# TEST & ALIGNMENT PROCEDURES

for

# 160A & 260A Q Meters

**BOONTON DIVISION**
**Hewlett-Packard Company**

The following articles in the BRC Notebook supplement the information in this manual. Copies of the Notebook are available through your nearest Hewlett Packard Sales Office.

Most of the service information in the BRC Notebooks has largely been incorporated in this manual; the service articles are added here only for completeness.

| | Article | BRC Notebook No. |
|---|---|---|
| Theory: | The Nature of Q | 1 |
| | Q Meter Comparison | 2 |
| | A Versatile Instrument - The Q Meter | 4 |
| | Circuit Effects on Q * | 8 |
| | The Evolution of the BRC Q Meter | 23 |
| Applications: | A Versatile Instrument - The Q Meter | 4 |
| | Check Your Q Readings by the ΔC Method | 4 |
| | Audio Frequency Measurements Using the Coupling Unit Type 564A | 5 |
| | Measurement of Dielectric and Hi Q Capacitors with the Q Meter | 8 |
| | A Standard for Q & L | 12 |
| | Q Meter Techniques | 13 |
| | Calibrating and Inductance Standard | 15 |
| | The RX Meter or the Q Meter | 16 |
| Service: | The Q Standard | 1 |
| | Replacing the Thermocouple Assembly Type 565A in the Q Meter Type 260A | 1 |
| | Q Meter Comparison (160A and 260A) | 2 |
| | Check Your Q Readings by the ΔC Method | 4 |
| | Calibration of the Internal Resonating Capacitor of the Q Meter | 7 |
| | Correction of Low Q Reading on Q Meter Type 160A | 8 |
| | Frequency Calibration of Q Meter Type 260A | 10 |

Note: A Manual of Radio Frequency Measurements, containing the basic measurement technique using Q Meters is available from your -hp- Sales Office for $2.50.

* Also includes "Correlation of 190A and 260A Q Meters on overlapping Frequency Ranges.

# TABLE OF CONTENTS

SECTION PAGE

I

## TECHNICAL DATA AND SPECIFICATIONS

II

## PERFORMANCE TESTING

III

## TEST AND CALIBRATION

# TABLE OF CONTENTS

SECTION PAGE

III G. SIGNAL INJECTION SYSTEM

H. OVERALL PERFORMANCE USING Q STANDARDS

IV PARTS IDENTIFICATION AND SCHEMATICS

A. 160A

B. 260A

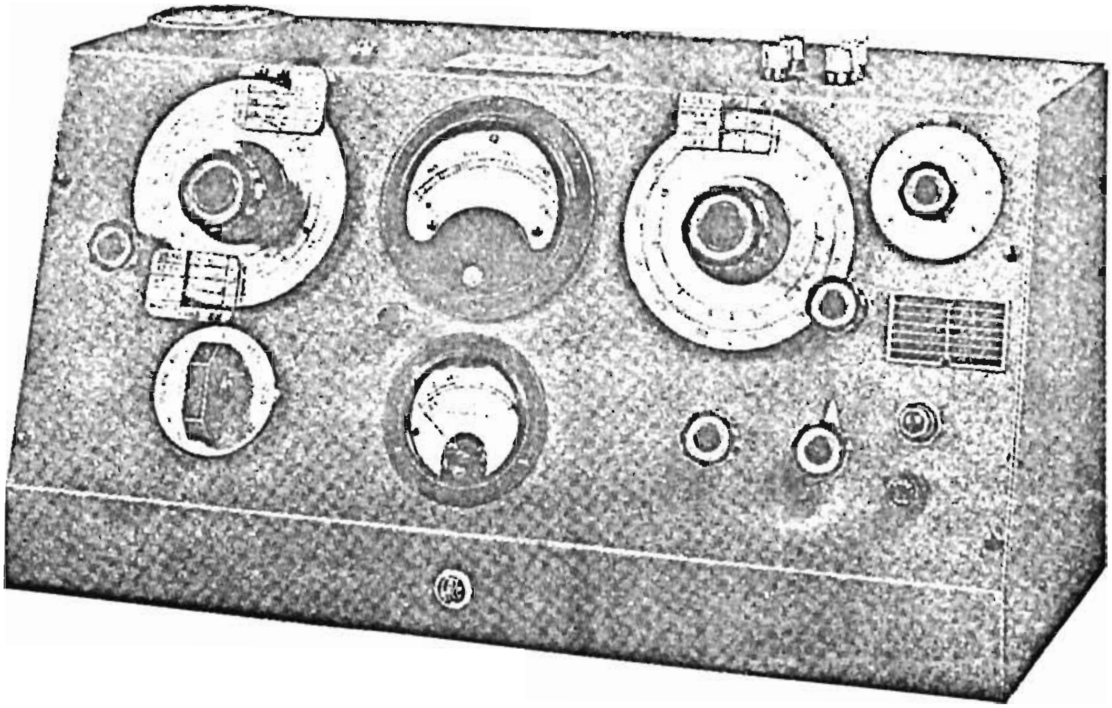
V APPENDIX

## LIST OF TABLES

# SECTION 1

# TECHNICAL DATA AND SPECIFICATIONS

# Q METER TYPE 160-A



*Frequency Range 50 KC-75 MC*

## OPERATING PRINCIPLE

The symbol Q is commonly used to designate the ratio of reactance to resistance of a coil ($Q=2\pi fL/R$) or of a condenser ($Q=1/2\pi fCR$). This factor is of fundamental significance in circuit design, since it is a "figure of merit" of the reactive elements. For example, the higher the value of Q the greater the selectivity and the amplification of a stage in which the reactors are used.

The Q of a simple resonant circuit may be measured by impressing a known voltage in series in the circuit and measuring the voltage across one of the circuit reactances when the circuit is resonated to the frequency of the impressed voltage. The ratio of the voltage across the reactance to the impressed voltage is the Q of the circuit. If the impressed voltage is constant, the voltmeter may be calibrated directly in Q, and, if most of the circuit losses occur in the coil, the Q measured in this way will be very closely the Q of the coil.

This method of measuring Q has been employed in the Q-Meter because it is simple and accurate and requires only a single operation — resonating the circuit — to measure Q.

The Q-Meter contains (1) an r.f. oscillator, (2) a measuring circuit consisting of main and vernier tuning condensers which tune the external coil to be measured, (3) a vacuum tube voltmeter of special design which reads the voltage developed across the tuning condenser and (4) a means for introducing a known amount of the oscillator voltage in series in the measuring circuit.

The procedure in measuring Q consists of either adjusting the oscillator to a predetermined frequency and tuning the circuit under measurement to resonance, or conversely of tuning the circuit with a predetermined capacitance and adjusting the oscillator to resonance. At resonance, the voltmeter indicates directly the Q of the circuit.

## USES

The instruction book which accompanies each Q-Meter describes in detail the many applications of this instrument. A few of the more common uses are as follows:

**R.F. Coils:** The Q of all types of coils commonly used in radio frequency circuits may be determined by simply connecting the coil to the terminals provided, resonating this coil to the oscillator frequency and observing the Q as indicated on the Q voltmeter. The effective inductance of the coil may be determined directly from the decade inductance scale on the dial of the Q tuning condenser. Coils may be rapidly matched and Q simultaneously observed.

**A.F. Coils:** The Q and inductance of large inductance coils such as are used in supersonic and AF circuits (down to 1 kilocycle) may be measured. For this purpose provision has been made whereby the output of an external oscillator (1 kilocycle to 50 kilocycles) may be coupled into the oscillator transmission line within the Q-Meter. The same procedure as used with r.f. coils is employed.

**Variable Condensers — Small Fixed Condensers:** By substituting the condenser under observation for a part of the capacitance of the Q tuning condenser, the effect of the test condenser upon the circuit is directly indicated in terms of a loss in Q. By a simple computation the Q (or the power factor) of the test condenser may be determined. The change in setting of the Q tuning condenser is a direct measure of the capacitance of the condenser under test.

**Insulating Materials — Dielectrics:** For the measurement of insulating materials, a specimen Condenser is made by securing conducting surfaces on opposite sides of a plate of the material. The same technique used in measuring fixed condensers is employed.

**Antennae:** The effective series resistance, capacitance, inductance and fundamental frequencies of small antennae may be determined over a wide frequency range.

## SPECIFICATIONS

**Oscillator Frequency Range:** Continuously variable from 50 kilocycles to 75 megacycles in eight self-contained ranges. (In conjunction with an external oscillator the frequency range of the Type 160-A Q-Meter may be extended from 50 kilocycles to 1 kilocycle for coil measurements.

**Oscillator Frequency Accuracy:** Generally better than ±1%, except the 50-75 megacycle range which is approximately ±3%.

**Range of Q Measurements:** The Q voltmeter is calibrated directly in Q, 20-250. The "Multiply Q By" meter, which measures the oscillator voltage injected in the Q measuring circuit, is calibrated in tenths from x1 to x2 and also at x2.5. The reading of the Q voltmeter scale is to be multiplied by the setting of the "Multiply Q By" meter. Hence, the total range of circuit Q measurements is from 20 to 625. Condensers, dielectrics, etc., which are measured by placing these in parallel with the measuring circuit, may have Q's as high as 5000.

**Accuracy of Q Measurements:** The accuracy of the direct reading measurement of circuit Q (for Q voltmeter readings between Q=50 and Q=250) is approximately 5% for all frequencies up to the region of 30 megacycles, and decreases with increasing frequency. Correction may be made for the error above 30 megacycles as it is principally a frequency effect. The accuracy of the measurement of condensers, dielectrics, etc. is generally better than 10% for Q's below 5,000 and up to 30 megacycles.

**Capacitance Calibration Range:** Main Tuning condenser 30-450 mmf., calibrated in 1 mmf. divisions from 30 to 100 mmf, and in 5 mmf divisions from 100 to 450 mmf. Vernier condenser, plus 3 mmf, zero, minus 3 mmf, calibrated in 0.1 mmf divisions.

**Accuracy of Capacitance Calibration:** Main tuning condenser, generally better than 1% or 1 mmf, whichever is the greater. Vernier tuning condenser ±0.1 mmf. The internal inductance of the tuning condenser at the binding posts is approximately .015 µhy.

**Voltmeter:** The Q Voltmeter is also calibrated in volts. A specially calibrated tube, type BRC 105A tube, is used.

**Power Supply:** 105-120 volts, 50-60 cycles. Also 210-240 volts, 50-60 cycles. Power consumption 50 watts.

**Tubes:** The instrument is supplied complete with the following tubes:

1 Type BRC 102-A*
1 Type BRC 105-A*
1 Type 5W4
1 Mazda 47

**Specially selected.*

**Dimensions:** Height 12.5", length 20", depth 8.5".

**Weight:** 25 lbs.

# Q METER TYPE 260-A

**FSN 6625-537-5699**

*Frequency Range 50 KC to 50 MC*

## Description

The Q Meter was first designed and introduced in 1934 as a means of measuring the Q or "Figure of Merit" of coils. Improved models and broadened applications have kept pace with a rapidly growing industry, and the Q Meter is recognized as a flexible general purpose device with a large number of uses. The Q Meter consists of a self-contained, continuously variable, stable oscillator, whose controlled and measured output is applied in series with a series-tuned, resonant circuit. A vacuum tube voltmeter with high output impedance is connected across the internal variable capacitor portion of the tuned circuit to measure the reactive voltage in terms of circuit Q. The coil portion of the tuned circuit is connected externally and represents the unknown to be measured. By inserting low impedances in series with the coil or high impedances in parallel with the capacitor, the parameters of unknown circuits or components can be measured in terms of their effect on the circuit Q and resonant frequency. Because of the high quality components used in the manufacture of the Q Meter, coupled with a design engineered to minimize unwanted inherent residuals, the instrument is extremely sensitive.

## Features

As a result of our studies, field information and suggestions received from our custsomers, we have incorporated in our present Q Meters those modifications and additions which it was felt would increase the usefulness of the instrument.

1. "Lo Q" Scale. Direct reading expanded scale permits the measurement of Q down to 10.
2. "△ Q Scale." Also direct reading expanded scale to permit the reading of very small changes in Q resulting from the variation of test circuit parameters.
3. Thermocouple Protection. The Type 260-A utilizes a rugged thermocouple operating at 1/2 rated power, and the output of the oscillator is adjusted at the factory to avoid overload. Both of these features guard against accidental thermocouple overload.

**BOONTON RADIO COMPANY**

*A Division of Hewlett-Packard Company*

GREEN POND ROAD
ROCKAWAY, NEW JERSEY 07866

*Precision Electronic Instruments since 1934*

TELEPHONE: 201-627-6400 • TWX: 201-627-3912 • CABLE ADDRESS: BOONRACO

4. Power Supply Regulation. Through the use of an internal regulating transformer and an electronically regulated power supply, the operation of the instruments is not affected by normal power line voltage fluctuations.

5. Teflon insulation has been provided for the terminals of the 260-A, providing mechanical stability and low electrical loss. The oscillator output is controlled by varying the screen grid voltage of the oscillator tube to obtain smooth operation as well as good waveshape. A 0.02 ohm annular insertion resistor is used to improve Q meter accuracy. Provision is made for the use of an external oscillator to supply the Q Meter through a matching transformer (Type 564-A) to provide operation below 50 kc. down to 1000 cycles per second. A scale is also provided to read inductance directly at selected frequencies.

6. Meter scales with mirror reflectors are used to eliminate error due to parallax.

7. The instrument has been designed to minimize internal residual inductance and resistance.

8. The thermocouple as well as all tubes can be replaced by the customer without returning the instrument to the factory.

## Uses

**Coils:** Circuit Q is read directly from a parallax-free meter. From the measurements made on coils, the distributed capacitance, effective inductance, and self-resonant frequency can be determined.

**Capacitors:** Capacitance from 0.1 pf to 100 K pf, and Q from 10 to 10,000 can be evaluated from measurements made on the Q Meter with and without the component connected. The self-resonant frequency of capacitors can be determined within the range of the instrument.

**Resistors:** The effective rf resistance, inductance or capacitance, and Q of resistors over a wide range can be determined.

**IF and RF Transformers:** Measurements can be made of effective impedance, Q, coefficient of coupling, mutual inductance, and frequency response.

**Dielectrics:** The Q Meters measure dielectric constant and dissipation factor, power factor, etc., of various grades of insulating materials and ceramics, including very low loss types. Samples with foils applied can be measured in a Hartshorn-Ward type of holder, or mounted directly on the O Meter using a simple flat ground plate and connecting clip. Liquids held in a suitable container can also be measured.

**Miscellaneous:** The resistance, reactance, Q, and impedance of miscellaneous passive circuits, networks, filters, etc., can be determined with dc bias voltages applied if desired. Measurements can be made of antennas and coupling networks. Transmission line parameters necessary to compute characteristic impedance, attenuation, and velocity of propagation can be evaluated.

## Specifications

### Radio Frequency Characteristics

RF RANGE:
Total Range: 50 Kc. to 50 Mc.
1 Kc. to 50 Kc.*
*With external oscillator
No. Bands: 8
Band Ranges:

| | |
|---|---|
| 50 — 120 Kc. | 1.7 — 4. Mc. |
| 120 — 300 Kc. | 4.2 — 10 Mc. |
| 300 — 700 Kc. | 10 — 23 Mc. |
| 700 — 1700 Kc. | 23 — 50 Mc. |

RF ACCURACY: ±1% approximately.

RF CALIBRATION: Increments of approximately 1%.

### Q Measurement Characteristics

Q RANGE: Total Range: 10 to 625
Low Range: 10 to 60
△ Range: 0 to 50

Q ACCURACY: ±5%* 50 Kc. to 30 Mc.
±10%* 30 Mc. to 50 Mc.
*For circuit Q of 250 read directl on indicating meter.

Q CALIBRATION:
Main Scale: Increments of 5 from 40 to 250
Low Scale: Increments of 1 from 10 to 60
△ Scale: Increments of 1 from 0 to 50
XQ Scale: Increments of 0.1 from 1 to 1.5
Increments of 0.5 from 1.5 to 2.5

### Inductance Measurement Characteristics

L RANGE:
0.09 μh to 130 mh (effective inductance).*
*Direct reading at six specific frequencies.

L ACCURACY: ±3%*
*For resonating capacitance >100 pf and inductance >5μh.

### Resolating Capacitor Characteristics

CAPACITOR RANGE:
Main: 30 to 460 pf
Vernier: —3.0 to +3.0 pf

CAPACITOR ACCURACY:
Main: ±1% or 1 pf whichever is greater
Vernier: ±0.1 pf

CAPACITOR CALIBRATION:
Main: 1 pf increments 30 to 100 pf
5 pf increments 100 to 460 pf
Vernier: 0.1 pf increments

### Accessories

FURNISHED: None

AVAILABLE: Type 103-A Inductors
Type 513/518A Q Standards
Type 564-A Coupling Unit

### Tube Complement

1 — OA2
1 — OB2
1 — 535-A
1 — 5763
1 — 6X4

### Mechanical Characteristics

MOUNTING: Sloping front cabinet, for bench use.

FINISH: Gray wrinkle, engraved panel (Other finishes available on special order).

DIMENSIONS: Height: 12-1/2" (31.7 cm)
Width: 20" (50.8 cm)
Depth: 8-1/2" (21.6 cm)

WEIGHT:
Net: 40 lbs. (18 kg); Gross Export: 98 lbs. (44.2 kg); Gross Domestic: 55 lbs. (24.8 kg); Legal Export: 50 lbs. (22.7 kg).

### Power Requirements

260-A: 95-130 Volts, 60 Cps, 65 Watts

260-AP: 95-130 Volts, 50 Cps., 65 Watts

**Price: 260-A: $990.00 260-AP: $990.00**

# Q-STANDARDS TYPES 513-A & 518-A
# INDUCTORS TYPE 103-A

**0.5 MC-1.5 MC** — **Type 513-A**
**1.5 MC-4.5 MC** — **Type 518-A3**
**5 MC-15 MC** — **Type 518-A2**
**15 MC-45 MC** — **Type 518-A1**
**50 KC-150 KC** — **Type 518-A5**
**150 KC-450 KC** — **Type 518-A4**

## Type 513-A

The Q-Standard Type 513-A is a shielded reference inductor which has accurately-measured and highly-stable inductance and Q characteristics. Specifically designed for use with Q-Meters Type 260-A and 160-A, the Q-Standard is particularly useful as a check on the overall operation and accuracy of these instruments, as well as for providing precisely-known supplementary Q-circuit inductance desirable for many impedance measurements by the parallel method. The Q-Standard consists of a specially-designed, high-Q coil of Litz wire, wound on a low-loss Steatite form. The coil is hermetically sealed inside a copper shield can which is filled with an inert gas under pressure. The desired Q-versus-frequency characteristics are provided by a carbon film resistor shunted across the coil. Two replaceable banana plug connectors mounted on the base serve to connect the unit to the Q-meter circuit. The Q-Standard is supplied in a convenient wooden carrying and storage case. Each unit is individually calibrated and marked with its true inductance (L), distributed capacity ($C_d$), and effective Q ($Q_e$) and indicated Q ($Q_i$) at 0.5, 1.0 and 1.5 mc, respectively. Tolerance: L ±1%—$C_d$ ±2%—$Q_e$ ±3% measured at 73°F. $Q_i$ is an average Q-Meter reading. Any instrument deviating more than ±7% from the marked value is not operating in accordance with original specifications.

**Nominal Values for Type 513-A**

| L - 250 µh | | Cd - 8 pf | |
|---|---|---|---|
| | 0.5 mc | 1.0 mc | 1.5 mc |
| $Q_e$ | 190 | 250 | 220 |
| $Q_i$ | 183 | 234 | 200 |

Actual values of all these quantities are marked on the name plate of the Q-Standard.

With the unit in the Q-circuit, approximate resonant frequencies of 500, 1000 and 1500 kc are obtained with tuning capacitance of 400, 100 and 50pf, respectively.

**Temperature Coefficients:**

L and $C_d$ — Negligible

| $Q_e$ — freq. | %△Qeff/°F |
|---|---|
| 0.5 mc | —0.128 |
| 1.0 | —0.083 |
| 1.5 | —0.042 |

Overall Q-Standard Dimensions:
3″ (7.6 cm) diam. x 4-1/2″ (11.4 cm) h. (approx.)
Net Weight (including case): 28 oz. (1 kg) (approx.)

**Price: Type 513-A: $97.00 ea.**

# Types 518-A1 to 518-A5

Supplementing the Q-Standard Type 513-A, BRC has designed five additional Q-Standards Type 518-A. 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. The units are useful as precision inductors and as a fast, convenient method for checking the overall operating accuracy of Q Meters.

Each model is supplied in a convenient wooden carrying and storage case and is individually calibrated and marked with its indicated Q and resonating capacitance (C) at each of three (3) discrete frequency points.

