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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

A PIEZO-ELECTRIC OSCILLATOR OF IMPROVED STABILITY

SINCE the studies of performance of the Type 575-A Piezo-Electric Oscillator described in the *Experimenter* for October and for November, 1930, increased demands have been made for even higher accuracies and higher stabilities, notably as a result of the Federal Radio Commission General Order No. 116 requiring broadcasting stations to maintain their frequencies within plus or minus fifty cycles of the assigned value. The new Type 575-D Piezo-Electric Oscillator described below was developed primarily to serve as a frequency standard in conjunction with the Type 581-A Frequency Deviation Meter as a visual monitor complying with the requirements of the General Order.

The rigid requirements which must be met by such frequency standards led to investigations of various circuits to improve the frequency stability and the operating characteristics. One of the more serious defects of the older oscillators was the necessity of calibrating the quartz plate in the oscillator with which it was to be used. If changes occurred in the circuit constants due to shipment or to ageing, the user was not aware of these changes or the resulting shift in frequency. Further, in cases where readjustments or recalibrations were to be made it was necessary to return not only the quartz plate but the entire oscillator to our laboratory.

The circuit finally chosen overcomes most of the objections. A definite indication of proper adjustment is provided by the plate current meter which indicates a minimum current when the circuit is properly adjusted. Regardless of changes in the circuit constants, supply voltages, and tubes, adjustment of the circuit to the minimum plate-current point will give the same frequency to within exceedingly small limits.

The schematic circuit is shown in Figure 1. A screen-grid tube is employed to reduce the capacitance between control grid and plate. The

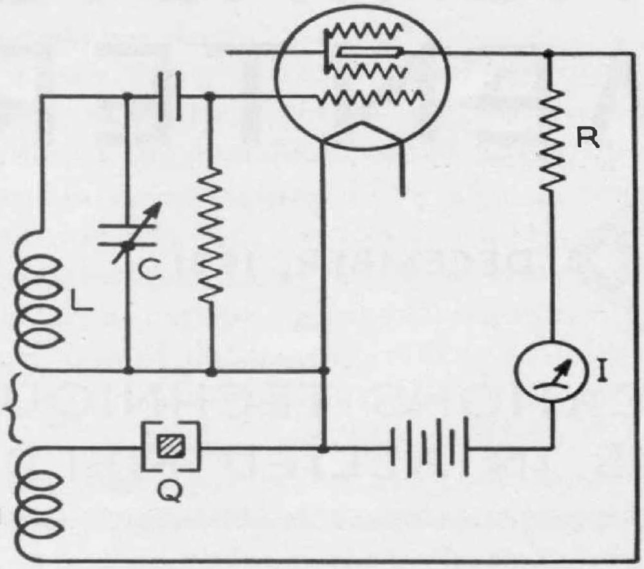

FIGURE 1. Functional diagram for TYPE 575-D Piezo-Electric Oscillator

quartz plate is connected in the plate circuit in series with the feed-back coil L_1. The resistance R serves to supply plate voltage to the tube from the plate battery and also serves as a radio-frequency coupling mechanism. The small capacitance between grid and plate and the resistor R serve to prevent the circuit from functioning as an inverted crystal oscillator of the usual type* where feed-back is obtained in the inter-electrode capacitance and the crystal presents an inductive reaction of appreciable magnitude. It will be noticed that the current through the crystal is the current through the feed-back coil L_1 — consequently the crystal may be thought of as controlling the oscillator by control of the feed-back. Current in R produces no feed-back.

The performance of this oscillator is characterized by (*1*) oscillation over a very narrow range of adjustment of C, (*2*) very reliable oscillation when the condenser is adjusted to the middle of this range, and (*3*) a minimum plate current indicated by the meter I when adjustments are properly made.

