The GENERAL RADIO EXPERIMENTER

VOL. VII. No. 8 JANUARY, 1933

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

# RECENT DEVELOPMENTS IN MICA CONDENSERS

IN precise electrical circuits mica condensers have, for many years, played a very important part. Due to their low losses, they have been particularly successful in high-frequency communication circuits. The two general types available heretofore have been the very accurately adjusted primary standards of capacitance and the inexpensive moulded types which are usually adjusted only approximately to capacitance and are not particularly intended for use where their adjustment or constancy of capacitance is important. The precision kind is necessarily quite expensive and the cheaper ones have not been entirely satisfactory in many electrical circuits because of their drift due to atmospheric conditions and aging. This is particularly true in stable tuned circuits, as for instance beat-frequency oscillators, where the stability of adjustment depends upon the condensers remaining constant.

SIGNIFICANT improvements in the design and manufacturing methods have resulted in a new mica condenser having low losses, stability of calibration, temperature compensation, and several other features common in condensers of the precision-standard type. Yet the cost of the new unit is only a little more than that of the commercial types used as grid- and by-pass condensers in experimental equipment.

The General Radio Company has felt for some time the need for a well-designed mica condenser falling between these two classes. These condensers must not have appreciable drift with time, must not vary with atmospheric conditions, must have low losses, and must be adjusted to, and hold, a good accuracy.

With these requirements in mind, Mr. Greenleaf W. Pickard developed for the General Radio Company a completely different line of mica condensers.

Mica has established itself as one of the most efficient dielectric materials known. It is, however, a fair adsorbent for water. A thin film of moisture, perhaps a molecule thick, will collect on

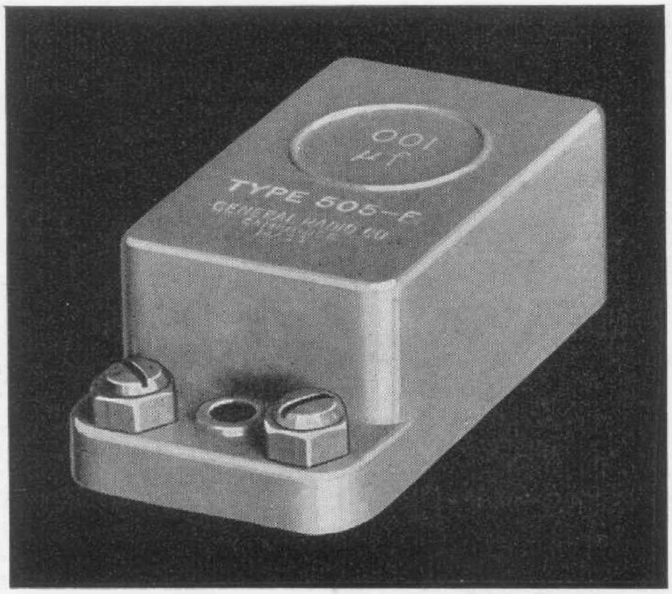



**Figure 1. Photograph of a Type 505 Condenser**

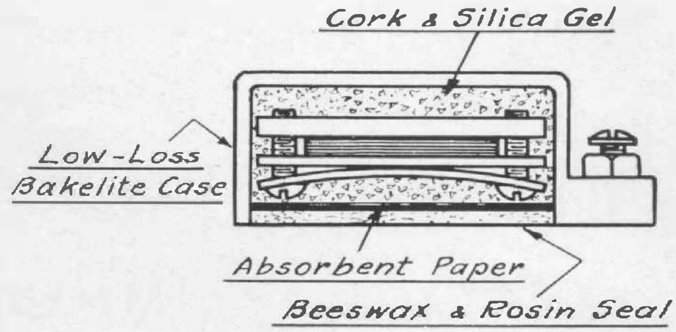



**Figure 2. Cross section of a Type 505 Condenser showing the method of construction**

the faces of mica and will increase its dielectric loss tremendously. In fact, the presence of such moisture can be detected most easily by the measurement of power factor. Therefore, the dielectric for the new condensers is kept at a temperature of 300° F. for a considerable time before the material is used. It is kept hot from the time that it is received until it is built into the condenser. In production, the mica and the conducting material are kept on a hot plate during assembly so that the elements are between 250° F. and 300° F., thus insuring dryness until they are finally sealed in their containers.

