



The NOTEBOOK

BOONTON RADIO CORPORATION · BOONTON, NEW JERSEY

JAN 26 1955

A Versatile Instrument - THE Q METER

What Can Be Done With a Q Meter - Besides Measure Q

LAWRENCE O. COOK, *Quality Control Engineer*

Lawrence Cook became associated with BRC in 1935, shortly after the company's founding. He started as an Electrical Inspector at the time the original Q Meter was being produced. Since then his activities have followed closely the development of subsequent Q Meter Models. Mr. Cook was graduated from Bliss Electrical School in Washington D.C. and was employed by Sparks-Withington Co. prior to BRC. He is an associate member of I.R.E. and a member of the Radio Club of America.

INTRODUCTION

A Q Meter contains in one instrument a frequency-calibrated RF oscillator, a system for RF voltage injection and measurement, a vacuum tube voltmeter, a calibrated variable capacitor, and four terminals for the connection of components to be measured. All of these elements (but two terminals) are

employed in measuring the Q of a coil, the normal connections being shown in Figure 1. But these elements, in part or in combination, may be employed in the performance of various other functions. It is the purpose of this article to describe some of these applications of the versatile Q Meter.

CAPACITANCE MEASUREMENT

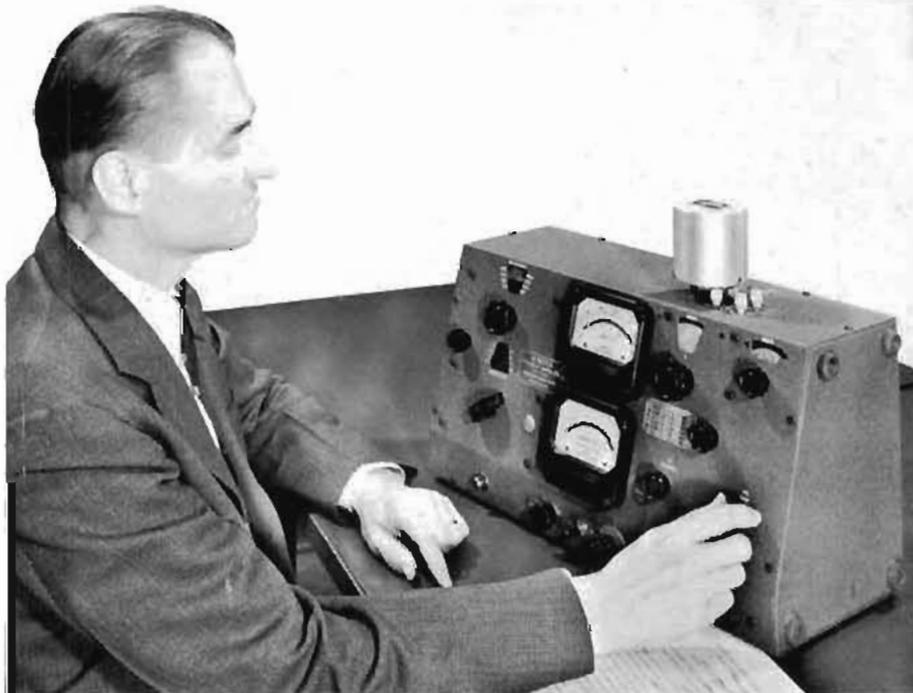
For capacitance measurements convenient use can be readily made of the calibrated variable capacitor just mentioned. Let us assume that a coil is connected to the COIL posts and re-sonated to the oscillator frequency (see Figure 2). Note the reading of the calibrated variable capacitor dial C_1 . If an unknown capacitor C_x is now connected to the Q Meter CAP terminals (*), it will be placed in par-

allel with the variable capacitor. Next, if the Q Meter is re-resonated by adjustment of the variable capacitor to a lower value, calling the reading C_2 , the quantity $C_1 - C_2$ represents the effective value of the unknown capacitor C_x .

The above measurement is preferably made at a low frequency, e.g. 1 mc., thus avoiding lead inductance effects. However, by employing a higher frequency, e.g. 50 mc. or 100 mc., the rise in effective capacitance of the unknown as a result of lead inductance may be readily observed. Fractional-inch variations in lead length will be found to have a pronounced effect on the measured quantity $C_1 - C_2$.

The parallel type of measurement just described can be extended in capacitance range as follows: first measure a capacitor by the method described, calling the measured capacitance C_a . Then, to measure a

(*These terminals are designated CAP on Q Meters Type 190-A and 260-A and COND on 160-A and 170-A.



The Author, using a Q Meter 260-A, measures the capacitance of a fixed capacitor by the Parallel Method.

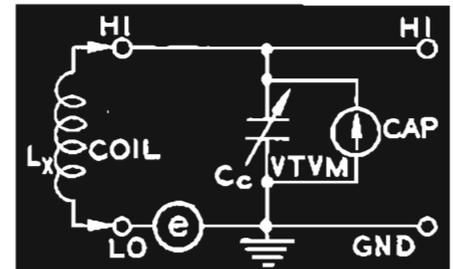


Figure 1. Q Meter Simplified Diagram. HI--Calibrated injection voltage derived from RF oscillator, C_c --Calibrated variable capacitor, VTVM -- Vacuum-tube-voltmeter measuring voltage across C_c . Terminals for connection of components to be measured are indicated as HI, LO, GND, and L_x -- coil being measured.

