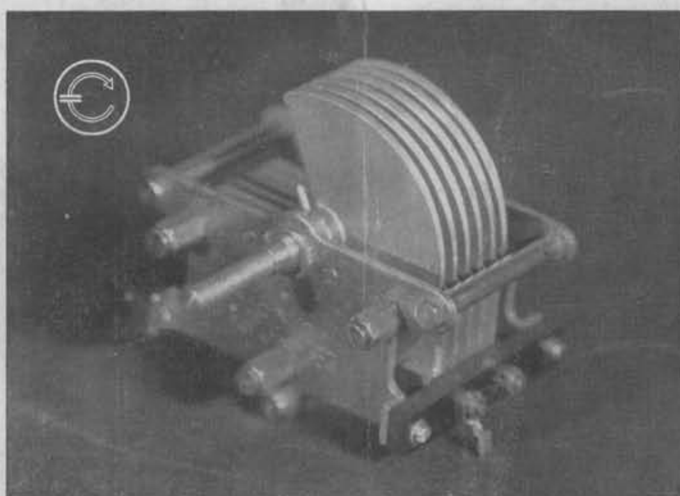
Cardwell Condensers



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We take pride in the perfection of our instruments, and the return to us of units found to be in any respect unsatisfactory is earnestly requested.

The following twelve pages contain an article reprinted from "Radio Broadcast."

We take this opportunity to extend to the publishers of this magazine our appreciation of their courtesy in allowing us to use it.

Please note that although this article was written four years ago, a number of facts which of late have been much talked of as new developments, such as straight line tuning, were well known at that time.

What You Should Know About Condensers

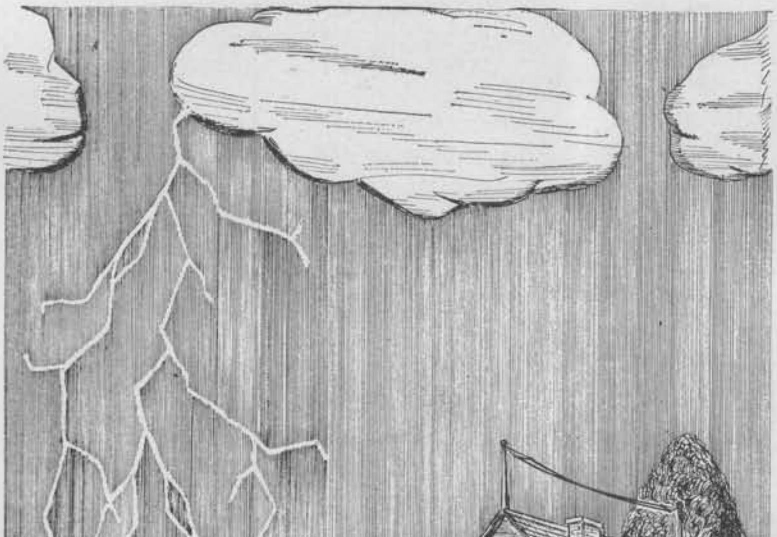
Molecules, Elements, Conductors, and Dielectrics. The Action of Electrons at Condenser Plates. Capacity, Inductance, and Resistance

By ALLEN D. CARDWELL

PART I

If receiving set owners would buy their variable condensers after a survey of the mechanical and electrical characteristics of the types on sale, rather than from a comparison merely of general appearance, hearsay and price, there would be less trouble with thousands of receiving sets and less apparatus of inferior quality on the market. Of course, to the uninitiated, a 43-plate condenser, for instance, is simply one unit in a collection of junk that he has to buy and connect up before he can hear the evening programs. So he trots down to the store, looks at his list and buys, among other things, "1 variable condenser (43-plate)." Now, when we are dealing in electrical circuits passing inconceivably weak currents, *the best is none too good* in a condenser to be used in these circuits. It seems to us, then, that a familiarity with good and bad condenser construction is worth any enthusiast's while to obtain; and we feel sure that any one who reads the two installments of this article by Mr. Cardwell, will find the knowledge he has gained to be of practical dollar-and-cents value to him.—THE EDITOR.

RECENT research into the nature of electrical phenomena has given us substantial ground work on which to rationalize the rather complex theory of condensers and their effects. We no longer say that electricity is a "current" and do not have to avoid specifying what it is. To-day we understand electricity to be a characteristic movement of electrons. We can explain practically all radio problems on the electron theory, and it is hardly possible to understand the action of condensers without some general idea of electron currents and their characteristic effects.