The next problem after the condenser is thoroughly dried is to keep it in that condition. This has been solved by placing the assembly in its case, together with a mixture of silica gel and ground cork, and enclosing it with a seal of rosin and beeswax. Silica gel is a very active desiccating agent. It will adsorb about 30% of its own weight in water and will maintain, in a closed space, a relative humidity of less than 0.5%.

The cases have less than a cubic inch of free air space. Enough silica gel is sealed in to adsorb all of the moisture that can be present in completely saturated air to a volume of 2000 times the free air in the containers before it will saturate. That is, there can be 2000 complete changes of air due to leakage before this desiccant will be used up; and this is for air having 100% relative humidity at room temperatures. It is estimated that it will take perhaps fifty years before this much breathing can occur.

Another most important cause for an increase in power factor is physical damage to the mica. Mechanical injuries, such as tiny scratches or any other accident that disturbs the crystalline structure, will cause large dielectric losses. Because of this, each piece of mica that is used in these condensers is very carefully inspected for physical damage. Thus, the two important causes for high dielectric loss have been taken care of, and, as a result, the condensers possess a remarkably low phase angle.

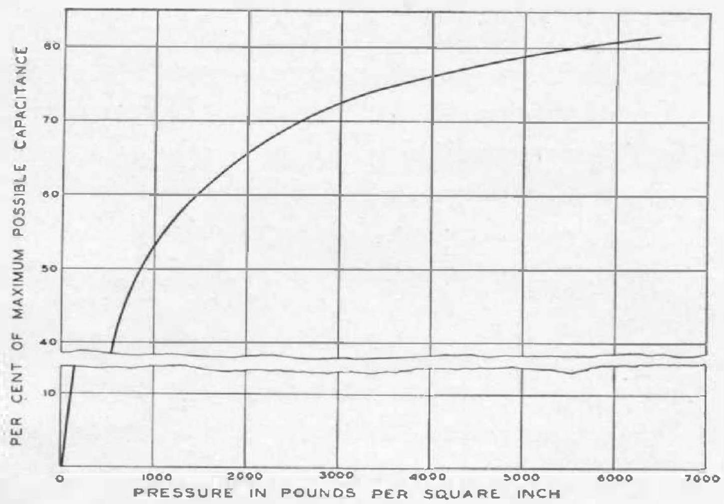



**FIGURE 3.** Variation of the capacitance of a mica condenser with pressure

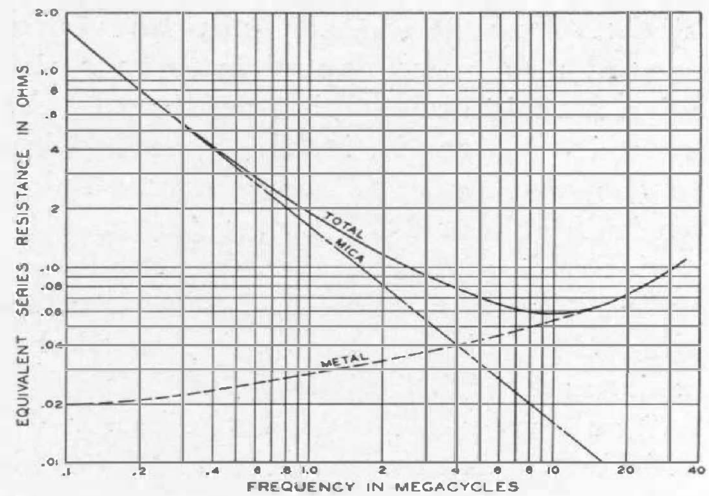



**FIGURE 4.** Equivalent resistance *vs.* frequency characteristic of a 400 $\mu\mu$f TYPE 505 Condenser. Note that the effect of the metal is important only at high radio frequencies

Figure 2 shows in cross section how the TYPE 505 Condensers are assembled.