Performance data for a representative broadcast-frequency quartz plate are presented below in the same form as the data of the article in the November, 1930, *Experimenter*. The deviation resulting from changes in any variable, the other factors remaining constant is summarized below:

Temperature Changes (*Figure 2*). The quartz plate employed was of the "Y" or "30-degree" cut having a positive temperature coefficient. It will be noticed that for a change of ±0.1°C from the normal temperature of 50°C (1/5 of 1%) the resulting frequency change is within ±2.5 parts per million, which is definitely lower than for the same type of crystal in the older circuit. Dotted lines indicating the range of ±0.025° (which may be maintained under average room temperature conditions by the temperature control system furnished in the unit) show that ordinarily the frequency changes resulting from temperature variations will be less than ±0.75 part per million.

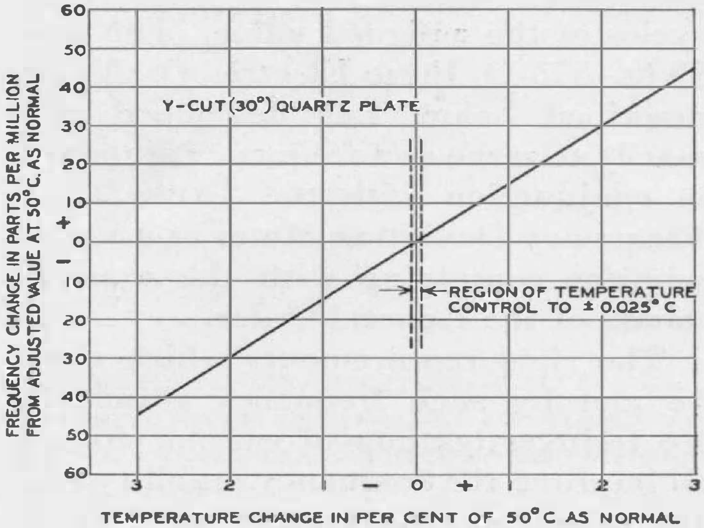

FIGURE 2. Variation in frequency of the new oscillator as a function of the temperature of the quartz plate

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*That is, one in which the crystal is placed in the plate circuit and the tuned element in the grid circuit.

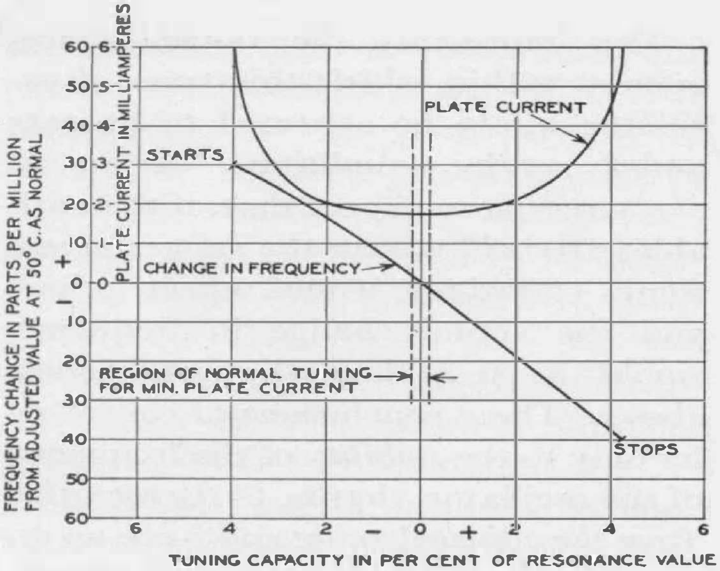

FIGURE 3. Variation in frequency as a function of grid-tuning capacitance

Tuning Changes (*Figure 3*). The frequency of oscillation is altered, when the grid tuning condenser is varied. In the region of the plate current minimum, where definite changes in the reading of the plate current meter are observable (as shown in the upper curve) the change in frequency is within ±1.5 parts per million.

Plate Voltage Changes (*Figure 4*). It is at once evident that moderate changes in plate voltage have no effect on the frequency of oscillation. This is in definite contrast to the changes obtained with the older circuit.

