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Circuit Effects On Q

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The Q of a practical simple resonant circuit is always lower than that of the component coil or capacitor because of additional losses in the circuit which often appear quite unexpectedly. In a measuring circuit, as used in a Q Meter, small internal losses are always present, whose significance is often not fully realized. Under the general heading of circuit effects on Q, this article points out how the loading accumulates in some practical circuits and examines the appreciable effect of residual parameters in Q Meter circuits on Q-readings obtained. Due to the effect of differences in residual parameters, Q-readings of the same coil but from different Q Meters may differ. Correlation of results between the low frequency Q Meter Type 260-A and the high frequency Q Meter Type 190-A in overlapping ranges is presented.

About Simple Resonant Circuits

A few assertions will be made about the simple resonant circuit to serve as a starting point for later discussion.

For a reactive component, either capacitive or inductive, if the Q is greater than 10, the following transformation is valid as shown in Figure 1.

$$X_s = X_p = X$$

$$Q = \frac{X_s}{R_s} = \frac{R_p}{X_p} \quad \text{i.e.} \quad R_sR_p = X^2$$

It is customary to talk about shunt loss or series loss in either a coil or a capacitor. But as long as either of them is considered as a two terminal component, it is simply an impedance and can be expressed either in the series or the shunt form as shown above. The following transformation illustrates this, $Q > 10$ being assumed:

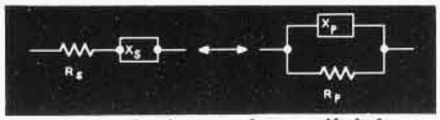

Figure 1. Series and parallel forms of impedance.

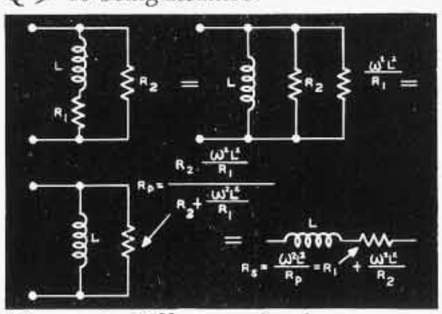

Figure 2. Different circuit representations for a coil.

The extent to which any change of loss affects the Q depends upon the loss already present. A resonant circuit of reactance X and quality factor Q has

$$R_s = \text{series resistance} = \frac{X}{Q}$$

$$R_p = \text{shunt resistance} = QX$$

Consider a 250μh coil which resonates with about 100$\mu\mu$f at 1 mc. Assume Q of the whole circuit is 320.

$$X = \omega L = \frac{1}{\omega C} = 1600\ \Omega$$

$$\therefore \quad R_s = \frac{1600}{320} = 5\ \Omega$$

$$R_p = 320 \times 1600 = 512{,}000\ \Omega$$

From these figures, it can be reasoned, for example, that any change of 0.02Ω in series resistance would be of little consequence but any additional shunt load of 5 megohms would have appreciable effect.

If a certain Q value is implicitly assumed, then the magnitude of X is itself an indication of impedance level, which is

$$R_s = \frac{X}{Q}$$

in the series case and

$$R_p = QX$$

in the parallel case. Thus at a fixed frequency, low resonating capacitance means a high impedance level. Consequently, at a low C, a shunt loss will have a great effect on Q while the effect of an additional series loss will be negligible.

Considerations In Practical Circuits

Taking the view point of a simple resonant circuit, the following circuit aspects will be examined to see how the circuit loss accrues and how circuit Q is affected:

1. *Single tuned interstage coupling circuit:*

For a narrow band or a single frequency amplifier, a special form of impedance coupling is a parallel tuned circuit as shown in Figure 3. When the coupling capacitor C_c is large enough so that its reactance is negligible, (this is the usual case), then the interstage circuit has only two terminals and is in fact a simple resonant circuit in parallel form. The resulting Q of the circuit is of interest because it concerns not only the stage gain but also the passband or frequency selective characteristics. Usually, the circuit Q is much lower than the combined Q of the coil and tuning capacitor C because there are several other losses involved.

a. *r_p of the first stage:* Expressed in equivalent circuit form, the first stage becomes a current source of $g_m e_g$ with r_p, the plate resistance of the tube, as a shunt load across the resonant circuit. Therefore, a pentode is almost always

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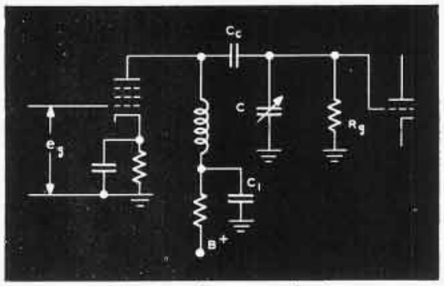

Figure 3. Single tuned interstage coupling circuit.

used as the first tube since its higher r_p means less loading.

b. *Input loading of the following stage:* Vacuum tube input impedance is generally considered high, but relative to the impedance of a parallel resonant circuit, the contrary is more often the case especially at higher frequencies.

c. *Stray capacitances with associated losses:* This could be important if the stray capacitance is an appreciable part of the total resonating capacitance. To keep Q high, the metal parts with which the stray capacitance is associated should be well grounded and dielectrics involved should have low loss.

d. *Grid resistor R_g loading on the resonant circuit:*

e. *Loss due to B+ feeding circuit:* As shown in Figure 3, the decoupling capacitor C_1 may introduce some series loss into the coil. And if parallel feed through a choke is used, a shunt load is added.

