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Calibration of An Instrument for Measuring Low-Level R-F Voltages

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The sensitivity of a radio receiver is one of its most important attributes. Often, this sensitivity is in the order of one microvolt or less. Unfortunately, the only devices capable of detecting the presence of these low-level voltages are the receivers under test. Using a receiver of unknown sensitivity to measure these voltages would not be an accurate process. What is needed, is a device which will provide a source of r-f voltages, at microvolt levels, which can be established with a definite and reasonable accuracy without measurement at low levels. This article presents a discussion of some of the techniques employed and problems encountered in designing and evaluating such a device. Basically the device under discussion combines a carefully calibrated r-f voltmeter with a very fine attenuator. See figure 3.

Figure 1. The author uses the 245-B to perform receiver sensitivity measurements.

Voltmeter Design

The voltmeter selected for this device is a reasonably straight forward UHF germanium cartridge diode. The only innovation is that the diode operates with an accurately monitored bias current at zero signal. The bias is such that the input voltage swing is always on the square-law portion of the diode characteristic and never crosses the zero voltage axis. This tends to make the sensitivity relatively independent of temperature and aging effects.

What must be determined however, is the frequency characteristic of this diode voltmeter. At the design stage it was quite obvious that the series resonance of the voltmeter was above 1,000 mc, but the exact frequency was not known. As the series resonance is approached, the diode will increase in sensitivity and the output of the instrument will drop. On the low frequency end, the sensitivity will decrease as the impedance of the by-pass capacitors increase. Since it is most desirable to calibrate this voltmeter at 1,000 cps, where accurate voltages are available, the low frequency characteristics must also be known. A factor to be considered, is that two capacitors are used as a filter over the entire frequency range and that they have a 5-ohm damping resistor between them. Below a certain frequency, this 5-ohm resistor is in series with the r-f circuit of the diode and decreases the sensitivity slightly. For accurate work this must be evaluated.

Voltmeter Performance Checks

The basic problem at the input of the voltmeter system is to accurately measure the voltage applied to the attenuator system over a range of 1 kc to 1,000 mc for a constant indication of the output meter. In order to extend the frequency response downward to 1,000 cycles, an additional 60 μf had to be added to the by-pass circuit. To be sure that this had no effect on the normal calibration, it was necessary to check the meter indication at the lowest operating frequency of 100 kc, with and without the 60 μf capacitor. It was found that this had no effect. It was also found that 60 μf was adequate for 1,000 cps. This was checked by adding more capacitance and noting that no change in sensitivity took place. Operation of the by-passing was observed by evaluation of the effect of the 5-ohm damping resistor at frequencies where the high frequency by-pass has no effect. This was accomplished by a relative check of sensitivity at 1,000 cycles, with and without the damping resistor. Results showed about a 1% change. This 1% increase in sensitivity occurs between 10 and 20 mc as the test frequency is raised. Since this is known, it can be taken into

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account. This condition precludes the possibility of sharp, uncontrolled changes occurring unexpectedly due to series resonance of the two capacitors and their accumulated inductances.

DC to Audio

The most accurate place to begin determination of standard voltage is at a Weston standard cell. In this case, dc was passed through a stable glass film type resistor of 50-ohms dc resistance. This current was monitored with a Weston thermo milliammeter whose calibration was known up to 2 mc. An L and N laboratory potentiometer was used to compare the standard cell voltage with the voltage developed across the resistor. Accurate readings of the thermo milliammeter were taken at the voltages desired for calibrating. In as much as the thermo milliammeter and the resistor are flat to at least 1,000 cycles, the dc source was replaced with a low distortion, 1,000-cycle, power source. By producing the same currents at 1,000 cycles that were produced at dc, the same voltages which were accurately checked with the standard cell at dc were now being produced at 1,000 cycles. These standard levels were used at this frequency to check the accuracy of a Ballantine ac-dc precision calibrator which would serve as a convenient stable 1,000-cycle standard for further use in the testing. The calibrator is continuously variable in level up to 10 volts, (rms, peak, or dc) and is accurately read out to 4 significant figures. This instrument operates well within its rated ½% accuracy.

Audio to 2 mc

The 50-ohm resistor used in the transfer test was known to be flat to well above 2 mc and the thermo milliammeter was nearly flat with a known slope supplied by the manufacturer. By varying the frequency into the system, a calibration curve was produced for a Ballantine Model 310 vacuum tube voltmeter up to 2 mc. This calibrated meter was then used to monitor the input of the voltmeter in the range from 1 kc to 2 mc. For purposes of these tests, the nominal calibration voltage was required to produce the proper meter reading at 1,000 cycles. This nominal voltage was derived by calculating the attenuation of the attenuator to be calibrated from its measured dc values. The voltage was measured at the input end of the input cable. Since the cable length of 30 inches is quite short at 2 mc, it was not necessary to consider any change due to cable mismatch. However, the voltmeter and attenuator in combination were adjusted so that they presented a 50-ohm load having very low VSWR through most of the 1,000-mc band. The input cable is a special 50-ohm cable made to close tolerances for this application. It is necessary to repeat for emphasis at this point, that in any use of the low-level r-f measuring device and throughout all tests and calibration procedures, the dc resistance of the external circuit feeding the device's input cable is 50 ohms, because part of the dc return for the diode is through this path. The procedures to this point have an absolute calibration up to 2 mc, leaving 998 mc to be calibrated.