Filament Voltage Changes (*Figure 5*). For changes in filament voltage of several per cent., which are easily observed on the filament voltmeter of the new oscillator no appreciable change in frequency results. If the filament voltage is decreased far enough, the frequency rises, as shown by the upper curve. But if, for each value of filament voltage, the tuning condenser is readjusted to give minimum plate current, the change in frequency is entirely negligible, as shown by the lower curve.

Tube Changes (*Figure 6*). Changing tubes, the circuit being readjusted to minimum plate current for each tube, resulted in the frequency changes shown. Twelve tubes, some of which were new and some old, all gave operating frequencies within ±1 part per million. If tubes No. 2 and No. 5 were rejected, the remaining 10 tubes give frequencies practically within the limits of the ±0.5 part per million.

Vibration. In making tests for vibration, the entire unit was subjected to heavy shocks. These resulted in two types of frequency change: that due to motion of the quartz plate in the mounting, and that due to shifts in the tuning of the grid circuit. The latter could be compensated for by readjustment of the tuning condenser for minimum plate current. With readjustment, the shifts remaining after the

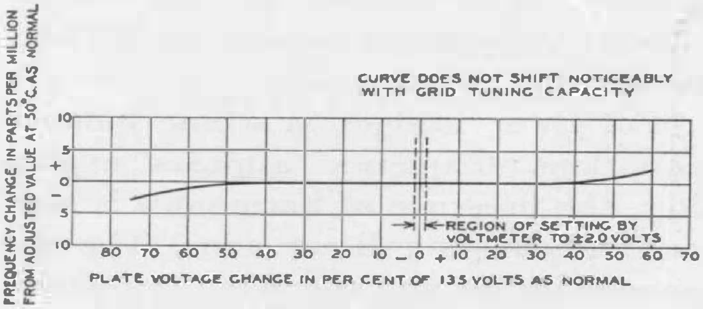

FIGURE 4. Variation in frequency as a function of plate voltage expressed as a per cent of normal

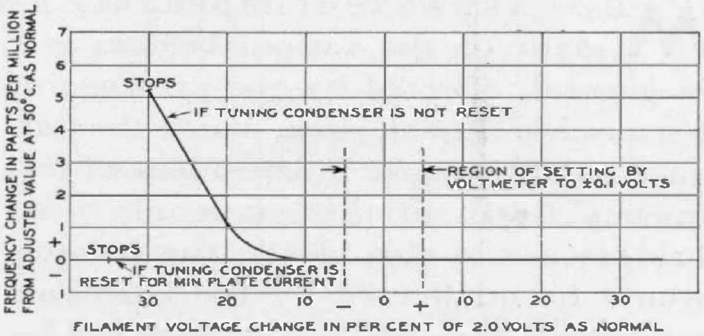

FIGURE 5. The frequency shows no perceptible change with filament voltage if the condenser is reset for minimum plate current

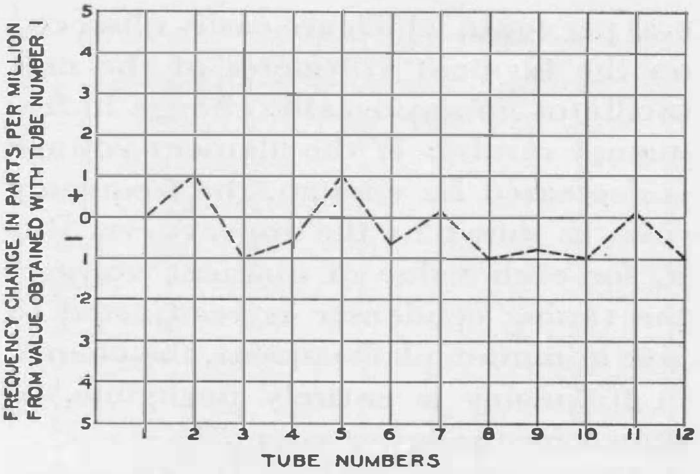

FIGURE 6. Frequency shifts very slightly when tubes are changed

vibration stopped were within ±1.5 parts per million.