If R_p is the final equivalent shunt losses of the whole circuit, including losses of coil and capacitor, then

$$Q = \frac{R_p}{\omega L}$$

and the input voltage to the next stage will be $g_m e_g R_p$.

2. Feeding a parallel resonant circuit by a signal generator:

When a signal generator like BRC Sweep Signal Generator Type 240-A is used to feed a parallel resonant circuit, care must be taken so that the output impedance of the generator does not unduly affect the Q of the circuit. The output impedance of a signal generator is generally 50 ohms, which is much too low to be connected directly across the resonant circuit. (Also too high to be used for series feeding the resonant circuit). The usual practice is to increase the output impedance by inserting a high series resistor, R, in series with the signal generator. This resistor, R, should be high relative to the tuned impedance ($R_p = Q\omega L$), because $R+50$ is indeed loading the circuit. Any detector connected across the resonant circuit, of course, is an additional load.

Similar considerations hold when the cathode output of a tube is used to feed a resonant circuit.

3. Physical aspects of components in a circuit:

What is under consideration here is the change that is involved when a component is physically connected into a circuit. When, for example, a coil is shunted across a capacitor, in an idealized circuit analysis, this means nothing more than putting two symbols together. But actually, changes are involved in two general aspects: (1) due to proximity of two components, change of both inductance and capacitance is possible; (2) the physical connecting link, perhaps a copper strap, may have an effect on circuit performance which cannot be ignored. This kind of critical consideration primarily arises in problems of measurement, but in practical circuits stray capacitance and lead inductance mean practically the same thing. This situation becomes more important as the use of lumped constant circuit elements is extended to higher frequencies where coils become small and series impedances very low. A $0.1\mu h$ coil at 50 mc has a reactance of about 32Ω. A Q of 320 means a series resistance of $32/320 = 0.1\Omega$. If at such a low impedance level, the contact resistance of a plug-in connection is of the order of a milliohm, it will show an appreciable effect on the Q of the coil. When this same coil is measured on a Q Meter, a poor connection will lead to a jitter in the Q reading or wide variations of results.

4. Circuit Q and Effective Q:

Why does a coil of Q = 300 measure only 280, for example, on the Q Meter? Why do different types of Q Meters sometimes give different readings for the same coil? These are the questions to be clarified here.

The coil:

Consider a coil expressed in a series form with inductance L and resistance R_s; i.e., a two-terminal element of impedance $Z = R_s + j\omega L$. It has a quality factor of

$$Q = \frac{\omega L}{R_s}.$$

The Q and Z are primarily characteristics of the coil alone. But when the coil is connected into a circuit, the proximity effect can change the distributed capacitance and create mutual inductance. Hence, it should be realized that strictly speaking an impedance, hence its Q, is not completely defined until the way it is connected into a circuit is specified.

The measuring circuit:

The Q Meter measuring circuit consists of a signal source, a variable tuning capacitor, and a voltmeter. Ideally with the coil connected, the circuit should be as shown in Figure 4a, but actually the circuit for the Q Meter Type 260-A should be represented as in Figure 4b. (For Q Meter Type 190-A, see its Manual). These spurious elements that are unavoidably introduced are known as residuals — residual inductance and residual shunt or series losses.

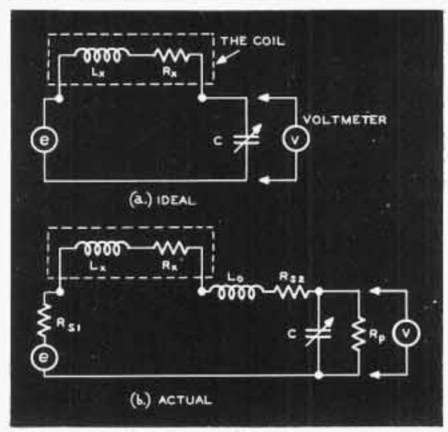

Figure 4. Q Meter circuit.

R_{s1} is due to the oscillator injection circuit.

R_{s2} includes series resistance of binding posts, connecting straps, etc.

L_o is the residual inductance of binding posts and connecting straps.

R_p includes the voltmeter input resistance, the 100 megohm grid resistor and other dielectric losses across the capacitor.

The Q Meter is designed to read the Q of the whole circuit. The reactance is now $L_o + L_x$ instead of L_x and internal losses are added. The resulting Q is of course not the same as the Q of the coil. Recognizing the effect of the internal losses, two kinds of Q are defined: (a) *Circuit Q:* Q of the whole Q measuring circuit including losses of the coil, all the internal residual losses and the effect of the residual inductance. (b) *Effective Q:* Q of the coil itself as mounted on the Q Meter used (proximity effect included). In many but not in all cases, circuit Q is essentially equal to effective Q.

The term *indicated* Q is often used; this refers to the circuit Q as indicated by the Q Meter which is designed to indicate circuit Q. This means that the difference between *indicated* and *circuit* Q is strictly a matter of the accuracy of the Q Meter. If accuracy of the Q Meter is not in question, *indicated* and *circuit* Q mean the same thing.