"Indicated Q" is an average Q-Meter reading — any instrument deviating from the marked value by more than ±8% from 50 KC to 30 MC, increasing to ±13% at 50 MC, is not operating in accordance with original specifications. Resonating capacitance accuracy: ±0.5% ±0.5 pf.

| | 518-A1 | 518-A2 | 518-A3 | 518-A4 | 518-A5 |
|---|---|---|---|---|---|
| INDUCTANCE | 0.25 μh | 2.5 μh | 25 uh | 2.5 mh | 25 mh |
| Low Freq. Data: | | | | | |
| Frequency | 15 MC | 5 MC | 1.5 MC | 150 KC | 50 KC |
| Resonating C | 420 pf | 395 pf | 440 pf | 440 pf | 400 pf |
| Indicated Q | 175 | 195 | 175 | 170 | 90 |
| Middle Freq. Data: | | | | | |
| Frequency | 30 MC | 10 MC | 3 MC | 300 KC | 100 KC |
| Resonating C | 100 pf | 95 pf | 105 pf | 100 pf | 85 pf |
| Indicated Q | 235 | 235 | 225 | 180 | 130 |
| High Freq. Data: | | | | | |
| Frequency | 45 MC | 15 MC | 4.5 MC | 450 KC | 150 KC |
| Resonating C | 40 pf | 40 pf | 45 pf | 40 pf | 35 pf |
| Indicated Q | 225 | 205 | 230 | 135 | 125 |

(Table shows nominal values)

**Price: Type 518-A: $97.00 ea.**

**Set of five Type 518-A and one 513-A: $525.00**

9-63

# TYPE 103-A

*Illustrating construction, also relationship between Q and tuning capacitance for typical inductor*

These inductors are designed specifically for use in the Q circuit of the Type 160-A and 260-A Q-Meters, for measuring the radio-frequency characteristics of capacitors, including materials, resistors, etc.

| Type | Inductance | Approx. resonant frequency for tuning capacitance of: 400pf | 100pf | 50pf | Approx. Q | Capacitance pf |
|---|---|---|---|---|---|---|
| 103-A1 | 1 μh | 8 | 16 | 20 mc | 180 | 6 |
| 103-A2 | 2.5 μh | 5 | 10 | 14 mc | 200 | 6 |
| 103-A5 | 5 μh | 3.5 | 7 | 10 mc | 200 | 6 |
| 103-A11 | 10 μh | 2.5 | 5 | 7 mc | 200 | 6 |
| 103-A12 | 25 μh | 1.5 | 3 | 4.5mc | 200 | 6 |
| 103-A15 | 50 μh | 1.1 | 2.2 | 3 mc | 200 | 6 |
| 103-A21 | 100 μh | 800 | 1600 | 2000 kc | 200 | 6 |
| 103-A22 | 250 μh | 500 | 1000 | 1400 kc | 200 | 6 |
| 103-A25 | 500 μh | 350 | 700 | 1000 kc | 170 | 7 |
| 103-A31 | 1 mh | 250 | 500 | 700 kc | 170 | 7 |
| 103-A32 | 2.5 mh | 150 | 300 | 450 kc | 170 | 8 |
| 103-A35 | 5 mh | 110 | 220 | 300 kc | 160 | 8 |
| 103-A41 | 10 mh | 80 | 160 | 200 kc | 140 | 9 |
| 103-A42 | 25 mh | 50 | 100 | 140 kc | 110 | 9 |
| | | 100 pf | | 35 pf | | |
| 103-A50 | 0.5 μh | 20 mc | | 35 mc | 225 | 5.5 |
| 103-A51 | 0.25 μh | 30 mc | | 50 mc | 225 | 5.5 |
| 103-A52 | 0.1 μh | 45 mc | | 75 mc | 225 | 3.5 |

Each Type 103-A Inductor consists of a high Q coil mounted in a convenient shield and provided with plug terminals which plug directly into the coil terminals of the Q-Meter to facilitate the quick interchange of inductors for measurements at various frequencies.

Complete shielding eliminates errors in measurement due to coupling between the inductor and the test component and again with nearby objects, which coupling might alter the Q circuit constants during a measurement. Perfect shielding provides the desired stability.

The Q of the majority of the Type 103-A Inductors is in the region of 200, over the normal range of tuning capacitance of from 50 to 400 pico-farads. The approximate variation in Q with tuning capacitance of a typical 103-A Inductor is shown in the above curve. A few of the higher inductance inductors have a Q of less than 200. The approximate Q of each inductor is listed.

The true inductance of types A1 through A42 is adjusted to within 2 per cent of their nominal value. Tolerance on other coils is slightly wider. The total distributed capacitance varies as indicated.

For convenience in selecting the correct inductance, the approximate frequencies at which each inductor resonates with two or three different tuning capacitances is included in the list at the left.

**Price: $17.75 each. Set of 16 Inductors for 260-A: $255.00 Set of 17 Inductors for 160-A: $270.00**

# SECTION II

# PERFORMANCE TESTING

Table II-1. Comparison of 260A and 160A Markings

| 260A Panel Engraving and Text Designation | 160A Marking |
|---|---|
| XQ COARSE | None (Item 1, See page 38) |
| XQ FINE | None (Item 29, See page 38)<br>NOTE: Not included on early 160A's |
| Q ZERO ADJUST | None (Item 20, See page 38) |
| CIRCUIT Q METER | Q |
| MULTIPLY Q BY | MULTIPLY Q BY |

Table II-2. Equipment Required for Performance Testing

| Instrument | Model | Required For | Ref. Para. | Required Characteristics |
|---|---|---|---|---|
| Audio Oscillator | -hp- 200CD | Capacitor Check | B3 | 20 KC at 5 V RMS |
| Q Standards | BRC 513A or 518A Series | Voltmeter Check<br>Q Check | B4 | Accurate $Q_i$ |
| Standard Variable Capacitor * | Gen'l Radio 1722 DP | Capacitor Calibration | C2 | 35-115pf±0.03% or±0.01pf<br>100 - 600pf±0.03% or±0.1pf |
| Shielded Inductor | BRC 103A-32 | Capacitor Calibration | C2 | Shielded 2.5 mh<br>Q Approx. 170 |
| Q Meter | BRC 260A | Capacitor Calibration | C2 | Oscillator and resonance indicator |
| Crystal Calibrator | Ferris 33 | Frequency Calibration | C1 | 50 KC to 75 mc, accuracy better than 0.01% |
| or | | | | |
| Electronic Counter | -hp-5245L | | | |
| with | | ** | | |
| Amplifier | -hp-461A | | | preamplifier for 20 mv RMS sensitivity of counter |
| and | | | | |
| Plug in | -hp-5251A | | | Only needed for 160A |

* Depending on testing accuracy required, substitution may be made. Refer to Paragraph C-2 on page 15 for details.

** Requirements are listed for testing both 160A and 260A Q-Meters. For testing only 260A's use the 5245L and a 5261A video amplifier.

# SECTION II

## PERFORMANCE TESTING

The following performance check is intended as an in-cabinet check of the 260A and 160A Q Meters to verify proper performance. Access to internal test points is not necessary as part of the procedure. The tests can be used for incoming quality control and routine preventive maintenance checks.

Subsection B gives preliminary chekcs as an indication of the operation of the instrument.

Subsection C presents procedures for testing specified accuracies of the Q Meter.

The following procedures refer to controls and front panel engraving on the 260A Q Meter. For equivalent markings on the 160A, refer to Table II-1.

### A. EQUIPMENT REQUIRED

Test equipment used in the performance testing of the 260A Q Meters is given in Table II-2. This table lists the type of equipment to be used, the critical specifications required for testing, and recommended commercially available test equipment.

### B. GENERAL OPERATION CHECKS

Instrument should be ON and in operation a few minutes.

1. Zero Controls

   (a) Short HI and GND posts together

   (b) On the 260A only: Adjust Q ZERO ADJUST for no movements of the CIRCUIT Q Meter when the front panel lever switch is alternately depressed and released from the LOW Q position.

   (c) The meter should read zero, exactly, if the meter mechanical zero is correct.

   On the 160A: Omit (b) and (c). Instead, adjust zero knob (item 20, page 38) for a zero reading on the Q Meter.

2. Oscillator - To see that the RF oscillator is oscillating and has sufficient output over its entire frequency range, proceed as follows:

   (a) Place the oscillator range on 50-120 KC. (50-150 KC on the 160A). Rotate XQ FINE control fully clockwise. (Early 160A's did not have a fine control).

(b) Advance the XQ COARSE control until the MULTIPLY Q BY Meter indicates 2.0. Rotate the frequency control through the entire range of the band and set the frequency to that point in the band where the MULTIPLY Q BY deflection is least.

NOTE: The performance of the Q Meter is not specified beyond the band edges as defined by the panel engraving (260A) or printing on the fiducial (160A), even though calibration marks may extend beyond the band limits.

(c) Advance the XQ COARSE control slowly and check that it is possible to get a MULTIPLY Q BY deflection at least X 1.0.

(d) Rotate the XQ COARSE control fully counter-clockwise (without actuating the power switch) before changing ranges. This is a normal operating precaution to prevent thermocouple damage.

(e) Repeat (b), (c), and (d) on each frequency range.

3. Resonating Capacitor Check - To determine that no obvious malfunction, such as shorted capacitor plates, exists at some particular dial setting, proceed as follows:

(a) Connect an audio oscillator (-hp- 200CD or equivalent) between the HI and GND posts. Set the frequency to approximately 20 KC, output voltage for near full deflection on the CIRCUIT Q Meter.

(b) Rotate the main Q capacitor and vernier capacitor through their entire range. A shorted plate would cause the meter indication to drop to zero.

(c) Remove audio oscillator.

4. Q Voltmeter - To check the voltmeter functions, proceed as follows:

(a) Connect a 513A, 518A-3, A4, or A5, Q Standard across the COIL terminals and, using normal Q Meter technqiues, see that the coil resonates.

Omit steps (b), (c), and (d) for the 160A.

(b) With a resonance peak, as indicated on the CIRCUIT Q Meter, adjust the XQ COARSE and XQ FINE controls for a CIRCUIT Q Meter reading of 60. Check peak. Depress the lever key to the LOW Q position. Repeak. Note that the CIRCUIT Q Meter now indicates 60 on the LOW Q scale. (Meter tracking inaccuracies will normally prevent an indication of exactly 60).

(c) Adjust the XQ controls for a MULTIPLY Q BY indication near 1.0. Raise the lever key to the ΔQ position and adjust the ΔQ BALANCE controls for a CIRCUIT Q Meter indication of zero on the ΔQ scale. The scale on the skirt of the ΔQ COARSE control should approximately agree with the CIRCUIT Q reading when the lever key is released.

(d) Check for smooth meter operation when the ΔQ BALANCE controls are varied.

## C. TESTING SPECIFIED ACCURACIES

### 1. Oscillator Frequency

(a) Connect a crystal calibrator between the LO and GND terminals (20 mv is available when XQ = 1.0). Maintain the MULTIPLY Q BY Meter deflection within a few percent of 1.0 since there is a slight shift of oscillator frequency at other XQ settings.

(b) Check frequency at convenient increments across each frequency range.

SPECIFICATIONS: ± 1% of the dial setting (260A)
± 2% of the dial setting below 50 mc and
± 5% of the dial setting above 50 mc (160A)

NOTE: More than 1/2 VRMS is available at the 160A phone jack on the cabinet top or at the 260A thermocouple block by installing a BNC Tee (remove the access door). However, ANY connection will seriously affect the frequency calibration at the higher frequencies.

Frequency calibration with an electronic counter connected to the oscillator output should be restricted to frequencies below 1 mc. Above this frequency, connection should be made only between LO and GND posts. An amplifier, such as the -hp- 461A may be used as a preamplifier for an electronic counter.

### 2. Resonating Capacitor

The internal resonating capacitor, Items 19 and 20 on the 160A schematic (page 39) or C201 in the 260A, is used to adjust the capacitance across the circuit under test to resonate it at the measurement frequency.

The calibration method described in this Manual is based on substitution of a known amount of capacitance from a precision capacitor for an indicated amount of capacitance in the Q Meter, using a resonant circuit and a second Q Meter as an indicator. Calibration is done at a relatively low frequency with respect to the operating range of the instrument in order to prevent stray inductance effects.

To avoid repetition, the complete procedure including the adjustment technique will be found in Section III D "Resonating Capacitor Adjustments".

Where only a check on the resonating capacitance calibration is desired, the 513A or 518A series Q-Standards may be used. The capacitance required to resonate the 513A may be calculated from nameplate information. (For details refer to APPENDIX C, page 5, of BRC Notebook #1 or the Applications Instructions for Q Standard Type 513A). The nameplate information on the 518A series Q-Standards includes the resonating capacitance required for three frequencies. The values given are accurate to ± 0.5% or ± 0.5 pf, whichever is greater. The frequency of the oscillator should set accurately with an external standard to eliminate frequency error.

## 3. Circuit Q Measurement Accuracy.

The specified accuracy of the 260A is ± 5% to 30 mc, ± 10% from 30 mc to 50 mc for a circuit Q of 250 read directly on the indicating meter (when XQ = 1.0.) Circuit Q is the indicated Q on the 260A which includes the measuring circuit losses as well as the effects of the residual circuit parameters. (These are completely discussed in the 260A Manual).

The 160A accuracy is specified as approximately ± 5% for all frequencies up to the region of 30 mc for circuit Q values between 50 and 250 (when XQ = 1.0.)

Boonton manufactures Q-Standards for the purpose of checking the overall performance of BRC Q Meters. The nameplate on the standards gives the indicated Q (Qi) for the coil when measured on a properly functioning Q Meter. A data sheet containing Q-Standard information is included in Section I of this manual. Additional information may be found in Appendix A where a "Note on Q-Standards" is reprinted from an NBS publication.

For the purpose of verifying the accuracy of Q readings, it should be sufficient for the 260A to indicate the Q-Standard indicated Q (Qi) within ± 7% when using the Type 513A Inductor, or ± 8% with the 518A types (± 13% above 30 mc). Set the MULTIPLY Q BY Meter to 1.0 for these checks.

Allow a warm-up time of 1/2 hour or more for the 160A, 2-1/2 hours or more for the 260A.

Corrections must be applied to the 160A Q readings when using the 518A type coils. Refer to BRC Notebook number 8 or the Applications Instructions accompanying a 518A coil. No corrections are required when the 513A Q-Standard is used.

The number of Q-Standards to be used for verifying Q-Meter performance and accuracy will depend upon the users requirements. Where there is no need for extensive checking through the entire frequency range, two Q-Standards, the 513A and 518A-1, are the recommended minimum for normal overall performance checks.

Refer to Section III, H1 and 2 for details of their application.

# SECTION III

# TEST AND CALIBRATION

Table III-1. Equipment Required for Test and Calibration

| Instrument | Model | Required For | Ref. Para | Required Characteristics |
|---|---|---|---|---|
| Crystal Calibrator | Ferris 33 | Frequency Calibration | B2 | 50 KC to 75 MC<br>Accuracy better than 0.01% |
| or | | | | |
| Electronic Counter | -hp- 5245L | See footnote marked on page 12 | | |
| with | | | | |
| Plug In | -hp-5251A | | | (To extend range to 75 mc for 160A calibration) |
| and | | | | |
| Amplifier | -hp- 461A | | | Preamplifier for 20 mv RMS Sensitivity |
| Shielded Inductor | BRC103A-32 | Capacitor Calibration | D1 | Shielded 2.5 mh Q≈170 |
| Q Meter | BRC 260A | Capacitor Calibration | D1 | Oscillator and Resonance Indicator |
| | | Q Circuit ΔQ Check | F2 | |
| Standard Variable Capacitor | Gen'l Radio 1422 DP | Capacitor Calibration | D1 | 35-115pf 0.03% or ± 0.01 pf<br>100 - 600pf ± .03% or 0.1pf<br>(with special calibration chart) |
| Shielded Inductor | 103A-22 | Backlash Check<br>Q Circuit ΔQ Check | C1 | 250 μh shielded<br>Q≈200 |
| Shielded Inductor | 103A-51 | RF Contact Resistance | C2 | 0.25 μh shielded, Q 225 |
| Audio Oscillator | -hp-200CD | Voltmeter Calibration | E1 | 10 V RMS at 100 KC |
| Precision Attenuator | Gertsch RT Ratio Tran | Voltmeter Calibration | E1 | Accurate Division to 0.2 V |
| 2 ea. 1 μfd. 200 V W DC Low Loss Capacitors | -hp- Part 0170-0073 | Voltmeter Calibration | E1 | 1.0 μf ± 10% 200 W V DC<br>Polystyrene dielectric |
| Q Standards | BRC 513A or 518A series | Overall performance | H1 | Accurate Qi |
| VTVM | -hp-400H<br>-hp-400L | Signal Injection Calibration | G2 | Calibrate at measurement frequency with -hp-738A, 739A |

# SECTION III

# TEST AND CALIBRATION

# SECTION III

# TEST AND CALIBRATION

## A. EQUIPMENT REQUIRED

Test equipment used in the test and calibration of the 260A and 160A Q Meters is given in Table III-1. This table lists the type of equipment to be used, the critical specifications required for testing, and commercially available test equipment.

## B. OSCILLATOR ADJUSTMENTS

### 1. Mechanical

(a) When the tuning capacitor plates are at the full mesh stop, the line on the upper half of the fiducial should coincide with the end line below the low frequency ranges. The line on the lower half of the fiducial should coincide with the end line below the low end of the high frequency ranges.

(b) Check for free operation of the friction drive and that no contact is made with the fiducial.

(c) The range switch contact clips and both sets of shorting arm contact clips should be checked to make certain that each of the two sides of each clip deflect outward when coil cradle contact pin entry is made on each range. Only the tip of the clip should contact the pins.

(d) Oxidized contacts usually cause erratic MULTIPLY Q BY meter indications. It is recommended that the contacts be cleaned with fine abrasive and lubricated with BEACON 325 grease (an Esso product) or equivalent.

### 2a. Frequency Calibration (260A)

The general conditions outlined in Section II, paragraph C-1 apply.

Each frequency range has two calibration adjustments; a threaded magnetic core to calibrate the low frequency of the range, and a trimmer capacitor to set the high frequency end. An additional trimmer, C129, is shunted across the oscillator tube to compensate for tube variations when replacement becomes necessary. C129 is normally set to mid-range before a complete calibration is made.

Usually a small readjustment of C129 is all that is necessary after replacing the oscillator tube.

The coils for the eight ranges are wound on four coil forms mounted in cradles on a turret, each coil form being used for two ranges. The threaded magnetic cores to adjust coil inductance are turned into each end of the form and fastened with Q-MAX when the oscillator is tested as the factory. Because of the physical arrangement of the coils, four bands cannot be conveniently adjusted without removing the oscillator assembly from the front panel. This exposes the cores and allows them to be loosened with acetone so adjustment can be made. CAUTION: Do not use GLYPTAL Thinner to loosen the cores. Coils (and corresponding cores) are identified on the end frame of the turret by the letters "B" (for back) and "F" (for front) with the band number. The high end adjusting capacitors are also identified by numbers.

Table II-2 shows the range, band number and location on the turret

Table III-2. 260A Oscillator Coil Location

| Band | Freq Range | Coil Location |
|---|---|---|
| 1 | 50 - 120 KC | Front |
| 2 | 120 - 300 KC | Front |
| 3 | 300 - 700 KC | Back |
| 4 | 700 - 1700 KC | Front |
| 5 | 1.7 - 4.2 MC | Back |
| 6 | 4.2 - 10 MC | Front |
| 7 | 10 - 23 MC | Back |
| 8 | 23 - 50 MC | Back |

To provide for tracking adjustment, the outer rotor plates of the tuning capacitors are slotted. Any adjustment required should be minor. For tracking of the 10 - 23 MC and 23 - 53 MC ranges, adjust the 13 plate section. For ranges 300 - 700 KC, 700 - 1700 KC, 1.7 - 4.2 MC, 4.2 - 10 MC, adjust the 25 plate section. It is suggested that tracking be done on bands 4 and 8. Small readjustments may be necessary to bring the other bands within specifications.

### 2b. Frequency Calibration (160A)

The general conditions outlines in Section II, Paragraph C-1 apply.

The oscillator is tuned-grid, tickler feedback circuit. There are no metallic cores or trimmer capacitors on all the coils to make the necessary adjustments for frequency calibration. Adjustment is made by changing coil locations or turns.

In general, the removal of grid turns from the coil group lowers the self inductance of the grid coil and its distributed capacitance. The total effect is to raise the frequency for a given setting of the dial, with a greater change occuring at the lower frequency end of the band.

Removal of plate turns, or an increase in plate to grid coil spacing decreases the mutual inductance between the plate and grid windings and the frequency will be raised for a given dial setting. The change will be more pronounced at the high frequency end of the band.

Refer to Table III-3 for a convenient guide to 160A frequency adjustments. The table gives the necessary adjustments to RAISE the frequency for a given Capacitor setting. The opposite adjustments are made to lower the frequency.

Metallic flaps are provided on both sections of the oscillator tuning capacitor. Their adjustment will affect the minimum capacitance and consequently the high frequency end of the ranges.

The outer rotor plates of the oscillator tuning capacitor are slotted to provide minor adjustments of the frequency dial tracking. Any adjustment necessary should not allow rotor to stator spacing of less than 0.008".

The oscillator output voltage is adjusted by changing the output coil position on each range except the 25-50 mc range, where a loop inside the coil form is adjusted. There is no adjustment on the 50-75 mc range. On any range, the frequency and output voltage adjustments interact. Thus, if any adjustments are made, both frequency calibration and output voltage must be checked.

NOTE: Some of the frequency ranges have dial calibrations extending beyond the limits shown on the fiducials. The specifications do not apply to the portions of the dial marking beyond the limits marked on the fiducials.

## SPECIFICATIONS

Frequency - ± 2% below 50 mc, ± 5% above 50 mc.

Output Voltage - Sufficient to produce a MULTIPLY Q BY meter deflection of at least 1.0 at all frequencies.

Table III-3. A Convenient Guide to 160A Frequency Adjustments

| Frequency Range and Band Number | Adjustment Necessary to RAISE the Frequency for a Given Tuning Capacitor Setting | |
|---|---|---|
| | GRID COIL | PLATE COIL |
| | General shift at all frequencies slightly more at the low end of band | Pronounced change at high end of band |
| 50 - 150 KC<br>1 | Remove turns | Remove turns |
| 150 - 450 KC<br>2 | Remove Turns | Plate turns cannot be removed. Instead, mutual inductance is lowered by pushing grid coil toward end of plate coil. |
| 450 - 1500 KC<br>3 | Shift turns from large section over to section having fewer turns | Push plate winding off grid winding |
| 1.5 - 4.5 MC<br>4 | | |
| 4.5 - 12 MC<br>5 | | |
| 12 - 25 MC<br>6 | Same as Band 3 - 5 | Push plate wire crossing inside of tube toward cradle side of coil form. This tends to make the half turns double back on the outside turns and reduces its self inductance. |
| 25 - 50 MC<br>7 | Push grid wire crossing away from cradle side of coil form. This tends to make the half turn double back on the outside turns. | Spread part of an outside turn slightly. |
| 50 - 75 MC<br>8 | No adjustment | No adjustment |

## C. RESONATING CAPACITOR CHECKS

Before calibration of the resonating capacitor is begun, it is suggested that backlash and RF contact resistance be checked. Repair work may alter the calibration.