The only other place where some electrical loss can be expected is in the possible absorption of power in the mounting case or the desiccating compound. The latter is eliminated because the field in it is essentially zero. The internal wiring and terminal arrangements are such that the electrostatic field through the case is very weak.

For this reason, ordinary moulded bakelite could be used. However, the added loss due to using a standard bakelite case can actually be measured because of the low power factor achieved in the condenser itself. Therefore, a low-loss bakelite composition is used, the electrical loss in which is a fraction of that in bakelite. It is especially compounded for low-loss operation and is designated "XN-262 Natural" by the Bakelite Corporation.

It is well known that changes in pressure in a mica condenser will cause very appreciable changes in capacitance. Figure 3 indicates how this change in capacitance looks when plotted against pounds per square inch pressure as applied to the condenser stack. The curve is asymptotic and has a pronounced knee at approximately 2000 pounds per square inch. Since it is evident that changes in temperature will vary the pressure and, hence, the capacitance, the pressure on these condensers is adjusted well beyond the knee of the curve where the change in capacity with pressure is small.

As the temperature changes, a part of the contraction or expansion of the material with the resultant change in pressure is compensated for in the construction of the units. The amount that remains will vary the pressure somewhat, but, due to the fact that the change occurs over the flat portion of the curve, the total change in capacitance from this cause amounts to an exceedingly small increment. The temperature coefficient of capacitance is less than 0.006% per degree Centigrade from 0 to 50° Centigrade.

As has been mentioned previously, the electrical loss in the condenser is slight. Any condenser can be represented as a pure capacitance in series with a resistance which represents the electrical losses in it, the combination of the resistance and capacitance being an indication of the power factor. The series resistance representing the loss is called the equivalent series resistance. Figure 4 indicates the variation of this resistance with frequency.

The curves show how the losses divide between the metal parts of a typical TYPE 505 Condenser and the mica. Because of the fact that in solid dielectric condensers $R\omega C$ is approximately a constant, the equivalent series resistance due to the mica alone drops off nearly inversely as the frequency for a given capacitance. This straight-line relationship holds as long as the losses in the metal or conducting parts of the condenser are negligible. However, at the very high frequencies (above 3 megacycles), the metal losses, which are due to the eddy currents in the conducting and supporting material, and to skin effect, become appreciable as compared with the dielectric loss and the curve of the total equivalent series resistance begins to curve upward again above 10 megacycles. These curves were taken on a stock condenser having a capacitance of 400 $\mu\mu f$ and a power factor at 1000 cycles of 0.04%.

Data taken on a large number of condensers have proven the TYPE 505 Condensers to be remarkably uniform in characteristics. The power factors are well under 0.05%. The power factor of all condensers is checked at the factory at 1000 cycles and, as will be noted from the curve in Figure 4, will not depart appreciably from this value for any frequency under 2 megacycles. At 30 megacycles, the power factor is only 0.7%. The power factor is measured at room temperature. It changes with temperatures so that for an increase of 17° C. the power factor doubles; for a decrease of 17° C., it halves.

The strict specification for freedom from drift has been met adequately by the sturdy mechanical construction and a design that essentially eliminates changes due to temperature and humidity.

Tests in our laboratory for a period of over six months have indicated that the drift with time of both capacity and power factor is entirely negligible.