Now, circuit Q depends on coil loss as well as internal losses. Therefore, as internal losses may differ among different Q Meters, either of the same type or of different types, the circuit Q measured on different Q Meters will differ from each other even if the coil measured is the same one. This difference is usually small, especially if the Q Meters used are of the same type. But in the overlapping ranges (20—50 mc) of the 260-A and 190-A Q Meters, it can be as much as 50% in some unusual cases. This may seem startling but as explained in the next section, this difference can be completely accounted for by the difference in residuals, which are much lower in the 190-A Q Meter since it is designed to cover a higher frequency range.

Correlation of 190-A and 260-A Q Meters in Overlapping Frequency Ranges

When the residual parameters in a Q Meter are all known, correction can be made on the circuit Q to allow for the effects of the residuals and thus obtain the effective Q by computation. The effective Q readings for the same coil as computed from the circuit Q in different Q Meters should be the same, except for a possible difference due to the difference in proximity effects and contact resistance. When proper care is taken, this difference should be very small.

In the overlapping ranges (20—50 mc) both Type 190-A and 260-A Q Meters can be represented by the circuit shown in Figure 5a, which can be transformed into Figure 5b and 5c. (A more refined circuit for the 190-A Q Meter is given in its Manual).

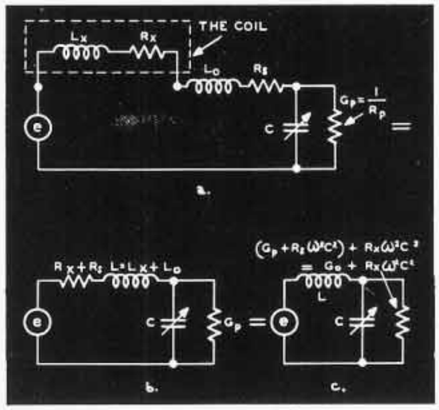

Figure 5. Q Meter equivalent circuits.

where

L_x, R_x = inductance and resistance of coil

L_o = total internal residual inductance

R_s = total internal series resistance

$$G_p = \frac{1}{R_p} = \text{total internal shunt conductance.}$$

$G_o = G_p + R_s\omega^2C^2$ = total internal loss expressed as shunt conductance.

The correlation of the two Q readings of the same coil in Type 260-A and 190-A Q Meters will be demonstrated by comparing the results of effective Q computed in each case from the indicated Q readings. The indicated Q will be taken the same as circuit Q; i.e., each Q Meter is assumed to have perfect accuracy. To get effective Q, the correction has two parts; (A) for residual inductance, (B) for residual losses.

A. Correction for residual inductance: Here the reactance of the coil itself will be computed.

$$L_x = L - L_o$$

$$\omega L_x = \omega L - \omega L_o$$

$$\text{since } \omega L = \frac{1}{\omega C} \text{ at resonance}$$

$$\omega L_x = \frac{1}{\omega C} - \omega L_o$$

$$= \frac{1}{\omega C}(1 - \omega^2 L_o C)$$

$$= \frac{1}{\omega C}\left[1 - \omega^2(L_o+L_x)C\frac{L_o}{L_o+L_x}\right]$$

$$= \frac{1}{\omega C}\left(1 - \frac{L_o}{L_o+L_x}\right)$$

$$\text{since } \omega^2(L_o+L_x)C = \omega^2 LC = 1$$

The equivalent capacitance that will resonate with L_x is

$$C_x = \frac{1}{\omega^2 L_x} = \frac{C}{1-\omega^2 L_o C}$$

$$= \frac{C}{1 - \dfrac{L_o}{L_o+L_x}}$$

$$L_o = \begin{cases} 0.015 \ \mu h \text{ in 260-A Q-Meter} \\ 0.0026 \ \mu h \text{ in 190-A Q-Meter} \end{cases}$$

At 50 mc, 100 $\mu\mu f$ is in resonance with 0.1μh. Evidently, L_o in 260-A Q Meter becomes appreciable then.

B. Correction for residual losses.

Q_i = circuit Q = indicated Q (Perfect Q Meter accuracy assumed)

Q_e = effective Q

$$Q_i = \frac{\omega C}{G_o + R_x\omega^2C^2}$$

$$Q_e = \frac{1}{R_x\omega C_x} = \frac{1-\omega^2 L_o C}{R_x \omega C}$$

Q_i, G_o, ω, C and L_o are known quantities. Q_e can be computed by eliminating R_x between equations for Q_i and Q_e above. So the computation for Q_e is straightforward in principle and does not require discussion. The method outlined is only to minimize the work of computation and also give an indication as to the relative weight of different parameters and their interrelation.