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second but larger capacitor C_x , use the previous method but connect C_a in parallel with the Q Meter CAP terminals (*) when determining C_1 ; then disconnect C_a , connect C_x , and readjust the calibrated variable capacitor to determine C_2 .

$$\text{Then } C_x = C_1 - C_2 + C_a .$$

Alternatively, a series type of measurement may be employed to extend the range upward by approximately 10:1 (see Figure 3). The unknown capacitor is connected in series with

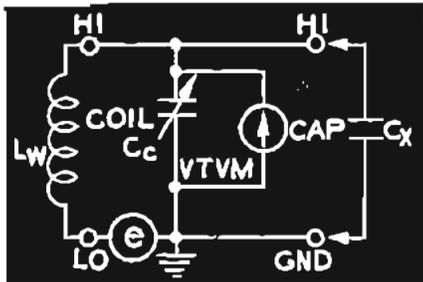


Figure 2. Capacitance Measurement, Parallel Method. L_w -- workcoil (such as Type 103-A or 590-A), C_x -- unknown capacitor (or dielectric sample) to be measured.

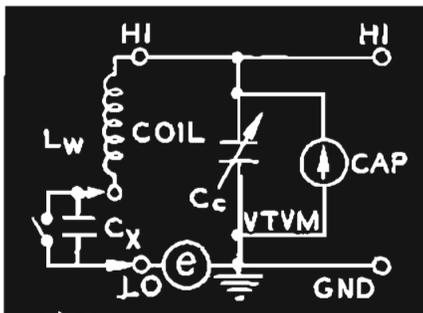


Figure 3. Capacitance Measurement, Series Method.

the measuring circuit between the low potential side of the coil and the Q Meter LO terminal; the circuit is resonated, preferably at a high reading on the calibrated variable capacitor, this reading being called C_2 . The unknown capacitor is then removed from the circuit, or prefer-

ably left in position but short-circuited to minimize changes in circuit inductance, the variable capacitor is readjusted for resonance, the reading being called C_1 . The effective value of the unknown capacitor is then

$$C_x = \frac{C_1 C_2}{C_2 - C_1}$$

MEASUREMENT OF DIELECTRICS

Dielectric samples (insulating material samples) for electrical measurement purposes are usually in sheet form and of 1/16 inch to 1/4 inch in thickness. If, to the sample surfaces, are attached metal foil electrodes, a capacitor is formed whose electrical properties depend largely upon the sample material.

The metal foil electrodes are usually of lead or aluminum, of 0.00075 inch to 0.0015 inch thickness, and are attached to the sample surfaces by means of a thin film of vaseline (petroleum jelly). The foil area is usually adjusted to provide a sample capacitance of 20 to 80 μmf depending upon the Q or power factor of the material to be measured and the type of Q Meter to be used. Sample discs of 2 inch diameter with foils extending to the sample edges are frequently used.

A parallel measurement is used on the Q Meter (see Figure 2). An inductor is connected to the Q Meter COIL terminals and resonated at the measurement frequency. The Q and tuning capacitance, Q_1 and C_1 , are read. The sample foils are then connected to the Q Meter CAP terminals (*), the tuning capacitor C_c is readjusted for resonance, the Q and tuning capacitance, Q_2 and C_2 , are read.

Neglecting edge and stray effects the following formulas apply.

The Q of the sample is

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

The power factor of the sample (for values less than 10%) is

$$\text{P. F. } (\%) = \frac{100}{Q_x} = \frac{100 C_1 (Q_1 - Q_2)}{(C_1 - C_2) Q_1 Q_2}$$

The dielectric constant of the sample is

$$\epsilon = \frac{C_1 - C_2}{C_a} = \frac{4.45 (C_1 - C_2) t}{A}$$

where C_a = Calculated capacitance (micro-micro-farads) of equivalent capacitor

with dielectric replaced by air.

t = Dielectric material thickness in inches.

A = Dielectric active area between electrodes in square inches.

C_1 and C_2 are in micro-micro-farads.

At frequencies above 10 mc the measurement method just described is sometimes unsatisfactory because of the effects of lead inductance, foil resistance, etc. For such conditions a somewhat different measuring technique is used with a specially designed sample holder which provides a constant circuit inductance for the "sample in" and "sample out" readings. This holder also permits, for certain measurements, elimination of the foil electrodes and their associated resistance. The General Radio Company Dielectric Sample Holder Type 1690-A is suitable for this work. Fabrication drawings of a mounting plate for attaching this Dielectric Sample Holder to Q Meters Types 160-A, 170-A, 190-A and 260-A are available from Boonton Radio Corporation.

Oils and other fluids require a cell or container with suitable electrodes between which the fluid to be measured may be placed.

INDUCTANCE

The calibrated oscillator frequency and calibrated variable capacitance scales of the Q Meter provide a convenient means of determining coil inductance. For this purpose the unknown coil is connected to the Q Meter COIL terminals and resonated as for reading Q (see Figure 1). The frequency, f , and tuning capacitance, C_1 , are read and inserted in the following formula for inductance.

$$L_s = \frac{1}{\omega^2 C_1}$$

where L is in henries
 ω is 2π times the frequency in cycles
 C is in farads
 or,

$$L_s = \frac{2.53 \times 10^4}{f^2 C_1}$$

where L is in microhenries
 f is in megacycles
 C is in micro-micro-farads

In either instance the inductance value obtained is the effective inductance of the coil including the effect of distributed capacitance.