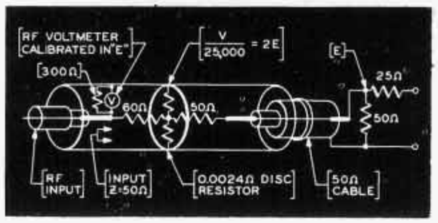

Figure 2. RF attenuator and voltmeter.

2 mc to 1000 mc

Voltage levels at higher frequencies are best measured with a bolometer bridge. In this way the accurately known 1,000-cycle voltages can be compared in their effect to the higher r-f voltages. There is in use in the BRC laboratories a specially constructed bolometer bridge which operates with more than normal sensitivity. This instrument is usable to compare levels of voltage down to 0.03 volts. Space is not available to describe the construction of this special instrument except to say that it compares the heating effect of accurately measured 1,000-cycle voltages to the heating effect of r-f voltages up to 1,000 mc. Since this bridge presents a load resistance of 50 ohms to a coaxial cable and its response is due to a heating effect, it is really a power measuring device and must be considered as such. The reason for this will be developed.

The r-f voltmeter is fed from a 50-ohm source having low VSWR and the level is adjusted until the meter gives standard indication. The signal generator output is then transferred without change to the bolometer bridge. The bridge is then balanced and the r-f is removed and replaced with enough 1,000-cycle energy to rebalance the bridge. The 1,000-cycle voltage is simultaneously measured on a Ballantine voltmeter whose calibration has been verified by the precision ac-dc calibrator. This voltage will then be a measure of the absolute voltage at the diode when certain corrections are applied. The output of the signal generator used was connected, by means of a specially adjusted terminating pad at the end of the coaxial cable, to the input cable of the low-level r-f voltage device.

Corrections

This cable and terminating pad were then transferred to the input jack of the bolometer. Since this jack is connected directly to the bolometer element, loss due to attenuation in the input cable of the low-level r-f voltage device had to be accounted for and subtracted from the indicated bolometer reading. This loss in the cable was calculated from the cable manufacturers rated loss per 100 feet and a knowledge of the cable length. The bolometer element is not exceptionally well matched compared with the low-level r-f voltage device, but since it is a power sensitive device and not a voltmeter, a VSWR as high as 1.5 does not cause an appreciable error. The amount of power reflected from a load having a mismatch of 1.5 is 4%. The resistance of the bolometer is precisely 50 ohms at the 1,000-cycle comparison frequency, so that the error in voltage is only the square root of the power error, or 2%. However, for precise work, the VSWR characteristic of the bolometer must be determined and this error taken into account. The indication will always be lower than actual, because the bolometer rejects some of the power delivered to it. Therefore, the error must be added to the indicated results.

Additional data was derived for design of an accurate voltmeter correction curve by actually determining the resonant frequency of the voltmeter. This was done by scanning the band from 800 to 3000 mc with a microwave signal generator which was known to be reasonably flat. A pronounced minimum in the output was observed at 1400 mc which represented the series resonant frequency. This information was used to confirm the slope of the curve obtained from previously used methods. While this type data does not give actual quantitative information as to the actual magnitude of the resonance, it is used to add credence to the previous quantitative measurements.

Attenuator Design

The basic concept of the attenuator is shown in figure 2. It is a voltage divider composed of a 60-ohm resistor in series with a 0.0024-ohm resistor. The input voltage is fed in across the series combination and the output is taken across the 0.0024-ohm resistor. Since the 0.0024 ohms is not a significant part of the total resistance, the attenuation ratio can be taken merely as the ratio of the two resistors, which in this case is 25,000. Of course, each of these two elements must be the same value from dc to 1,000 mc in order to obtain the desired results.

For the larger 60-ohm resistor, a natural solution was presented in an article by D. R. Crosley and C. H. Pennypacker.[1] It was demonstrated mathematically in this work that if: (1) the central conductor of a coaxial transmission line is a uniform resistive cylinder, (2) this transmission line is shorted on one end, and (3) the geometric dimensions of the line are such that its characteristic impedance X $\sqrt{3}$ is equal to the total series resistance of the central conductor; this section of line, when

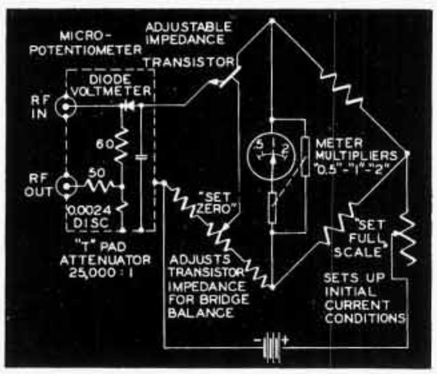

Figure 3. RF voltage standard-basic circuit.

viewed from the open end, will look like a pure resistor equal to the total series resistance of the central conductor. Compared to its dc value, this resistor would have a VSWR of 1.01 when the length of the line is less than 1/100 of the wave length, or less than 1.03 when the length of the line is less than 1/30 of the wave length. The central conductor of this line in practice is a glass rod onto which has been evaporated, in a vacuum, a thin film of metal. In this case, the film is thin enough to be considered without thickness for skin depth considerations. The line is 1 cm long, or 1/100 of the wave length at 300 mc and 1/30 at 1,000 mc. Therefore, in theory, the resistor is within 1% of the dc value at 300 mc and within 3% at 1,000 mc.