### 1. Backlash

(a) Connect a 103A-22 Inductor (or equivalent) to the COIL terminals. Set the frequency range to 300-700 KC (260A) or 450-1500 KC (160A), and the resonating capacitor vernier at zero.

(b) Approach 450 pf on the main capacitor dial from a CCW direction and stop at 450 pf with no overshoot. Resonate the coil with the frequency dial (coarse tuning) and vernier capacitor (fine tuning). Note vernier reading.

(c) Approach 450 pf from the opposite direction, stopping at 450 pf with no overshoot. Re-resonate with the vernier capacitor only. Subtract readings.

(d) If backlash ($\Delta C$) is greater than .7 pf there is mechanical trouble in the resonating capacitor.

(e) Check backlash at 250 pf for less than 0.4 pf and also at 70 pf for less than 0.3 pf, changing the oscillator frequency to establish resonance as in 1 (b) above.

### 2. RF Contact Resistance

RF Contact Resistance at the ends of the rotor shaft or at the disc and fingers connected to the top plate will cause erratic Q readings and interfere with establishing a resonance peak. To check for this condition, proceed as follows.

(a) Connect a 103A-51 coil (or equivalent) to the COIL terminals.

(b) Set the resonating capacitor to 100 pf, the frequency to the 23-50 mc range (25-50 mc on the 160A) and resonate the coil with the frequency dial.

(c) Set the MULTIPLY Q BY reading to 1.1. Detune the circuit to the low C side and using the main C dial friction drive, retune slowly. Note the Q reading.

(d) Offset to the High C side and again retune, noting the Q reading.

(e) The readings noted in (c) and (d) should be equal. The retuning from an off resonance condition should result in a smooth rise in Q reading.

(f) Repeat at 200 pf and 400 pf using the 10-23 mc oscillator range (12-25 mc on the 160A) for these settings.

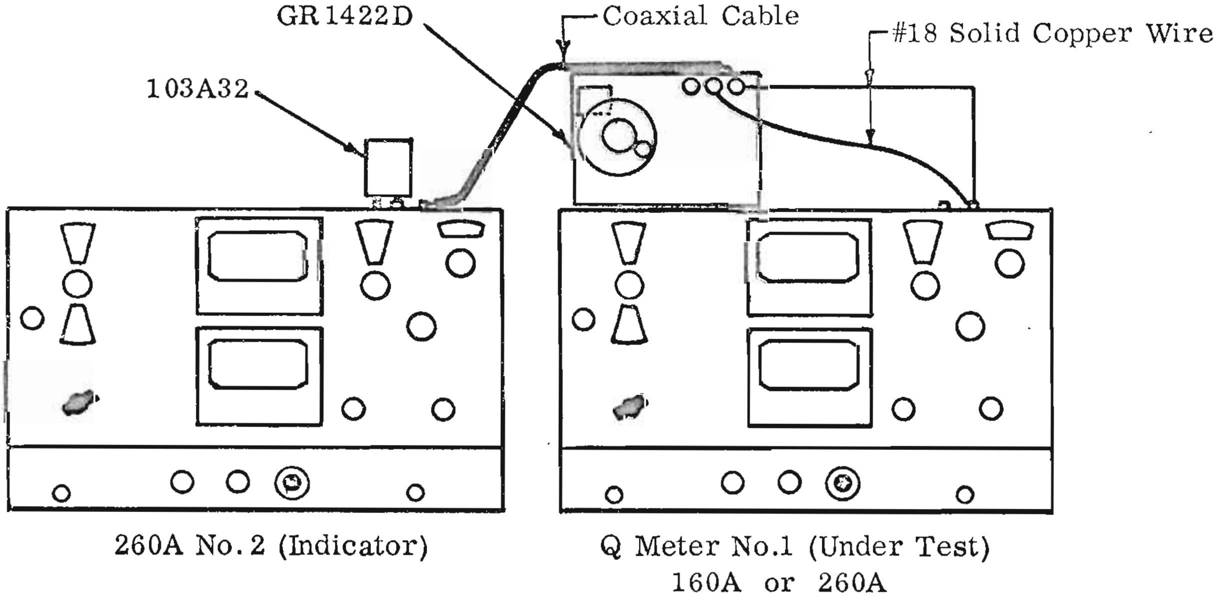
## D. RESONATING CAPACITOR CALIBRATION AND ADJUSTMENT

In the following procedure the Q Meter to be calibrated will be referred to as No. 1, the indicator 260A as No. 2. (The 160A Q Meter is not recommended as the indicator because of the difficulty in obtaining adequate definition of the peak of resonance in the procedure.)

### 1. Vernier Capacitor Calibration

The vernier capacitor is difficult to adjust because of its precise accuracy specification. The calibration technique differs from the recommended adjusting technique so they are treated separately. Calibration is made with reference to the 0.0 pf dial reading. The adjustment starts with the -3.0 pf dial reading as a reference. To calibrate the vernier proceed as follows:

(a) Refer to Figure III-1 for physical placement of the units. Turn on No. 2. (No. 1 remains OFF) Connect a 103A-32 coil to the No. 2 coil terminal. Connect LOW range of the precision capacitor to the HI and GND terminals of No. 2 through a short piece of coaxial cable. Set the internal capacitor of No. 2 to minimum capacitance.



(b) Connect the ground and low range terminals of the precision capacitor to the GND and HI CAP terminals, respectively, of Q Meter No. 1. (HI COND terminals if No. 1 is a 160A)

(c) Set the precision capacitor to a convenient point in its range (100.00 pf, for example). Call this dial reading $D_o$. Set the vernier capacitor of No. 1 to 0.0 pf.

(d) Resonate the coil with the frequency dial of Q Meter No. 2 (coarse) and the vernier capacitor (fine). Raise the lever key and adjust the ΔQ BALANCE controls for an on-scale indication on the CIRCUIT Q Meter. Repeak the circuit with the lever switch in the ΔQ position. This method increases the sensitivity of the indicator 5 times and allows more accurate adjustment of resonance. The XQ reading need not be maintained at X1.0 but can be somewhat lower.

(e) Adjust the vernier of No. 1 to 1.0 pf and re-resonate with the precision capacitor, lifting the lever switch to the ΔQ position to refine the peak. Record the precision capacitor dial reading as $D_{-1}$.

(f) Calculate $\Delta C$ in the following manner. Consult the calibration chart supplied by the manufacturer of the precision capacitor, calling $e_o$ the correction at $D_o$, $e_{-1}$, the correction at $D_{-1}$. Then

$$C_o = D_o + e_o, \quad C_{-1} = D_{-1} + e_{-1}$$

where $C_o$ and $C_{-1}$ are the corrected capacitances at dial readings $D_o$ and $D_{-1}$ respectively.

Then $C_{-1} - C_o = \Delta C$, the change in capacity, which should be 1.0 pf ± 0.1 pf.

(g) Set the vernier of No. 1 to -2.0 pf and re-resonate with the precision capacitor, calling the dial reading of the precision capacitor $D_{-2}$. Calculate $C_{-2} - C_o$ which should be 2.0 pf ± 0.1 pf.

(h) Continue the calibration of -3.0, + 2.0 pf.

2. Vernier Capacitor Adjustment

The same equipment setup in the preceding section is used, except the vernier to be adjusted is set at -3.0 pf and the precision capacitor corrections are not used.

(a) Set the precision capacitor to a convenient reading (100.00, for example). Set the vernier of No. 1 to 3.0 pf and resonate the circuit with frequency (coarse) and No. 2 vernier (fine).

(b) Remove exactly 1.0 from the precision capacitor dial. (The time required to make the adjustments can be minimized by not using the dial corrections and adjusting the vernier plates as accurately as possible in the following steps).

(c) Resonate with No. 1 vernier. If the vernier dial does not read -2.0 very closely, bend plates as necessary, checking the reference at -3.0 pf as often as it is found necessary.

(d) Remove another 1.0 pf from the precision capacitor and repeak with No. 1 vernier, which should read - 1.0 pf and -1.0 pf. If not, bend plates to bring the resonance as close to -1.0 as possible.

(e) Recheck -3.0 pf reference and -2.0 pf and -1.0 pf readings again. Bending of the slotted sections can affect the previous adjustments slightly.

(f) Continue adjusting the other cardinal points on the vernier. Try to keep the dial errors on one side.

(g) Now calibrate the vernier capacitor by following section 1A above.

## 3. Main Capacitor Calibration and Adjustment

(a) Connect the equipment as in Section 1A (a) above. Connect a wire between the precision capacitor ground and Q Meter No. 1 GND terminal.

(b) Suspend another No. 19 AWG copper wire (solid) from the low range terminal on the precision capacitor to a point in air 3/8" above the HI CAP terminal on Q Meter No. 1. The tip of this suspended lead must be straight, without hooks or loops, and must point down to the terminal. Isolate this lead from surrounding objects.

(c) Set the precision capacitor to the high end of the low range. Record the dial reading as $D_0$. Set the main capacitor of No. 1 to 30.0 pf, approaching the point in a clockwise direction without overshoot. Set No. 1 vernier capacitor to 0.0 pf.

(d) Resonate the circuit with Q Meter No. 2 frequency (coarse) and vernier capacitor (fine). Use the $\Delta Q$ function to improve the peak as described in 1A (d) above.

(e) Touch the suspended wire to the HI CAP terminal with the least movement of the wire. Re-resonate the coil with the precision capacitor. Note the dial readings as $D_1$.

(f) Calculate the Q Meter capacitance at this setting: Determine the precision capacitor corrections, $e_o$ for $D_o$, $e_1$ for $D_1$. Then $C_o = D_o + e_o$ $C_1 = D_1 + e_1$. The true capacitance corresponding to a dial reading of 30 pf is equal to $C_o - C_1 + 0.15$pf. (The Q voltmeter adds 0.15 pf when the Q Meter is energized for normal operation.) If the capacitance is not 30 ± 1 pf, adjust the minimum C adjustment vane. (See Fig. III-2.)

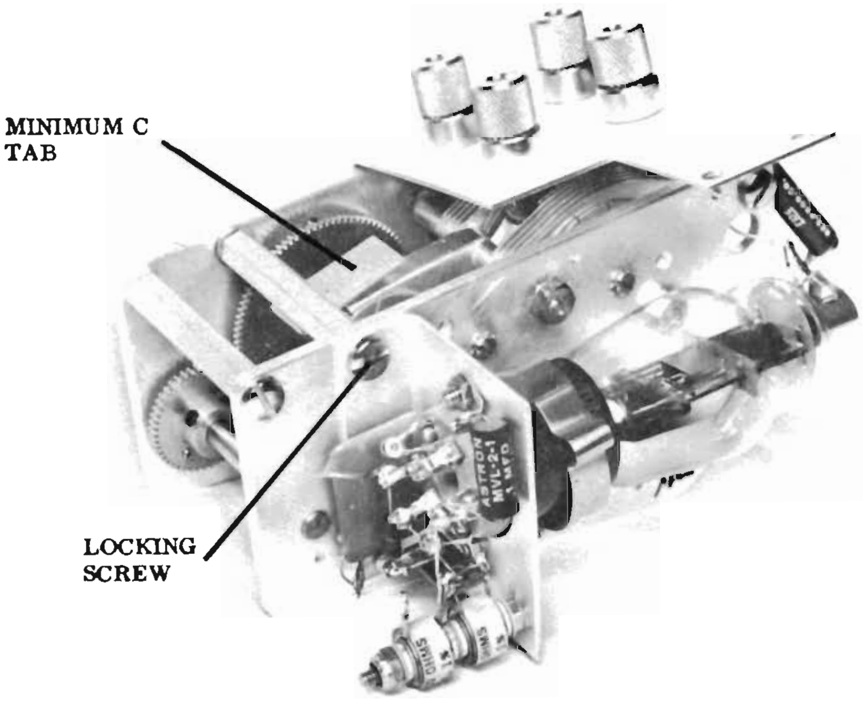


Figure III-2. Location of Minimum C Adjustment Vane

(g) Continue calibration at 40 and 60 pf, bending plates as necessary. Always set the dial from a clockwise direction to eliminate backlash. Note: A convenient calibration table can be drawn to make computations quickly. See Table III-4 for a sample calibration.

Table III-4. Sample Work Sheet for Capacitor Calibration

| MMFD Dial | Precision Cap. Dial D | Correction | Corrected | Difference from Ref. | + .015 = Actual C, pf |
|---|---|---|---|---|---|
| Ref | 115.0 ($D_o$) | -.05 ($e_o$) | 114.95 | | |
| 30 | 84.82 ($D_1$) | +.01($e_o$) | 84.83 | 30.12 | 30.27 |
| 40 | 74.50 | -.02 | 74.48 | 40.47 | 40.62 |
| 60 | 54.95 | -.03 | 54.92 | 60.03 | 60.18 |
| (etc) | | | | | |

(h) The low range of the precision capacitor can be used to calibrate up to 80 pf on the dial so the high range must be used to continue the calibration. Switch the wires to the high range and set the precision capacitor or dial for at least 600 pf. Establish a resonance condition with No. 1 HI CAP terminal disconnected as in step (b) above. Call the precision capacitor dial reading $D_O$ again.

(i) Connect the suspended wire to the HI CAP terminal, set the main capacitor of No. 1 to 100 pf (clockwise approach), and re-resonate with the precision capacitor.

(j) Continue the calibration at dial settings 150, 200, 300, 400, and 450 pf, adjusting the slotted rotor plates as necessary to meet the specifications of ± 1% or ± 1 pf whichever is larger.

(k) Enter the reference and new dial readings on the previously prepared table to simplify computations.

## E. Q VOLTMETER

### 1. General

The voltmeter circuit is adequately bypassed for the frequencies generated by the Q Meter. Because the frequency response falls off below 20 kc (7 kc on the 160A), calibration should be done above this frequency unless additional bypassing is temporarily added to the voltmeter circuit to extend the low frequency response.

The addition of 1 $\mu$fd capacitors from the Q voltmeter tube plate and cathode pins to ground will extend the low frequency response below 1 kc. Any accurate, variable, low distortion source of 1 kc can then be used for calibration. An -hp-200CD oscillator, -hp-400H VTVM (for monitoring the oscillator output), and a Gertsch RT-10 RATIOTRAN have been used successfully.

If bypassing is not added, it is necessary to use a higher frequency and a VTVM accurately calibrated at the frequency to be used (100 kc is recommended). The special calibration is required from 0.2 to 5V RMS for the 260A calibration, 1 to 5V RMS for the 160A.

The following general precautions should be taken when setting up the equipment.

The resonating capacitor should be at minimum C to reduce shunt loading of the source.

The external resistance across the HI and GND posts should be 3 megohms or less to reduce gas current effects in the voltmeter tube. (This precaution should be taken if substitute calibration equipment is used.)

Only one instrument should be grounded through the power attachment plug to eliminate ground loops.

### 2. Main Q Scale

(a) After 1/2 hour warmup, turn off the power and wait 2 minutes for the filter capacitors to discharge and the Q voltmeter tube cathode to cool. Adjust the meter movement mechanical zero. Turn power back on.

(b) Allow the Q Meter to return to stable operation.

On the 160A: With the power supply HI-LO switch on HI, oscillator at 1 mc and XQ at 1.0, adjust the electrical zero while shorting the HI and LO posts.

On the 260A: Short the HI and GND posts and adjust the Q ZERO ADJUST control for no deflection of the CIRCUIT Q meter when the front panel lever switch is alternately depressed and released. The meter should read exactly zero. Remove short.

(c) Apply 4.0 V RMS between HI and GND posts.

<u>On the 160A:</u> Adjust VTVM calibration control, item 31 (see 160A Mechanical Parts) for a reading of 200 exactly. (early 160A's did not have a calibration control. The voltmeter is checked to a tolerance of ± 5 Q.)

<u>On the 260A:</u> Adjust R310 for a reading of 200 exactly.

(d) Apply 5.0 V, 3.0 V, 2.0 V, and 1.0 V RMS successively and check meter tracking. The meter should read 250, 150, 100, and 50, respectively, within 2% of full scale ( ± 5 Q).

### 3. LO Q Scale (260A Only)

(a) Apply 1.0 V RMS between HI and GND posts. Adjust R308 for a LO Q reading of 50.

(b) Apply successively 1.2, 0.8, 0.6, 0.4, and 0.2 V. The meter should read 60, 40, 30, 20, and 10, respectively, ± 2.5% of full scale (± 1.5 Q on the LO Q scale).

### 4. ΔQ Scale (260A Only)

(a) Apply 3.0 V RMS between HI and GND terminals. Adjust ΔQ BALANCE controls for a ΔQ scale reading of 50.

(b) Increase input to 4.0 V. Adjust R305 for a ΔQ scale reading of 0 (full scale).

(c) Repeat (a) and (b) until no further adjustment is necessary.

(d) Check voltmeter linearity by applying 1.0 V, balancing the ΔQ BALANCE controls for a 50 reading (on the LO Q scale) and increasing the input to 2.0 V. The meter should deflect 49 divisions ± 2 on the ΔQ scale. (Give a reading of 1 ± 2 Q)

(e) Repeat (d) for 2.0 - 3.0 V and 4.0 - 5.0 V. The meter should deflect 50 divisions ± 2. (give a reading of 0 ± 2 Q)

(f) Apply 4.0 V and adjust ΔQ balance controls for full scale. The engraved skirt on the ΔQ BALANCE coarse knob should indicate 200. If not, loosen the setscrews and slip the knob as necessary.

## F. OTHER VOLTMETER CHECKS

### 1. Q Voltmeter Grid Current

(a) Allow at least 1 hour warmup.

(b) Short the HI and GND terminals and electrically zero the Q Meter. Remove the short.

(c) The Q Meter should indicate less than 60 Q. If not, the Q Voltmeter tube has excessive grid current and should be replaced.

## 2. Q Circuit $\Delta Q$

This check is principally a troubleshooting technique to verify that the external circuit under measurement is not shunted by losses in the terminals, resonating capacitor assembly, or voltmeter tube. It need not be made if the Q Meter agrees with Q Standard nameplate information, particularly at low resonating capacities and high Q readings.

(a) Place the Q Meter to be tested to the rear of another Q Meter, separated by 3" with both instruments facing the operator. Attach the 103A-22 coil to the front Q Meter. Apply power to both Q Meters.

(b) Interconnect the GND terminals of the two instruments. Suspend a length of solid #18 wire from the front Q Meter HI CAP terminal so the free end points directly down and is 1" removed from the HI CAP (HI COND on the 160A) terminal on the rear of Q Meter.

(c) Preset controls as follows

Front Q Meter: Frequency 1000 KC approx. Resonating capacitor 70 pf.

Rear Q Meter: (being tested)
Resonating capacitor set to 30 pf. (If the instrument is a 160A, also set the oscillator to 1200 KC, XQ= 1.2, this is to place normal load on the unregulated power supply).

(d) Resonate the coil with the frequency control of the front Q Meter. Measure the Q of the coil (call it $Q_1$). If the front Q Meter is a 260A, balance the $\Delta Q$ BALANCE for full scale ($\Delta Q = 0$).

(e) Connect the suspended wire to the HI terminal of the rear Q Meter. Re-resonate the circuit with the capacitor of the front Q Meter, calling the Q reading $Q_2$. Determine $Q_1 - Q_2$ (or $\Delta Q$). The amount of $\Delta Q$ indicates the additional losses introduced into the Q measurement by the connection of the second Q circuit. $\Delta Q$'s in excess of 15 should be investigated by repeating the measurement with the power off and the Q voltmeter tube grid connection removed. If the new $\Delta Q$ is significantly lower than before, the voltmeter tube should be replaced. If not, major circuit losses occur in the terminal post insulation, Q capacitor stator insulators or in the grid resistor of the voltmeter tube.

## G. SIGNAL INJECTION SYSTEM

### 1. General

The BRC 260A and 160A Q Meters use the resonant rise method of Q measurement, where, if $Q \geq 10$, $\frac{E}{e} = Q$ (See Appendix B and C). E is the voltage measured by the Q voltmeter (5 V full scale) and e is the voltage developed across the injection resistor in the thermocouple assembly.

In the 260A, approximately 1 amp flows through the thermocouple at XQ = 1.0, developing 20 MV across an annular (low inductance) 0.02 Ω resistor. In the 160A, approximately 0.5 amp flows through a 0.04 Ω strip resistor when XQ = 1.0.

To minimize errors in the injection system, it is necessary to consider the thermocouple and MULTIPLY Q BY meter as a matched combination. The calibration and scale tracking tolerances on the meter movement and the shape of the thermocouple output vs input current characteristics all combine to form poor calibration accuracy unless the two components are matched. For this reason, it is necessary to furnish the instrument serial number when ordering replacement thermocouples or XQ meters. A replacement can then be selected and calibrated to match the original as closely as possible. Ultimate accuracy would be achieved by returning the meter to the factory when ordering a thermocouple so the two can be checked together.

The calibration of the injection system may be done in the field with an accurately calibrated -hp- 400H or 400L VTVM. The Q Meter oscillator provides the power to the thermocouple. A frequency is chosen where low oscillator distortion reduces the waveform errors in the calibration.

The factory calibration method uses DC to power the thermocouple and DC standard meters to measure the characteristics of the thermocouple assembly. The resultant accuracy is better than the method suggested above, but involves the use of costly instruments that may not be readily available for field calibration.

### 2. Calibration

(a) Allow 2-1/2 hours of warmup for the 260A. The injection resistor has a positive temperature coefficient, requiring calibration at operating temperature.

