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

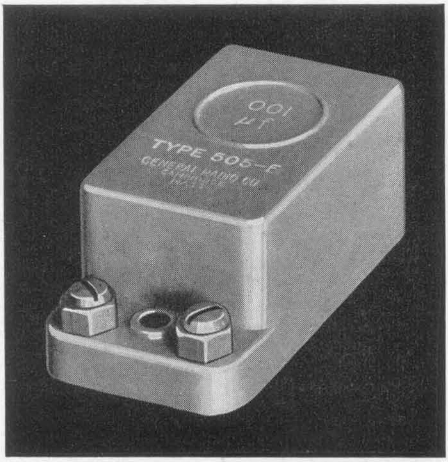

FIGURE 1. Photograph of a TYPE 505 Condenser

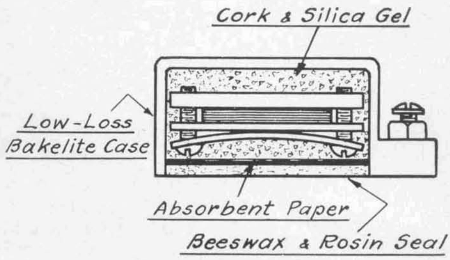

FIGURE 2. Cross section of a TYPE 505 Condenser showing the method of construction

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.

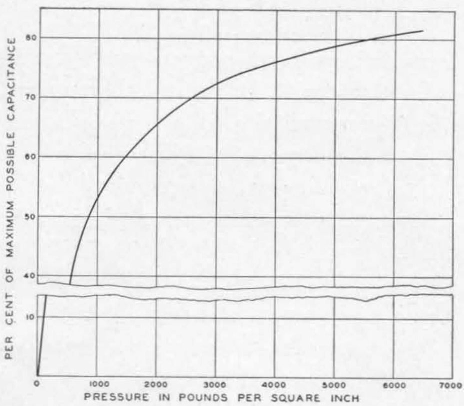

FIGURE 3. Variation of the capacitance of a mica condenser with pressure

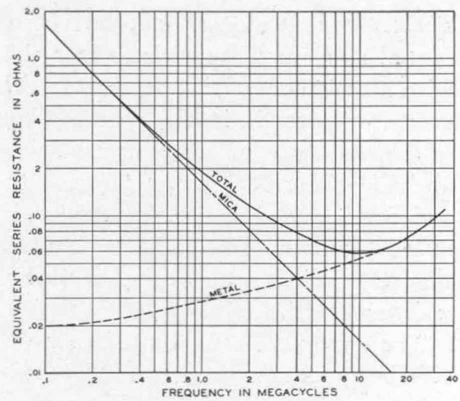

FIGURE 4. Equivalent resistance *vs.* frequency characteristic of a 400 $\mu\mu$f TYPE 505 Condenser. Note that the effect of the metal is important only at high radio frequencies

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 μf	1%	700 volts	CONDENDRAM	3.50
505-G	0.002 μf	1%	700 volts	CONDENEYRE	3.50
505-K	0.005 μf	1%	500 volts	CONDENFACT	4.00
505-L	0.01 μf	1%	350 volts	CONDENGIRL	4.00
505-M	0.02 μf	1%	350 volts	CONDENHEAD	4.00
505-Q	0.05 μf	1%	350 volts	CONDENJACK	4.50