The 0.0024-ohm resistor becomes the short circuit at the end of the transmission line. A natural resistor for this type of use is suggested in an article by M. C. Selby.[2] This resistor consists of an annular film of conducting material which bridges the gap between the inner and outer conductors of the coaxial line. For purposes of evaluation, this film can be considered to be a series of square bars whose width is the film thickness. Assuming, for now, uniform penetration of current, the inductance can be evaluated. Consider one bar to be called a. Bar a will have mutual inductance with all other bars. For each bar at an angle ϕ from a, there will be another bar at $-\phi$ from a. These bars will have mutual inductance of equal value, but will have opposite sign and cancel. Bar a will then have mutual inductance with a bar 180° from it. Assuming that the inductance of the disc is the result of all bars in parallel that approximate the disc, (Inductance may be actually less than this because some area is unaccounted for.) total inductance is computed as follows:

$$\text{L Total} \leqq \frac{\text{d}}{2\pi \text{r}} (\text{La} + \text{Maa}_1)$$

$$\text{La} \leqq 0.002l \left[\log \frac{2l}{0.447\text{d}} - 1 + \frac{0.447\text{d}}{l}\right] \mu\text{h}$$

Where:
d = thickness of bar = 2.5×10^{-4} cm
l = length of bar = 0.25 cm
r = radius of inner conductor = 0.36 cm

$$\text{Maa}_1 = -0.002\,[(2l + 2\text{r}) \log (2l + 2\text{r}) + 2\text{r} \log 2\text{r} - 2 (l + 2\text{r}) \log (l + 2\text{r})]\,\mu\text{h}$$

$\text{La} \leqq 1.329 \times 10^{-3}\ \mu\text{h}$, $\text{Maa} \leqq -5.6 \times 10^{-5}\ \mu\text{h}$

$\text{LA} \leqq 0.1406\ \mu\mu\text{h}$

The inductive reactance is $4.36 \times 10^{-4}\ \Omega$ at 500 mc and $8.72 \times 10^{-4}\ \Omega$ at 1,000 mc, and is in quadrative with the resistance. This results in a 1.65% error in impedance at 500 mc and a 6.25% error at 1,000 mc.

Uniform current in the bar is indicated, because the effective skin depth in the film at 1,000 mc is roughly 2 times the actual film thickness. It develops that when the skin depth is equal to the film thickness, the resistance is equal to 103% of the dc value, and when the skin depth is equal to twice the film thickness, the resistance is equal to 101% of the dc value. Since the current tends to be more dense on the input side of the annular resistor, this slight inequality of distribution tends to reduce the voltage appearing on the side of the film opposite the side from which the output is taken. This reduction tends to offset the increase due to the disc inductance.

Attenuator Performance Checks

In addition to checking the voltmeter characteristics it is desirable to check the attenuation at various frequencies. The theoretical attenuation is of course derived from accurate and careful dc measurements, but the r-f attenuation must be ultimately checked by judicious comparison with a precision piston attenuator. The piston attenuator can be a rigorously accurate device if used carefully, but it can also be a totally inaccurate device if used improperly. The attenuation of the useful mode in the circular wave guide is well known, but other modes are also propagated into the tube under some conditions. These modes are all attenuated at a rate higher than the normally used TE_{11} mode. If one does not use the attenuator with the probe too close to the driven end of the tube, and if a driving element is chosen which is of such geometry as to favor the TE_{11} mode, the calculated attenuation rate can be used quite safely. Careful checking of small increments of the attenuator output in the high output regions against small precision pads, should reveal the region where the attenuation rate starts to decrease as the driven end of the tube is approached. This region should be avoided. The TE_{11} mode is produced most purely by a symmetrically placed driving loop whose plane is precisely coincident with the plane of the pick-up loop. The pick-up loop should also be symmetrical in the tube.

In order to check the low-level r-f voltage device's attenuator, a signal generator was used to feed a precision piston attenuator. This attenuator output fed into the device's attenuator which in turn fed a very sensitive, stable receiver equipped with an easily read output meter. The piston attenuator output was increased to a level which gave a good sound reading above the noise on the carefully tuned receiver. Care was used to avoid the inaccurate region of the piston attenuator. The attenuator under test was then removed and the piston attenuator withdrawn until the receiver was observed to give the output reading it formerly had given. The measured attenuation was then the total length traveled by the piston times the attenuation per unit length. Using this procedure, the absolute attenuation of the piston is of no interest. In order that this replacement be valid, the piston attenuator output must be adjusted to 50 ohms. Fortunately, receivers operating at these microvolt levels are square-law detectors and therefore power measuring devices. This being the case, slight differences in mismatch between the output of the piston attenuator and the device's attenuator do not matter. The low-level r-f voltage device used as a standard at BRC checked against the piston attenuator within the readability of the measurement.