Allow 1/2 hour warmup for the 160A. The injection resistor temperature coefficient is very low - the time is required for oscillator stabilization.

(b) Set the oscillator to the low end of band 2 or 3. (120 KC or 300 KC on the 160A, 150 KC or 450 KC on the 260A). Connect the VTVM between the LO and GND posts. Avoid ground loops through the power line.

(c) Increase oscillator output until XQ meter indicates 1.0. The VTVM should read 20.0 MV ± 1%, not including frequency and scale errors in the VTVM.

If the injection voltage is not correct, adjust the value of the calibrating resistors on the 260A thermocouple assembly (only one is used on the 160A - connected at the XQ meter terminal).

A + 1 Ω change in calibrating resistance results in a + 1/2% change in injection voltage, approximately.

The calibrating resistors in the 260A form part of an RF filter network. It is advisable to keep the difference between them less than 5 Ω. The resistor values should always be more than 10 Ω.

Note: The 260A should be allowed to return to operating temperature after the cabinet is opened to effect a resistor change.

(d) Check the XQ meter linearity by reducing the oscillator output until the meter reads X2.0. The VTVM should read 10.0 MV ± 4% (260A) or ± 5% (160A). If the error is greater, (not including VTVM errors) the meter and thermocouple are no longer matched.

(e) If necessary, check the injection at XQ readings of 1.2, 1.5, and 2.5. The millivolt readings should be 16.67 ± 3%
13.33 ± 3%
and 8.00 ± 6% (260A)
or ± 7% (160A), respectively.

(all tolerances do not include VTVM errors)

## H. OVERALL PERFORMANCE USING Q STANDARDS

### 1. General

The Q of standard inductors should be measured on the Q meter. Details have already been presented in Section II C-3 (page 16). The readings may also be checked using the ΔC technique. For further details consult BRC Notebook 4.

### 2. Troubleshooting

Six Q-Standards are available from BRC. Two of these will provide for normal overall checking. (The types 513A and 518A-1) One coil checks the low frequency performance around 1 MC, the other the high frequency performance to 45 mc. These two coils are very effective troubleshooting aids as illustrated by Table III-5.

Table III-5. Troubleshooting Chart using 513A and 518A-1 Q Standards
Allow a warmup period of 1/2 hour for 160A, 2-1/2 hours for 260A

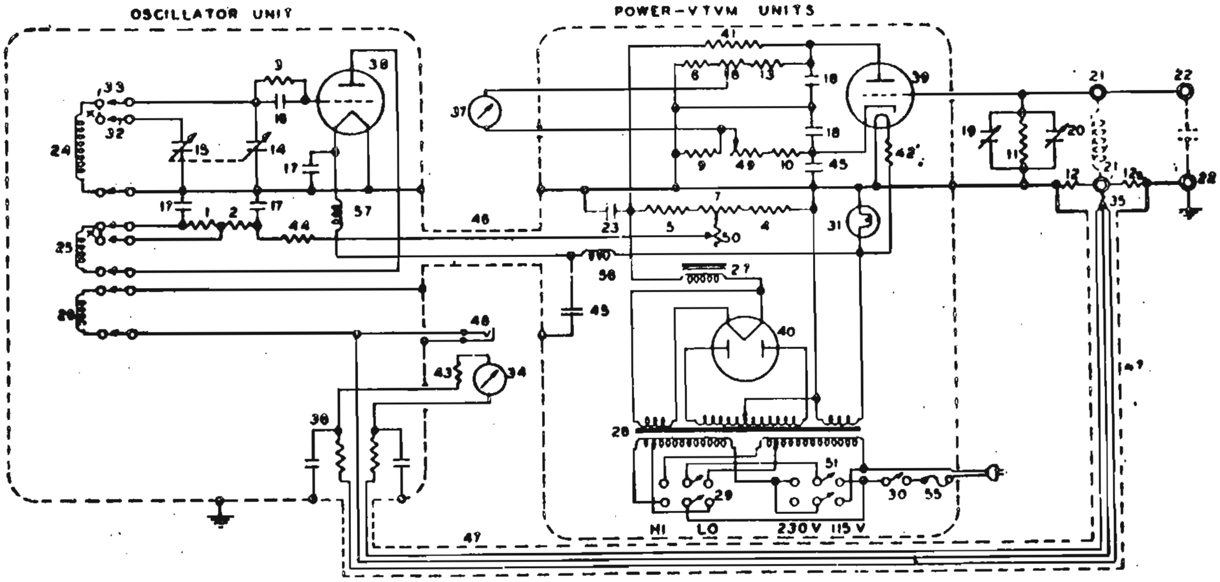
| Trouble Indication | | | Possible Cause |
|---|---|---|---|
| General increase in Q indications (compared) with Q Standard label date) as frequency is increased. | | | Thermocouple assembly injection resistor has become inductive |
| Indicated Q is higher with higher XQ settings | | | Q voltmeter tube non-linearity |
| Measurements taken with 513A Q-Standard ($Q_i$ tolerance ± 7% of value on label) | | | |
| 0.5 mc | 1.0 mc | 1.5 mc | |
| high Qi<br>low Qi | high Qi<br>low Qi | high Qi<br>low Qi | XQ or Q voltmeter calibration |
| Qi in spec | Qi in spec | low Qi | Q voltmeter tube input conductance too high. (shows up at low C setting because tank impedance is high.) |
| Qi in spec | low Qi | Qi in spec | On 260A only. Suspect Q Voltmeter tube (High Q reading with a high Z tank impedance shows grid circuit clipping) |
| Measurements taken with 518A-1 Q Standard: (Qi tolerance ± 8% up to 30 mc, ± 13% mc to 50 mc) | | | |
| 15 mc | 30 mc | 45 mc | |
| high Qi<br>low Qi | high Qi<br>low Qi | high Qi<br>low Qi | XQ or Q voltmeter calibration |
| low Qi | Qi in spec | Qi in spec | Worn or tarnished terminals, dirt in Q capacitor or poor plate spacing. (There are high circulating currents at high C settings) |
| Qi in spec | Qi in spec | low Qi | Insulation losses, contamination of insulators, dirt in Q capacitor, Q voltmeter tube. |
| Qi in spec | low Qi | Qi in spec | On 260A only. Suspect Q voltmeter tube (with Q 249 signal voltage is near maximum. Clipping in grid circuit shows up.) |

518A-1 nameplate data must be corrected when used with a 160A. Refer to "Application Instructions for the Q Standard Type 518A" supplied with the 518 series Q standards.

# SECTION IV

# PARTS IDENTIFICATION AND SCHEMATICS

## 2. Electrical Parts



160A Schematic

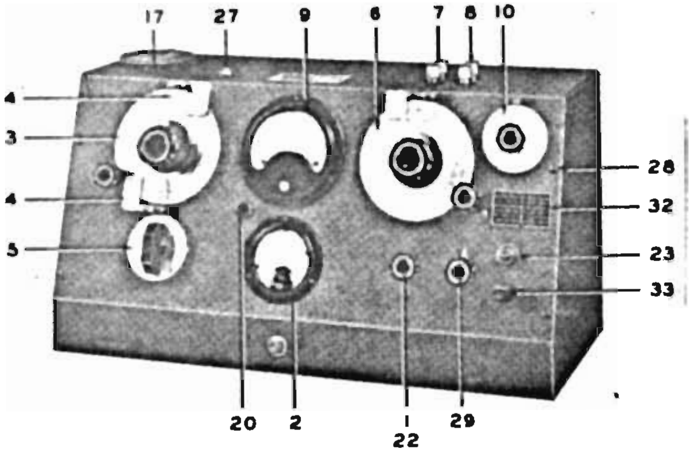
| Item | Description | Part Number |
|---|---|---|
| 1 | Resistor, fixed, WW, 1 K Ω ± 5%, 4W | BRC 80145 |
| 2 | Resistor, fixed, WW, 200 Ω ± 5%, 10 W | BRC 80107 |
| 3 | Resistor, fixed, comp., 82 K Ω ± 5%, 2W (two in parallel ) replaces original 40 K | -hp- 0692-8235 |
| 4 | Resistor, fixed, WW, 2.4 K Ω ± 5%, 10 W | BRC 80286 |
| 5 | Resistor, fixed, WW, 750 Ω ± 5%, 10 W | BRC 80140 |
| 6 | Resistor, fixed, WW, 200 Ω ± 5%, 1W | BRC 80103 |
| 7 | Resistor, var., WW, 8 K Ω 50 W with switch | BRC 81335 |
| 8 | Resistor, var., WW, 200 Ω ± 10%, 2W | -hp- 2100-0844 |
| 9 | Resistor, fixed, comp., 24 K Ω ± 5%, 1W | -hp-0689-2435 |
| 10 | Resistor, fixed, WW, 22 K Ω ± 1%, 1/2 W | -hp- 0811-0292 |
| 11 | Resistor, fixed, film, 100 M Ω ± 15%, 1W | -hp- 0732-0001 |
| 12,12a | Resistor, fixed, part of thermocouple | not separately replaceable |
| 13 | Resistor, fixed, comp., 27 K Ω ± 5%, 2W | -hp- 0692-2735, 2 in parallel |
| 14,15 | Capacitor, var., air (Oscillator Tuning) | BRC 84701 |
| 16 | Capacitor, fixed, mica, 100 pf ± 5% | -hp- 0160-0789 |
| 17 | Capacitor, fixed, mica, 3000 pf ± 5% | BRC 82321 |
| 18 | Capacitor, fixed, mica, 5100 pf ± 5% | BRC 82333 |
| 19,20 | Capacitor, var., air, special | BRC 84067 |
| 21,22 | See mechanical parts, Items 7, 8 | |
| 23 | Capacitor, fixed, electrolytic, 3 X 10 $\mu$f/450V | -hp- 0180-0250 |

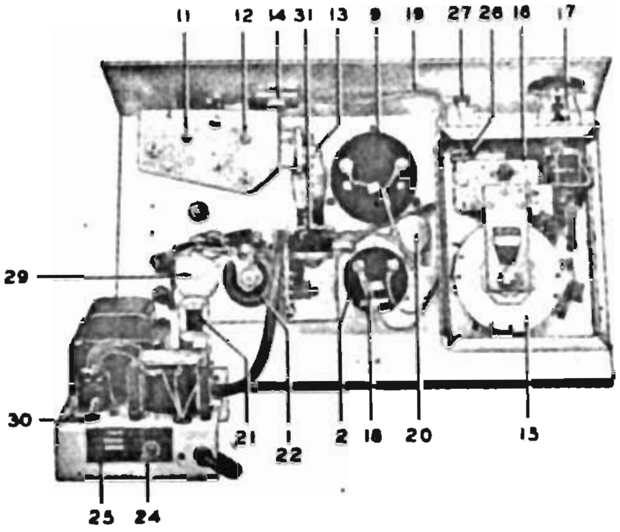
| Item | Description | Part Number |
|---|---|---|
| 24,25,26 | Oscillator Coils | |
| 27 | Choke, filter, 10h, 80 ma/dc | -hp- 9110-0094 |
| 28 | Transformer, power | BRC 85006 |
| 29 | Switch, toggle, DPDT | -hp- 3101-0005 |
| 30 | Switch, part of item 7 | |
| 31 | Lamp, incandescent, #47 | -hp- 2140-0009 |
| 32 | Contacts, switch, oscillator range (3 types used) | BRC 60067 short<br>BRC 60137 long<br>BRC 302019 bent |
| 33 | Turret assembly, oscillator | |
| 34 | Meter, MULTIPLY Q BY | BRC 92015R - exchange only Supply serial of 160A |
| 35 | Thermocouple Assembly | BRC 165A - supply serial of 160A |
| 36 | Filter Assembly, consisting of: | |
| | 2 ea. Resistor, fixed, WW, 20 Ω ± 2%, 1/2 W | BRC 80016 |
| | 2 ea. Capacitor, fixed, mica, 1000 pf ± 5% | -hp-0140-0018 |
| 37 | Meter, CIRCUIT Q | BRC 92012R - exchange only |
| 38 | Tube, oscillator | BRC 536A - selected 45, (was BRC 102A) |
| 39 | Tube, Q Voltmeter | BRC 535B - selected 1659 (535A may be used also) |
| 40 | Tube, rectifier, 5Y3 | -hp- 1930-0010 |
| 41 | Resistor, fixed, comp., 1 K Ω ± 5%, 1W | -hp-0689-1025 |
| 42 | Resistor, fixed, WW, 0.3 Ω special | BRC 80709 |
| 43 | Resistor, fixed, WW, value selected at factory | BRC 80015, included with type 165A thermocouple assy. * |
| 44 | Resistor, fixed, WW, 100 Ω ± 5%, 1W | BRC 80064 |
| 45 | Capacitor, fixed, paper, 0.1 μf, 400V | BRC 83001 |
| 46,47 | Cable, shielded | part of thermocouple assy. |
| 48 | Jack, phone, single circuit | BRC 89038 |
| 49 | Resistor, variable, WW, 3 K Ω ± 10%, 4W | -hp- 2100-0848 |
| 50 | Resistor, variable, WW, 1 K Ω ± 5%, 4W | BRC 81109 |
| 51 | Switch, same as item 29 | |
| 55 | Fuse, 1-1/2 amp, 3AG | BRC 93250 |
| 56 | Choke assembly, rf, special | BRC 60929 |
| 57 | Choke, 1.07 μh, special | BRC 300098 |

* 80015 is the BRC part number for a family of resistors. The ohmic value must also be specified. Values are available from 8 Ω to 63 Ω.

## A. 160A

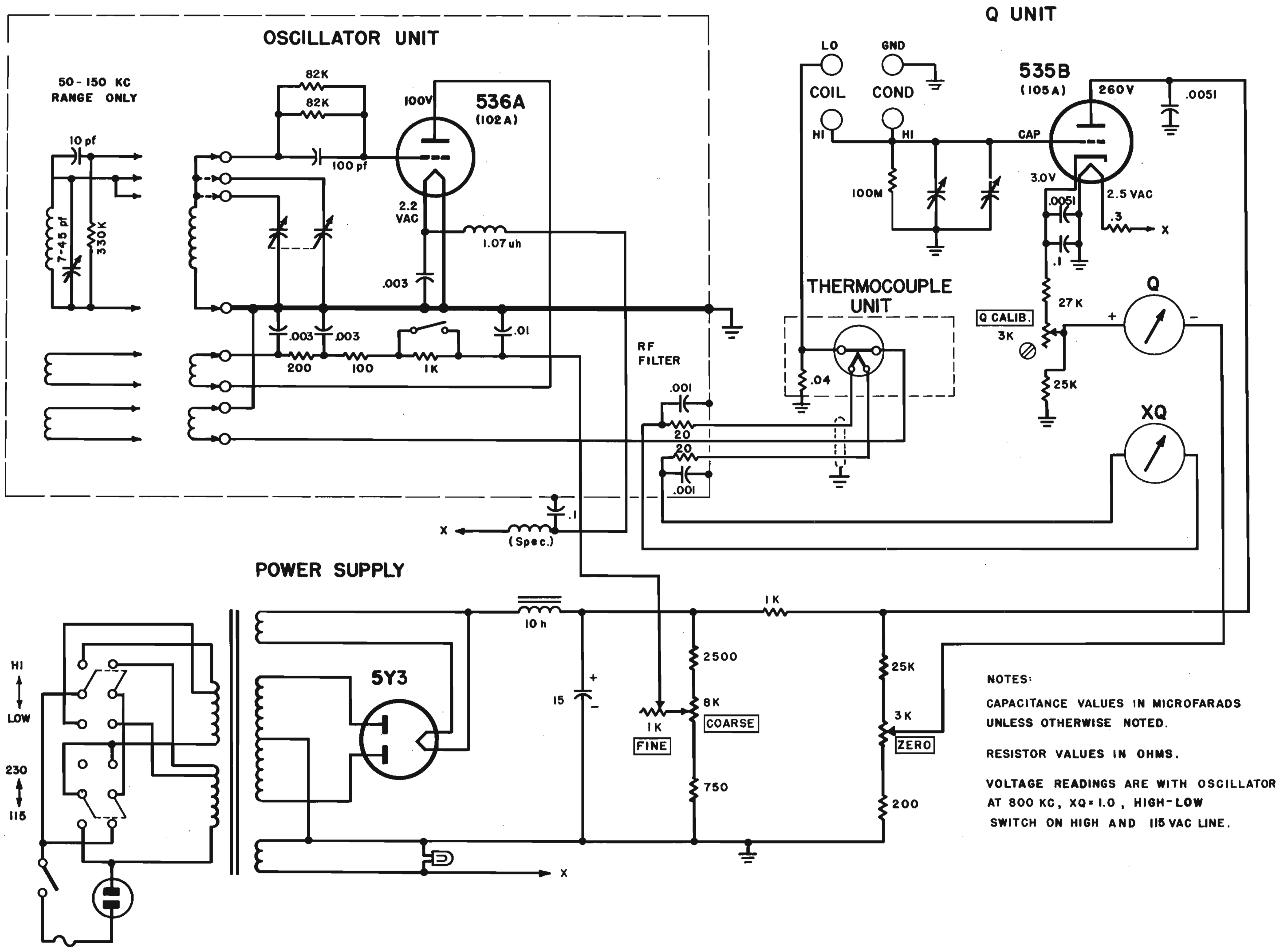
### 1. Mechanical Parts





| Item | Description | BRC Part No. | |
|---|---|---|---|
| 1 | Knob | 300648 | |
| 2 | Meter, MULTIPLY Q BY | 92015R | exchange only |
| 3 | Frequency Dial & Knob Assy. | 60077 | |
| 4 | Fiducial (KC) | 60005 | |
| | Fiducial (MC) | 60006 | |
| 5 | Range Switch Knob Assy. | 60076 | |
| 6 | Capacitor Dial & Knob Assy. | 60132 | |
| | (L-C Dial conversion kit for early 160A's) | 560A | |
| 7,8 | Terminal nut | 60081 | |
| | complete binding post Assy. | 60086 | |
| 9 | Meter, circuit Q | 92012R | exchange only |
| 10 | Vernier Capacitor Dial & Knob Assy. | 60075 | |
| 11,12 | Q Capacitor | 84067 | |
| 13 | Q Voltmeter Tube | 535B | selected |
| 14 | Thermocouple | 165A * | |
| 15 | Oscillator Turret | 301107 | |
| 16 | Oscillator Tuning Capacitor | 84701 | |
| 17 | Oscillator Tube | 536A | selected 45 |
| 18,19 | | part of thermocouple | |
| 20 | VTVM Zero Adjust Knob | 87003 | |
| 21 | Rectivier | 5Y3 | |
| 22 | ON/OFF Switch, part of Output Control | not separately available | |
| 23 | Pilot Lamp, #47 | 90904 | (-hp-2140-0009) |
| 24 | HI-LO Toggle Switch | 88059 | |
| 26 | Thermocouple Filter Unit | 60065 | |
| 27 | Jack | 98038 | |
| 29 | Output Vernier Knob | 87002 | |
| 30 | 115/230 Switch | 88059 | |
| 31 | VTVM Calibration Control | 81210 | |
| 32 | Frequency Reference Plate | 93726 | |
| | Vernier Knobs (2) | 87003 | |
| | Vernier Disc Assy | 301422 | |
| | Fiducial for Q Capacitor | 60722 | |

* Serial number of 160A required when ordering replacements.



NOTES:

CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE NOTED.

RESISTOR VALUES IN OHMS.

VOLTAGE READINGS ARE WITH OSCILLATOR AT 800 KC, XQ = 1.0, HIGH-LOW SWITCH ON HIGH AND 115 VAC LINE.