—A. E. THIESSEN

TYPE 505 Condensers are made in 9 sizes and each is mounted in a bakelite case 2½ inches long by 1¼ inches wide and 1 inch high.

| *Type* | *Capacitance* | *Adjusted to Within* | *Maximum Peak Voltage* | *Code Word* | *Price* |
|---|---|---|---|---|---|
| 505-A | 100 $\mu\mu f$ | 10% | 1200 volts | CONDENALLY | $3.50 |
| 505-B | 200 $\mu\mu f$ | 5% | 1200 volts | CONDENBELL | 3.50 |
| 505-E | 500 $\mu\mu f$ | 2% | 1200 volts | CONDENCOAT | 3.50 |
| 505-F | 0.001 $\mu f$ | 1% | 700 volts | CONDENDRAM | 3.50 |
| 505-G | 0.002 $\mu f$ | 1% | 700 volts | CONDENEYRE | 3.50 |
| 505-K | 0.005 $\mu f$ | 1% | 500 volts | CONDENFACT | 4.00 |
| 505-L | 0.01 $\mu f$ | 1% | 350 volts | CONDENGIRL | 4.00 |
| 505-M | 0.02 $\mu f$ | 1% | 350 volts | CONDENHEAD | 4.00 |
| 505-Q | 0.05 $\mu f$ | 1% | 350 volts | CONDENJACK | 4.50 |

# A COMBINATION MONITOR AND FREQUENCY METER FOR THE AMATEUR


The Type 535-A Frequency Meter-Monitor

Due either to failure to use any frequency-measuring device or to lack of confidence in the stability of their home-made frequency meters, amateurs in increasing number are attempting to operate their transmitters by setting them to a frequency "somewhere near the middle" of each amateur band. This condition tends to aggravate the already severe interference present in most of these bands.

Many amateurs whose transmitters are equipped with quartz-crystal control or with other power-amplifier combinations with oscillators of comparatively high stability assume that precise frequency-measuring apparatus is not required. Since many amateur power oscillators are operating in a highly regenerative state, it is comparatively easy for these amplifiers to oscillate, emitting signals which may be far outside of the band in which they were intended to function. In addition, transmitters, even of the power-amplifier type, when operating near the extremities of any amateur band, may easily drift out of the band through the normal shift in frequency caused by changes in temperature, supply voltage, and other effects. The amateur equipped with an accurate heterodyne frequency meter is able to operate on a frequency away from crowded portions of the band and to set his transmitter anywhere within the band.

For these reasons General Radio feels that a need exists for an amateur and experimental heterodyne-type frequency meter, the characteristics of which are such that the instrument may be used over comparatively long periods of time without recalibration.

Inherently, the Colpitts oscillator is probably the most stable of all the common oscillator circuits. This circuit, however, must be provided with additional stability before it can be used as a heterodyne frequency meter of relatively high precision. If the electron-coupled circuit is applied to the Colpitts and if voltage stabilization is secured, a frequency meter well suited to amateur and experimental use can be designed.

In the past, amateurs have made use of both a frequency meter to measure frequency and a separate monitor to check the character of actual transmissions. The need for two instruments has been due to the fact that, when sufficient coupling to the transmitter is secured to use the frequency meter as a monitor, the calibration of the frequency meter is impaired. In a new General Radio instrument the functions of both frequency meter and monitor are successfully combined, since the electron-coupled Colpitts circuit does not appreciably shift in frequency when coupled to an external load.

## FREQUENCY STABILITY

For amateur use, certain factors which contribute to the absolute stability of a heterodyne frequency meter, such as temperature variations over a wide range, aging, change in tubes, mechanical shock, etc., may be disregarded since the calibration of an amateur frequency meter may be checked very readily when any such factors enter.

Under normal conditions of use, the General Radio frequency meter will have a working stability as follows:

| *Variable* | *Range* | *Parts per Million at 2000 Kilocycles* |
|---|---|---|
| Supply Voltage | 45-112 Volts | 25 |
| External Load | . . . . . . . . . . . | 5 |
| Temperature | ±5° F. | 500 |
| Heater Voltage | ±20% | 10 |
| Total (assuming all errors occur in the same direction) | | 540 |

The total deviation (deviation capability) of 540 parts per million represents the maximum to be encountered under normal operating conditions, when all of the variables cause a deviation in the same direction. The deviation capability of amateur heterodyne frequency meters has been grossly disregarded in rating the accuracy of such devices in that many factors adversely affecting the frequency stability have been ignored in order to claim greater precision. Practically, it is obvious that variation in "B" supply voltage from 112 to 45 volts will not be encountered, 90 to 67½ representing the probable maximum. Also heater voltage variation of 20% would result in the equipment being operated in semi-darkness!