Standard Unit

The above tests were performed on a number of low-level r-f voltage devices and the best unit, in our judgment, has been retained as a standard. To control the quality of further units, it was necessary to determine to what precision the outputs of the various production units could be compared with this standard unit, considering the equipment to be used and the personnel who would be likely to make the tests.

The meter of the standard unit differs from a production model in that it is calibrated in percentage deviation from standard input. This is used to indicate how much the input voltage of the standard must be changed to produce an output which will have the same effect in a receiver as a unit under test. If the meter reads zero error, the unit is considered to be identical w·h the test unit at the test frequency. Of course, test frequencies are spotted all through the 0.1 through 1,000-mc band. To evaluate the precision to be expected, a considerable number of units were run through the same comparison tests three times by four different persons who are expected to run these tests during production. The results of these tests, shown in figures 4 and 5, were used to improve the operation of the receiver equipment in regions where the spread was unreasonable, and to incorporate the subsequent reasonable spread in the accuracy specifications to be published on the instrument. This tends to make the accuracy rating worse than it probably is, but in a device such as this these findings should be considered.

RF Voltage Standard Type 245-B

Articles concerning the design and application of the Type 245-B RF Voltage Standard have appeared in previous issues of the Notebook.[3,4] Briefly, the instrument is a very fine attenuator used in combination with a carefully

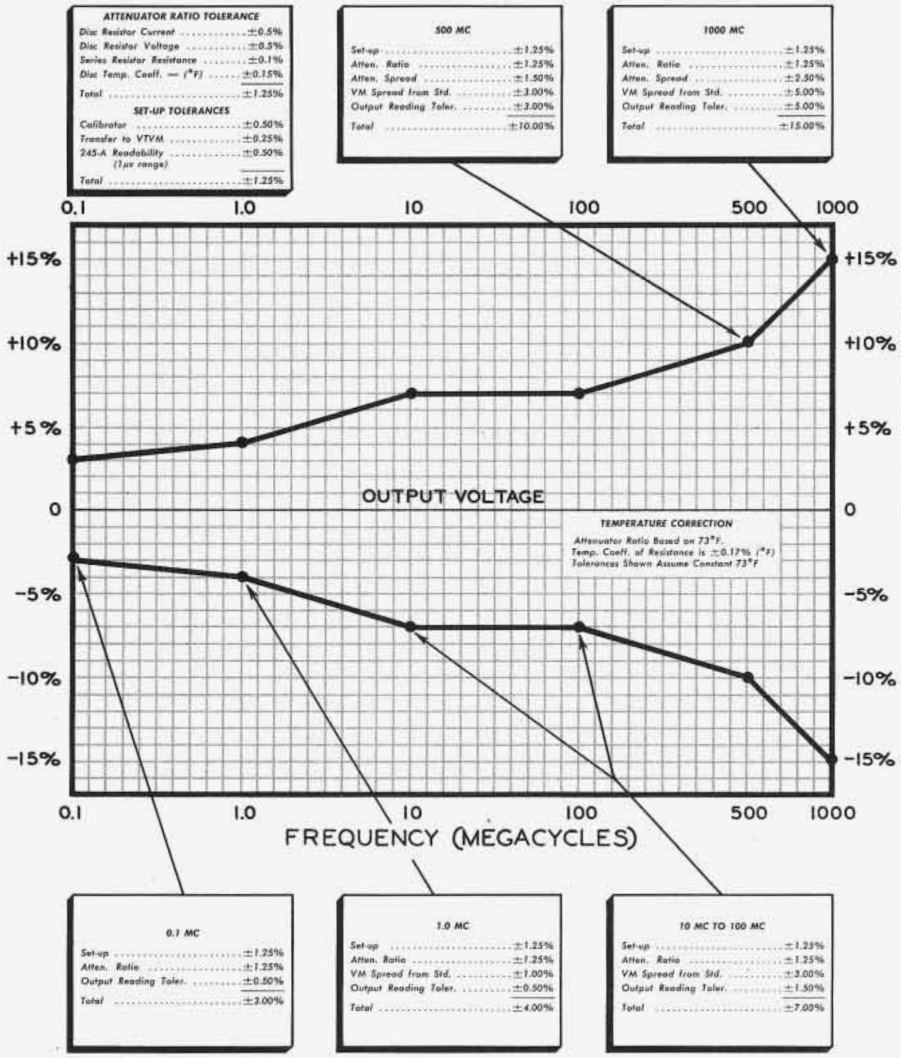

Figure 4. Production accuracy tolerance for RF Voltage Standard Type 245-B.