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All Q Meters Type 260-A and 160-A of late manufacture, include a calibrated inductance scale on the calibrated variable capacitor dial. (An LC Dial Kit Type 560-A is available for adding this feature to early Q Meters Type 160-A). A chart provided on the Q Meter front panel permits use of any one of six inductance ranges by selection of the proper oscillator frequency. The inductance scale then reads directly in terms of effective inductance.

If the distributed capacitance of the inductor is known, the true inductance can be readily determined. With the variable capacitor dial adjusted to the effective inductance value, note the corresponding reading on the capacitance scale in micro-micro-farads immediately above. Add the distributed capacitance to this reading; adjust the dial to indicate the sum just obtained. Although the measuring circuit is now detuned from resonance, the true inductance of the coil may be read on the inductance scale immediately below.

DISTRIBUTED CAPACITANCE

All coils have distributed capacitance and a measurement of this quantity is often required. The measurement may be made on the Q Meter by the following method:

Connect the coil to be measured to the Q Meter COIL terminals (Figure 1). Resonate the Q Meter, calling the oscillator frequency dial reading f_1 and the calibrated variable capacitor dial reading C_1 (C_1 should be preferably in the lower part of the scale).

Readjust the oscillator to a considerably lower frequency f_2 , equal to f_1/n . Restore resonance by readjusting the variable capacitor, calling the new reading C_2 . The distributed capacitance is then

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

If f_2 is made exactly equal to $f_1/2$, then

$$C_d = \frac{C_2 - 4 C_1}{3}$$

An average of several measurements employing different values of C_1 and C_2 will improve the accuracy of the results.

SELF-RESONANCE

The self-resonant frequency of an inductor, i.e. the resonant frequency with nothing connected externally to the inductor terminals, can be readily determined with the Q Meter. Looking into the terminals of the inductor, re-

actance conditions vs frequency will be seen as in Table 1, columns 2 and 3. The Q Meter distinguishes readily between conditions a, b, c, thus providing an accurate determination of the self-resonant frequency, as will be explained in detail with the aid of column 4.

In making the measurement the first step is the determination of leads required to connect the unknown inductor to the Q Meter CAP terminals (1). These leads are then permanently connected to the CAP terminals and the inductor is disconnected. This procedure minimizes the effects of lead capacitance on the self-resonant frequency.

Next, the Q Meter is resonated with a work or accessory coil (preferably shielded, such as the Types 103-A or 590-A) connected to the Q Meter COIL terminals (see Figure 4). The frequency chosen should be in the region

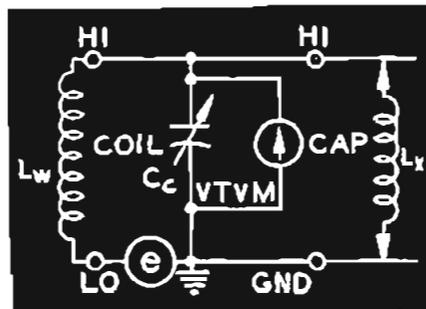


Figure 4. Inductor or Choke Measurement, Parallel Method.

of the estimated self-resonant frequency of the inductor to be tested. Now connect the unknown inductor L_x to the CAP terminal leads previously established. Re-resonate the Q meter by means of the capacitance dial C_c , noting the direction of movement of this dial as referred to the original setting.

Unless the unknown inductor is found to be non-reactive at the measurement frequency first chosen, the test pro-

cedure is now to be repeated at a somewhat higher or lower frequency as determined by reference to Table 1, columns 2 and 4. Successive frequency adjustments will eventually achieve the desired condition where the capacitance dial reading for resonance is unchanged as a result of connecting the unknown inductor to the Q Meter CAP terminal leads. The unknown inductor is then non-reactive and self-resonant at the frequency indicated by the oscillator dial.

CHOKE COILS

A choke coil, to provide proper isolation characteristics, must exhibit a high impedance throughout its operating frequency range. Failure to meet this requirement may result in low operating efficiency, frequency error in calibrated circuits, etc.

The Q Meter provides an ideal means for the measurement of choke coil characteristics. A work coil, preferably shielded, is connected to the Q Meter COIL terminals (Figure 4). Leads of short length may be used, if required, to connect the unknown choke coil to the Q Meter; these leads are now to be attached to the Q Meter CAP terminals (1) but the choke coil is to be disconnected. The work coil is resonated at the frequency of measurement, called f , the Q reading being called Q_1 , and the calibrated variable capacitor reading being called C_1 . Temporarily remove the Q Meter CAP terminal leads. If used, and note the increase required in the calibrated variable capacitor reading for resonance; call the increase C_1 , re-connect the leads. Next the unknown choke coil L_x is connected to the Q Meter CAP terminals leads and the calibrated variable capacitor is readjusted for resonance. Call the Q reading Q_2 and the capacitor reading C_2 .

The above procedure should be repeated at other frequencies within the

TABLE 1

INDUCTOR SELF-RESONANCE DATA

(1) Con- dition	(2) If Frequency Is	(3) Inductor Reactance Will Be	(4) Q Meter Capacitance Dial Test Reading
a	Below self-resonance	Inductive	Increases
b	At self-resonance	Non-reactive	No change
c	Above self-resonance	Capacitive	Decreases

operating range of the choke coil (C_L) may be assumed to be constant and need not be re-checked when the frequency is changed).

