitude modulation* either of two methods may be employed.

*Method a.* This is the familiar trapezoidal pattern method. A frequency converter, providing conversion of the signal generator output frequency to a frequency suitable for the oscilloscope, and having a linear input voltage vs output voltage relationship, is interposed between the signal generator output and the oscilloscope input.

*Method b.* This method is particularly adaptable to generators having a modulation meter actuated by the modulation component of the RF carrier, in addition to the usual RF carrier monitor meter.

The basic formula is

$$\% \text{ AM} = \frac{141.4 V_{ac}}{V_{dc}}$$

where  $V_{ac}$  and  $V_{dc}$  indicate respectively the AC voltage (RMS) and DC voltage components of the demodulated carrier voltage.

For best accuracy a correction, usually of a minor nature, for the rectifier characteristic curvature should be determined.

*Harmonic distortion* is usually measured by connecting a distortion analyzer to a suitable point in the RF monitor circuit and reading the distortion present in the AC portion of the demodulated carrier voltage.

### Microphonism

FM microphonism can be very troublesome when making tests involving small values of FM deviation. Bench vibration may be conducted to a signal generator resting on the bench, or vibrations may be set up within the generator by airborne sounds within the room in which the generator is used.

Within the generator a major item of susceptibility is the oscillator section of the main tuning capacitor. Vibrations transmitted to the plates or blades of this variable capacitor cause undesired FM of the signal generator output frequency, thus interfering with normal usage of the output signal.

Analysis of this problem indicates that maximum cancellation of vibration-caused capacitance variations is obtained when the plate spacing is uniform throughout the capacitor. In practice visual inspection of plate spacing, a very important but not self-sufficient operation, is required to be followed by an electrical check of vibration-induced FM, additional adjustments of the plate spacing often being necessary. It is emphasized that this adjustment is a specialized technique requiring considerable time and experience to acquire the necessary skill.

### Spurious AM on FM

In our types 202-B, -C, -D, -E, and -F Signal Generators, which embody a frequency modulated oscillator followed by amplifying or frequency-doubling stages, the generation of undesired amplitude modulation when employing frequency modulation is largely a problem of interstage tracking accuracy. For example, if the RF output stage tuning is "out of track" as referred to the oscillator frequency, the output stage will be operated (or "swung") over a sloping portion of its resonance curve and spurious amplitude modulation will be generated (see Figure 5)<sup>4</sup>.

Tuning adjustments of the individual stages are usually made during the inspection of each unit to obtain satisfactory interstage tracking accuracy. The tank circuit resonance curve is observed on an oscilloscope while the generator, operating on FM, is tuned across its range. In this manner spurious AM as a result of FM is kept to a low value, although direct checks of spurious AM are not routinely made.

### RF Unit Adjustments

The interlocking nature of various adjustments made within the RF unit (i.e. by potentiometer adjustment or

bending of tuning capacitor plates) appears to be worthy of mention.

Examples, particularly applicable to FM Signal Generators, are:

Adjustment For	Affects
(a) FM Deviation calibration	Output frequency calibration accuracy and interstage tracking accuracy.
(b) Microphonism	Spurious AM on FM
(c) Interstage tracking accuracy	Interstage tracking accuracy (spurious AM on FM and maximum RF output voltage)
(d) Output frequency calibration accuracy	

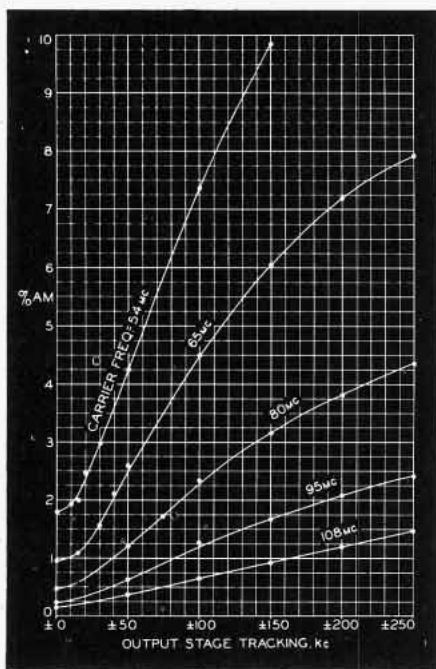


Figure 5. Showing Effect of RF Output Stage Tracking (as Referenced to Oscillator) on Spurious AM on FM. (Type 202-E Sig. Gen.; FM Dev. = 75 kc.)