Steps to compute Q_e will be given below with a derivation outlined later. Due to difference in expressions for shunt loss, the 260-A and 190-A Q Meters have to be treated separately:

1. For the 260-A Q Meter:

a.) Compute C_x from $C_x = \dfrac{C}{1-\omega^2 L_o C}$

b.) Find α from α vs C^2 graph (Figure 6)

c.) Correct α to get $\alpha' = \alpha + \dfrac{1}{3}\left(\dfrac{250}{Q_i} - 1\right)$, if this appears significant.

d.) Compute γ by $\gamma = 0.00114\dfrac{Q_i f_{mc}}{C\mu\mu f}\alpha'$

e.) Obtain Q_e by $Q_e = \dfrac{C}{C_x} \bullet \dfrac{1}{1-\gamma} Q_i$

where α

$$\alpha = \frac{\text{equivalent shunt loss due to residual series resistance}}{\text{actual internal shunt loss}} + 1$$

γ = Total internal loss as a fraction of total circuit loss

So α shows the relative importance of shunt and series residual losses.

And if $\gamma = 0.10$, it means 10% of the total circuit loss is not due to the coil measured but due to the internal loss of the Q Meter. The effective Q should therefore be higher than the circuit Q by the factor

$$\frac{1}{1-\gamma} = \frac{1}{1-0.1} = 1.11$$

The $\frac{C}{C_x}$ factor in $Q_e = \frac{C}{C_x} \bullet \frac{1}{1-\gamma} Q_i$ takes care of the effect due to residual inductance. When frequency and capacitance are changed, the resulting effect on γ, i.e., on the difference between effective Q and circuit Q can be easily estimated from the expression

$$\gamma = 0.00114 \frac{Q_i f_{mc}}{C\mu\mu f} \alpha'$$

together with the α vs C^2 graph.

The α to α' correction refers to level effect not discussed so far. In the 260-A Q Meter, at a frequency above 20 mc, the voltmeter loading increases as the signal level (i.e., the Q reading) decreases. The given correction for α is good for $Q_i > 100$.

2. For the 190-A Q Meter.

a.) Compute C_x from $C_x = \frac{C}{1-\omega^2 L_o C}$

b.) Find β from β vs C^2 graph (Figure 7)

c.) Compute η by $\eta = \frac{0.00573\, Q_i}{C\mu\mu f} \beta$

d.) Obtain Q_e by $Q_e = \frac{C}{C_x} \bullet \frac{1}{1-\eta} Q_i$

where the physical meaning of β and η correspond respectively to those of α and γ.

Outline of derivation of above relations (for 260-A Q Meter):

$$\gamma = \frac{G_o}{G_t} = \frac{G_p + R_x\omega^2 C^2}{\frac{\omega C}{Q_i}}$$

$$= \frac{Q_i G_p}{\omega C}\left(1 + \frac{R_x \omega^2 C^2}{G_p}\right)$$

$$\alpha = \frac{R_x \omega^2 C^2}{G_p} + 1, \quad G_p = kf^2$$

$$\therefore \gamma = \frac{Q_i\, fk}{2\pi C} \alpha = 0.00114 \frac{Q_i f_{mc}}{C_{\mu\mu f}} \alpha$$

$$Q_e = \frac{1}{R_x \omega C_x}$$

$$G_t = G_o + R_x \omega^2 C^2$$

Eliminate R_x between Q_e and G_t.

$$Q_e = \frac{\omega^2 C^2}{G_t - G_o} \bullet \frac{1}{\omega C_x}$$

$$= \frac{C}{C_x} \bullet \frac{1}{1 - \frac{G_o}{G_t}} \bullet \frac{\omega C}{G_t}$$

$$= \frac{C}{C_x} \bullet \frac{1}{1-\gamma} Q_i$$

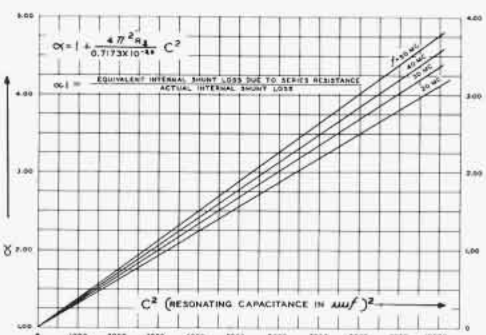

***Figure 6.** α versus C^2 graph for Q Meter Type 260-A.*

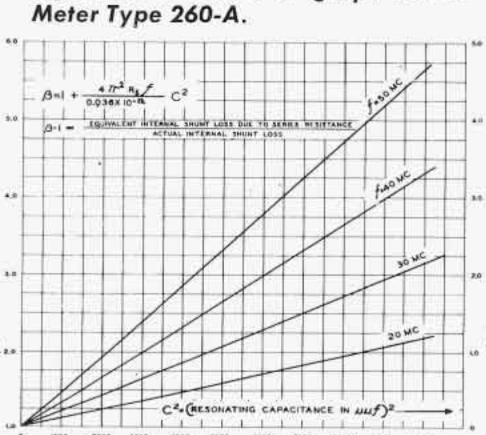

***Figure 7.** β versus C^2 graph for Q Meter Type 190-A.*

Example: Computation of Q_e from measured data of a 0.1 μh Coil at 50 mc.