The effective parallel resistance, R_p , and effective parallel reactance, X_p , of the choke are

$$R_p = \frac{Q_1 Q_2}{\omega(C_1 + C_L)(Q_1 - Q_2)}$$

and

$$X_p = \frac{1}{\omega(C_2 - C_1)}$$

where R_p , X_p are in ohms

$$\omega = 2\pi f \text{ (cycles)}$$

C is in farads.

$$\text{Or, } R_p = \frac{1.59 \times 10^5 \times Q_1 Q_2}{f(C_1 + C_L)(Q_1 - Q_2)}$$

$$\text{and } X_p = \frac{1.59 \times 10^5}{f(C_2 - C_1)}$$

where R_p , X_p are in ohms

f is in megacycles

C is in micro-micro-farads.

NOTE: The sign of the quantity ($C_2 - C_1$) indicates the type of effective reactance. A positive quantity indicates inductive reactance. A negative quantity indicates capacitive reactance.

MUTUAL INDUCTANCE AND CRITICAL COUPLING

(a) The mutual inductance and coefficient of coupling of RF coils may be measured on the Q Meter at high frequencies by the familiar method often employed at low frequencies with audio frequency bridges.

This method is used for large coupling coefficients, i. e. 0.5 or greater. Four measurements are made (on the Q Meter COIL terminals) at or near the operating frequency and preferably at one frequency.

Measure L_1 and L_2 separately. Then measure L_a (mutual aiding) with L_1 and L_2 connected series aiding, and L_b (mutual bucking) with L_1 and L_2 connected series bucking (Figure 5).

The mutual inductance then is

$$M = \frac{L_a - L_b}{4}$$

The coefficient of coupling is

$$K = \frac{L_a - L_b}{4\sqrt{L_1 L_2}} = \frac{M}{\sqrt{L_1 L_2}}$$

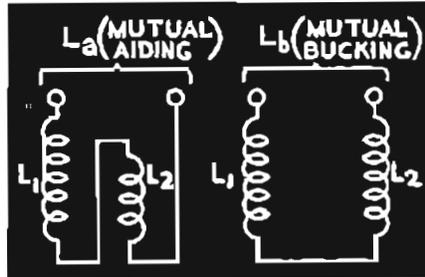


Figure 5. Mutual Inductance Connections, L_1 L_2 -- first and second coupled coils, respectively.

If the measurements are made at one frequency

$$K = \frac{\left(\frac{1}{C_a} - \frac{1}{C_b}\right) \sqrt{C_1 C_2}}{4}$$

where $C = Q$ Meter tuning capacitance necessary for resonance with mutual aiding connection, mutual bucking connection, and single inductors respectively.

(b) With RF coils most commonly used the critical coefficient of coupling (i. e., the condition where the resistance that the secondary circuit at resonance couples into the primary circuit is equal to the resistance of the primary circuit) occurs at a low value of coupling coefficient. Design-wise, the critical coupling condition is important because it yields the maximum value of secondary current and it may be readily determined as follows.

Connect one of the two coils to the Q Meter COIL terminals with the second coil open-circuited (see Figure 6) and adjust the Q Meter for resonance. Read Q_1 . Now complete the secondary circuit and, by means of its trimmer, resonate it to the same frequency as indicated by a minimum Q reading, Q_2 .

If Q_2/Q_1 equals 0.5 the coils are critically coupled; if greater than 0.5 the coupling is less than critical, and if less than 0.5 the

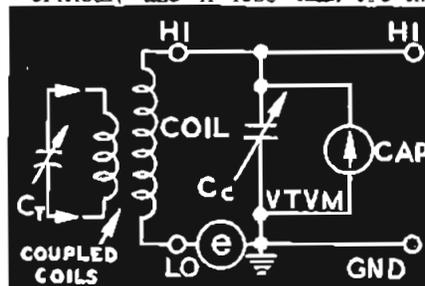


Figure 6. Critical Coupling. C_c --Secondary coil Trimmer.

coupling is greater than critical.

These results will be with respect to the coils only. If it is desired to include the effects of tube and circuit loading, resistors duplicating these loading effects should be added to the coils before making the measurements.

GAIN OF COUPLED COILS

The Q Meter is essentially a gain measuring device, i. e., Q is measured by determining the ratio of two voltages. This instrument is thus readily adaptable to the gain measurement of coupled coils within its range.

For example, a transformer used to couple a low-impedance loop antenna to a receiver input may be measured. Referring to Figure 7, the transformer primary circuit including the loop (a coil may be used to simulate the loop) is connected to the Q Meter GND and LO terminals. The transformer secondary is connected to the Q Meter GND and HI terminals. The Q Meter injection voltage thus excites the transformer primary circuit and the transformer secondary voltage is fed to the Q voltmeter. Adjustment of the calibrated variable capacitor C_c for resonance will now yield a "Q reading" which is numerically equivalent to the transformer circuit gain. The Q scale reads gain directly when the "Multiply Q By" meter is set to x1.

By completion of the proper connections the above method can obviously be extended to include stage gain measurements.