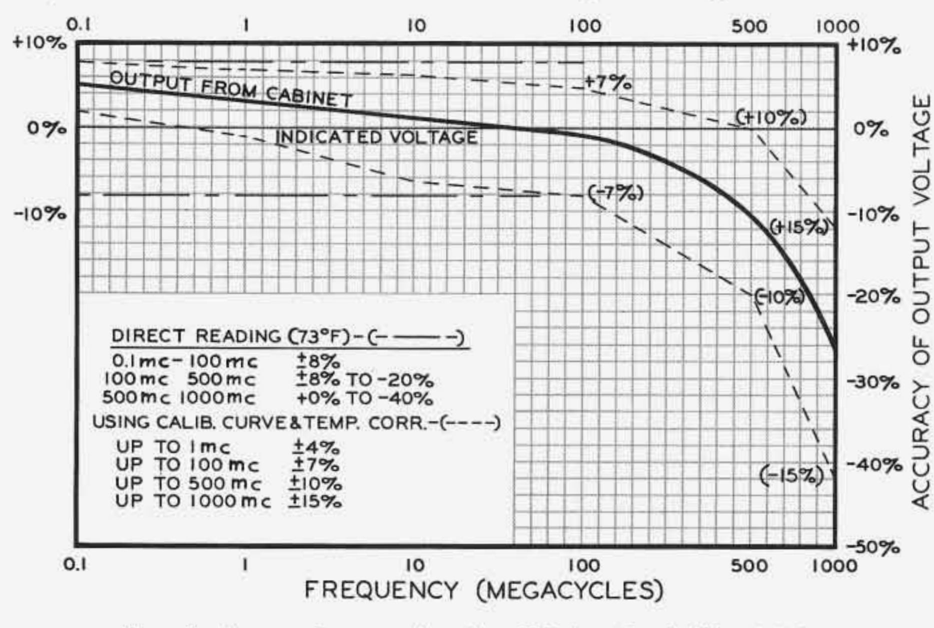

Figure 5. Accuracy of output voltage from RF Voltage Standard Type 245-B.

calibrated r-f voltmeter. When used in conjunction with a signal generator capable of producing 0.1 volt across a 50-ohm load, this device can serve as an indicator of the proper level which is to be fed to the fixed precision attenuator built into the device. The 245-A will deliver 2, 1, or 0.5 μv (depending on the voltmeter range selected) from the 50-ohm output cable of the internal precision attenuator. These levels can be considered standard levels, which are independent of the age, condition, or state of calibration of the signal generator used. The only limitation to be placed on the signal generator is that it have a dc output resistance of roughly 50 ohms (30-70).

The instrument is light-weight, operated from battery power, and small enough to be carried in a shoe box to the most remote locations. Using whatever generator may be on hand, the performance of the generator, or more important the performance of the receiving station, can be evaluated and compared with equipment in other locations.

Conclusion

It is apparent that measuring accurate voltage levels at frequencies of UHF and below is tedious and time consuming. The care which has been taken in its calibration should serve as encouragement to those who are willing to accept the Type 245-B RF Voltage Standard as a standard.

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The Use Of Standards With A Film Gauge

ANTS PIIP, *Development Engineer*

The Film Gauge, Type 255-A can be used for measuring film thicknesses of a variety of film-basis combinations, whether they be conductive films on nonconductive basis, conductive films on conductive basis, or nonconductive films on conductive basis. However, a calibrated standard is required for nearly every film-basis combination, if absolute measurements are to be undertaken. The preparation of these standards can usually be carried out by the user without too much difficulty. This article describes a few new kinds of standards, and gives a few pointers on how to increase the utility of prepared standards. The actual preparation of standards has already been covered in previous issues of the Notebook. [1, 2]

Actual Basis Material Slightly Different From The One Used On The Standard Card

The basis and plating materials of the piece to be measured and the standards should be identical if the meter readings are to have any value. However, if the basis materials are not too different, the instrument can still be made to give useful readings with the balancing procedure slightly modified as follows:

Set up and calibrate the instrument in the normal manner, using the samples on the standard card.

Without touching any controls, move the probe to a sample of the bare basis material actually used in the work. If the meter reading is not more than approximately one-half scale, the standard can be used with the new basis material.

With the probe on the new basis, rezero the instrument using only the SET BASIS control. The errors introduced by this small shift in the zero point are negligible. This method is applicable both on combinations having the same kind of conductive plating, or where the coating is a nonconductor (i. e., paint, ceramic, plastic, anodizing, etc.). In the latter case, the basis materials can differ by somewhat more than one-half scale; e.g., standards with an aluminum basis work perfectly on brass. The same procedure can also be followed for work which is not perfectly flat.

Inhomogeneous Basis Material

The situation is somewhat similar if the actual basis materials happen to be nonuniform (cold formed steels are notorious in this respect). The uniformity and variations-from-norm of the basis material can be checked by noting the 255-A readings on different spots or pieces of basis material. If a piece of coated material and one of the bare basis (identical to the basis on the first) are available, the feasibility of using the Film Gauge for film thickness measurement can be ascertained as follows:

Set up the instrument and adjust the sensitivity by means of the SET STANDARD control, until a nearly full-scale deflection is obtained with the thickest expected coating.

With these adjustments, analyze the actual basis materials to be used in the coating process. If the readings on the various basis pieces do not vary more than 10° from zero (basis), then the errors in thickness measurement should not become excessive. The readings will be unreliable for very thin coatings, where the deflections due to nonuniformities of the basis are comparable to those due to the coating. The readings above half-scale do however, give a reasonably true indication of film thickness.