SCHEMATIC DIAGRAM - 160A

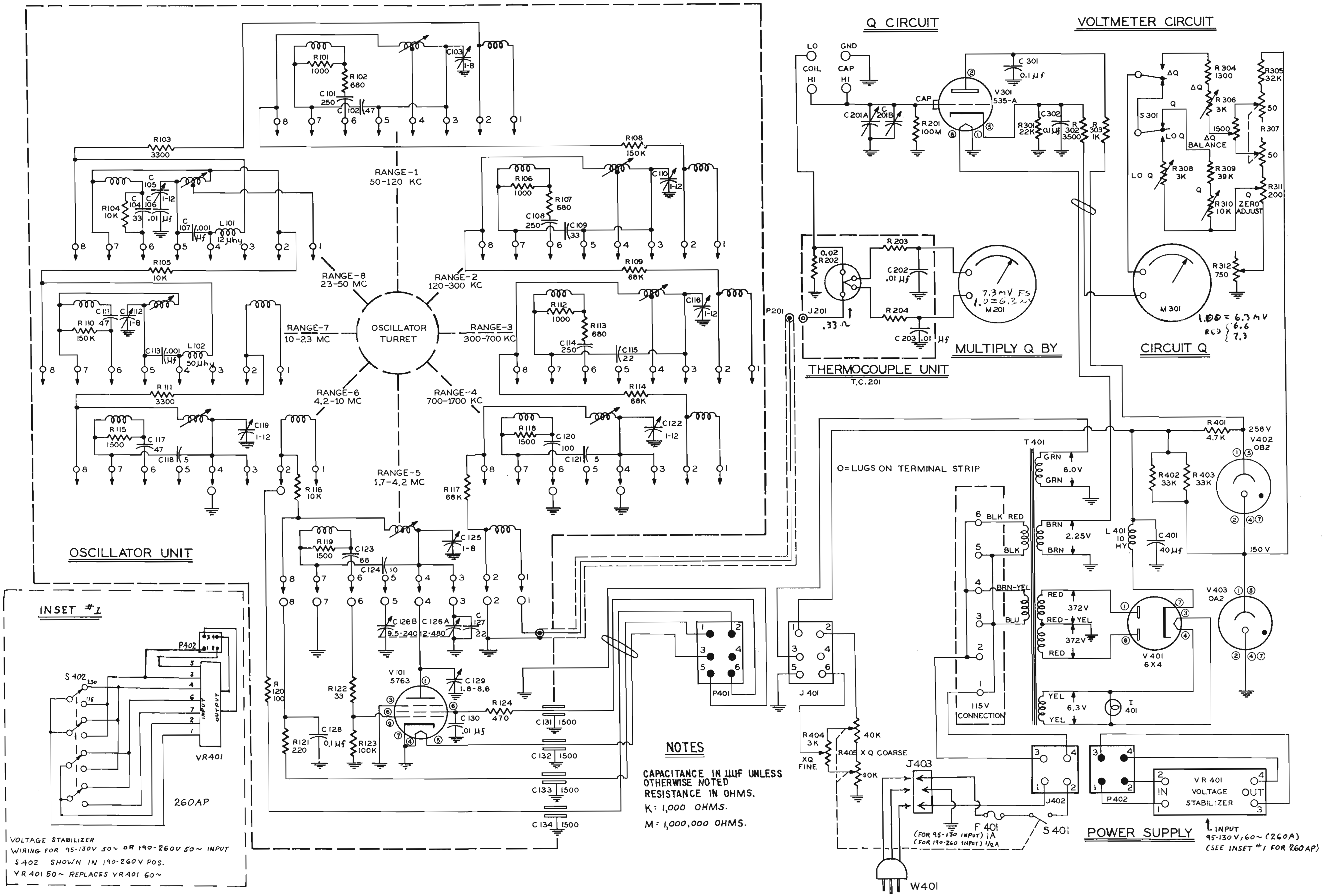
# MECHANICAL PARTS

## 260A

| Description | Old BRC Stock No. | New -hp- No. |
|---|---|---|
| **OSCILLATOR UNIT PARTS** | | |
| Tube Shelf Assy | 301688 | 00260-60006 |
| Tube Shield | 301684 | 1220-0047 |
| Contact Spring Bracket Assy | 301644 | 00260-60007 |
| Plug - 6 prong | 301749 | 1251-0407 |
| Cable Clamp | 93247 | 1400-0187 |
| Thermocouple Cable Assy | 301693 | 00260-60009 |
| Ground Strip Assy | 301410 | 00260-60043 |
| Connector Strip Assy | 301409 | 00260-60010 |
| Contact, straight (part of 301409) | 60139 | 00250-00040 |
| Contact, bent 45° (part of 301409) | 302019 | 00250-00048 |
| Turret Shaft | 301417 | 00260-20002 |
| Retaining Ring for 3/8 Shaft | 301673 | 0510-0244 |
| Washer, Spring 13/16 OD, for 3/8 Shaft | 301674 | 3050-0316 |
| Detent Arm Assy | 301387 | 00260-60012 |
| Vernier Shaft Assy | 301422 | 00260-60013 |
| Osc Dial Assy with Spring Fingers | 301619 | 00260-60014 |
| Fiducial, Oscillator | 301384 | 00260-20004 |
| Retaining Ring for 5/16 shaft | 301671 | 0510-0243 |
| Washer, Spring 7/15 OD, for 5/16 shaft | 301424 | 00260-00001 |
| Shield, top | 301398 | 00260-00002 |
| Shield, bottom | 301385 | 00260-00003 |
| Turret, Complete Assy | 301690 | 00260-60011 |
| Detent Plate (part of 301690) | 301393 | 00260-60005 |
| Felt Washer, 2" OD, 1" hole | 302152 | 00250-00046 |
| Coil and Cradle Assy, ranges 1 & 8 | 301729 | 00260-60017 |
| Coil and Cradle Assy, ranges 2 & 3 | 301721 | 00260-60018 |
| Coil and Cradle Assy, ranges 4 & 5 | 301735 | 00260-60019 |
| Coil and Cradle Assy, ranges 6 & 7 | 301733 | 00260-60020 |
| Core, powdered iron, ranges 1,2,3,4,5,6 | 301731 | 9170-0122 |
| Core, powdered iron, ranges 7 & 8 (coded blue) | 302481 | 9170-0121 |
| **POWER SUPPLY PARTS** | | |
| Strain relief (used on Serials before 3381 approx.) | 94014 | none |
| Power Cord (used on Serials before 3381 approx.) | 01019 | none |
| Power Receptacle, 3 prong (used on Serials above 3380 approx.) | 308087 | 1251-0148 |
| Power cord (used on serials above 3380 approx.) | 308086 | 8120-0078 |

| Description | Old BRC Stock No. | New -hp- No. |
|---|---|---|
| **Q UNIT PARTS** | | |
| Complete assembly, tube shelf & terminals | 301883 | 00260-60033 |
| Q Capacitor only | 301752 | 00260-60021 |
| Tube Bracket Assy | 301503 | 00260-60034 |
| Binding Post & Plate Assy | 301882 | 00260-60035 |
| Binding Post Top Nut, Gold plated | 60081 | 00260-20012 |
| **CABINET PARTS** | | |
| Front Panel Assy | 301904 | 00260-60001 |
| Fiducial, vernier | 301569 | 00260-20042 |
| Fiducial, Main C Dial | 301570 | 00260-20043 |
| Bushing, eccentric | 301315 | 00260-20011 |
| Vernier Shaft Assy | 301647 | 00260-60038 |
| Pilot light - red | 303387 | 1450-0099 |
| Dial, ΔQ Balance Assy | 301903 | 00260-60039 |
| Knobs - ΔQ Balance Vernier Coarse | 306575 | 0370-0024 |
| Freq Vernier | 306579 | 0370-0028 |
| Main C Dial Vernier | 306579 | 0370-0028 |
| Q Zero Adjust | 306579 | 0370-0028 |
| Vernier C Knob | 306579 | 0370-0028 |
| XQ Fine | 306579 | 0370-0028 |
| XQ Coarse | 306579-1 | 0370-0029 |
| Main C Dial | 306588 | 0370-0038 |
| Freq Coarse | 306588-2 | 0370-0044 |
| Osc. Range | 306598 | 0370-0049 |
| Fuse Holder | 306511 | 1400-0084 |
| Rubber foot (8) | 94025 | 0403-0045 |
| Rear Ground Post Assy | 300735 | 00260-60003 |
| Jones Plug, 4 prong | 301756 | 00190-20005 |

NOTE: 27 different kinds of Black Oxide coated hardware used on Boonton Instruments is available under the Stock Number W9115. The assortment is contained in an EQUIPTO "Little Gem" cabinet, and contains approximately 100 each of each kind. A complete description of the contents of the kit is available from any -hp- service facility.



VOLTAGE STABILIZER WIRING FOR 95-130V 50~ OR 190-260V 50~ INPUT

S402 SHOWN IN 190-260V POS.

VR401 50~ REPLACES VR401 60~

**NOTES**

CAPACITANCE IN µµF UNLESS OTHERWISE NOTED

RESISTANCE IN OHMS.

K: 1,000 OHMS.

M: 1,000,000 OHMS.

# SECTION V

# APPENDIX

# APPENDIX A. Note on Q Standards

Q standards are most frequently employed as a means of checking the performance of Q meters. They are inductors which, in some cases, have been shunted by a high resistance in order to achieve a broader Q vs frequency characteristic. Their values are determined, at the factory, with a Q meter which serves as a standard for all other instruments of that particular type. Q standards, in addition to serving as transfer standards for instrument comparison, may be used as supplementary inductors to increase the measurement capabilities of the Q meter. They also may be employed as "shelf" standards and used in conjunction with other circuitry for a wide variety of measurement applications.

The value of resonating capacitance and indicated Q for a coil, as given by the manufacturer is the value which should be observed on a properly functioning Q meter. However, the value given for indicated Q is the ratio of reactance to resistance of the entire circuit which includes the coil as well as the measuring circuit of the Q meter. On the other hand, the effective value of Q reported by NBS is the ratio of reactance to resistance of the coil in the absence of the measuring circuit of the Q Meter. The difference between indicated and effective value is caused by the residual parameters of the Q meter circuit and includes both series resistance and series inductance. Beginning at about 5 megacycles this difference becomes increasingly more pronounced as the frequency increases and may reach 100 percent in Q and 10 percent in resonating capacitance at 50 megacycles. If all of the residual characteristics of the Q meter circuit were known then it would be possible to correct the indicated value and arrive at the proper effective value. This, of course, would require extensive calibration of the Q meter.

In order to perform a complete calibration of a particular Q meter the instrument in question would have to be submitted along with a set of Q standards, so that the oscillator, the thermocouple circuit, the voltmeter, the insertion resistor, and the resonating capacitor could be calibrated. This would not only be expensive, but would provide NBS with a workload which it is not prepared to handle with presently existing facilities.

In the measurement of a complex impedance the real and imaginary parts are physically inseparable and hence each must be measured in the presence of the other. Therefore, all impedance measuring devices must measure impedance either in the form of $R \pm JX$ or $Z\underline{/0}$ rather than R or X individually, and correspondingly the accuracy of the measurement must be in terms of the total impedance. In the case of a component which has a phase angle near either $0^{o}$ or $90^{o}$, the major component will have nearly the same accuracy as that of the total impedance, but a simple analysis will show that the minor component may vary widely without appreciably affecting this accuracy. In the measurement of Q then, it may be said that for a given accuracy of total impedance, the accuracy to which Q may be determined decreases as Q increases. Other complications, such as contact resistance and the lack of a connector with a definable plane of reference, contribute still other uncertainties particularly at the higher frequencies. For these reasons, no statements of accuracy are given at present for NBS Q standard calibrations.

Reprinted from NBS

# The Evolution of the BRC Q Meter

LAWRENCE O. COOK, *Quality Control Engineer*

Q is defined as $2\pi$ times the ratio of energy stored to the energy dissipated per cycle.[1,2] In electronics, the concept of Q is commonly used to designate the ratio of series reactance to series resistance of a coil ($Q = 2\pi fL/R$) or of a capacitor ($Q = 1/2\pi fCR$). While these and other relationships involving Q have been used in radio and electrical engineering for a great many years, the expression Q and its numerical value did not come into popular usage until early in the 1930's, during the time when the broadcast receiver industry was growing at a fast pace and a rapid means for measuring Q was sorely needed. Seeking to fulfill this need, the founders of Boonton Radio Corporation demonstrated the first Q Meter at the IRE Meeting in Rochester, N. Y. late in 1934.

## Fundamental Q Meter Circuit

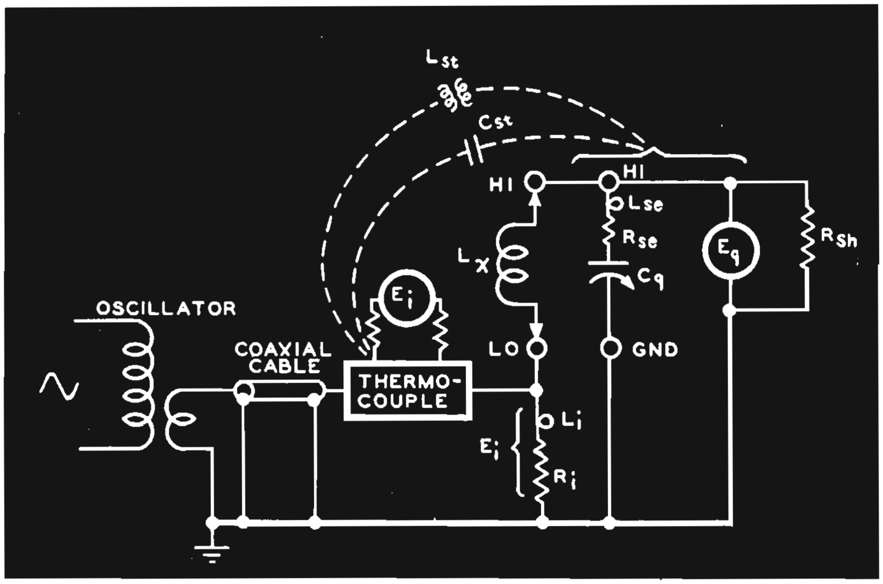
The early model Q Meter employed the "voltage step-up" (also known as "resonance rise") method of Q measurement still used in current models. A simplified schematic of the fundamental circuit is shown in Figure 1. The Q of a resonant circuit, comprising a capacitor ($C_q$) contained in the Q Meter and an external coil ($L_x$), is measured by impressing a known voltage ($E_i$) in series in the circuit and measuring the voltage ($E_q$) across the capacitor when the circuit is resonated to the frequency of the impressed voltage. Q of the circuit is the ratio $E_q/E_i$. With $E_i$ known, the voltmeter ($E_q$) may be calibrated directly in Q and, because the circuit losses occur mostly in the coil, the Q indication obtained closely represents the Q of the coil. By inserting low impedances in series with the coil or high impedances in parallel with the capacitor, the constants of unknown circuits or components may be measured in terms of their effect on the original circuit Q and tuning capacitance.

## Basic Design Problems

Though the fundamental Q measurement method just described is extremely simple, the achievement of accurate results over a wide range of frequencies requires the solution of several basic problems.

1. The injection voltage system must be frequency insensitive.

2. Stray coupling occurring between the oscillator (including the injection system) and the Q measuring circuit must be reduced to a negligible value.



$R_i$ Q circuit injection resistor (100-A and 160-A, 0.04 ohm; 260-A, 0.02 ohm)
$L_i$ Self inductance of $R_i$
$E_i$ Injection voltage and meter for same
$C_{st}$ Stray capacitive coupling
$L_{st}$ Stray inductive coupling
$L_x$ Coil under test
$C_q$ Calibrated internal resonating capacitor
$L_{se}$ Q circuit residual inductance (100-A, 0.08 $\mu$h, 160-A and 260-A, 0.015 $\mu$h)
$R_{se}$ Q circuit residual series resistance
$R_{sh}$ Q circuit residual shunt resistance
$E_q$ Q vacuum tube voltmeter
HI — LO External coil terminals
HI — GND External capacitor terminals

*Figure 1. Q Meter Fundamental Circuit — Including Residuals*

3. The Q measuring circuit residual inductance and series and shunt resistive losses must be minimized. Included are input circuit losses in the VTVM which measures the voltage across the resonating capacitor.

4. The oscillator waveform must be relatively free of harmonics.

These factors have been strenuously dealt with in Q Meter design and, over a period of many years, much progress has been made which benefits the user in terms of improved accuracy. Some of the results of this progress, in the LF and lower VHF range of frequencies, will be shown in the remaining paragraphs which trace the development of the Q Meter from the first model marketed, the Type 100-A, to a model currently in production, the Type 260-A.

## Type 100-A Q Meter

The Type 100-A Q Meter was the first model to be sold (in early 1935) and is readily recognized because of its 45° panel slope.

A Type 45 tube operated in a tuned-grid oscillator circuit having tickler feedback. Turret selection of 7 calibrated frequency ranges provided a total range of 50 kc to 50 mc, the entire oscillator assembly being shielded to provide isolation from the Q measuring circuit.

The oscillator output current, controlled by adjustment of the dc plate voltage, was fed through a coaxial cable to a thermocouple and then through a 0.04-ohm "voltage injection resistor". This resistor, a closely shielded resistance strip, provided a low value of self inductance so that the voltage drop developed across the resistor was relatively independent of frequency. The thermocouple operated a 3-inch dc meter which was calibrated at two Q range settings in terms of the voltage developed across the resistor at dc and at low frequencies.

The Q measuring circuit included a single-section, receiver-type capacitor having aluminum plates which provided a calibrated capacitance range of 37 to 460 $\mu\mu$f. Impregnated mica insulation was employed in the capacitor for low loss purposes, each mica insulator being tested under conditions of 90% relative humidity. The vernier capacitor was in a separate frame and employed similar insulation.

External terminals for connection of the coils and capacitors to be tested were

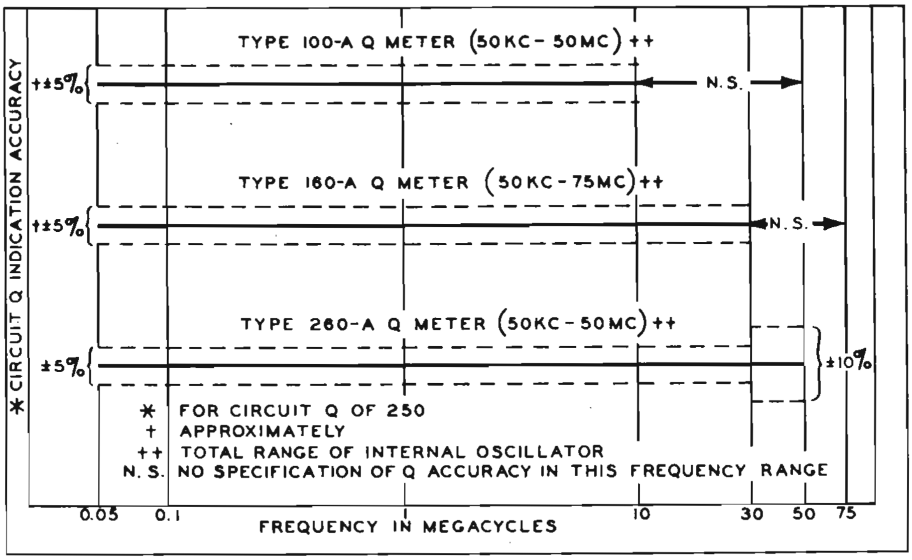


*Figure 2. Specification of Circuit Q Indication Accuracy vs Frequency*

of the commercial, nickel-plated type mounted on impregnated mica insulators.

The Q voltmeter circuit employed a triode tube operating as a form of "plate rectifier" with provision for zero balance of the cathode current meter. The Type 2A6 tubes were individually selected in the operating circuit for high input resistance at rf, normal input capacitance, low direct grid current, and normal rectified dc output versus ac signal voltage. The 3-inch meter was calibrated in two ranges of circuit Q (0 to 250 and 0 to 500) in addition to signal volts. The VTVM grid return resistor (100 megohms at dc) was of a design chosen for high effective resistance at rf.

The Q Meter power supply was of the unregulated type commonly used at that time.

Performance of this instrument, for the Q measurement of inductors and capacitors, was generally satisfactory at frequencies up to 10 mc, as shown in Figure 2. For increasing frequencies (i.e., above 10 mc) the accuracy gradually worsened because of the effects of injection resistor inductance, stray coupling between the thermocouple system and the Q measuring circuit, and Q measuring circuit residual inductance and residual resistance.

### Type 160-A Q Meter

Increased use of higher frequencies in the communications field created a need for improved Q Meter accuracy at these higher frequencies. To meet this need, a new model, the Type 160-A Q Meter, was developed and introduced in 1939, superseding the Type 100-A. In addition to greatly improved accuracy, this model had a 15° panel slope and a considerably different appearance.

The oscillator was essentially the same as used in the Type 100-A instrument except that an eighth frequency range (50 to 75 mc) was added. Mechanical reliability of the shielding was also improved.

The injection system provided a completely shielded thermocouple with the injection resistor being included in the same shielded assembly. Stray coupling to the Q measuring circuit was thus greatly reduced. Additional division lines on the "Multiply Q By" meter scale plate provided a wider (20 to 625) range of circuit Q measurements and improved accuracy.

The Q measuring circuit resonating capacitor, calibrated range 30 to 460 $\mu\mu$f, was of a design especially developed to provide low residual inductance and resistance for this purpose. Main and vernier capacitor sections were included in a single frame to avoid the inductance of a connecting lead. The main rotor and stator were split into two equal sections, the rotor being "center fed"; i.e., to provide a shortened current path, the rotor was grounded by fingers contacting a disk located on the shaft midway between the two sections. Rotor and stator plates fabricated of copper provided lowered rf resistance as compared to the aluminum material formerly used. (See Figure 3.) The stator insulators of this capacitor were at first of impregnated mica, but a subsequent design modification substituted pyrex glass balls for improved electrical reliability.

External terminals (Figure 1) were of gold-plated copper to provide high conductivity. To permit shortened internal leads the panel slope was changed from 45° to 15° and the external terminals were mounted integrally with the capacitor. The residual inductance of this unit, measured at the COIL terminals, was 0.015 $\mu$h, a considerable reduction from the Type 100-A inductance of 0.08 $\mu$h.

For improved readability, a 4-inch meter was used in the Q-VTVM. The meter was critically damped to eliminate the pointer over-swings found in the Type 100-A. The power supply was of the conventional unregulated type.

While the Type 160-A instrument achieved a wide usage in the electronic field and offered greatly improved accuracy at the higher frequencies over its predecessor the Type 100-A (Figure 2), its accuracy at frequencies above 30 mc was limited and the thermocouple factor of safety was low.

### Type 260-A Q Meter

Progress in the electronic and instrument art indicated that a revised Q

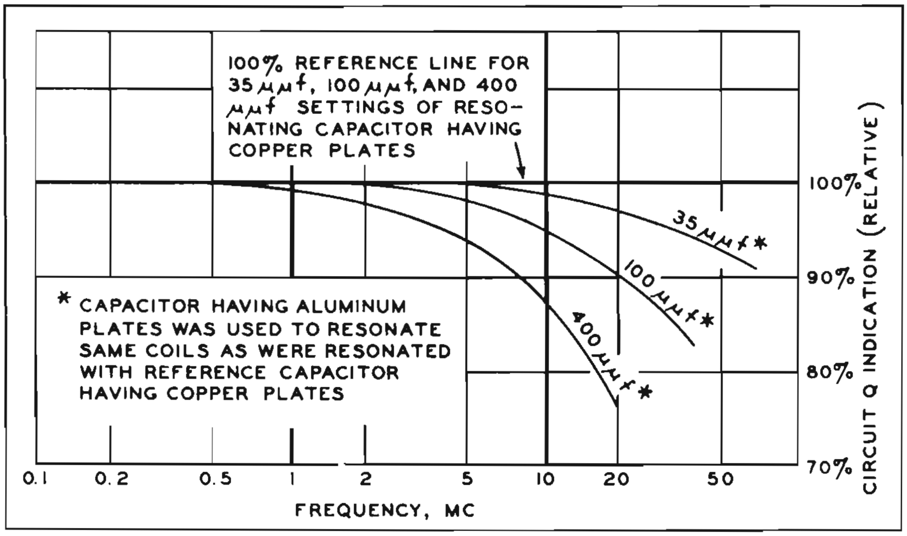


*Figure 3. Circuit Q Indication of Q Meter vs Resonating Capacitor Plate Material*

Meter of refined design and improved accuracy was needed. To meet this need, the Type 260-A Q Meter, superseding the Type 160-A, was developed in 1953 and is still being produced. This model is similar in shape and size to the Type 160-A but is recognizable by its recessed dials.