It is obvious that adjustment and correction of a particular type of RF unit fault may easily introduce a different type of fault. This is not an indication of technical inability on the part of the person performing the adjustments, but is the result of interaction of adjustments.

We wish to hereby discourage user field service of RF units because the end result of such service may, through unfamiliarity with the interactions involved, yield an instrument which is operating below peak performance. This would be to the user's disadvantage as well as ours.

### Tube Stability

The stability of vacuum-tube char-

acteristics plays an important part in the long-term stability of signal generator operation. This is particularly true in respect to the maintenance of adequate RF output voltage (RF monitor meter indication).

For tubes operating in class-C RF output amplifier service we have found it necessary to adopt a rack aging procedure employing a pulsed cathode current derived from a pulse generator. Pulse aged tubes are later installed in the instruments in which they are to be used, and operated before and after instrument calibration. This procedure eliminates a varying percentage of tubes from class-C service but has been found to yield greatly improved reliability in the field.

### Swept Frequency Range and Linearity

Sweep Signal Generators present problems peculiar to testing of the swept RF output signal.

For measurement of the linearity of frequency deviation of the swept RF output signal vs the low frequency sweep output voltage, a calibrated oscilloscope is needed. The calibration is obtained by connecting an adjustable calibrated voltage source to the oscilloscope X-axis terminals. The X-axis deflection to right and left of the scale window center, using the center as a reference point, is plotted vs the input voltage. For convenience marks, including test limits, may be placed on the scale window for equal voltage increments.

Such a calibrated oscilloscope is used in measuring the linearity of the swept RF output of our Type 240-A Sweep Signal Generator<sup>5</sup>. The type 240-A includes a built-in crystal-controlled frequency identification system. A harmonics generator generates a fence of crystal-controlled reference frequencies with a choice of spacings: 2.5 mc, 0.5 mc, or 0.1 mc. A sample of the swept RF signal beats, in a mixer-amplifier system, with the reference fence, giving "birdie" (zero beat type) markers at the same spacing as the reference fence.

The X-axis terminals of the calibrated oscilloscope are connected to the low frequency sweep output voltage terminals of the 240-A. The Y-axis terminals are connected to the output of the 240-A mixer-amplifier system (COMPOSITE SIGNAL OUT connector). The locations of the birdie markers now displayed on the screen are compared to the calibration marks or plot, thereby measuring the linearity of

the swept RF (i.e. the frequency deviation) vs the Signal Generator low frequency sweep output voltage.

The RF sweep width of the 240-A Signal Generator may be measured in the set-up just described, by using the reference fence of "birdie" markers of known frequency spacing.

### Amplitude Flatness of Swept RF Output Signal

The amplitude flatness of the swept RF output voltage is measured by interposing a simple broad-band detector between the signal generator RF output connector and the Y-axis input terminals of a DC amplifier type oscilloscope. When the oscilloscope X-axis terminals are connected to the signal generator low frequency sweep output voltage terminals the horizontal trace line now corresponding to the detector output voltage is an indicator of the amplitude flatness of the swept RF voltage. If the rectangular pattern is now expanded vertically by increasing the oscilloscope Y-gain by a known amount, variations in the height of the detector output trace from the horizontal zero reference (blanked RF output) trace will be indicated more accurately. Correction for detector non-linearity may be necessary.

### Summary

A signal generator, in order that it may be a useful testing tool, must be calibrated initially to an adequate degree of accuracy, and must maintain adequate accuracy and necessary operating characteristics over a long period of time. These important attributes require sound design, careful fabrication, and careful and thorough testing procedures. It is to this purpose that our testing and calibrating efforts are directed.