Ferromagnetic Materials

Care should be exercised when measuring ferromagnetic basis and coating materials, to make certain that readings are ever increasing with coating thickness. Use a series of samples of known coating thicknesses for this purpose. If there is a dip, or even an apparent plateau in the thickness-reading curve, a reversal or a loop in the unrectified thickness-reading curve is indicated for this range of thicknesses and for the frequency being used. The meter circuit of the 255-A contains a rectifier, and therefore the instrument is incapable of distinguishing between positive and negative readings: both show up as positive. This results in ambiguities in calibration, producing identical rectified readings at three different thicknesses. If similar results are obtained at the other frequency position on the 255-A, the combination cannot be handled by the instrument. It should be noted however, that these ambiguous loops in the calibration curve do not normally show up in both positions of the GAUGE HEAD selector switch; at least not for the same thicknesses.

Synthetic Standards

Several of the common plating metals are rather soft; e.g., silver, cadmium, etc., and calibration standards using thin films of these materials will have a limited lifetime of usefulness because of wear at the point of contact with the probe spacer rod. However, these plated samples can be simulated by homogeneous specimens (see Figure 1).

Once the calibration of the 255-A has been determined using the actual plated standards, a piece of a third material can usually be found that will give a deflection close to the *thick* end of the scale. After *apparent* thickness of this piece of material is noted, it can be used, together with a sample of the actual basis material, for calibrating the instrument. The original plated samples can be filed as "prime standards" and used only for preparing and checking calibration curves.

Since there is a multitude of alloy materials available (e.g., aluminum, brasses, bronzes, nickel silver, etc.), it should not prove too difficult to find suitable *synthetic* standards.

Because the *synthetic* standards are homogenous, wear caused by the probe tip will not change their conductivity and their "apparent thickness".

If possible, the *synthetic* piece should have a conductivity between that of the basis and plating materials. The "synthetic thickness" holds only for the frequency at which it was calibrated. A change in test frequency, will change the "apparent thickness" appreciably.

Extremely Thin Conductive Films

Measurement of extremely thin conductive films (less than one-tenth maximum measurable thickness) by the conventional method; i.e., with the instrument balanced on the bare basis, usually does not give good results, particularly if the basis is also conductive. One of the main reasons for this is the reduced sensitivity of the instrument at low meter readings.

Improved sensitivity can be obtained by using a modified calibration technique. Instead of initially balancing the instrument on the bare basis, a sufficiently thick (more than the penetration depth) film of the coating material is used for the reference point. The instrument is balanced first on this thick sample, then the probe is moved to the thinnest sample and the sensitivity adjusted to give a reading near full scale. With this setting the two intermediate thicknesses required for the generation of a calibration curve (figure 2) are measured. After the calibration has been established, the thick film can be cemented on the card in the space provided for the basis, and the instrument can be used in the usual fashion. Using this technique, the meter readings will be "upside down" (see figure 3.) compared to the normal method; i.e., thickest film at the top, thinnest at the bottom.

A thick, plated or deposited film is used for the reference instead of a solid slab of the film material, because deposited films are apt to differ somewhat from solid stock, leading to inaccuracies in measurement.

If it is desired to measure thin plated films; i.e., conductive films on conductive basis, a further refinement is advisable. The thinner the plating, the more sensitive the instrument becomes to variations in the basis metal. Therefore, to eliminate reading errors that

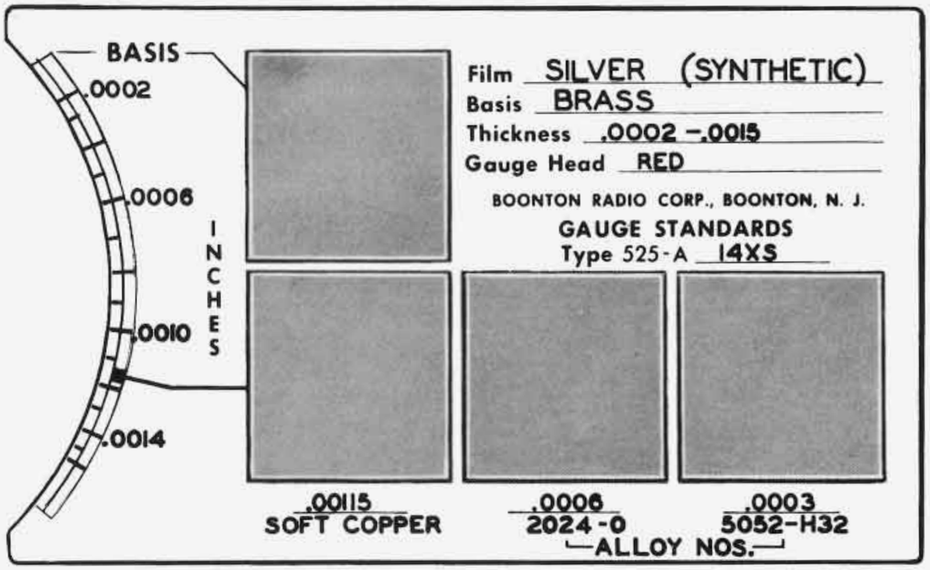

Figure 1. Gauge standard card utilizing synthetic material for plated samples.