An oscillator of complete redesign employs a modern tube and modern components. The circuit is designed for low harmonic content. Output current control is in the low wattage screen grid circuit. Turret selection of eight calibrated frequency ranges provides a total coverage of 50 kc to 50 mc.

The thermocouple and "Multiply Q By" meter circuit have been redesigned for a lower thermocouple operating temperature and consequent greater safety factor. Thorough shielding is employed and a 4-inch meter with mirror scale provides greater accuracy of setting the injection voltage.

The injection voltage resistor is a 0.02-ohm annular type providing essentially noninductive performance at frequencies as high as 50 mc, a welcome change from the inductive voltage rise experienced with the shielded resistance strip type of resistor used in Q Meters Type 100-A and Type 160-A. Figure 4 plots the error in the Type 160-A largely attributable to this cause. The error in the 260-A is negligible. The lowered resistance value of 0.02 ohms in the Type 260-A versus 0.04 ohms in the Types 100-A and 160-A (this resistor being in series with the Q measuring circuit) raises the measured circuit Q by as much as 15% at the higher frequencies[3]. Thus the circuit Q and the coil Q are brought into closer agreement.

The resonating capacitor (calibrated for a range of 30 to 460 $\mu\mu$f) is of the same design as was employed in the later 160-A's except that the external terminals are supported on a teflon insulator for improved uniformity, strength, and reliability. The direct reading capacitance scale is supplemented by a direct reading inductance scale for use at specified frequencies.

In addition to the usual main Q scale (40 to 250), the Q indicating meter provides a low Q scale (10 to 60) and a $\Delta$Q scale (0 to 50). These direct reading scales, when used in conjunction with the "Multiply Q By" meter (range X1.0 to X2.5) provide a circuit Q measurement range of 10 to 625. Each meter employs a mirror scale for the elimination of parallax error.

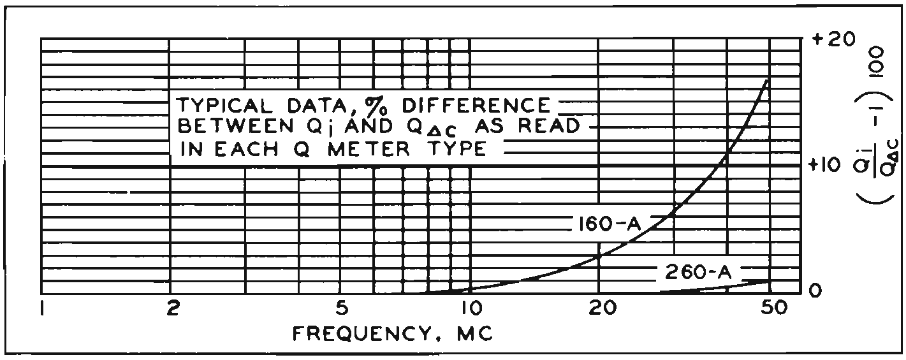


*Figure 4. Q Indicated ($Q_i$) vs Q by Delta-C ($Q\triangle_C$) Method*

The power supply voltages are regulated by a voltage stabilizing transformer and "glow tubes", thus providing stability of meter indications in the presence of power line voltage fluctuations.

Figure 5 offers a quick review of the design highlights which contribute to the improved performance of the Type 260-A Q Meter. Note that the Q indication accuracy specification now extends upward to include the full frequency range of 50 kc to 50 mc (Figure 2).

### Accessory Inductors

The Type 103-A Inductor has long been available as a "work coil" for use in Q Meter measurement of capacitors and other components. The more recently introduced Types 513-A and 518-A Q Standards provide a ready means for the user to check the accuracy of his Q Meter, thus assuring instrument accuracy at the time of Q measurement.

### Conclusion

Twenty-five years of electronic engineering effort has brought forth many advancements in the electronic field. We believe that Q Meter design has kept pace in terms of improved accuracy of measurement, improved reliability, and improved stability of operation.

### References

1. Moore, W. C., "The Nature of Q", BRC Notebook No. 1, Spring 1954.
2. Stewart, John L., "Circuit Theory and Design", John Wiley and Sons, Inc., 1956, p. 344.
3. "Q Meter Comparison", BRC Notebook No. 2, Summer 1954.

| ITEM | 100-A Q METER | 260-A Q METER |
|---|---|---|
| Oscillator Harmonic Content | High at some frequencies, causing Q indication error. | Low at all frequencies, negligible Q error. |
| Oscillator Output Thermocouple<br>(A) Overload factor<br>(B) Shielding | (A) Small, susceptible to burnout.<br>(B) Poor, causing Q indication error. | (A) Large, burnout rare.<br>(B) Good, negligible Q indication error. |
| Injection Voltage Resistor | Inductance causes Q indication error at higher frequencies. | Inductive effect negligible; lowered resistance value improves circuit Q. |
| Resonating Capacitor (Q Measuring Circuit) | Receiver type with aluminum plates, vernier separate, external COIL and COND terminals separately mounted, impregnated mica insulation. | Specially designed, silver plated copper plates, rotor current center-fed, vernier in same frame, external COIL and CAP terminals integrally mounted, teflon and pyrex insulation, residual inductance and resistance greatly reduced. |
| Circuit Q Measurement Range | 10-500 | 10-625; includes low Q Range and $\triangle$Q range for better accuracy. |
| Meters | 3 inch | 4 inch, mirror scale. |
| Power Supply | Unregulated | Regulated; meter indications stabilized against line voltage fluctuations. |

*Figure 5. Highlights of Q Meter Design Differences*

# SALES AND SERVICE OFFICES IN THE U.S. AND CANADA

### ALABAMA

Huntsville, 35801
Hewlett-Packard
Southern Sales Division
Holiday Office Ctr., Suite 18
(205) 881-4591

### ARIZONA

Scottsdale, 85251
Hewlett-Packard
Neely Sales Division
3009 No. Scottsdale Rd.
(602) 945-7601

Tucson, 85716
Hewlett-Packard
Neely Sales Division
232 So. Tucson Blvd.
(602) 623-2564

### CALIFORNIA

Los Angeles Area
Hewlett-Packard
Neely Sales Division
3939 Lankershim Blvd.
North Hollywood, Calif. 91604
(213) 877-1282 and 766-3811

Sacramento, 95821
Hewlett-Packard
Neely Sales Division
2591 Carlsbad Ave.
(916) 482-1463

San Diego, 92106
Hewlett-Packard
Neely Sales Division
1055 Shafter Street
(714) 223-8103

San Francisco Area
Hewlett-Packard
Neely Sales Division
501 Laurel Street
San Carlos, Calif. 94071
(415) 591-7661

### COLORADO

Denver (Englewood) 80110
Hewlett-Packard
Lahana Sales Division
7965 East Prentice
(303) 771-3455

### CONNECTICUT

Middletown, 06458
Hewlett-Packard
Yewell Sales Division
589 Saybrook Rd.
(203) 346-6611

### FLORIDA

Miami
Hewlett-Packard
Florida Sales Division
2907 N.W. 7th St.
(305) 635-6579

Orlando, 32803
Hewlett-Packard
Florida Sales Division
621 Commonwealth Ave.
(305) 425-5541

St. Petersburg, 33708
Hewlett-Packard
Florida Sales Division
410-150th Ave., Madeira Beach
(813) 391-0211

### GEORGIA

Atlanta, 30305
Hewlett-Packard
Southern Sales Division
3110 Maple Drive, N.E.
(404) 233-1141

### ILLINOIS

Chicago, 60645
Hewlett-Packard
Crossley Sales Division
2501 West Peterson Ave.
(312) 275-1600

### INDIANA

Indianapolis, 46205
Hewlett-Packard
Crossley Sales Division
3919 Meadows Dr.
(317) 546-4891

### KENTUCKY

Louisville, 40218
Hewlett-Packard
Southern Sales Division
Suite 4, 3411 Bardstown Rd.
(502) 459-4140

### MARYLAND

Baltimore, 21207
Hewlett-Packard
Horman Sales Division
6660 Security Blvd.
(301) 944-5400

Washington, D.C. Area
Hewlett-Packard
Horman Sales Division
941 Rollins Avenue
Rockville, Md. 20852
(301) 427-7560

### MASSACHUSETTS

Boston Area
Hewlett-Packard
Yewell Sales Division
Middlesex Turnpike
Burlington, Mass. 01804
(617) 272-9000

### MICHIGAN

Detroit, 48235
Hewlett-Packard
Crossley Sales Division
14425 West Eight Mile Road
(313) 342-5700

### MINNESOTA

St. Paul, 55114
Hewlett-Packard
Crossley Sales Division
842 Raymond Avenue
(612) 646-7881

### MISSOURI

Kansas City, 64131
Harris-Hanson Company
7916 Paseo Street
(816) 444-9494

St. Louis, 63144
Harris-Hanson Company
2814 South Brentwood Blvd.
(314) 647-4350

### NEW JERSEY

Asbury Park Area
Hewlett-Packard
Robinson Sales Division
Shrewsbury, New Jersey
(201) 747-1060

Englewood, 07631
Hewlett-Packard
RMC Sales Division
391 Grand Avenue
(201) 567-3933

### NEW MEXICO

Albuquerque, 87108
Hewlett-Packard
Neely Sales Division
6501 Lomas Blvd., N.E.
(505) 255-5586

Las Cruces, 88001
Hewlett-Packard
Neely Sales Division
114 S. Water Street
(505) 526-2486

### NEW YORK

New York, 10021
Hewlett-Packard
RMC Sales Division
236 East 75th Street
(212) 879-2023

Rochester, 14625
Hewlett-Packard
Syracuse Sales Division
800 Linden Avenue
(716) 381-4120

Poughkeepsie, 12601
Hewlett-Packard
Syracuse Sales Division
82 Washington St.
(914) 454-7330

Syracuse, 13211
Hewlett-Packard
Syracuse Sales Division
Pickard Bldg., E. Molloy Rd.
(315) 454-2486

### NORTH CAROLINA

High Point, 27262
Hewlett-Packard
Southern Sales Division
1923 N. Main Street
(919) 882-6873

### OHIO

Cleveland, 44129
Hewlett-Packard
Crossley Sales Division
5579 Pearl Road
(216) 884-9209

Dayton, 45409
Hewlett-Packard
Crossley Sales Division
1250 W. Dorothy Lane
(513) 299-3594

### PENNSYLVANIA

Camp Hill
Hewlett-Packard
Robinson Sales Division
(717) 737-6791

Philadelphia Area
Hewlett-Packard
Robinson Sales Division
144 Elizabeth Street
West Conshohocken, Pa. 19428
(215) 248-1600 and 828-6200

Pittsburgh Area
Hewlett-Packard
Crossley Sales Division
2545 Moss Side Blvd.
Monroeville, Pa. 15146
(412) 271-5227

### TEXAS

Dallas, 75209
Hewlett-Packard
Southwest Sales Division
P.O. Box 7166, 3605 Inwood Rd.
(214) 357-1881 and 332-6667

Houston, 77027
Hewlett-Packard
Southwest Sales Division
P.O. Box 22813, 4242 Richmond Av
(713) 667-2407

### UTAH

Salt Lake City, 84115
Hewlett-Packard
Lahana Sales Division
1482 Major St.
(801) 486-8166

### VIRGINIA

Richmond, 23230
Hewlett-Packard
Southern Sales Division
2112 Spencer Road
(703) 282-5451

### WASHINGTON

Seattle, 98109
ARVA, Inc.
1320 Prospect Street
(206) 662-0177

After Jan. 1, 1965
Seattle (Bellevue)
Hewlett-Packard
Neely Sales Division
11656 N.E. 8th St.
(206) 454-3971

### CANADA

Montreal, Quebec
Hewlett-Packard (Canada) Ltd.
8270 Mayrand Street
(514) 735-2273

Ottawa, Ontario
Hewlett-Packard (Canada) Ltd.
1762 Carling Avenue
(613) 722-4223

Tronto, Ontario
Hewlett-Packard (Canada) Ltd.
1415 Lawrence Avenue, West
(416) 249-9196

Spring, 1954

Number 1

The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

# The Nature Of Q

**W. CULLEN MOORE** *Engineering Manager*

***A discussion of the physical concepts underlying a familiar and useful, but not always fully appreciated, quantity -- "Quality Factor."***

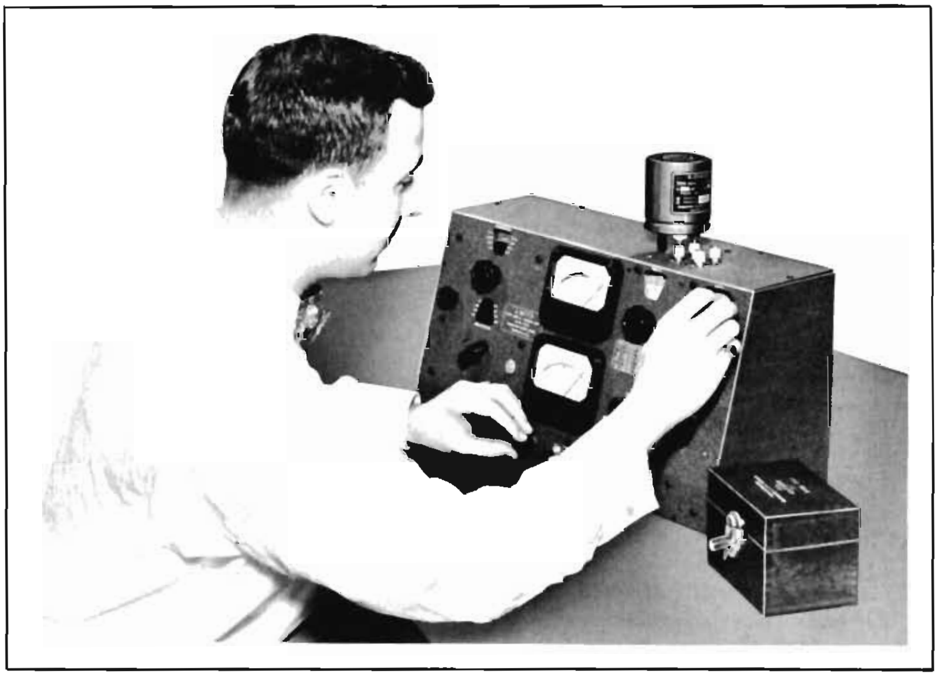


***Figure 1. The importance of the quantity Q in the analysis of electronic circuits and components has made the Q Meter a familiar laboratory tool. Here, H. J. Lang, BRC Sales Engineer, is checking the accuracy of a Q Meter Type 260-A with the new Q-Standard.***

The familiar symbol, Q, has something in common with a certain famous 19th century elephant of Indostan. You may recall that in the poem six blind men each investigated the same elephant with the agreement that they would report their findings to each other and thereby determine the true nature of an elephant. One chanced to touch the side of the elephant and reported "God bless me! But the elephant is very like a wall." Another, touching the tail, proclaimed an elephant was like a rope. The third, chancing upon a leg, avowed the elephant to be kind of a tree, and so on. The confusion of reports prompted the poet to observe in conclusion that, "Each was partly in the right, and all were in the wrong."

And so it is with Q. The concept of Q which each engineer favors is the one based on the way in which he uses Q most frequently. It might be to describe selectivity curves, or the resonant rise in voltage, or the impedance of a parallel resonant circuit, or the envelope of a damped wave train. If one were to ask for a definition of Q, the most common response probably would be "Q equals $\omega L/R_x$". But like the description of the elephant, this too is partly right and partly wrong. The reason is, that while one can obtain a numerical value for Q by dividing the quantity ($\omega L$) by R, it tells little or nothing about the real nature of Q.

The expression $\omega L/R_x$ is a dimensionless ratio and therefore a pure number. As such it enjoys no distinction from other pure numbers. If we are to look for the *meaning* of Q as a basis for its description, we must look for a physical concept. We may then explore the implications and applications of this concept in a variety of specific situations.

**YOU WILL FIND. . .**

Let us go one step further in our analysis of the expression $\omega L/R_x$. It is not immediately apparent why this *particular* numerical ratio should be chosen to describe certain characteristics of components and circuits over all the other similar ratios which might be set up. The reason for this choice once again refers back to the concept involved in the establishment of a definition for Q. We shall see presently that the basic idea leads directly to a simple expression by which we can determine a numerical magnitude.

In the first place, the Q of a circuit or component has practical significance only when an alternating current, usually sinusoidal in waveform, is flowing through it. The circuit parameters associated with alternating currents, namely capacitance and inductance, have the common characteristic of being capable of storing energy. An inductor stores energy in the form of an electromagnetic field surrounding its winding. A capacitor stores energy in the form of polarization of the dielectric. Each of these systems will deliver most of the stored energy back into the circuit from which it came. These common characteristics indicate that perhaps we should look to energy relationships for an appropriate description of the behavior of circuits.

As mentioned above, most, but not all of the energy stored in an inductor or a capacitor is delivered back into the total system. If we start with this energy concept, we are in a position to derive a *figure* of *merit* for the system in terms of its ability to store energy as compared with the energy it wastes.

*Continued on Page 2*

*THE BRC NOTEBOOK is published four times a year by the Boonton Radio Corporation. It is mailed free of charge to scientists, engineers and other interested persons in the communications and electronics fields. The contents may be reprinted only with written permission from the editor. Your comments and suggestions are welcome, and should be addressed to: Editor, THE BRC NOTEBOOK, Boonton Radio Corporation, Boonton, N. J.*

***The Nature of Q (continued)***

### DERIVATION OF $Q = \omega L/R$

In describing the behavior of a circuit in which an alternating current is flowing (as shown in Fig. 2), it is most convenient to use as our interval one complete current cycle. During this interval the system will have experienced all of its configurations of energy distribution and will have returned as nearly as possible to the starting condition. We are interested in the ratio of the total energy stored in the system to the amount of energy dissipated per cycle by the system.

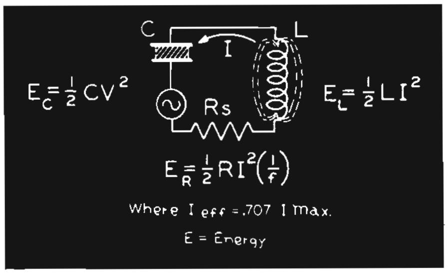


***Figure 2. Energy relationships in an elementary a-c series circuit.***

To calculate the total stored energy, let us select that portion of the cycle at which all the energy is stored in the field of the inductor. (This is quite arbitrary, as we could just as well assume all the energy to be stored in the capacitor.) We recall from electrical engineering that the energy stored in the field surrounding an inductor is equal to $1/2\ LI^2$. In this case I will be the peak current in amperes.

The *average power* lost in the resistor is $1/2R_sI^2$, where $R_s$ is the total series resistance of all elements in the circuit, and I is the peak current in amperes. The factor 1/2 appears because the (*effective* current) $= .707$ (*peak* current, I), and $(.707I)^2 = 1/2I^2$.

The energy lost per cycle is equal to the average power times the time of one cycle, $T = (1/f)$, or $1/2R_sI^2T$.

The ratio of stored energy to energy dissipated per cycle becomes:

$$\frac{\frac{1}{2} L I^2}{\frac{1}{2} I^2 R_s T} = \frac{1}{T}\frac{L}{R_s} = \frac{fL}{R_s} = \frac{1}{2\pi}\frac{2\pi f L}{R_s}$$

$$= \frac{1}{2\pi}\frac{\omega L}{R_s} = \frac{1}{2\pi} Q$$

Hence: $Q = 2\pi \dfrac{\text{total energy stored}}{\text{energy dissipated per cycle}}$

Thus we see that the familiar expression giving the magnitude of the quantity Q follows directly from the basic concept of the ability of a component or circuit to store energy and the energy dissipated per cycle.

### Q IN A PARALLEL CIRCUIT

The above analysis has been made on the assumption of a so-called series circuit which assumes all losses in the circuit to be represented by a single resistor in series with a lossless inductor and a lossless capacitor. We are now interested in obtaining an expression for the case in which we are looking at the circuit from the outside, or parallel connection, in which the resistor, the inductor, and the capacitor are all in parallel as shown in Fig. 3.

An equivalent expression for Q for the two circuits of Fig. 3 can be obtained most readily if we consider the current distributions when the applied alternating current has the same frequency as the resonant frequency of the R-L-C combinations. In Fig. 3-a, the current, I, flowing through the circuit from point A to point B is controlled by the parallel resonant impedance of the circuit:

$$Z_{AB} = \frac{(-j\frac{1}{\omega C})(j\omega L + R_s)}{(-j\frac{1}{\omega C}) + (j\omega L + R_s)}$$

At resonance: $\left|\frac{1}{\omega C}\right| = |\omega L| = X,$

where $|\ \ |$ indicates magnitude, so that

$$Z_{AB} = \frac{(-jX)\ (+jX + R_s)}{-jX\ + jX + R_s} = \frac{X^2 - jXR_s}{R_s}$$

$$= \frac{X^2}{R_s} + (-jX).$$

The absolute magnitude of this impedance is

$$Z_{AB} = \sqrt{\left(\frac{X^2}{R_s}\right)^2 + X^2} = X\sqrt{\frac{X^2}{R_s^2} + 1}.$$

Or, $\quad Z = \omega L \sqrt{Q^2 + 1}$

For most practical purposes this reduces to:

$$Z = Q\omega L,$$

which is the impedance of a parallel reasonant circuit. For the external current flowing through Figure 3-a we may then write, $I = E/Q\omega L$.