260-A Q Meter		190-A Q Meter	
Measured data:			
C	91.5 $\mu\mu f$	C	100.5 $\mu\mu f$
Q_i	187	Q_i	301
To get C_x:			
L_o	0.015 μh	L_o	0.0026 μh
$\omega^2 L_o C$	0.135	$\omega^2 L_o C$	0.0258
$\frac{C_x}{C} = \frac{1}{1-\omega^2 L_o C}$	1.16	$\frac{C_x}{C} = \frac{1}{1-\omega^2 L_o C}$	1.026
C_x	106	C_x	103.1
To get Q_e			
C^2	8380	C^2	10100
α from α vs C^2 graph	4.15	β from β vs C^2 graph	5.70
Correction for α $\frac{1}{3}\left(\frac{250}{Q_i} - 1\right)$	0.113	———	
$\alpha' = \alpha + \frac{1}{3}\left(\frac{250}{Q_i} - 1\right)$	4.263	———	
$\gamma = 0.00114 \frac{Q_i f_{mc}}{C\mu\mu f} \alpha'$	0.4957	$\eta = \frac{0.00573\, Q_i}{C\mu\mu f} \beta$	0.0979
$Q_e = \frac{C}{C_x} \bullet \frac{1}{1-\gamma} Q_i$	320	$Q_e = \frac{C}{C_x} \bullet \frac{1}{1-\eta} Q_i$	326

Measurement of Dielectric Materials and Hi Q Capacitors with the Q Meter

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Figure 1. The author measuring the dissipation factor of Teflon.

Dissipation Factor of Insulating Material

A considerable amount of material has been published on this subject by many experts in this field describing the various techniques and the precautions to be observed in making measurements. From our own field work with companies involved in these measurements, we have come to realize the need of methods for use where the expediency required for process control work can be obtained at some possible sacrifice in accuracy by eliminating specially-developed specimen holders, guard rings, etc. It is in this sense that we offer the following suggestions for making measurements of this nature.

To review the overall operation very briefly, let it suffice to say the sample to be measured will be converted into a capacitor by adding suitable electrodes to the two parallel surfaces, and measurements made of its equivalent parallel capacity (C_p) and resistance (R_p). From these two parameters, the Dissipation factor

$$D = \frac{1}{Q} = \frac{1}{\omega C_p R_p}$$

can be determined. The whole operation can be resolved into a sequence of logical steps, with the necessary precautions, described below:

Operating Procedure

The ground plate and clip shown in Fig. 2 have been used with very satisfactory results. Prepare a plate and clip as shown and install on the Q Meter (see Figure 1).

Select the desired frequency and allow the Q Meter to warm up. Use a shielded coil whose inductance is such that it will resonate at the desired frequency with the Q Capacitor set at approximately 50 $\mu\mu$f. It is desirable to use the least possible amount of capacitance to resonate the coil since any dielectric specimen loss added to the circuit later will be more conspicuous when paralleled across a low capacity (high impedance) than a high capacity (low impedance). In any case, the lowest capacity that can be used will equal the sum of the sample capacity plus the minimum capacity (30 $\mu\mu$f) of the Q Meter internal resonating capacitor.

Selection and Preparation of Samples

Inasmuch as the ratio of loss and capacitance vary uniformly, there is quite a latitude in the choice of sample size. Very often either a 2″ diameter, 1/8″ thick, round disc, or a 4″ x 4″ square sample is chosen. It is of some advantage to use a configuration whose area can be readily computed if the dielectric constant is to be measured. In any case, increasing the area or decreasing the thickness will tend to increase the measurable "lossiness" which is desirable when measuring materials having very low dissipation factors. The sample should be clean and handling of the *edges* should be avoided to preclude the possibility of any contamination. Apply a very thin layer of Petrolatum and add aluminum or soft lead foils cut to sample size to both sides of the sample. Be sure to "roll out" any air pockets so that intimate contact is made at all points. It is also possible to employ commercially available conductive coatings which can be painted or "vacuum evaporated" on the sample.

Measurements with Sample Connected

With the ground plate secured to the case of the Q Meter and connected to "Lo" Capacitor post, mount the specimen on the plate and hold in position with the spring clip connected to the "Hi" Capacitor post. After having adjusted the "Q Zero adjust" knob, increase the oscillator output control until the "Multiply-Q-By" Meter indicates "1". Be sure this needle is at this point during all measurements. Rotate the Q Capacitor to obtain resonance as indicated by a maximum deflection on the "Circuit Q" meter. If the main condenser is set at the nearest calibration on the dial and the vernier condenser adjusted for resonance, a much closer reading can be made of capacitance. Make a record of Q_2 and C_2 at this point. (These readings are designated as Q_2 and C_2 since in Q Meter measurements they are usually recorded as the second reading). The procedure has been reversed here since specimens can be removed faster than they can be mounted and it is desirable to minimize the elapsed time between readings.

Those using a 190-A or 260-A Meter will want to take advantage of the "Delta Q" scale on the instrument. Inasmuch as the Q_1 reading will be higher than the Q_2 reading just made, the "Delta Q" adjustment will not be referenced to zero but to some other convenient point on the scale. It is also very advantageous to hold the "Delta Q" key in its operated position long enough to take advantage of the increased meter sensitivity and refine the circuit tuning as needed. The reference point finally chosen should be recorded.