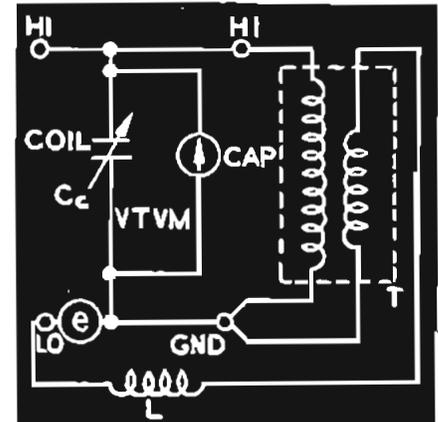


Figure 7. Transformer Gain Measurement.

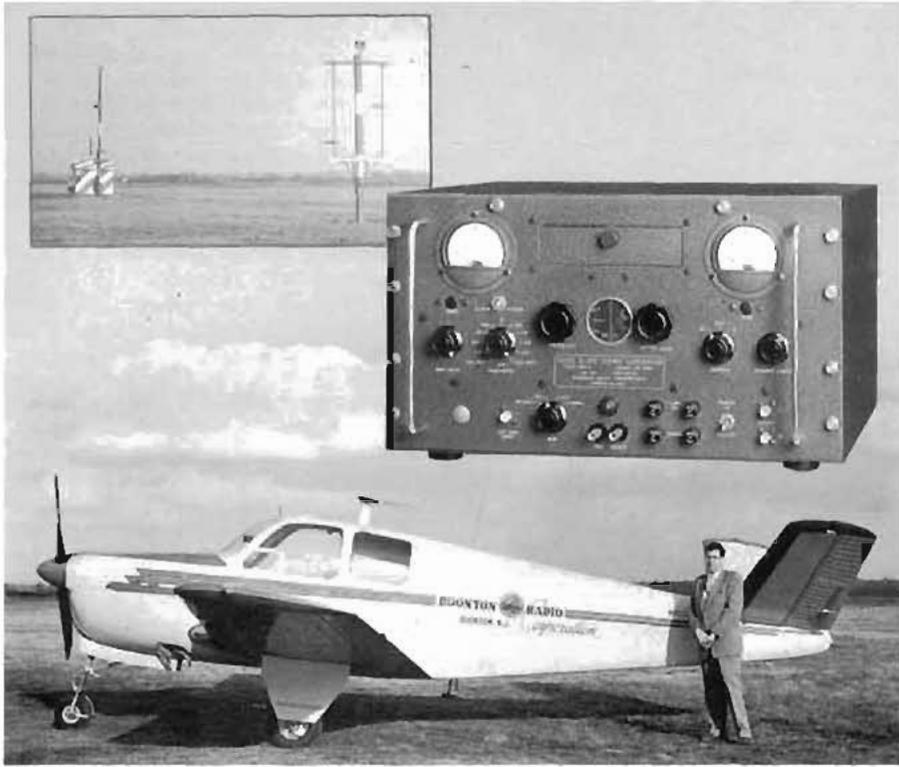
SUMMARY

We have described some of the "extra-curricular" uses to which a Q Meter may be put. No attempt was made to write an exhaustive article and we are sure that our many customers have devised other ways of utilizing this versatile instrument.

May we draw this conclusion: that, when an RF measurement problem is at hand, the Q Meter may do the job.

BAD WEATHER FLYING

EDSON W. BEATTY, *Chief Pilot*



The Author standing beside the BRC Bechcraft Bonanza. The aircraft is fully equipped for Instrument flight and provides a valuable source of information relevant to actual aircraft operation under all flight conditions. Inset upper left is a typical Instrument Landing System Glide Slope field installation. The BRC Glide Slope Signal Generator Type 232-A (center) provides calibrated RF signals and modulation on all Glide Slope frequencies-- thus providing manufacturers and service organizations with an instrument capable of simulating any or all signals transmitted in the Glide Slope Section of the Instrument Landing System.

Ever been delayed at the airport by weather or arrive several hours behind schedule? Most of us have, but have you noticed recently these delays are not occurring as often? We here at BRC feel that with our test equipment we are helping to contribute a part towards reducing these occurrences.

Today, on board a modern high speed air transport, we give little thought of the problems brought about by the increase in speed, traffic density and type of weather now considered flyable. Just as an example, an aircraft traveling at 150 MPH with a course error of 5° will be approximately 4 miles off course after 30 minutes time. However, at 350 MPH with the same course error for 30 minutes, the aircraft would be over 8-1/2 miles off course. Now commercial flights are being made daily with little more than part of the airport runway being visible. Experi-

mental flights are being made under visibility conditions where great difficulty in ground or taxiing handling is encountered. The writer had an experience recently when, rolling down the runway after landing in a heavy fog, the control tower called by radio from 1/4 mile away and requested "Have you landed yet?"

These improvements in air navigation and communications have all been brought about through electronic equipment. The primary aids now used are Omnidrange for navigation, Instrument Landing System for blind landing and VHF Communications.

THE VOR SYSTEM

Omnidrange, sometimes referred to as VOR (Visual, Omni-directional Range), is a recent development in radio navigation aids. The Omnidrange is designed, as are other air navigation

systems, to furnish directional guidance to an aircraft in space. It is the primary aid in point-to-point air navigation. The word Omni is derived from Latin "Omnis" meaning all. These stations are so named because they have an infinite number of courses, whereas, the facility they replace has only four courses.