Referring to Figure 3-b, we may consider that the combination of C and L, with all losses now accumulated into the equivalent parallel resistor $R_p$, forms at resonance an infinite impedance circuit in shunt with a finite resistor $R_p$. The current flowing through such a circuit will be $I = E/R_p$.

Equating: $\dfrac{E}{Q\omega L} = \dfrac{E}{Rp};$ or, $Q\omega L = Rp$

Rewriting: $Q = Rp/\omega L.$

where $R_p$ = total effective parallel circuit resistance in ohms.

It is convenient to remember that for the series case, $R_s$ is in the denominator and Q becomes very large as the dissipative component $R_s$ becomes small. In the case of the parallel resonance circuit, the larger the shunt resistance the larger the value of Q.

Summarizing:

$$Q = \frac{\omega L}{R_s} = \frac{1}{\omega C R_s} = \frac{Rp}{\omega L} = \omega C Rp$$

### SELECTIVITY

We have seen how the expression $Q = \omega L/R_s$ can be derived directly from power consideration in an R-L-C circuit. By extending the analysis of power relationship in such circuits we can also derive an expression which describes the selectivity, or response-versus-frequency, curve for circuits in the vicinity of their natural resonant frequency.

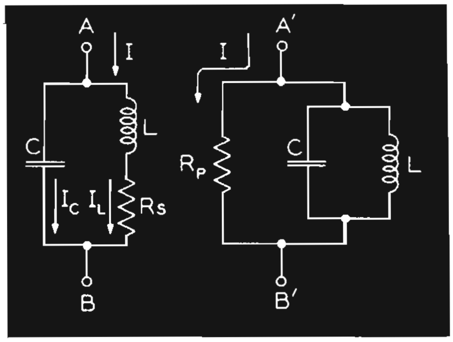


***Figure 3. Current distributions in parallel resonant circuits.***

To begin with, we will need to establish two points on the resonance curve for reference. A convenient choice of points is one in which the net circuit inductive or capacitive reactance equals the resistance in the circuit. These two points can be shown to lie at frequencies at which the power in the circuit is one half the power at the maximum response frequency. (See Fig. 4.)

Assume that the reactance equals the resistance. Then the total circuit impedance is equal to the following:

$$Z = \sqrt{R_s^2 + X^2} = \sqrt{R_s^2 + R_s^2}$$

$$= \sqrt{2R_s^2} = 1.414R_s$$

We must remember that this new impedance consists of the original resistance plus some reactance. Only the resistance component of the impedance consumes power. If we apply the same voltage to this circuit at the selected frequency as at the resonant frequency, the current at the new selected frequency will be $I_f = 0.707\ I_0$ where $I_0$ is the current at resonance. The power dissipated in the circuit is then

$$W_f = I_f^2 R_s = (.707 I_0)^2 R_s = .5\ I_0^2 R_s$$

$$= .5\ W_0$$

Let us now see what frequency relationships are involved. Near resonance, if we change the frequency by a small amount $\Delta f$ toward a higher frequency, the net reactance of the circuit will change due to two equal contributions in the same direction: (1) there will be a small increase in the inductive reactance due to the increased frequency, and (2) there will be an equal amount of decrease in the capacitive reactance. The net change in reactance is the sum of these two equal changes. The change in reactance due to the increased inductive reactance alone is $\Delta X_1 = 2\pi\Delta fL$, and the change in the total reactance is

$$\Delta X = 2(2\pi\Delta fL) = 4\pi\Delta fL.$$

Choose $\Delta f$ equal to the difference between the frequency at either of the half-power points, $f_1$ or $f_2$, and the resonance frequency, $f_0$. Since we have seen that at the half-power points $X = R$, we can write the two following equations:

$$R_s = 4\pi(f_0 - f_1)\,L$$
$$= 4\pi f_0 L - 4\pi f_1 L$$

$$R_s = 4\pi(f_2 - f_0)\,L$$
$$= -4\pi f_0\,L + 4\pi f_2\,L.$$

Adding these two equations:
$2R = 4\pi(f_2 - f_1)\,L.$

Re-arranging and multiplying both sides by $f_0$

$$\frac{f_0}{(f_2 - f_1)} = \frac{2\pi f_0 L}{R_s} = \frac{\omega L}{R_s} = Q$$

This is the application of Q which is most familiar to radio engineers; namely, an expression of the selectivity of a resonant circuit in terms of Q. As we see above, it is based on the *power* dissipated in the circuit at two selected frequencies.

## RESONANT RISE IN VOLTAGE

Let us now look at another common manifestation of the Q of a resonant circuit; namely the voltage multiplication phenomena.

Consider once again the series circuit of Fig. 2 having a total equivalent series resistance, Rs, and a circulating current caused by a small sinusoidal voltage, e, injected in series with the circuit. At series resonance the current circulating within the resonant circuit is limited only by the resistance and will be $I_o = e/R_s$. This circulating current will produce a voltage across the inductor equal to $E = I_o\,\omega L = (e/R_s)\,\omega L$.

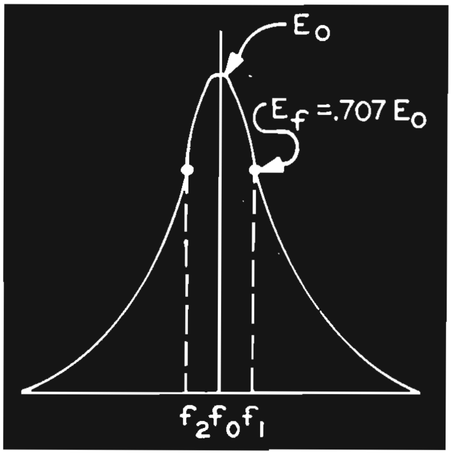


*Figure 4. Resonance curve, showing half-power points.*

The resonant rise in voltage then is

$$\frac{E}{e} = \frac{\omega L}{R_s} = Q$$

This is often written
$E = Qe.$

For relatively high values of $R_s$ (corresponding to low Q) we must also account for the drop across the resistor:

$$E = I_0\sqrt{R_s^2 + \omega^2 L^2}$$

$$= \frac{e}{R_s}\sqrt{R_s^2 + \omega^2 L^2} = e\sqrt{1 + \frac{\omega^2 L^2}{R_s^2}}$$

So for this case

$$E = e\sqrt{1 + Q^2}$$

Of course we could just as well have analyzed this circuit from the standpoint of the voltage across the capacitor, but we would have arrived at exactly the same results.

## POWER DISSIPATION

Proceeding directly out of the method by which we derive Q, namely from the standpoint of energy, we can see that the net Q of the complete oscillator circuit describes the manner in which the circuit causes the current to flow in alternate directions, and describes the energy lost per cycle in the process. This lost energy per cycle must be made up by the power supply of the system or oscillation will die out.

We know that a circuit consisting of an inductor, a capacitor and a resistor in series, which is charged and allowed to oscillate, will experience an exponential decay in the magnitude of the peak current. This decay follows the form $\left(\epsilon^{-\frac{R}{2L}T}\right)$. The portion of this expression R/2L is defined as the *damping coefficient*, and describes the amount by which each successive cycle is lower than its predecessor, as shown in Fig. 5. If we multiply the damping coefficient by the time for one cycle, we obtain the expression known as the *logarithmic decrement* of a circuit, which includes the effect of frequency. In each successive cycle of period T we obtain the following current ratios:

$$\frac{I_2}{I_1} = \epsilon^{-\frac{R}{2L}T} = \epsilon^{-\delta}$$

But $T = \frac{1}{f}$, so $\delta = \frac{R_s}{2fL}$, or $\delta = \frac{\pi}{Q}$

Rewriting: $Q = \frac{\pi}{\delta}$

We see that in this application Q is intimately linked with the rate of decay of oscillation in a dissipative circuit. Before we leave the subject of Q and power, let us mention briefly two other factors which find common usage in electrical engineering. The first of these is the *phase angle* between the current and the driving voltage in a circuit containing reactance and resistance. If we once again arbitrarily limit ourselves to consideration of inductors, the expression for phase angle is the familiar formula:

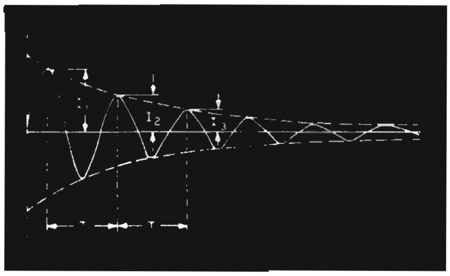


*Figure 5. Q as a damping factor.*

$$\tan\phi = \omega L/R_s = Q$$

Or: Q = (tangent of the phase angle.)

Closely associated with the phase angle is the *power factor*. The power factor of an inductor is the ratio of the total *resistance* absorbing power to the total *impedance* of the device, and is designated by Cos $\phi$:

$$\cos\phi = \frac{R_s}{\sqrt{R_s^2 + \omega^2 L^2}} = \frac{R_s}{R_s\sqrt{1 + \frac{\omega^2 L^2}{R_s^2}}}$$

$$= \frac{1}{\sqrt{1 + Q^2}}$$

This is approximately $\cos\phi = \frac{1}{Q}$.

## THE Q METER

Practically all of the relationships mentioned above have been used in radio and electrical engineering for a great many years. However, the expression Q and its numerical value of $Q = \omega L/R_s$ did not come into popular usage until the early 1930's. The need for the rapid measurement of Q arose with the growth of the broadcast receiver industry, and Boonton Radio Corporation demonstrated the first *"Q-METER"* at the Rochester IRE Meeting in November, 1934.

A numerical quantity for Q might be obtained by measuring each of the parameters involved in any of the various forms which have been given above. However, certain of these expressions lend themselves to direct measurement much more readily than others. Originally, the favored method was to actually measure $\omega L$ and $R_s$. Later, measurements of Q were based on the frequency relationship, using a heterodyne detector system. This method is feasible but demands great accuracy of the variable frequency generator in order to obtain resasonable accuracy of the final result.

An expression equivalent to the frequency relationship can be written in terms of capacitance. For the series resonant case we obtain the following:

$$Q = \frac{2C_0}{C_2 - C_1}$$

The multiplier 2 is introduced because the change in frequency is proportional to the square root of the change in capacitance. For incremental quantities this reduces to 2.

The relationship which has found almost universal acceptance in the design of instruments for the direct measurement of Q makes use of the resonant rise of voltage principle outlined above. In such instruments, a small radio frequency voltage of known magnitude is injected into the resonating circuit across a very small series resistor. At resonance this voltage causes a current to flow which is limited only by the magnitude of the total equivalent series resistance of the circuit. The current flowing through the inductor results in the resonant rise of voltage given by $E = eQ$. This magnified voltage is read by a vacuum tube voltmeter connected across the resonating capacitor. Since the series voltage injected into the circuit is known, it is possible to calibrate the scale of the voltmeter directly in values of Q.

### CONCLUSION

We have seen that the conventional expression for the magnitude of Q can be derived from the basic concept of energy stored compared to energy dissipated per cycle in a resonant system. Its use as a measure of the damping effect in decaying wave trains, its relationship to phase angle and power factor, and the selectivity of a resonant circuit are seen to come out of energy and power considerations. In addition to these factors, such critical basic measurements as radio frequency resistance of a wide variety of components, the loss angle of capacitors, dielectric constants, characteristics of antennas, and transmission line parameters are all part of the continually expanding list made practical by a simple, direct-reading instrument for the measurement of Q, the *Q-Meter*.

### BIBLIOGRAPHY

While the equations given above for the various quantities involving Q may be found in many places, the references below offer an excellent presentation of the energy concept:

*Principles of Radio Communication;* 2nd Edition, 1927, J. H. Morecroft; John Wiley and Son; Page 255 and following.

*Radiotron Designers Handbook;* 4th Edition, 1952, Radio Corporation of America; Harrison, New Jersey, Page 409 and following.

*Vacuum Tube Oscillators,* 1st Edition, 1953, William A. Edson; John Wiley and Son; Pages 20-21.

*Vacuum Tube Circuits;* 1st Edition, 1948, Lawrence B. Arguimbau, John Wiley and son; Pages 184-185.

## THE AUTHOR

W. Cullen Moore was graduated from Reed College in 1936 with a B.A. degree in physics. He studied advanced Electrical Engineering, specializing in microwaves and UHF, at Northwestern University between 1939 and 1942, and received an M.A. in physics from Boston University in 1949. From 1940 to 1947 he was Senior Project Engineer for Motorola, Inc., where he directed work on FM receiver design and signal generating equipment. During the war, he had charge of the development of the SCR-511 "Cavalry Set", the redesign of the SCR-536 "Handie-Talkie", and airborne communications equipment.

Between 1947 and 1951, Mr. Moore was a Project Supervisor at the Upper Air Research Laboratory at Boston University, where he supervised the design of rocket-borne electronic equipment. During the same period he taught electronics as an instructor in the B. U. Physics Department. In 1951 he joined Tracerlab, Inc., where he remained as Chief Engineer until 1953, when he accepted the position of Engineering Manager of Boonton Radio Corporation.

# Basic Formulas Involving Q

## A. TWO-TERMINAL IMPEDANCE

### FORMULAS RELATING EQUIVALENT SERIES AND PARALLEL COMPONENTS

$$Q = \frac{X_s}{R_s} = \frac{\omega L_s}{R_s} = \frac{1}{\omega C_s R_s} = \frac{R_p}{X_p} = \frac{R_p}{\omega L_p} = R_p \omega C_p$$

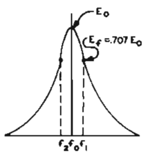
| General Formula | Q greater than 10 | Q less than 0.1 | General Formula | Q greater than 10 | Q less than 0.1 |
|---|---|---|---|---|---|
| $R_s = R_p \frac{1}{1+Q^2}$ | $R_s = \frac{R_p}{Q^2}$ | $R_s = R_p$ | $R_p = R_s(1+Q^2)$ | $R_p = R_s Q^2$ | $R_p = R_s$ |
| $X_s = X_p \frac{Q^2}{1+Q^2}$ | $X_s = X_p$ | $X_s = X_p Q^2$ | $X_p = X_s \frac{1+Q^2}{Q^2}$ | $X_p = X_s$ | $X_p = \frac{X_s}{Q^2}$ |
| $L_s = L_p \frac{Q^2}{1+Q^2}$ | $L_s = L_p$ | $L_s = L_p Q^2$ | $L_p = L_s \frac{1+Q^2}{Q^2}$ | $L_p = L_s$ | $L_p = \frac{L_s}{Q^2}$ |
| $C_s = C_p \frac{1+Q^2}{Q^2}$ | $C_s = C_p$ | $C_s = \frac{C_p}{Q^2}$ | $C_p = C_s \frac{Q^2}{1+Q^2}$ | $C_p = C_s$ | $C_p = C_s Q^2$ |

## B. TUNED CIRCUIT

1. Selectivity

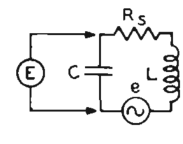
$$Q = \frac{f_0}{f_1 - f_2} = \frac{2C_0}{C_2 - C_1}$$

Where $f_1$ and $f_2$ are half-power points and $C_0$, $C_1$, and $C_2$ are capacitance values at $f_0$, $f_2$ and $f_1$ respectively.



2. Resonant Rise in Voltage $Q = \frac{E}{e}$

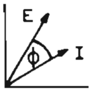
For relatively large $R_s$ (low Q), $E = e\sqrt{1+Q^2}$



3. Power Dissipation

a. Power Factor = cos $\phi$ $= \frac{R}{\sqrt{R^2+L^2\omega^2}} = \frac{1}{\sqrt{1+Q^2}}$

and for inductors, Q = $\tan = \frac{\omega L}{\phi}$



b. Damped Oscillations $Q = \frac{\pi}{\delta}$, where $\delta$ is the logarithmic decrement.

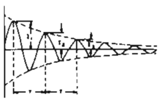


*Figure 1. The Q-Standard Type 513-A*

# The Q-Standard

## A NEW REFERENCE INDUCTOR FOR CHECKING Q METER PERFORMANCE

**Dr. Chi Lung Kang**
**James E. Wachter**

Widespread acceptance of the Q Meter as a basic tool for electronic research and development has lead, in recent years, to an increasing demand for some convenient means of checking the performance and accuracy of the instrument periodically in the field.

As a result of this demand, BRC engineers have developed the recently-announced Q-Standard Type 513-A, a highly stable reference inductor, intended specifically for use in checking the performance of Q Meters Type 160-A and 260-A. By comparing the accurately-known parameters of this inductor directly with the corresponding values read on the Q Meter, the user may now obtain a dependable indication of the accuracy with which his Q Meter is operating.

The Q-Standard is designed and constructed to maintain, as nearly as possible, constant electrical characteristics. In external appearance the unit is 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 have been required to provide the high degree of electrical stability demanded of such a unit.

The inductance element consists of a high-Q coil of Litz wire wound on a low-loss steatite form. After winding, the coil is heated to remove any moisture present, coated with silicone varnish, and baked. A stable, carbon-film resistor is shunted across the coil to obtain the proper Q-versus-frequency characteristics. The coil form is mounted on a copper base which in turn is fitted to a cylindrical, copper shield can. The coil leads are brought through the base to replaceable banana plug connectors which allow the unit to be plugged directly into the Q Meter COIL posts. The low potential connector is mounted directly on the base, while the high potential connector is insulated from the base by a steatite bushing. To provide maximum protection against moisture, the unit is hermetically sealed, evacuated, and filled with dry helium under pressure.

### ELECTRICAL CHARACTERISTICS

The principal electrical characteristics of each individual Q-Standard are measured at the factory and stamped on the nameplate of the unit. These include the inductance (L), the distributed capacity ($C_d$), and 3 values of effective Q ($Q_e$) and indicated Q ($Q_i$), determined at frequencies of 0.5, 1.0 and 1.5 mc, respectively.

The effective Q may be defined as the Q of the Q-Standard assembly mounted on the Q-Meter, exclusive of any losses occurring in the measuring circuit of the Q Meter itself. It differs from the true Q by an amount which depends largely on the distributed capacitance of the inductor. At the frequencies for which $Q_e$ is given, the following relation is approximately correct:

$$\text{TRUE } Q = Q_e\,(1 + C'_d / C')$$

Where $C'$ and $C'_d$ are corrected values of resonating capacitance and distributed capacitance, respectively, as described below.

The Q of the unit as read on an average Q Meter (indicated Q) will differ from the effective Q by a small percentage which is the result of certain losses inherent in the measuring circuit of the instrument. These losses are minimized, and may usually be disregarded in all but exacting measurements. However, tó provide a more accurate check on the Q Meter reading, The Q-Standard is also marked with values of indicated Q. Small variations in the calibration of both the Q Meter and the Q Standard may cause individual instruments to deviate slightly from the expected reading, but a Q Meter Type 160-A or 260-A which indicates within ±7% of the $Q_i$ value marked on the Q-Standard may be considered to be operating within its specified tolerances. Although quantitative indications are not possible, it is worthwhile to note, when wider deviations are encountered, that an error which is greatest at 0.5 mc may indicate calibration inaccuracy, while one which becomes severe at 1.5 mc may be caused by excessive shunt loading effects.

In addition to checking indicated Q, the Q-Standard may be used to determine the calibration accuracy of the Q Meter resonating capacitor. This may be done readily by tuning the measuring circuit to resonance at any desired frequency within the resonant limits of the Q-Standard, and comparing the reading on the capacitor dials with the value predicted by the expression,

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

The measuring circuit of a Q Meter Type 160-A or 260-A, with a Q-Standard mounted on the COIL posts, is represented in Fig. 2-a. Here $R_q$ is the Q Meter shunt loss, Q is the

Q-indicating meter, $R_i$ is the Q Meter injection resistor, and C′ is the resonating capacitance. L, R and $C_d'$ represent the inductance, series resistance and corrected distributed capacitance, respectively, of the Q-Standard. The equivalent circuit shown in Fig. 2-b indicates the corresponding *effective* parameters of the Q-Standard, which are related to the values in Fig. 2-a as follows:

$$L_e = \frac{L}{1-\omega\ LC_d'}$$

$$R_e = \frac{R}{(1-\omega^2 LC_d')^2}$$

$$Q_e = \frac{\omega\ L_e}{R_e}$$

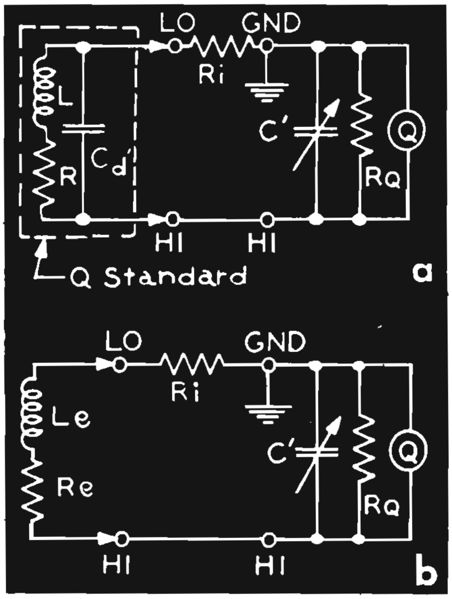


***Figure 2.** Schematic representation of Q Meter measuring circuit with Q-Standard attached.*

It is worthwhile to consider, briefly, the corrected value of distributed capacitance ($C_d'$) mentioned above. This value is the distributed capacitance of the Q-Standard when it is actually mounted on the Q Meter. It differs by a small, constant value from the distributed capacitance ($C_d$) marked on the nameplate, because of a capacitance shift caused by the proximity of the Q-Standard shield can to the Q Meter HI post. This proximity causes the transfer of a small value of capacitance from between the Q Meter HI post and ground to between the HI post and the Q-Standard shield can. This results in a change in the calibration of the resonating capacitor, and a corresponding change in the Q-Standard distributed capacity.