As an estimate of the absolute constancy of frequency of the system, it may be assumed that all of the variations observed take place in the same direction:

Variable	Range of Variation	Frequency Variation (parts per million)
Temperature	0.025°C	0.75
Tuning (by plate meter)		1.5
Plate voltage	2.0 volts	0.1
Filament voltage	0.1 volts	0.05
Tubes	(average)	1.00
Vibration	(heavy shocks)	1.5*
	Total	4.9

*Remaining after shock.

This represents the range of frequency within which this type of oscillator would be expected to operate under service conditions. There is every reason to expect that, if the variables are held within the ranges given, some variations would offset others and the actual change in frequency would be less than the total given above. These conclusions of course refer only to the *stability* of the frequency of the oscillator, that is, to *the variation from the adjusted value* and have no direct bearing on the accuracy of adjustment of the oscillator to a specified frequency.

Quartz plates suitable for use in the TYPE 575-D Piezo-Electric Oscillator and guaranteed to within ±0.002% for a period of one year are available. They are known as TYPE 376-J Quartz Plates. In adjusting these plates, the frequency is brought within one cycle of the specified frequency as determined by our primary frequency standard which is operated continuously and checked in terms of Arlington time.

The price of the TYPE 575-D Piezo-Electric Oscillator is $215.00; of TYPE 376-J Quartz Plates $85.00.

— JAMES K. CLAPP

ELIMINATING HARMONICS IN BRIDGE MEASUREMENTS

MEASUREMENTS of impedance as made on the various bridges are, in general, affected by the presence of harmonics. For those in which the balance conditions are independent of frequency (most of the commonly used bridges are in this class), the balance would be unaffected by the harmonic content of the source, if it were not for the fact that the resistance of a coil or a condenser varies considerably with frequency. The balance for the fundamental frequency is masked by the harmonics in the output.

For those bridges in whose balance equations frequency appears explicitly, the presence of harmonics is serious and causes a direct error. The resonance bridge and the Wien bridge are examples.

Voltages other than harmonic voltages also frequently appear in measuring circuits. They are induced in the circuit electromagnetically and electrostatically by the fields, usually of commercial frequency, which exist in most laboratories. They become important when the voltage to be measured is reduced to a sufficiently small value. For that reason they become the limiting factor in bridge balances by preventing the attainment of complete silence in the head telephones.

Spurious voltages, harmonic or non-harmonic, may be decreased in magnitude by the use of suitable filters which may be connected directly to the power source in order to decrease the harmonic content of the voltage applied to the measuring circuit. They would be so placed for the measurement of any element which might be affected by such spurious voltages.

Filters may also be connected between the bridge and the null detector. This is usually the preferable position, because in general the impedance of the null detector is greater than that of the bridge. Filters have in general sharper cut-offs the higher the impedance to which they are connected.

A band-pass filter made up of low-pass and high-pass sections is satisfactory for measurements made at a single frequency. The characteristic impedances of these sections should be chosen to be equal to or less than the load into which they work. Low-frequency non-harmonic voltages are suppressed by the high-pass section; high-frequency non-harmonic voltages, and all harmonic voltages by the low-pass section. The cut-off frequencies of these sections may be so chosen that the applied frequency may vary considerably without affecting their action.

The Type 330 Filter Sections* are built for three different cut-off frequencies, 500, 1000, and 2000 cps, and two different characteristic impedances, 600 and 6000 ohms. The attenuation obtainable with these sections

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*Described in Catalog F, page 97.