An Omnidrange station might be described as a very large wheel with 360 spokes (theoretically an infinite number) with the station being the hub. Any one of the spokes might be chosen as a guide in space. This is accomplished electronically by comparison of the phase difference between the audio modulation of two radiated radio frequency signals, the difference in phase varying with change in azimuth. The modulation on one of these signals is non-directional and has a constant phase throughout 360 degrees of azimuth. This is called the reference phase. In order to separate the two signals for comparison in the receiver and converter, a 10KC FM subcarrier is used to carry the reference signal. The phase of other signal rotates at a speed of 1800 RPM and varies in phase with azimuth. This is called the variable phase and is produced by a motor driven goniometer feeding an RF voltage into four antennae (two at a time). As the goniometer revolves, the RF voltage fed into the antennae (180 degrees apart) varies sinusoidally at the rate of 30 cps to produce a rotating field. The system is set up so at magnetic north the reference and variable signals are exactly in phase.

From a pilot's standpoint the operation is quite simple. Other than receiver, converter and antennae, there are four basic units in the aircraft. Although some manufacturers combine these units for simplicity, we shall discuss the primary type.

The pilot's controls are illustrated in Figure 1 and consists of:

1. Frequency Selector (conventional receiver control)
2. Azimuth Selector
3. Deviation Indicator (with signal strength indicating flag)
4. Sense Indicator

Further describing each unit:

1. Frequency Selector: tunes receiver to desired station frequency which is identified aurally with code (recorded voice also on some stations).
2. Azimuth Selector (Course Selector): selects the desired azimuth (or track) to control direction in space.
3. Deviation Indicator: indicates the difference between the selected azimuth and present position or,

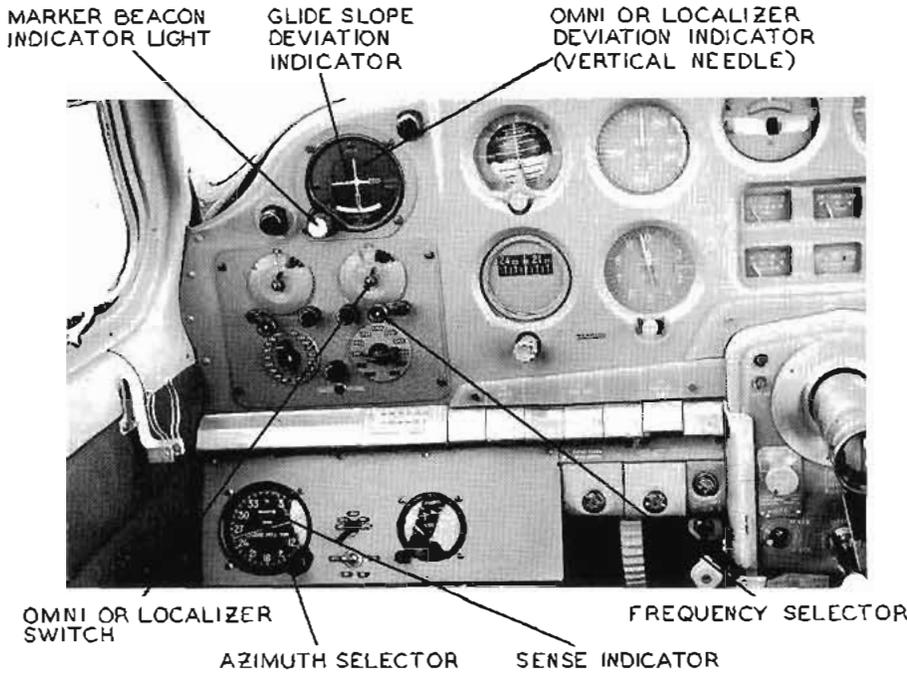


Figure 1. The Pilot's VHF Radio Controls installed in the instrument panel of the BRC Beechcraft Bonanza.

conversely, the azimuth from a station to the aircraft's position. Two or more stations may be used to establish position. Also included is an alarm indicator which indicates when a usable signal is being received.

4. Sense Indicator (To-From Meter); determines the phase comparison to establish the quadrant (i.e. north azimuth or south azimuth).

At the present time there are 392 omni stations now in use throughout the United States.

THE ILS SYSTEM

We have discussed point-to-point air navigation and although the omni-range may be used as a landing aid it is not the primary type. The Instrument Landing System (ILS) is the more effective type and considered the most practical from a cost and operational standpoint. Its purpose is to provide a predetermined, precise path to a landing runway without visual reference to the ground.

The system employs three elements;

1. Localizer
2. Glide Slope
3. Outer and Middle Marker

To explain each element:

1. Localizer: provides the directional guidance to and down the landing runway.
2. Glide Slope: provides the altitude guidance while approaching on the Localizer.
3. Outer and Middle Markers: provide fixes or locations on Localizer and Glide Slope.

In order to describe the operation of ILS, we shall consider each element separately.

The Localizer provides the directional guidance by radiating a field pattern directly down the center line of the instrument runway. The carrier is modulated at two frequencies, 90 and 150 cps, with each modulated carrier applied to a separate antenna system. They are arranged so that while on the approach end of the instrument runway facing the antenna, the 90 cps signal predominates on the left and the 150 cps on the right. With this arrangement, an equal signal ratio of 90 to 150 cps is projected down the in-

strument runway and continuing off into the approach area. The equal signal zone is designed to be approximately 5° wide.