Measurements with Sample Removed

Remove sample and Spring Clip Connector and resonate the circuit as above. Operate "Delta Q" key when *at resonance* and refine tuning with vernier. Read "Delta Q" value first and then the value of C_1. Q_1 will be equal to Q_2 *plus* the change (neglecting sign) in "Delta Q" reading. The needle, when in "Delta Q" operation, should always move to the right when going from the Q_2 reading (with sample) to the Q_1 reading (without sample). For those using older type Q Meters that do not have the Delta Q scale, it will be necessary to read Q_1 from the meter and compute the change.

Calculation of Dissipation Factor

The dissipation, D, is found to be:

$$D = \frac{C_1 (Q_1 - Q_2)}{(C_1 - C_2)\, Q_1 Q_2} \qquad (1)$$

And of course $Q_1 = Q_2 +$ "Delta Q" when the "Delta Q" scale is used.

Examination of the above formula emphasizes the importance of determining the $(Q_1 - Q_2)$ or "Delta Q" term as accurately as possible, since the measurement accuracy is in the same order as the determination accuracy of this term.

Example of Technique

As a means of illustrating the technique, the following measurements were were made at 1 mc on a piece of Teflon, 2″ in diameter and 0.077″ thick.

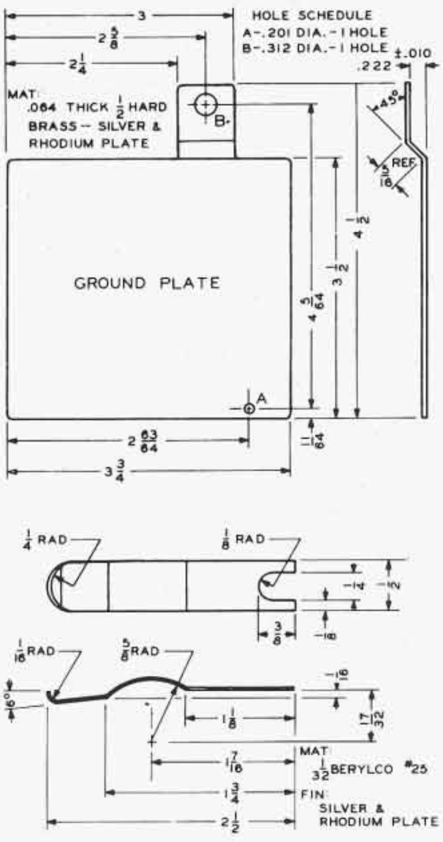

Figure 2. Details of dielectric test fixtures for Type 160-A and 260-A Q Meters.

With Sample Attached:

$C_2 = 73.0$ main condenser, and 0.12 for vernier condenser; total $= 73.12 \mu\mu f$

$Q_2 = 232$

"Delta Q" set at 25

Remove Sample:

"Delta Q" reading $= 21.2$

$\Delta Q = 25 - 21.2 = 3.8$

$C_1 = 93$ main condenser and 0.6 for vernier condenser; total $= 93.6$

$Q_1 = Q_2 +$ "Delta Q" $=$
$232 + 3.8 = 235.8$

Computations:

$$D = \frac{C_1 (Q_1 - Q_2)}{(C_1 - C_2)\, Q_1 Q_2}$$

$$= \frac{C_1 (\text{Delta } Q)}{(C_1 - C_2)\, Q_1 Q_2}$$

$$= \frac{93.6 \times 3.8}{20.48 \times 235.8 \times 232}$$

$$= \frac{3.56 \times 10^2}{1.12 \times 10^6}$$

$= .000318$ dissipation factor.

It might be worth noting that as the insulating properties of the materials tested become better, the quantity $(Q_1 - Q_2)$, called "Delta Q", becomes smaller to the extent that the use of the "Delta Q" scale, incorporated in both the 190-A and 260-A Q Meters, becomes mandatory.

Dielectric Constant

The dielectric constant, K, can be found from

$$K = \frac{4.45\, C_x t}{S} \qquad (2)$$

Where:

C_x = Sample capacity $= C_1 - C_2$ (from above)

t = average thickness of material in inches

S = area of active dielectric material between electrodes in square inches

Using the values determined above, the dielectric constant of the sample is:

$$K = \frac{4.45 \times 20.48 \times .077}{\pi}$$

$= 2.28$ for the sample tested.

If S and t are measured in centimeters

$$K = \frac{11.3\, C_x t}{S} \qquad (3)$$

Use of the Hartshorne Holder

Specimens of suitable size and thickness can be mounted in a Hartshorne type holder and measured in three ways:

1. "Resonant Circuit, Resonance Rise Method": This is similar to the technique shown above but refined to the extent of mounting the specimen in a Hartshorne Specimen Holder.

2. "Variable Susceptance Method with Air Gap": Here the specimen is mounted in a Hartshorne Holder and an Air Gap of 0.005″ to 0.050″ is introduced above the surface of the specimen. This method has been found suitable for measurements from 10 kc up to 100 mc.

3. "Variable Susceptance Method without Air Gap": This method, similar to the above except that the specimen is clamped in the holder instead of allowing an air gap, is employed for materials whose losses are too small to be measured by the air gap technique.

Boonton Radio Corporation Drawing Number C-302252 gives the specifications for the adapter plate used to mount the General Radio Type 1690-A Hartshorne Holder to any BRC Q Meter and is available upon request.

Measurements can also be made of insulating liquids with the provision of a suitable cell or container.