The General Radio frequency meter is designed to operate on any fundamental frequency between 1700 and 2000 kilocycles, this frequency range being spread over 265 divisions of the tuning dial. The meter is sufficiently rich in harmonics to be operated in any of the amateur bands up to the highest.

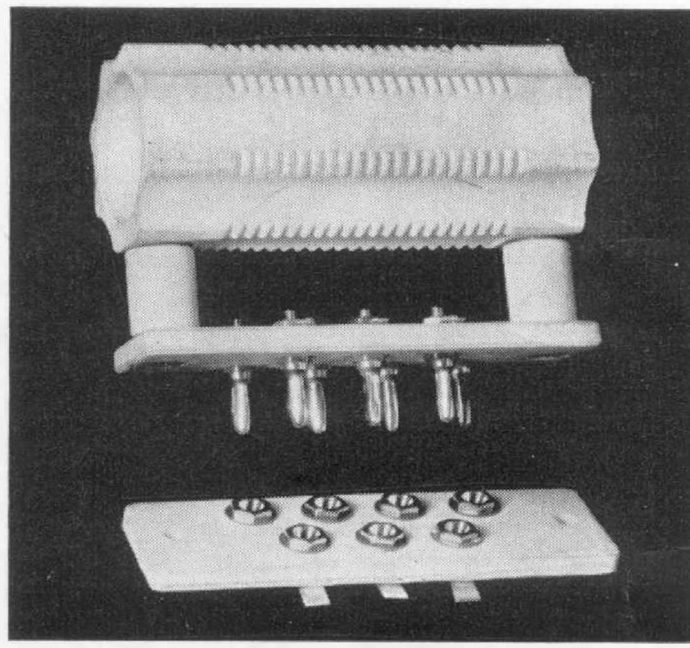
To enable the user to read the frequency as precisely as possible, the meter is equipped with the 6-inch General Radio Type 706-A Precision Dial having 300 divisions. By means of the glass magnifier it is possible to estimate accurately the setting to within 1/5th of a dial division, or to within

250 cycles in the 1700- to 2000-kilocycle band. This precision of setting is better than that which can be obtained with the usual 100-division dial and true vernier indicator. The precision of setting is further enhanced due to the use of a dial scale which is individually engraved (not etched or stamped) or a precision dividing engine.

The meter is supplied with a calibration chart, the settings for thirteen frequencies in the 1700- to 2000-kilocycle band being determined from the General Radio primary standard of frequency, which is accurate to better than one part in a million. Additional calibration charts to assist the user in recalibrating the meter from standard-signal transmissions, and twelve calibration curve sheets to which the user may transfer the calibration data, are furnished with each meter.

The meter costs $42.50 and is known as the General Radio Type 535-A Frequency Meter-Monitor.

## A NEW COIL FORM



For use by laboratories, amateurs, and experimenters in medium power oscillators, transmitters, and power amplifiers a need exists for a comparatively simple inductance form of low loss and moderate price.

The new General Radio Type 677-U Coil Form was designed for this purpose. This form is of moulded porcelain having six heavy ribs. The form is 2½ inches in outside diameter, 4⅝ inches long, and has twenty V-cut threads occupying a space of 3 inches. Any size wire up to No. 10 B. & S. gauge may be used. Twenty turns with a 500-micromicrofarad variable condenser will cover the 160-meter amateur band.