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## A Standard for Q and L

The widespread use of the Q meter in industry and research has brought about the need for some simple and practical means of checking the overall performance and accuracy of this instrument. Up to the present, the 103-A coil series has served this purpose in default of anything better.

Today, after considerable research, BRC engineers have evolved 5 new coils, the Q-Standards Type 518-A. These coils are well shielded and have been designed to maintain highly stable inductance and Q characteristics. Developed for use with Q Meter Type 260-A, the Q-Standards are useful not only as a check on the overall performance of this instrument but can be used as reference inductors for many impedance measurements. Similar in construction and performance to the 513-A, these Standards, in conjunction with the 513-A, provide frequency coverage from 50 kc to 50 mc- the entire range of Q-Meter Type 260-A.

### Construction Details

In external appearance the coils are very similar to the inductors Type 103-A which are available for use as accessory coils in a variety of Q meter measurements. This resemblance is only superficial, however, since highly specialized design and manufacturing techniques are required to provide the high degree of electrical stability demanded of such units.

The Q Standard unit consists of a

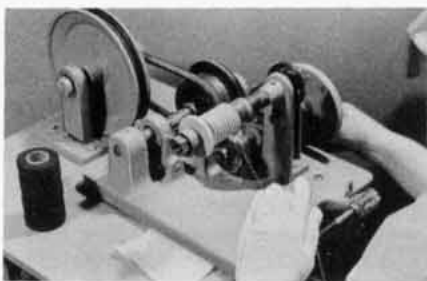


Figure 1. Winding of Coil on Steatite Form.

specially developed high-Q coil wound on a stable low-loss Steatite form and protected by a covering of low loss material (Figure 1). After winding, the coil is heated to remove any moisture present, coated with silicone varnish and baked (Figure 2). Desirable Q versus frequency characteristics are ob-



Figure 2. Varnishing and Baking the Coil Form.

tained where necessary by a carbon film resistor shunted across the coil. The coil form is mounted on a copper base fitted to a cylindrical shield can. The unit is hermetically sealed, evacuated and filled with an inert gas to a pressure of 1 p.s.i. above atmospheric pressure, (Figure 3). Coil leads are brought through the base to banana plug connectors which can be replaced if necessary without breaking the seal. The high potential connector is slightly longer than the low potential connector and is insulated from the base by a ceramic seal which serves as a stop to insure accurately reproducible positioning of the unit with respect to the Q-Meter cabinet.

### Electrical Characteristics

The principal electrical characteristics of each Q-Standard are measured at the factory and stamped on the nameplate of the unit. Three sets of data are thus provided to cover the low, middle and upper frequency ranges of the 260-A Q-Meter. Each set of data contains the following information: a check frequency and its associated values of resonating capacitance and indicated Q.

Indicated Q is defined as the circuit Q of the inductor and Q meter combina-

tion as read on an average Q meter. Any instrument whose readings vary from the nameplate values of indicated Q by more than  $\pm 8\%$  between 50 kc and 30 mc, increasing to  $\pm 13\%$  at 50 mc, is not operating in accordance with the original specifications.

Resonating capacitance is defined as the reading on the internal resonating capacitor dials of an "average" Q meter at resonance for stipulated frequencies which have been checked against a crystal calibrator. The 3 values of resonating capacitance marked on the nameplate are accurate to  $\pm 1/2\%$  or  $\pm 1/2\mu\mu\text{f}$  whichever is greater. (Figure 4).

### Applications

*Accuracy of Indicated Q:* The indicated Q values marked on the Q-Standard provide a convenient check on the accuracy of the Q-indicating meter readings. To make such a check proceed as follows:

Allow the Q-meter to warm up for one hour. Then plug the Q-Standard into the coil posts, making sure that the knurled binding post nuts are tightened and the Q-Standard properly seated. Now zero the meters and adjust the *internal resonating capacitor* to resonance at the three resonating frequen-



Figure 3. Sealing Operation of Q Standard..

cies marked on the nameplate. Adjust the XQ controls to obtain a reading of X1 on the Multiply-Q-By meter at each frequency setting of the 260-A. The reading of the Q-Indicating meter at each frequency should correspond to the indicated Q value marked on the Q-Standard within the tolerance mentioned above. For best results, the frequency of the Q meter should be set using a crystal frequency calibrator.