The Glide Slope provides altitude guidance while approaching on the localizer. This is accomplished in much the same manner as the localizer with the exception of the direction of equal signal zone. The carrier is modulated at two frequencies, 90 and 150 cps with each modulated carrier supplied to a separate antenna system. These systems are arranged so an equal signal zone, or tone ratio, is 2-1/2° to 3° from parallel to the earth's surface and is approximately 1° wide.

The ILS markers, there are two, called outer and middle, serve as radio fixes to check progress on Localizer and Glide Slope. Both are vertically-radiated, low-power signals (always 75MC) elliptical in shape and directed so the center is directly under the localizer on-course signal. The Outer Marker is located between 4 and 7 miles from runway threshold. The carrier is modulated at 400 cps and keyed to emit continuous dashes. The middle marker is located between 1250 ft. and 3500 ft. from runway threshold. Its carrier is modulated at 1300 cps and keyed to emit alternate dots and dashes.

The equipment aboard the aircraft (other than receivers and antenna) consists of the following:

1. Frequency Selectors; (one each for Localizer and Glide Slope).
2. Deviation Indicators; (two meter movements in same instrument each with signal strength indicator alarm).
3. Marker Beacon Indicator Lights; (fixed frequency receiver).

From the pilot standpoint, the controls serve as follows:

1. Frequency Selector for Localizer (108-112MC): tunes the proper localizer which is identified aurally. Glide Slope (329.3 to 335MC) is tuned with a separate control and may only be identified by flag alarm opposite deviation indicator.
2. Deviation Indicators; provide guide for following Localizer and Glide Slope, the vertical indicator for Localizer and horizontal for Glide Slope.

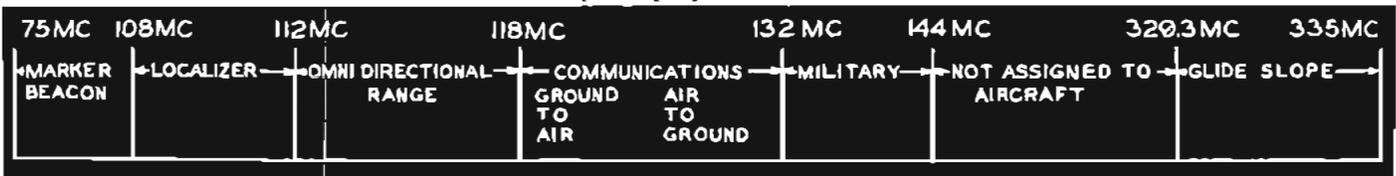


Figure 2. F.C.C. Frequency Assignments -- Aircraft Navigation and Communications.

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3. Marker Beacon Lights: indicates by flashing signal which marker is being passed over, also, these signals may be identified aurally.

At the present time there are 146 ILS systems in operation in the United States not including military installations.

With the assignment of new frequencies following World War II (See Figure 2) there was tremendous need for a stable Signal Generator between 88 and 140MC. The BRC Signal Generator Type 202-B has been accepted and purchased by The Civil Aeronautics Authority and widely used throughout the industry. During the development of the Omnirange system, a phase shift was encountered in the Type 202-B

which was not desirable. In 1948, a completely new Signal Generator, the Type 211-A was announced, eliminating this problem. Due to increasing demand for a crystal controlled stable Glide Slope Generator, the Type 232-A was placed on the market in 1953. All these units are approved by The Civil Aeronautics Authority as part of the necessary equipment to obtain a CAA licensed Radio Repair Station.

Already the CAA is making additions to the Omnirange and ILS systems by equipping them with DME (Distance Measuring Equipment); at present only in high traffic density areas. This together with Radar Monitoring of air traffic, bring closer the day of no-weather delays.

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CHECK YOUR Q READINGS By the Delta C Method

JAMES E. WACHTER, *Project Engineer*

There are instances not covered by the Q Standard Type 513-A in which the Q Meter user may question the Q values indicated by his instrument and, lacking a quick cross-check, believes he must content himself with questionable information. This is not necessarily so, since in many cases the "Delta C" method is both convenient and reassuring. Convenient in that the check can be conducted relatively quickly and at any frequency within the Q accuracy specification of the instrument; reassuring when it substantiates the Q Meter.

The check is based upon the equation:

$$Q_C = \frac{2C_R}{\Delta C} \sqrt{\left(\frac{V_R}{V_1}\right)^2 - 1} \quad (1)$$

the derivation of which is too lengthy to include here.* The quantities involved in the equation are from the following Q Meter equivalent circuit including the external inductor and its associated voltage-capacitance curve:

C_R = capacitance to resonate the circuit.

V_R = voltage across the Q Meter capacitor at resonance.

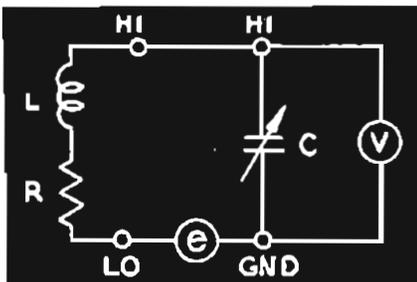


Figure 1. Equivalent Circuit of Q Meter.