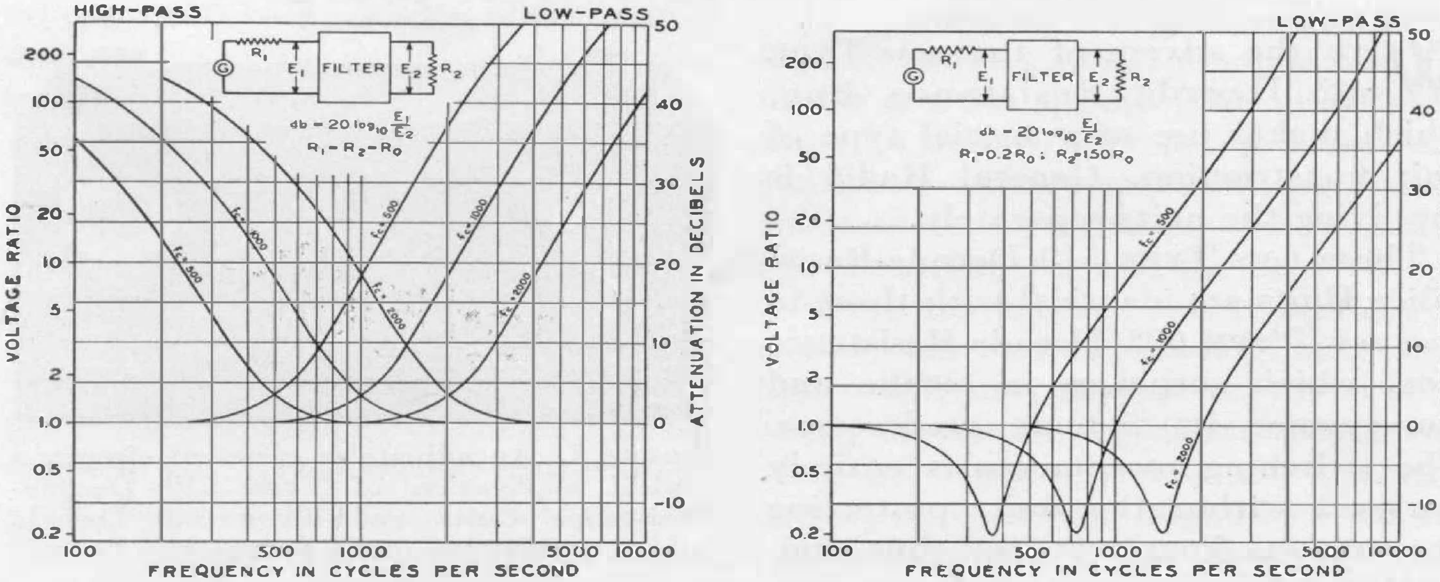


Figure 1 (left) and Figure 2 (right). Attenuation characteristics of Type 330 Filter Sections for the values of terminating impedance shown. *fc* is the cut-off frequency and *Ro* is the characteristic impedance (either 600 or 6000 ohms) specified in Catalog F when terminated in their characteristic impedances are shown in Figure 1. The three curves for each type of section are alike, being merely displaced along the frequency axis.

The 500-cps high-pass filter section is suitable for suppressing the usual low-frequency non-harmonic voltages. The three low-pass filter sections are suitable for suppressing the high-frequency harmonic voltages. The attenuation to the second harmonic, which is usually the strongest, exceeds that to the fundamental by at least 15 db (a voltage ratio of 5.5 to 1). The frequency of the fundamental may increase by 50% before the attenuation to it becomes 10 db.

When a filter section is connected to a load resistance much larger than its characteristic impedance, the ratio of input to output voltage is decreased in the transmission band, if, in addition, the input resistance is made much smaller than the characteristic impedance of the filter. This ratio becomes less than unity at a frequency near the cut-off frequency, thus giving a voltage characteristic similar in some respects to that of a resonant circuit.

Such curves for the three low-pass filter sections are shown in Figure 2. They are for the case of input and load resistances 0.2 and 150 times their characteristic impedance. The attenuation to the second harmonic is on the average the same as for the previous case. The fundamental frequency may, however, vary from 0.6 to 1.5 times the cut-off frequency, without causing the discrimination between fundamental and second harmonic to fall below 15 db. Within this range the attenuation to the fundamental varies between —14 db and +10 db. The range of the three filter sections overlap and together they cover the frequency band from 300 to 3000 cps. Other sections may be built on special order, which will extend this range up to 7500 cps and down to 60 cps.