**Accuracy of Internal Resonating Capacitor Calibration:** The coil may be used to check the accuracy of internal resonating capacitor dial readings. This is done in the following manner:

Allow the Q-meter to warm up for one hour before mounting the Q-Standard on the coil posts. Adjust for a Multiply-Q-By reading of X1 while adjusting the oscillator to the desired frequency (which has previously been checked against a crystal calibrator). Now tune the circuit to resonance by



Figure 4. Checking Calibration of Q and C.

means of the *internal resonating capacitor* dials. Reading obtained should be the same value as indicated on the nameplate within the tolerances of the instrument and the coil.

**Use as a Work Coil:** The Q-Standard is useful as an extremely stable work coil for accurate measurements by the parallel method with Q-Meters Type 260-A

and 160-A. A knowledge of the coil's inductance and distributed capacitance will be helpful in this application.\*

**Distributed Capacitance ( $C_d$ ):** The value of distributed capacitance (the effective distributed capacitance of the coil assembly as measured in position on the Q-meter) for the Q-Standard can be determined by the following formula. Any two of the three sets of data given on the nameplate of the coil may be used.

$$C_d = \frac{C_2 - n^2 C_1}{n^2 - 1}$$

Where

$C_1$  = internal resonating capacitance reading at the first frequency ( $f_1$ ).

$C_2$  = internal resonating capacitance reading at the second frequency ( $f_2$ ), where the first frequency is an integral multiple of second.

$n$  = ration of  $f_1$  to  $f_2$

\*For a full discussion of this subject see Boonton Radio Corporation's instruction manuals on Radio Frequency Measurements, the Type 260-A Q-Meter or Type 160-A Q-Meter.

**True Inductance ( $L$ ):** The true inductance of the coil may be determined by

$$L = \frac{1}{\omega^2 (C_r + C_d)}$$

and **Effective Inductance ( $L_e$ ):**

$$L_e = \frac{L}{1 - \omega^2 L C_d}$$

The resonating capacitance for any point may now be determined by—

$$C_r = \frac{1}{\omega^2 L} - C_d$$

#### Use With Q-Meter Type 160-A

The low frequency and the high frequency performance of the Type 160-A Q-Meter (designed in 1938) is not as good as the current Type 260-A Q-Meter to which the Q data on the coil directly applies. The following table shows the approximate multiplying factor which must be applied to the Q data stamped on the nameplate of the 518-A, making it generally applicable to an average Type 160-A Q-Meter.

#### CORRECTION TABLE

Coil No.	Frequency Range
518-A1	15 mc - 45 mc
518-A2	5 mc - 15 mc
518-A3	1.5 mc - 4.5 mc
518-A4	150 kc - 450 kc
518-A5	50 kc - 150 kc

#### Approximate Resonating Capacitance

400 $\mu\mu\text{f}$	100 $\mu\mu\text{f}$	40 $\mu\mu\text{f}$
0.86	0.96	1.15
0.95	0.98	1.00
1.00	1.00	1.00
0.99	0.97	0.95
0.97	0.90	0.83

For additional information on these correction factors see "Q Meter Comparison", BRC Notebook, No. 2, Summer, 1954.

## Service Note

#### Low-frequency adjustment of RX Meter, Type 250-A

Occasionally, a situation develops where it is impossible to achieve balance at the lower frequencies when using the RX Meter, Type 250-A. The following discusses the method by which this condition may be corrected.

All adjustments of the 250-A RX Meter bridge circuit are made at B.R.C. before the  $R_p$  drum dial is calibrated. The actual calibration itself, entails the painstaking hand marking of every point along the effective 28 inches of the scale.

However, since the nature of the instrument is such that at frequencies above 100 MCS, the zero balance of the bridge is of necessity, very sensitive to minute variations in internal circuit capacitance; a screw driver trimmer adjustment, described on page 7 of the Summer 1954, Number 2 issue of the Notebook, is provided to compensate for any slight changes that may occur after the dial is engraved.