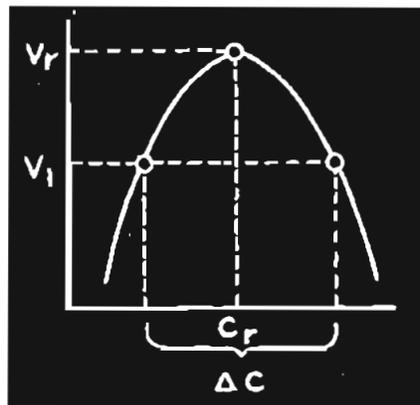


Figure 2. Capacitance Curve of the Q Meter Circuit.

V_1 = voltage across the Q Meter capacitor at a point other than resonance.

ΔC = capacitance between two points of equal voltage (V_1), one on either side of resonance.

Q_C = circuit Q = $\omega L/R$ where R includes all losses in the coil and the Q Meter circuit.

It is worthwhile to note here that since the Q-voltmeters of all BRC Q Meters are linear with respect to voltage and Q, equivalent values of indicated Q may be substituted in the ratio V_R/V_1 . Equation 1 contains an approximation which is negligible when Q is greater than 100.

An easy level at which to make the ΔC measurement is at the half voltage or half Q points ($V_R/V_1 = 2.0$), in which case the preceding equation becomes

$$Q_C = 3.4641 \frac{C_R}{\Delta C} \quad (2)$$

Another frequently used level is at the 0.707 voltage or Q points where:

$$Q_C = \frac{2 C_R}{\Delta C} \quad (3)$$

An outline of the procedure using equation (2) and applicable to all Q Meters manufactured by Boonton Radio Corporation is:

1. Set the Q Meter oscillator to the desired frequency.
2. Adjust the XQ control for unity.
3. Connect a shielded inductor requiring a capacitance setting near the maximum available reading for a Q Reading near full scale.
4. If Q Meters Type 160-A or 260-A are being checked, set the vernier scale to zero.
5. Resonate the circuit with the internal resonating capacitor.
 - a. Record the resonating capacitance indicated on the Q capacitor dial as C_R .
 - b. Record the Q at resonance as indicated on the Q voltmeter as Q_R .
6. With the internal resonating capacitor (vernier capacitor on Q Meters Type 160-A and 260-A) detune the circuit on either side of resonance to the point where the Q indicated by the Q voltmeter is equal to $Q_R/2$. Record the capacity between these two points as ΔC .
7. To avoid errors due to mechanical and electrical backlash all settings of the Q condenser should be approached with the same direction of rotation. To minimize errors in reading all settings and readings should

be made several times and then averaged.

8. Insert the values of C_T and ΔC in equation (2) and calculate Q_C .

Now, if the value of Q_C calculated in step 8 agrees with the value of Q_T recorded in step 5.b. within ± 15 percent all is well and good and the Q Meter can be assumed to be performing satisfactorily.

The method of Q Meter checking discussed here does not take into account variations in Q indication resulting from changes in loading across the measuring terminals (see " Q Meter Comparison ", Notebook 2, Summer 1954.) Difficulties (if indicated) lie elsewhere. For methods of isolating the problem see the Maintenance Section of the applicable Instruction Book.

* Hartshorn, L., and Ward, W.H., Institute of Electrical Engineers, (London, 1936), equation 6. - pp. 79, 597, 609.

EDITOR'S NOTE....

THE Q CLUB OF BRC

A BRC Employee had a bright idea back in 1942. The idea was born of the Shop and Office collection problem-- a problem that probably is common to any firm employing three or more persons. The idea provided

a club for the purpose of remembering fellow workers on special occasions and to assist in arranging picnics etc.. Club dues would supply the needed funds and individual employees would no longer face the Shop and Office collections. The Company's best known instrument was the Q Meter and the new organization was befittingly named the Q Club of BRC.

Today the Q Club is a thriving organization sponsoring activities in which the great majority participate and enjoy and remembering fellow members of the BRC Family on special occasions. But we are still bothered by collections. The Q Club has gone a long way in controlling the problem but never has been fully able to meet the goal set in the original idea.

Some of the Club's inability to eradicate collections can be traced to an aspect of the Club's existence which was not fully apparent to the founders. This important aspect is the Club's healthy influence on employee relations. When a new employee starts work at BRC, he or she is soon greeted by a Q Club Representative--there is a representative for each ten employees. The Representative explains the Club's history, purpose and informs the new employee that he or she will be eli-

gible for membership after the probation period. Fellow workers are introduced and the new employee soon has a feeling of friendship and belonging to a group. In short, employee relations are off to a good start and where friendly relations flourish, the ideas and desires for collections also flourish. The Q Club treasury always falls a little short of the good will it has created and fostered.

The good will emanating from the Q Club activities reflects itself in the BRC operations. Few people take more pains and pride in their work than members of the BRC Family. They are understanding of company production and engineering problems. On the other hand, supervisors are more understanding of the individual's problems.

Yes, Shop and Office collections have greatly benefited Boonton Radio Corporation-- they brought about the Q CLUB OF BRC!

BRC is proud of several other employee organizations. The BRC Men's Bowling League is ABC sanctioned and its weekly "Bowling Nights" regularly draw 35% of all male employees. The BRC Camera Club was recently organized and is very popular. The photos on pages 5 and 6 were taken by our Camera Club President.

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