— Robert F. Field

CONVENIENT DECADE-SWITCH UNITS

With the advent of the new Type 602 Decade-Resistance Box, which makes use of a special type of unit construction, General Radio is supplying the units separately.

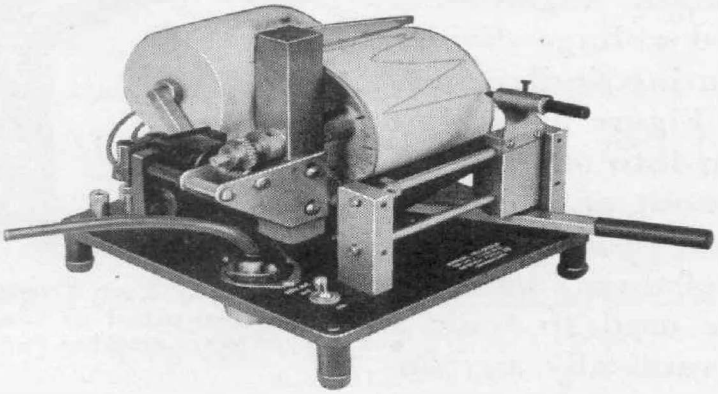
These new Type 510 Decade-Resistance Units are identical with those in the new Type 602 Decade-Resistance Box, which surpasses in results and convenience its famous predecessor. The switching mechanism is entirely enclosed within the unit, protecting the contacts from dust, and thus eliminating a frequent source of poor contact and leakage. Each individual unit is provided with a cylindrical shield and an etched dial plate to facilitate mounting on a panel.

Figure 1. An adjustable resonant circuit, a typical application of Type 510 Decade-Resistance Units and Type 380 Decade Switches and Condensers

(Continued on page 8)

A MANUAL RECORDER

Curve-drawing equipment makes it possible for engineers to record variable phenomena and interpret or compare results at their convenience.



Type 459-A Manual Recorder. Moving the handle simultaneously moves the pen and the slider on a potentiometer

Early in 1927 the Type 289 Fading Recorder was developed by the General Radio Company* in conjunction with the study of radio transmission carried on by G. W. Pickard. The Type 459-A Manual Recorder shown on this page has just been designed. In this new instrument standard 3½ inch adding machine paper is carried past a recording point at a uniform rate and the position of this point may be varied manually to follow and trace the curve of the variable being studied.

The main drum is driven by a small 60-cps, 110-volt synchronous motor and the gearing is so adjusted that the paper travels exactly one inch a minute. The drive is made positive by small points projecting through the drum, and these are so spaced that the perforations caused by them in the paper are exactly one inch apart.

The drum on the standard units makes five complete revolutions an hour, but the gearing of course can be changed to meet special conditions, giving a rather wide variation of speeds. The drum may also be loosened from the drive shaft by a thumb nut. A spring slider carries both the recording point and the contact arm of a potentiometer. A lever makes it possible to follow the desired variations either by maintaining a constant deflection or a null point on a galvanometer.

The Type 459-A Manual Recorder is used in a manner similar to the earlier Type 289 Fading Recorder for the study of fading of radio transmissions. In recording the variation in signal intensity, the necessary changes of the arm to balance them result in a trace on the recording paper of magnitudes corresponding to the changes in signal strength.

The potentiometer in the standard instrument is a tapered card having a maximum value of approximately 2000 ohms. To meet special conditions this card may easily be replaced.

The slider has a long bearing and is kept in contact with the guide bar by means of a flat spring. This allows the slider to move freely at all times but eliminates unnecessary side play and compensates for contact friction on both the potentiometer and the drum.