This is the only adjustment of the bridge circuit that should be made in the field.

About an inch and a half to the right and slightly to the rear of this trimmer is another screw driver adjustment, designated, C 109 on the schematic, which can be seen when the top cover of the instrument is removed. (Figure 1). The setting of this trimmer is extremely critical and upon it depends, to a great extent, both the accuracy of the  $R_p$  calibration and the proper balancing

of the bridge at all frequencies. Under no circumstances, therefore, should this trimmer be disturbed.

In cases where users of the 250 have, nevertheless, turned this trimmer and ended up with a bridge which cannot be made to balance, especially at low frequencies, the following procedure will in most cases restore the instrument to normal operation.

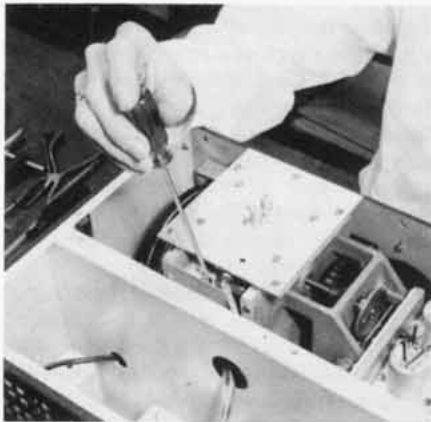


Figure 1. Location of Trimmer, C109 for Adjustment Purposes.

1. Set the frequency to .5 mc and the  $R_p$  dial to  $\infty$ .
2. Adjust the "detector tuning" knob in the normal manner for maximum deflection of the meter.
3. Position both the "R Coarse" and "R Fine" balance knobs so that the set screws are at "10 o'clock".
4. Turn the "C" balance knob fully clockwise.
5. Using the  $C_p$  crank knob and the trimmer C 109 mentioned above, balance the bridge. This should occur at zero or within 10 mmfds in the silver portion of the  $C_p$  dial. For the final balance, a slight adjustment of the "R Fine" balance might be necessary.
6. Using precision film resistors, check the accuracy of the  $R_p$  dial at 10 k and at 200 ohms (Frequency still at 0.5 mc). If the 200 ohm resistor reads low, turn the "R Coarse" knob a little more counter-clockwise and repeat steps 1, 2, 4, 5 and 6. If the 200 ohm resistor reads high, turn "R Coarse" knob clockwise and repeat as before.
7. Replace cover and check for balance.
8. Check for balance at 200 and 250 mcs as covered in the manual.

## The Price of an Instrument

FRANK G. MARBLE, *Vice President—Sales*

A general increase in our prices was put into effect on December 1, 1956; the first such adjustment in many years. This change was necessary because increased material costs and operating expenses could no longer be completely compensated by engineering and production ingenuity and increased volume. These factors had "held the line" for a remarkably long time; one instrument recently replaced by a new model, sold at the same price for almost ten years.

The present necessity for a price change and the long period of stable prices in face of continuing increases in prices in the general economy, gave rise to some consideration of the price of an instrument. Just how does a company establish such a price? Having established the price, how can it maintain that price over sustained periods and still pay its expenses and make a profit?

To produce an instrument, once a market is determined to exist and specifications have been established; engineering, development, and design must be undertaken to prepare models and information from which manufacture can be undertaken. The market determination and specification establishment are overhead expenses applicable to any instrument development while the costs of engineering the instrument are for the most part specific and must be paid out of sales of the instrument. To produce the instrument, materials must be purchased, labor expended and the instrument must be advertised and called to potential customers attention.

The price must be set prior to sale and thus calls for estimates and judgment, since actual specific experience is not available. The costs of engineering can be ascertained since final pricing usually takes place near the completion of the engineering cycle. The length of time over which the engineering costs will be spread and the expected number of sales in that period must be estimated. The engineering costs can then be divided by this number of units which result now forms part of the instrument's cost. Material estimates and labor time estimates, yield additional costs. Finally, overhead, representing the costs of services; purchasing, selling,

supervision, building, tool costs, etc. and profit are added and the price becomes available.