SOME NOTES ON INSTRUMENT REPAIR

One of the responsibilities of a manufacturer of precision electronic instruments is to provide facilities for repairing and maintaining his products. In a sense this responsibility begins in the development and design stages of an instrument's history for it is in this stage that proper design will minimize the need for later repair. Also at this stage arrangements which facilitate later repair can be made.

Boonton Radio Corporation operates a factory repair facility and also has authorized repair of its instruments by competent groups operated by its Representatives throughout this country and Canada. When your instrument requires repair, contact the office nearest to you, included in the list on the back page of this issue.

When your instrument is to be returned to the factory for service the following steps will expedite the repair.

1. State as completely as possible both on an instrument tag as well as on your order the nature of the problem which you have experienced. Too much information is far better

Inspector aligning the RF section of Signal Generator Type 211-A to track with the frequency dial.

than too little. If the problem is intermittent in nature be very specific. We sometimes have instruments with this type of trouble which refuse to misbehave for us.

2. State on your order whether we may proceed and bill you in accordance with our standard pricing system or whether you require that we secure your approval of the price before proceeding. The price will be the same in both cases but delay in delivery will be minimized by your permission to proceed in accordance with our standard system. Your acknowledgement copy of the order will always show the price.
3. Return the complete instrument even though you may think that some portion is not at fault. Some of our Signal Generators consist of two units (the power supply and signal generator); send both.
4. If you have made a change in your instrument and want the instrument back in the same form tell us so. Our Inspection Department will always want to make your instrument standard.

Some of our instruments have been in production for several years and we have built up a reasonable amount of repair history. For these instruments we have established standard prices based on our average experience. These prices are based on the age and condition of the instrument. Thus all instruments in a given age bracket in average condition for that age will be priced at one of our standard prices. These prices are studied and modified at the end of each year. This system saves you money and time since it avoids the necessity of a cost analysis on each individual repair.

A good repair facility requires good communication between customer and factory. If you have justified abnormal requirements for quick return of your instrument let us know. We will do our very best to accommodate you. Ask only if you have a real need. If everybody asks we cannot improve our speed for anybody.

Correction of Low Q Reading On Q Meter Type 160-A

SAMUEL WALTERS, *Editor, The Notebook*

Occasionally the mica plate which supports the measuring terminals on top of the Q Meter Type 160-A must be replaced because of surface contamination or cracking of the surface which breaks the moisture-proofing compound. The resultant rf leakage from the HI post measuring terminal to ground effectively adds a shunt resistance across the circuit under test causing a low Indicated Q reading. Sometimes the rupture or contamination is not visually apparent although just as electrically defective as the obvious case. However, the mica terminal insulator should not as a matter of course be changed when abnormally low Indicated Q readings are observed since there are three other conditions that will cause shunt losses and excessive loading of the circuit under test. These other conditions are:

1. Cracked mica internal resonating capacitor stator insulators (in later Q Meters pyrex glass was used which rarely causes trouble).
2. Defective Q voltmeter tube (105-A).
3. Grid leak associated with 105-A (100 megohm resistor) in deteriorated condition.

Before proceeding to isolate the condition causing the shunt loss, one must first determine whether the low Q readings are due to shunt losses or some other cause. This can quickly be determined with the use of the Q Standard Type 513-A*, a shielded reference inductor designed to maintain accurately calibrated and highly stable inductance and Q characteristics. Assuming shunt losses are indicated, we proceed to the next step: the isolation of the condition causing the shunt loss.

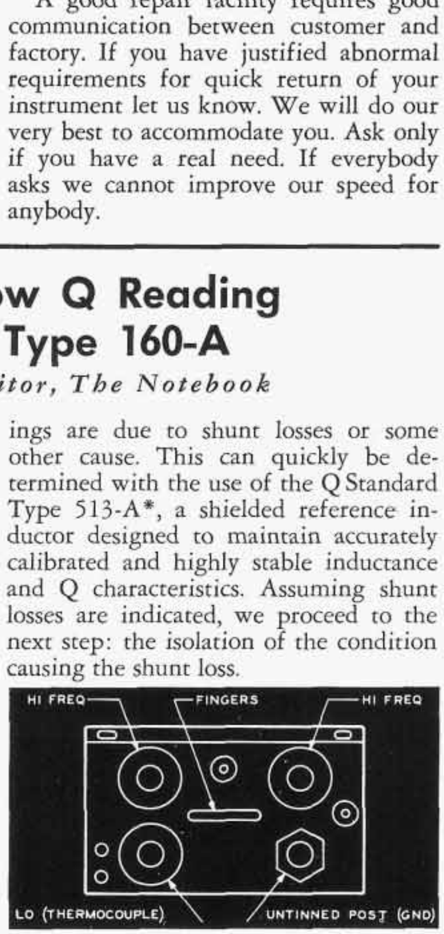

Figure 1. Bottom View: Binding post plate assembly — Q Meter Type 160-A.