While the original intent of the recorder was to study fading, it is felt that it will serve to draw curves so necessary for the intelligent interpretation of many other phenomena. For example, the recorder might be used in conjunction with a beat-frequency oscillator driven by a similar synchronous drive in studies of acoustics.

The price is $85.00.—H. S. Wilkins

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*See *General Radio Experimenter* for April, 1927.

(Continued from page 6)

These units can be used in many ways. For instance, they are invaluable in the construction of adjustable impedance-matching networks, special attenuators, or harmonic analyzers. Provision has been made so that several units can be "ganged" together. A very useful calibrated voltage divider can be made by mounting similar units "back to back" (see Figure 3) so that when resistance is cut into one unit, it is simultaneously cut out of the other, thus keeping the total resistance constant. Any number of these "back-to-back" units may be used to build a voltage divider for practically any desired range and degree of precision.

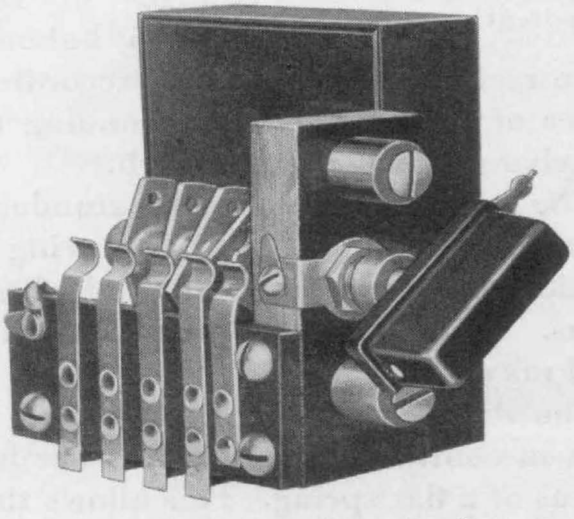

FIGURE 2. TYPE 380 Decade Switch and Condensers

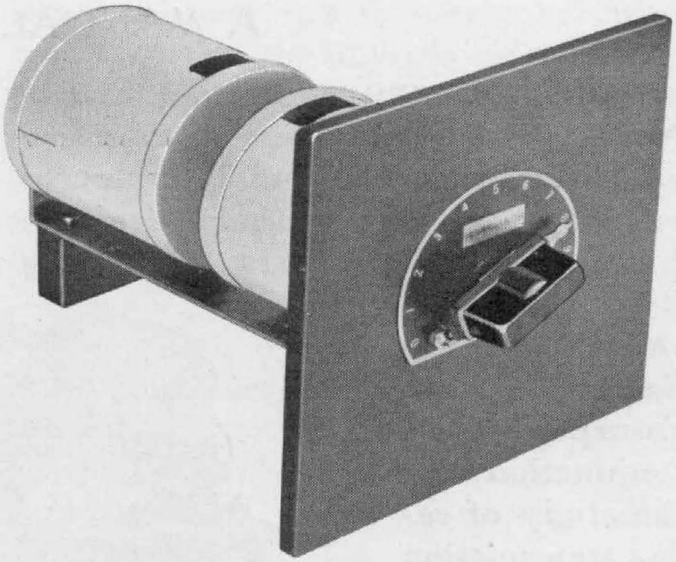

FIGURE 3. Two TYPE 510 Decade-Resistance Units mounted in tandem to make a voltage divider (potentiometer)

Another example of the decade-unit idea is the TYPE 380 Decade Switch and Condenser, which provides a corresponding unit for capacitance.

These decade-condenser units (see Figure 2) are identical with those in the TYPE 219 Decade Condenser. Due to their compact construction, they are very useful in the construction of oscillators, harmonic analyzers, and other laboratory equipment.

Figure 1 shows a typical piece of laboratory equipment using both decade-resistance and decade-condenser units. The advantage to any engineer in being able to obtain these self-contained decade units is evident. Complete technical information regarding their characteristics is contained in Catalog F.

— H. H. SCOTT

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