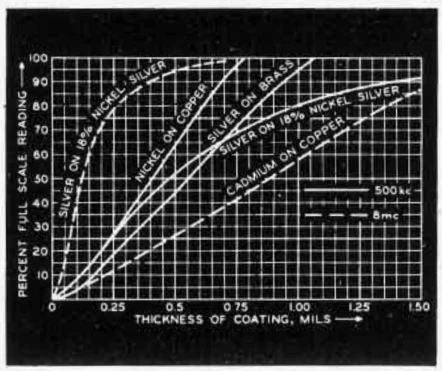

Figure 2. Typical samples of calibration curves.

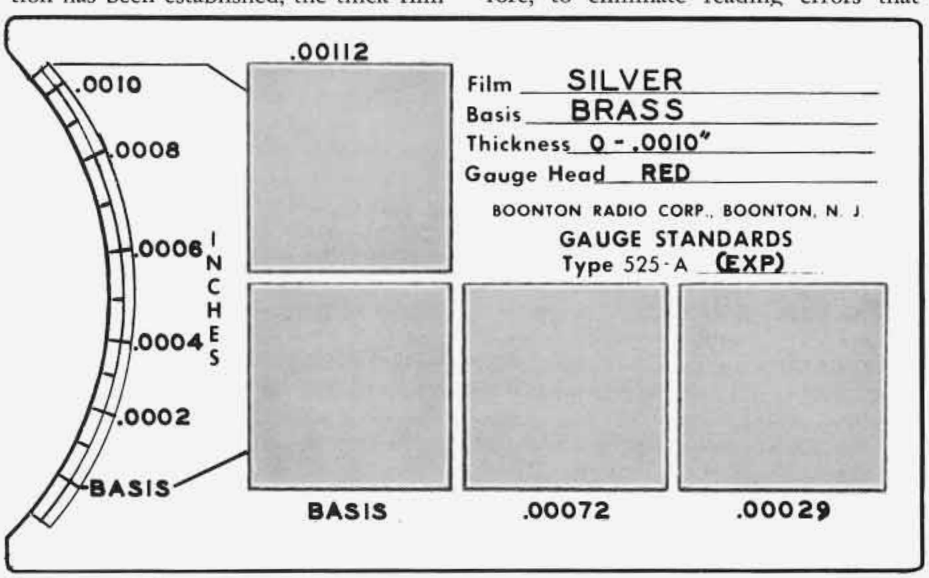

Figure 3. Gauge standard card used for measuring extremely thin films.

may be introduced because of variations of the basis, the last (thinnest) specimen of plating should be replaced with a piece of the bare basis. The calibrating or measuring procedure will be as follows:

Balance the instrument on the thickest film, using the SET BASIS control.

Adjust the sensitivity on the bare basis with the SET STANDARD control. If the actual basis should be slightly different from the one used in the standards, the instrument can be "touched up" by placing the probe on a piece of actual basis material and adjusting the SET BASIS control until the meter reading is the same as required by the standard. In doing this, be careful to keep the instrument tuned to the proper side of zero, i.e., in the direction where the meter does not pass through zero at the top end of the scale.

Thin Conductive Films On Nonconductors

Metal foils and metallizing are considered thin conductive films on nonconductors. It has been found that readings obtained for this type of film are rather insensitive to the probe-foil spacing. The readings remain unchanged from contact between probe and foil to a clearance of about $\frac{1}{32}$ inch. Calibration of the instrument for this type of film can be performed simply by using multiple thicknesses of the foil to establish the calibration point. Imperfect contact between layers does not show up on the 255-A. This insensitivity of spacing makes possible the use of the instrument as a noncontacting foil thickness gauge.

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BRC Celebrates Shipment Of Its 10,000th Q Meter

FRANK P. MONTESION, *Editor, The Notebook*

On May 10, 1957, Boonton Radio Corporation commemorated its 23rd year in the instrument design and manufacturing field with the shipment of its 10,000th Q Meter. The occasion was marked at a special ceremony held at the Company's plant. Highlighting the ceremony were brief congratulatory talks by Mrs. W. D. Loughlin, widow of the founder of the company, and Dr. G. A. Downsbrough, President and General Manager of BRC. Dr. Downsbrough told the company employees that the 10,000th Q Meter would be given to Rutgers University, the State University of New Jersey, for use in its engineering laboratories. "It is befitting," he said, "that this instrument be given to an institution of higher learning, and that the institution be located in New Jersey, where BRC was established and still makes its home."

Following the talks by Mrs. Loughlin and Dr. Downsbrough, was a talk by Mr. Lawrence Cook, Quality Control Engineer and BRC's senior employee. Mr. Cook related some interesting and amusing facts about the company's rise from a six-employee, one-telephone concern to a full-grown manufacturing organization. The celebration ended with the serving of refreshments to all company employees.