Thus, if the tuning dial of the resonating capacitor is adjusted to a value, C, with nothing attached to the coil posts, the actual value of tuning capacitance will be reduced by a small constant to a new value, C′, when the Q-Standard is connected. At the same time, the distributed capacitance of the Q-Standard is increased to become Cd′. The magnitude of this effect is 0.4 μμf, and we may write,

$$C' = C - 0.4\ \mu\mu f$$

$$C_d' = C_d + 0.4\ \mu\mu f$$

When the Q-Standard is used to check the calibration of the resonating capacitor, in the manner described above the value, Cd, indicated on the nameplate is used. In other applications, however, where accurate results are desired, the corrected values, C′ and Cd′, must be used. In determining $Q_e$ for example,

$$Q_e = \frac{\omega\ L_e}{R_e} = \frac{1}{R_e\ \omega C'},$$

it can be seen that the correction may assume some importance, particularly at 1.5 mc, where C′ is relatively small.

It should be noted that, in order to hold this proximity effect constant, particular care has been taken to provide for accurately-reproducible positioning of the Q-Standard with respect to the Q Meter HI post. For this purpose, the base of the high-potential connector serves as a mounting stop. When this connector is fully inserted in the HI post, the low potential connector (which is the shorter of the two) will not be fully seated in the LO post, and the insulated support attached to the Q-Standard base will not touch the top of the Q Meter cabinet.

If desired, a secondary standard inductor may be derived from the Q-Standard by means of a comparison method which is both simple and accurate. The accuracy of the Q Meter, which is the only equipment needed, has only higher order effects on the results.

The inductor selected should have electrical parameters and outside shield dimensions which are fairly close to those of the Q-Standard. The standardization (i.e. accurate determination of the effective Q of the secondary standard) is done as follows: First, plug the Q-Standard into the Q Meter and resonate the measuring circuit at one of the three frequencies (0.5, 1.0 or 1.5 mc) for which $Q_e$ is given on the Q-Standard nameplate. Then replace the Q Standard with the secondary standard and obtain readings of ΔQ (from the ΔQ scale) and ΔC ($C_1 - C_2$). With the data given on the Q-Standard nameplate, determine C′ from,

$$C' = \frac{1}{2L} - (C_d + 0.4\ \mu\mu f)$$

The effective Q of the secondary standard may then be determined from the relation,

$$Q_e(\text{unkown}) = \frac{\omega(C'+\Delta C)}{\frac{\omega C'}{Q_e} + \frac{\omega C'}{(Q+\Delta Q)}\left[(1+\frac{\Delta C}{C'})(1-\frac{\Delta Q}{Q+\Delta Q})-1\right]}$$

where $C_d$, L and $Q_e$ are given on the Q-Standard nameplate.

---

# Service Note

## REPLACING THE THERMOCOUPLE ASSEMBLY TYPE 565-A IN THE Q METER TYPE 260-A

It is the function of the Q Meter thermocouple to monitor accurately the voltage injected by the oscillator into the measuring circuit. Although the unit in the Q Meter Type 260-A has been made considerably more rugged than that of the older Q Meter Type 160-A, it is necessarily a sensitive device which may be subject to damage or burnout under prolonged overload. For this reason, care is necessary in operating the instrument to avoid increasing the oscillator output (indicated on the XQ Meter) into the "red-lined" region beyond the indicated X1 value.

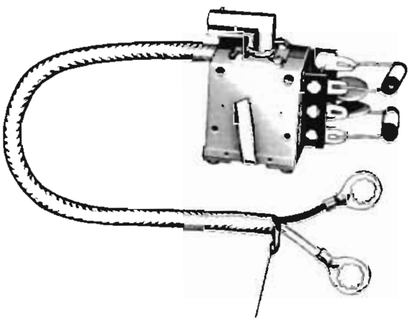


***Figure 1.** Thermocouple Assembly Type 565-A*

If thermocouple failure should occur, the assembly may be replaced, by the user, with a new assembly obtained from the factory, if the proper care is taken. In ordering, it is necessary to include the serial number of the Q Meter in which the thermocouple is to be used since they must be individually matched. The procedure outlined below is presented as reference material for the convenience of Q Meter Type 260-A owners.

CHECKING FOR THERMOCOUPLE FAILURE

If no reading can be obtained on the XQ meter, thermocouple burnout may be sus-

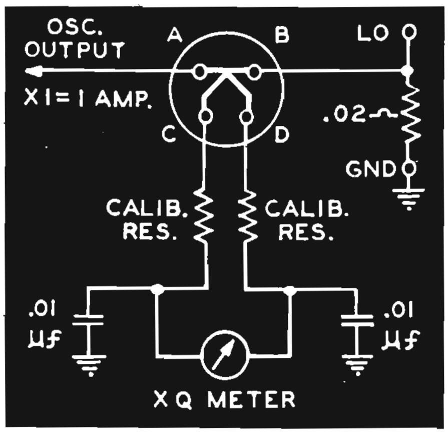


***Figure 2.** Thermocouple circuit of the Q Meter Type 260-A.*

pected. Since this symptom may also be produced by failure of the local oscillator, however, the output of the latter should be checked first. This may be done by measuring from point A (See Fig. 2) to ground with a vacuum tube voltmeter. If the oscillator produces a voltage across these points, disconnect one lead from the XQ meter and check for continuity between points A-C, A-B, B-D and C-D. An open circuit between any of these indicates thermocouple failure. The maximum resistance of the XQ meter is 65 ohms; the total resistance of the junction circuit loop, including the XQ meter, calibration resistors and thermocouple element, can vary from 85 to 115 ohms. CAUTION: Do not disassemble the thermocouple unit.

### REPLACEMENT PROCEDURE

The 565-A thermocouple replacement assembly for the Q Meter Type 260-A includes the thermocouple unit itself, a 0.02 ohm insertion resistor, two calibration resistors and two filter capacitors. Replacement of the assembly should be made as follows:

1. Remove the front panel and chassis assembly from the Q Meter cabinet and place it, face down, on a flat work surface.
2. Remove the UG-88/U plug from the receptacle at the rear of the thermocouple assembly.
3. Unscrew and remove the LO binding post terminal nut. Then, using a right-angle soldering iron (see Fig. 3), carefully unsolder the thin metal strap which connects the thermocouple unit to the bottom of the LO post.
4. Remove the terminal lugs from the XQ meter and unclamp the cable from the front panel and resonating capacitor frame.
5. Remove the four mounting screws from the thermocouple assembly, and carefully remove the assembly from the Q Meter.
6. Install the new unit and connect the attached cable to the XQ meter terminals, observing the indicated polarity. Clamp the cable to the front panel and resonating capacitor frame.

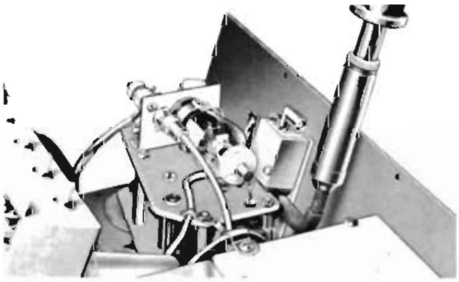


***Figure 3. Using a right-angle soldering iron to solder the thermocouple connecting strap in place***

7. Trim the connecting strap to a length which will permit it to reach the bottom of the LO post with a small amount of slack to allow for binding post movement. Solder this strap to the LO post, being careful not to leave the iron in contact with the strap any longer than necessary.
8. Replace the binding post nut and return the instrument to its cabinet.— **E.GRIMM**

# an introduction to BOONTON RADIO CORPORATION

**Frank G. Marble**, *Sales Manager*

The Boonton Radio Corporation was formed in 1934. Since that time it has been developing, designing, and manufacturing precision electronic instruments. To understand some of the details of the Company's growth, we must take a look at the field of electronics for a few years preceding 1934.

Many of the concepts that made wireless communication possible were discovered before the First World War. During this war many new ideas evolved and considerable practical experience was gained in the use of the new ideas. A keen public appreciation of the usefulness of the transmission of intelligence over a distance without wire connection appeared at this period. In the years following the war, manufacturers began devoting time and money to the use of radio devices for many purposes. They found it necessary to obtain component parts which were new to most of them, and they needed methods for testing both the component parts and their final products.

Under these conditions the Radio Frequency Laboratories was organized in Boonton, New Jersey. The staff consisted, at first, of one radio engineer, and their work concerned the manufacture of coil forms and other radio parts using insulating material. As time passed, additional technical personnel was added and the work of general engineering consultation was undertaken. This type of work naturally led to a good understanding of test equipment requirements.

In 1934, Mr. William D. Loughlin, who had been President of Radio Frequency Laboratories, together with several of his associates, formed the Boonton Radio Corporation. The first product of the new company was a Q Meter which read Q directly on a meter scale. Up until that time the measurement of Q had been made indirectly by use of bridges for measuring the effective reactance and resistance concerned. These measurements had been subject to error because of the techniques required, and useful measurements took a great deal of time. With the new Q Meter, measurements were simple and rapid, and the instrument proved capable of many additional valuable laboratory measurements on basic components and circuits. The flexible, accurate, easily used instrument was accepted almost immediately by the growing radio industry.

By 1941 a new model, replacing the earlier Q Meter, was introduced and the Company undertook development work on a frequency-modulated signal generator to meet the requirements for test equipment which the new frequency-modulated communication equipment demanded. Commercial instruments were made available and Boonton Radio Corporation continues to this date to make several forms of frequency-modulated test signal generators.

The early years of the Second World War brought the use of higher and higher frequencies, and a Q Meter similar to the earlier models, but applicable to higher frequencies, was designed. At the same time the activities of the Company were directed more and more to military applications. Its Q Meter and Frequency Modulated Signal Generators were widely used in military work and the Company produced a pulse modulated RF signal generator for use in testing radar systems. This instrument was produced in large quantities and is still used by all military services.

At the end of the War the FM Signal Generator was redesigned to permit coverage of a wider frequency range, to include AM as well as FM, and to obtain deviations in frequency which did not vary with carrier frequency. This instrument had very low leakage and a wide selection of accurately calibrated output voltages. It soon became the standard in its field and still maintains that position.

The aircraft transportation field in the 1940's was developing more accurate methods of navigation and better methods of landing in bad weather. A system for solving these problems was approved by the Civil

Aeronautic Administration and put in use both commercially and by the military services. Unusually accurate and specialized test equipment was required by this system and Boonton Radio Corporation was asked to undertake a design. A Signal Generator for Navigation equipment was produced in 1947 and an additional piece of equipment for testing receivers used in landing airplanes came very shortly after this. In 1952 the Company produced a more advanced model of the "Glide Path" testing equipment for the landing of aircraft.

In the last few years, the Company has turned its efforts to the development of self-contained, broad-band, flexible instruments containing RF bridges for measurement of components and cables. A new instrument, the RX Meter, was introduced which measures parallel resistance and parallel reactance of two-terminal networks over the LF and VHF ranges. The low frequency and high frequency Q Meters have been redesigned to include new features which increase the usefulness and accuracy of the equipment.

Companies, like people, have characteristics which identify them. From its formation to the present time, the Boonton Radio Corporation has built products of high quality. No attempt has been made to produce cheap instruments, and the quality and usefulness per invested dollar has been kept high. Close tolerances, high stability, mechanical soundness, and broad applicability have all been built into the Company's equipment. The Company regards its products as fine general-purpose tools for electronics craftsmen.

# A Note From The Editor...

Since this is the first issue of THE NOTEBOOK, it seems appropriate to take a few lines to define the policies and purpose of our new publication. Briefly, THE NOTEBOOK has been planned and produced in order to distribute, to you and to as many interested persons as possible, information which we feel to be of value on the theory and practice of radio frequency testing and measurement.

In the past we have limited ourselves substantially to advertising, catalogs and instruction manuals for the broad distribution of such information. Inevitably, much important data was found to be too detailed for ads and catalogs; many new applications and techniques were learned or developed after publication of the instruction manuals. To provide a means, therefore, of informing you periodically of new methods and developments, and to furnish you with reference and background material of value in the application of our test equipment, THE NOTEBOOK has been established.

We feel that the name which we have selected is particularly appropriate, since much of the information which it will contain will be taken from our field and laboratory engineering notebooks, and since this and subsequent issues will, we believe, find a place in your own reference notebook. For the latter purpose, we have adopted standard notebook dimensions and punching in selecting our format.

Because the Q Meter is so well known and widely used, we have devoted most of the first issue to this instrument and the quantity which it measures. Our lead article discusses the nature of Q itself, using an approach somewhat different from the usual textbook handling of the subject. Then we have included some information on the recently-developed Q-Standard, a reference inductor designed to provide a check on Q Meter performance. A service note provides detailed information on the replacement of the thermocouple in the Q Meter Type 260-A. Finally, to introduce ourselves to you, we have included a brief outline of the history of our company.

THE NOTEBOOK will be published four times a year; in March June, September and December. A written request, giving your company, title and mailing address is enough to start you as a subscriber. If you have any suggestions, comments or questions concerning the contents or policies of THE NOTEBOOK, we would be happy to have you direct them to Editor, THE NOTEBOOK, Boonton Radio Corp., Boonton, N. J.

## ENGINEERING REPRESENTATIVES

*ALBUQUERQUE, New Mexico*
**NEELY ENTERPRISES**
107 Washington Street, S.E.
Telephone: 5-5586

*BOONTON, New Jersey*
**BOONTON RADIO CORPORATION**
Intervale Road
Telephone: Boonton 8-3200

*CHICAGO, Illinois*
**ALFRED CROSSLEY & ASSOCIATES**
4501 N. Ravenswood Avenue
Telephone: Uptown 8-1141

*DALLAS, Texas*
**EARL LIPSCOMB ASSOCIATES**
P. O. Box 8042
Telephone: Elmhurst 5345

*DAYTON, Ohio*
**ALFRED CROSSLEY & ASSOCIATES**
53 Park Avenue
Telephone: Oxmoor 3594

*HIGH POINT, North Carolina*
**BIVINS & CALDWELL**
Security Bank Building
Telephone: High Point 3672

*HOUSTON, Texas*
**EARL LIPSCOMB ASSOCIATES**
P. O. Box 6573
Telephone: Linden 9303

*LOS ANGELES, California*
**NEELY ENTERPRISES**
7422 Melrose Avenue
Telephone: Webster 3-9201

*MONTREAL, Canada*
**RCA VICTOR COMPANY, LTD.**
1001 Lenoir Street
Telephone: Wellington 7551

*NEW HAVEN, Connecticut*
**ROBERT A. WATERS, INC.**
1150 Whalley Avenue
Telephone: Fulton 7-6760

*PHOENIX, Arizona*
**NEELY ENTERPRISES**
1931 West Vermont Avenue
Telephone: Alpine 2-5290

*PITTSBURGH, Pennsylvania*
**H. E. RANSFORD COMPANY**
Grant Building
Telephone: Grant 1-1880

*ROCHESTER, New York*
**E. A. OSSMANN & ASSOC., INC.**
3 Juniper Street
Telephone: Culver 7640

*SACRAMENTO, California*
**NEELY ENTERPRISES**
1317 15th Street
Telephone: Gilbert 2-8901

*SAN DIEGO, California*
**NEELY ENTERPRISES**
1029 Rosecrans Street
Telephone: Bayview 8106

*SAN FRANCISCO, California*
**NEELY ENTERPRISES**
2830 Geary Boulevard
Telephone: Walnut 1-2361

*SARATOGA SPRINGS, New York*
**E. A. OSSMANN & ASSOC., INC.**
65 Webster Street
Telephone: Schenectady 6-5428

*ST. PAUL, Minnesota*
**ALFRED CROSSLEY & ASSOCIATES**
2388 University Avenue
Telephone: Prior 4955

*SYRACUSE, New York*
**E. A. OSSMANN & ASSOC., INC.**
308 Merritt Avenue
Telephone: Syracuse 9-3825

*WALTHAM, Massachusetts*
**ROBERT A. WATERS, INC.**
4 Gordon Street
Telephone: Waltham 5-6900

**BOONTON RADIO CORPORATION**
**BOONTON, NEW JERSEY**

***Printed in U.S.A.***

# SERVICE NOTE

P-165A

## STOCK NUMBER 165A

## THERMOCOUPLE ASSEMBLY

The thermocouple unit Stock No. 165A is a replacement for Boonton Radio Model 160A Q Meters. The thermocouple unit and associated calibrating resistor are calibrated at the factory for a particular Q Meter (indicated on the tag attached to the part) and should be installed only in that particular Q Meter.

The replacement thermocouple unit consists of:

(a) A shielded thermocouple mount
(b) An 0.04 ohm coupling resistor
(c) A thermocouple, and
(d) A shielded cable for connecting the thermocouple to the oscillator. Also included in the cable are the wires connecting the DC output from the thermocouple to the RF filter in the oscillator unit, and then to the MULTIPLY Q BY Meter.
(e) A guard plate, used for shipping, which protects the projecting thin tinned copper strip which connects to the Q Meter LO post.

### REPLACEMENT PROCEDURE

1. Remove panel from Q Meter. Remove nine screws around sides and top edge of panel. Place panel face down, preferrably on some soft material.

2. Remove oscillator shield box cover. Remove four screws on top surface of cover. Loosen three screws on outside edge and loosen three hex-headed screws on inside edge of shield box cover. Slide cover off.

3. Disconnect defective thermocouple unit. Unsolder the three wires connected to the RF Filter and oscillator output terminals within the oscillator shield box (see "interior" view of type 160A Q Meter, Fig. 4, item 26 in Instruction Manual for Q Meter , Types 100A, 160A, and 170A. NOTE: In early editions of manual see Fig. 2, item 26). Unsolder the thin tinned copper strip (leading from the thermocouple unit to the adjacent binding post) at the binding post.

**BOONTON DIVISION**
Hewlett-Packard Company

GREEN POND ROAD
ROCKAWAY, NEW JERSEY 07866
Precision Electronic Instruments since 1934

TELEPHONE: 201-627-6400 • TWX: 201-627-3912 • CABLE ADDRESS: BOONRACO

CAUTION: Use a hot iron and supply heat only long enough to free the solder to avoid overheating and possible damage to the mica insulating, the binding post, and also to the .04 ohm coupling resistor within the thermocouple unit. Care must be exercised in lifting the thin tinned copper strip from the binding post to avoid damage to this and to the .04 ohm resistor.

4. Remove the thermocouple unit from the panel by removing the two screws which secure it. These screws are accessable from the top of the panel.

5. Remove the calibrating resistor (this is located at the "Multiply Q Meter", see item 18 "interior" view).

6. Install the replacement thermocouple unit. Remove the guard plate from the replacement thermocouple unit by carefully removing the protective cardboard piece and the 6/32 binding head screws which secure the guard to the thermocouple unit.

   Secure the thermocouple unit in place in the Q-Meter with the two screws mentioned in paragraph 4. Reverse the operations mentioned in paragraph 2 and 3, using the same precautions.

   CAUTION: In soldering the thin tinned copper strip of the replacement thermocouple unit to the binding post, it is important that a slight amount of slack be left in the strip. It is also important that no part of the strip touch the nut which secures the binding post.

   CAUTION: Check the connections for correct polarity of the TC output leads to the "Multiply-Q-By-Meter". If incorrectly connected, these leads may be reversed at the meter.

7. Install the new calibrating resistor. Replace panel on cabinet.

   The Q Meter is ready for operation. No calibration of the thermocouple is necessary.

# SERVICE NOTE

P-00160-60001

STOCK NO. 00160-60001
(old No. BRC-60086)

## BINDING POST ASSEMBLY

The binding post assembly, Stock No. 00160-60001 is a replacement assembly for all BRC model 160A Q Meters.

## REPLACEMENT PROCEDURE

1. The Q Tuning unit is removed from the instrument. Facing the front of the Q unit find two screws ( on the upper left edge that secure the top plate. Remove screws. Do not attempt to remove plate until the end flaps of the copper strap are unsoldered from their stator connections. Lift plate straight up so that silver contactors will not be disturbed in their alignment.

2. Place plate on its back with " contacts " pointed up. Use 1/2 wrench on the one nut securing mica to plate. Remove nut and washer. Then using a heavy soldering iron running quite hot, quickly unsolder strap from binding posts. Apply high heat for a short period so that protective coating on mica is not injured. Then with copper strip off drop mica from plate.

3. Leave plate in same position and insert new terminal plate. It is imperative that the untinned binding post be used to secure the mica to the top plate. The remaining binding posts are tinned and should occupy the relative positions shown in Figure #1.

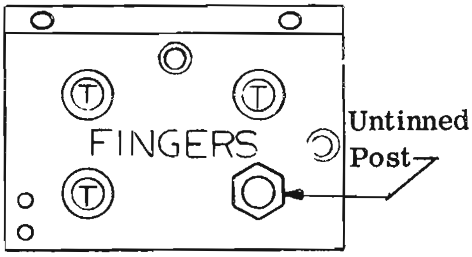


Figure #1

4. Solder copper strap across the two top posts that are pre-tinned for ease in doing this operation. At this point the capacitor is ready for re-assembly by reversing the foregoing procedure.

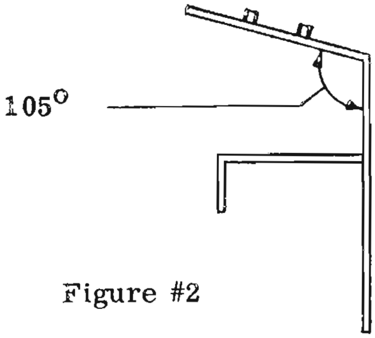


Figure #2

5. Special care should be taken so that the six silver fingers are in good contact with the disc on the capacitor rotor. An angle of 105 degrees should be maintained between front of capacitor and top plate as shown in Figure #2 above.

CAUTION: Do not handle mica with fingers. Use cotton gloves or tweezers.