The labor time estimates must be projected as an average over a period of time. The early instruments will always take much more time than the average for the life of the instrument. These early instruments will cost more than their selling price. Estimating this "learning curve" is important. As a minimum, the instrument must sell the number of units estimated within the time in which the engineering costs are to be repaid. If it sells additional units over a longer time, capital for additional engineering and a lowered price for subsequent instruments results. General attention to reasonable overhead costs must be continuously maintained.

If all this work is properly done, a reasonably priced instrument will result which attracts customers over a considerable period of time. A properly engineered and priced instrument will return its purchase price many times over to its user. We believe, that electronic instruments are one of the biggest bargains available in today's market.

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### EDITOR'S NOTE

It is widely feared our nation is falling behind in the technological race. The world's population is increasing at an accelerating tempo but the need for technically trained personnel in this age of automation increases at an even faster rate. While waiting for the educational system to re-adjust itself in the light of present day realities, most employers are searching for ways and means of improving the efficiency of our present crop of engineers. Magazines devoted to this problem have sprung up. Personality and environmental factors are coming in for more attention. Psychological terms — the "problem child", non-conformist, the unconscious, the subconscious, the semi-conscious and the no-account are now found liberally sprinkled throughout our technical literature.

No longer is Management concerned solely with the technical merit of the engineering applicant. In the larger corporations where Research and Development receives a significant share of the budget dollar, the biological or "animate sciences" — psychology, psychiatry, even phrenology are increasingly coming into use in the appraisal of applicants. In some corporations psychological testing is already routine. Sweating palms, twitching of the eyebrows (perhaps due to a sadistic mosquito that prefers applicants over interviewers) may be cause for rejection even though the applicant has his shoes shined, his Sunday suit pressed and an impressive background. A handshake that is too firm may indicate a potential "Stakhanovite," one who is geared up at a high rpm and may therefore cause a serious morale problem among those who work at a more normal rate. On the other hand, an engineer with a weak handshake might be suspect as a latent bohemian, a non-conformist indifferent to the need for "getting along".

If he is unfortunate enough to pass these batteries of tests and possesses the proper phrenological characteristics, he is hired. These phrenological requirements, incidentally, vary from company to company; some companies demand two bumps on the forehead and one aft, symmetrically spaced; others are more modest, requiring only one bump fore and aft. This matter of phrenological standards will be aired by an industry-wide Committee that is being estab-

lished to standardize criteria on employment as a guide for interviewers. The committee will be known as the Committee on Interview Criteria or the CIC committee (for phonic convenience it is rhymed with sick).



There follows assignment to an R/D team, which must be productive of new ideas to justify itself. Now ideas, creative ones, are difficult things to come by since the technically trained mind, it is believed, is something inhibited from seeing the true relation between things due to its peculiarly one-sided education and isolation from the administrative end of things where company policy is made. Nevertheless a brave stab is being made by utilizing the latest advertising technique of generating ideas for "selling" a product. This is called "brainstorming" or cranial ventilation and is similar to the free

association principle used in psychoanalysis to liberate facts from the "unconscious". It goes something like this—

The engineering team is placed around a large circular table in a room devoid of distracting decor such as pictures (especially nostalgic landscapes), curtains, etc. Lights are turned low, and binaural "think" music pours softly out of speakers hidden in the ceiling. A contemplative mood established, the engineers are now to toss any ideas that pop into their heads into a pot. This goulash is gingerly examined from time to time by the Idea Co-ordinator who hopes to find therein a few pearls of thought. But alas, it is being sadly admitted that no sooner do the lights dim than the "think" music is transformed through some perversity of the engineering brain into "dream" music that produces only yawns and snores.

The inevitable reaction is beginning to set in. There is now a real danger the policy of the "hard school" will take effect. This consists of placing the engineer's head in a wine press adapted for the purpose and squeezing. Ideas, if any, are caught in a large beaker of formaldehyde, the heaviest ideas settling to the bottom, the others remaining in suspension.

Any evidence obtained from "modern" methods to the contrary, engineering is still a profession for enthusiastic, hard-working-people well grounded in fundamentals. The horizons have broadened but the basic requirements are not different.

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