Determination of Shunt Loss

The procedure is as follows:

a) Position the Q Meter to be tested (Q Meter A) three inches to the rear of another Type 160-A Q Meter (Q Meter B used as an indicating unit). Both Q Meters are to face the operator.

b) Connect a Type 103-A22 Inductor to the COIL terminals of Q Meter B. Interconnect the GND terminals of the two Q Meters by means of a 15 inch length of No. 18 stranded copper wire. Suspend a 17 inch length of No. 20 or No. 18 bare tinned copper wire (single strand) from the HI-COND terminal post of Q Meter B so that the free end of this lead points directly down toward, and is one inch removed from, the HI-COND terminal post of Q Meter A. This lead should be positioned as far as possible from other objects.

c) Apply ac power to both Q Meters.

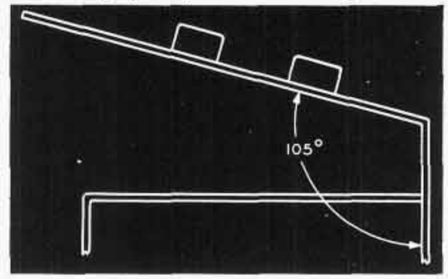

Figure 2. Angle of alignment of wiper fingers.

d) Adjust Q Meter A for oscillator frequency of approximately 800 kc and a Multi-Q-By reading of approximately 1.2. Adjust vtvm zero in usual manner and adjust capacitance dial to 30 $\mu\mu$f.

e) Adjust Q Meter B to read the Q of the Type 103-A22 Inductor at tuning capacitance dial reading of 70 $\mu\mu$f and an oscillator frequency of approximately 1.13 mc so that the Indicated Q reading should fall between 221-235. Note the exact value of this reading as Q_1[§].

f) Now interconnect the COND-HI terminal posts of the two Q Meters by inserting the tip of the suspended bare lead into the corresponding terminal hole of Q Meter A. Resonate Q Meter B by adjusting its capacitance dial. Note the new Q reading on Q Meter B as Q_2.

g) If $Q_1 - Q_2 = 14$ or less the cause of faulty Q Meter "A" Q reading probably lies elsewhere than in the internal Q measuring circuit.

h) If $Q_1 - Q_2$ exceeds 14 proceed as follows to more specifically locate the cause of excessive errors in Q reading. Turn ac power off Q Meter A. Disconnect grid connector clip from 105-A tube grid cap in Q Meter A, allowing grid lead from Q-unit to hang in space. With the two Q Meters interconnected as for reading Q_2 (see (f) above), but with the ac power still turned off Q Meter A, resonate Q Meter B by adjusting its capacitance dial. Note Q Meter B Q reading as Q_3.

i) If $Q_3 - Q_2$ exceeds 8, voltmeter tube 105-A should be replaced as defective.

j) If $Q_1 - Q_3$ exceeds 6, excessive

Q-unit ΔQ is indicated. Correction usually lies in replacement of binding post mica terminal insulator. In rare instances the trouble may lie occasionally in the Q capacitor stator insulators or in the 100 megohm grid resistor; extension of the above procedure will quickly indict the faulty component. Both components have a ΔQ of 2.

Replacement of Mica Terminal Insulator

The replacement of the mica terminal insulator is a relatively simple procedure. However, this procedure must be followed to avoid damage to the thermocouple and expedite the mica plate's removal and replacement.

1. Unscrew knurled knobs from gold plated binding posts.
2. Remove thermocouple mounting screws.
3. Unsolder thermocouple connecting strip from LO post using hot iron. (Prolonged heat will damage the 0.04 ohm resistor in the thermocouple. This is the main reason for removing knurled knob from binding post first).
4. Remove fiducial, main Q and Vernier dials.
5. Remove 2 top screws and 4 Internal Resonating Capacitor mounting screws located under dials. The Internal Resonating Capacitor can now be removed from the instrument. Facing the front of this capacitor are 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.

Place plate on its back with "contacts" sticking up. Use ½" wrench on the one nut securing mica to plate. Remove nut and washer. After unsoldering copper strip, drop mica from plate.

Leave plate in same position and insert new mica terminal insulator. It is important 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. 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.

Special care should be taken so that the six silver fingers are in good contact with the disc on the condenser rotor. An angle of 105 degrees must exist between front of condenser and top plate as illustrated in Figure 2.

There is one precaution in this operation: do not handle mica with fingers if possible. Use cotton gloves or tweezers.

* See *"The Q Standard — A New Reference Inductor for Checking Q Meter Performance" by Chi Lung Kang and James Wachter, Spring 1954, issue No. 1, of The Notebook.*

§ *If the Q reading is above or below this range the limits in described procedure do not apply. However, the general procedure can be used.*

NOTE FROM THE EDITOR

On September 19, 1955, Boonton Radio Corporation became the 56th recipient of the Bureau of Engineering and Safety Award. Sponsored by the Department of Labor and Industry in cooperation with the New Jersey State Industrial Safety Committee, the Award was established some years ago as part of a statewide accident prevention program.

Dr. George A. Downsbrough (right), president and general manager of Boonton Radio Corporation, shown accepting Safety Award from C. George Kruger, deputy director, division of labor of the State of New Jersey.

The goal of this year's effort is a 15% reduction in industrial accidents.

Boonton Radio Corporation was honored on the basis of its "very enviable record" of having worked the period from December, 1952 through April, 1955 with no lost time accidents and for its safety practices which produced this result.

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