To facilitate use in circuits where quick change of inductance is desired, the coil can be supplied with plug and jack plates of moulded porcelain. In amateur and experimental transmitters these forms are suited to use in oscillator, buffer, and amplifier circuits. Plate and grid or plate and antenna inductances may be wound on one form, proper connections being possible through the seven plug and jack terminals. Holes at irregular intervals are provided along the length of one rib of the form to allow easy termination of coils.

The complete assembly (sold separately as desired) consists of a Type 677-U Coil Form (35 cents), two Type 677-P1 Coil Form Spacers (15 cents each), a Type 678-P Plug Base with seven Type 274-P Plugs (70 cents), and a Type 678-J Jack Base with seven Type 274-J Jacks (65 cents).

# NEW PRECISION DIALS

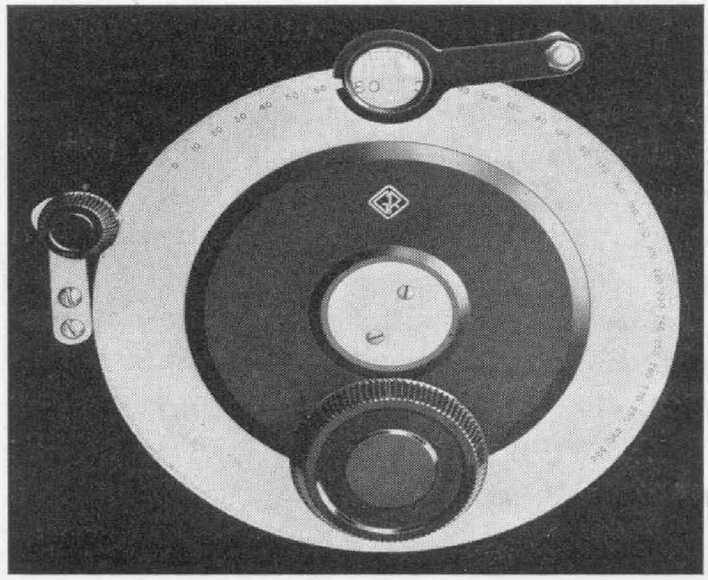
SEVERAL recent General Radio instruments are appearing with a new type of dial.

The new dials are distinguished by a smooth friction slow motion. An internal drive is used so that the driving knob rotates in the same direction as the dial. The black bakelite central portion of the dial is stationary.

The scale is carried on the nickel-plated moving rim. Divisions are engraved on a dividing head and are thus accurately spaced and identical in width.

The dials are easy to mount, requiring only one hole in the panel in addition to the instrument shaft hole. The new dials are made in four-inch and six-inch diameter with 180- and 270-degree scales.

Two other accessories are shown in the accompanying illustration. The TYPE 520-A Dial Lock can be mounted at the edge of the dial and can be used to lock the dial securely in position.



TYPE 706-A Dial with TYPE 519-A Lens and TYPE 520-A Dial Lock

This is desirable when the instrument is to be used at a single setting as a fixed standard.

The TYPE 519-A Lens is mounted above the indicator and serves to increase the accuracy of setting and reading. The features of the dials and accessories are summarized below.

| Type | Dial Diam. | Dial Arc | Scale Divs. | Diam. of Knob | Approx. Reduc. Ratio | Weight | Code Word | Price |
|---|---|---|---|---|---|---|---|---|
| 704-A | 4 in. | 180° | 200 | 1½ in. | 1:6 | 10 oz. | DABBY | $7.50 |
| 704-B | 4 in. | 270° | 300 | 1½ in. | 1:6 | 10 oz. | DAIRY | 7.50 |
| 706-A | 6 in. | 180° | 300 | 2 in. | 1:8 | 18 oz. | DASHY | 8.00 |
| 706-B | 6 in. | 270° | 450 | 2 in. | 1:8 | 18 oz. | DATUM | 8.00 |
| 519-A | .... | .... | ... | .... | ... | .... | ABASH | 1.50 |
| 520-A | .... | .... | ... | .... | ... | .... | ABATE | .75 |

*THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the*

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

PRINTED IN U.S.A.