Q-Meter History

The Q Meter was the first instrument to be designed and produced by BRC after the company was established back in 1934 by Mr. William D. Loughlin and several of his associates. Since that time, the words "Q Meter" and "Boonton Radio Corporation" have become

Figure 1. Prior to shipment to Rutgers University in New Jersey, BRC's 10,000th Q-Meter is viewed by, left to right, Mr. L. Cook, Quality Control Engineer, Dr. G. A. Downsbrough, President and General Manager of BRC, Mr. B. Barth, Inspection Foreman, and Mr. T. O'Grady, Shipping Foreman.

almost synonymous.

At the time BRC was established, Q measurement methods were complicated, time-consuming, and often unreliable. The need for improved techniques was certainly eminent. Actually, the design of the Q Meter was undertaken to solve a specific problem encountered by a local concern engaged in the manufacture of hard-rubber coil forms. These coil forms were inspected by this company and met all of its requirements. However, when the forms were inspected by the purchasers, many were returned because they did not meet requirements. Investigation revealed that test instruments and techniques used by the manufacturer of the coils and the purchasers were different and therefore produced results which were not always the same. The problem of BRC's engineering staff then was to establish standard techniques for measuring Q. This was accomplished, and the operating principal and unique possibilities of the first Q Meter, Type 100-A, were presented in November 1934, at the Institute of Radio Engineers' fall meeting held in Rochester, N. Y. Soon afterward, the instrument was accepted as a standard by industry and research

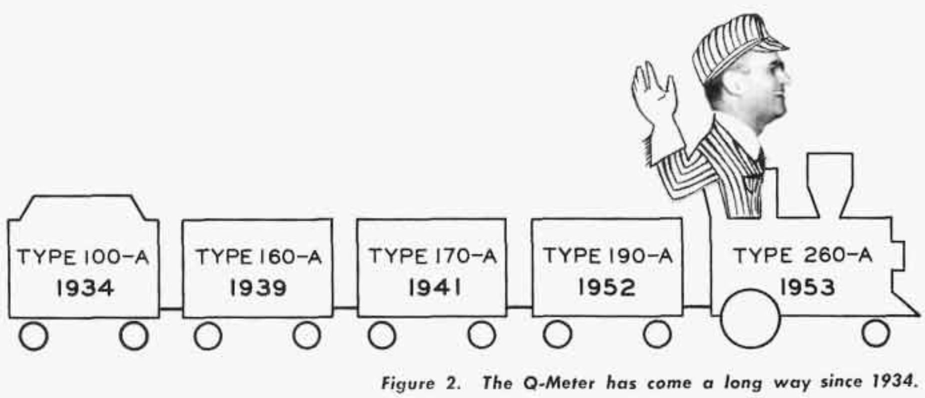

Figure 2. The Q-Meter has come a long way since 1934.

laboratories. Engineers and technicians in the growing radio industry received it enthusiastically.

With the advent of the Q Meter, simple, rapid, and accurate Q measurements became a reality. In the years that followed, improved models and broadened applications were introduced to keep pace with a rapidly growing industry (See figure 2). The Type 160-A Q Meter introduced in 1939, featured improved thermocouple shielding, more sensitive meters, and improved tuning capacitor design, adding together to provide for a much higher degree of accuracy in the high frequency range. In the early years of World War II, another Q Meter, Type 170-A, was designed to handle measurements in the very high frequency range. More recently, the 160-A and the 170-A were superseded by the 260-A and 190-A respectively, the latter instruments including such modifications as: "Lo Q" and "$\triangle$Q" scales, protection against thermocouple overload, power supply regulation, improved accuracy through the use of a newly developed annular insertion resistor, and other useful features.

Other Instruments

From this article, one might suppose that all of BRC's efforts during the twenty-three years since its establishment have been directed toward the development of the Q Meter. This is not the case. The engineering staff at BRC has been engaged in the development of numerous other electronic instruments which have found their way to electronic laboratories around the world.

EDITOR'S NOTE

Q Meter Winner

"The Q Meter is one of the basic instruments for any electronic laboratory and many hours of use have taught me to respect its accuracy and adaptability." Music to the ears of the BRC Sales and Engineering Departments were these words written by Mr. George S. Scholl winner of the Q Meter contest sponsored by BRC during the IRE convention in New York City last March. With his estimate of 338, Mr. Scholl outguessed almost 1,600 other hopefuls in trying to guess the Q of a coil displayed at the convention. Actual Q of the coil, as measured at BRC, was 336.7.

Mr. Scholl writes that he was born in Charleston, West Virginia and raised in Charlotte, North Carolina. After serving in the U. S. Army during World War II, he earned his BS degree in Physics in 1948 at the University of North Carolina. During the next few years, he was employed as a physicist at the U. S. Naval Ordnance Laboratory. He returned to UNC for two years graduate work, earning his MS in Physics in 1953. He worked again at NOL, this time as an electronic engineer, until 1956 when he joined the American Machine and Foundry Co., Alexandria, Virginia, where he is currently engaged in the development of instrumentation for measurement of air blast pressures. Mr. Scholl is married, has no children, and asserts that his chief hobby is "just relaxing."

Mr. George S. Scholl, Research Engineer with the American Machine and Foundry Co. of Alexandria, Va., is shown with the Type 160-A Q-Meter he won with his Q estimate of a coil displayed in the BRC booth at the IRE show in New York last March.

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