NATURAL CONDENSERS—STORM CLOUDS
The lightning discharge illustrates the rupture of the dielectric

THE CHEMICAL BASIS OF ELECTRICAL ENERGY

THE first approach toward electron study begins with chemistry. If we take any substance, we can break it down into certain chemical units which are called molecules. The molecule is the smallest unit of the material which will look, taste, smell, or react with the characteristic effects of the substance as a whole. For example, pure water always looks the same, tastes the same, and will interact in the same way with other given substances. The material we call water is a liquid, the smallest unit of which is the molecule. If we break

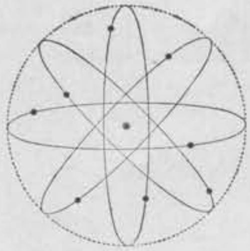


FIG. 1

Electron orbits about an atom. A theoretical illustration to visualize the general idea. The orbits are not necessarily in the same circumference, nor has it been proven that they revolve, some asserting that the electrons have a reciprocating motion

up the molecule by proper chemical agencies, we can further reduce its component units into indivisible particles which we call elements. There are some 80-odd elements that have been discovered thus far, from which we build up the entire physical universe—rocks, trees, animal life, metals, etc. Some of the elements are found in nature in a pure state; for example, a diamond is nearly pure carbon. Gold, silver, lead, etc., are 'metallic' elements often found isolated or uncombined with other elements. The elements are the units which give us by characteristic combinations, molecules and the molecules in turn give us the distinguishing qualities of any uniform or homogeneous substance such as sugar, water, air, granite, iron ore, etc. (Homogeneous does not include mixtures such as plaster, sealing wax, glass, etc.) We can go further, however, and break up the molecules into groups of atoms and these in turn we find are composed of characteristic combinations of electrons. The number of electrons in a characteristic group determines the atom, and the groups of atoms determine the molecule. All electrons are identical regardless of what molecule or element they may be a part of. The only distinguishing characteristic of an electron is its electrical state, it may either possess an electrical charge or it may be lacking in electrical energy. The average number of electrons without charges are counterbalanced by a like number with charges in the normal conductor which possesses no difference of potential between any given points. A preponderance of charged electrons or non-charged electrons will cause a difference of potential and a flow of electrical energy. Electrons which are similarly charged tend to repel one another so that in a conductor which possesses a preponderance of charged electrons this phenomena of mutual repulsion causes an equal distribution of current-carrying electrons, inasmuch as wherever there is a greater gathering of similarly charged electrons there is also a greater tendency to disperse them. It may seem absurd to reduce all forms of matter to one common base, but science has vindicated the conception of the atom as an aggregation of electrons revolving in fixed orbits about a neutral centre.

Electrons have these peculiarities:

1. They revolve about the neutral centre of the atom in fixed orbits (Fig. 1) at very high velocities (50 miles a second approximately.)
2. They are affected by heat and their speed increases at higher temperatures.
3. Some electrons are positive and some are negative in their electrical charge.
4. The weight of an electron has been calculated. Hence, electrical energy has weight!
5. The tension with which the electrons are bound together in the atom combination determines the relative "conductivity" or "insulation strength" of the substance formed by the electrons of the atoms in the molecules of the material.

CONDUCTORS AND DIELECTRICS

WE FIND that substances which are classed as "conductors" are such because some electrons in the atoms composing the material can be dislodged. That is, certain groups of electrons in each atom are revolving in outer orbits of the atoms and can be made to jump from atom to atom or into space. Elements, such as iron, aluminum, copper and silver, etc. are good conductors. The atomic weights are relatively high, and there are a larger number of electrons per atom. This gives us more active or floating electrons to serve as current carriers, but in all cases where these electrons are charged, they are called negative electrons. The positive electrons are not detachable from their atom base or centre. If by chemical or mechanical means, we withdraw some of these

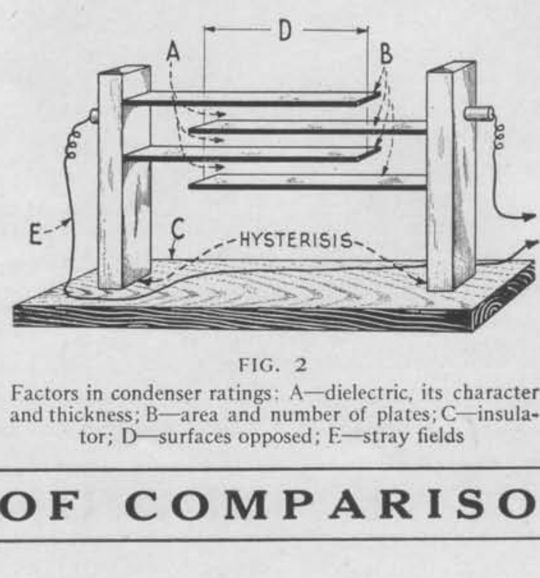


FIG. 2

Factors in condenser ratings: A—dielectric, its character and thickness; B—area and number of plates; C—insulator; D—surfaces opposed; E—stray fields negative electrons from a conductor, such as a wire, we make a current flow because there is created a shortage of electrons along the wire. The actual movement of the electrons is not direct along the wire. The electrons are measured in billions per inch of wire and their normal motions are very erratic so that a difference in potential at two points on a circuit creates only an "average" movement in one direction. This may be illustrated by the movement of a mob of people about a theatre or ball park entrance who may push and jam toward the doors, but a relatively small number actually pass in, during a given interval of time although the average or "net" push of the crowd can be tremendous, especially for those who happen to be near the gates or wall. The electrons in a conductor which can thus be used to set up an electric current are termed free electrons. Their speed, or average movement, depends upon the steepness of the "grade" created by an impressed force or shortage of electrons created at any point (Fig. 3) just as the speed with which a car will roll down hill depends upon the slope of the hill. It has been pointed out that approximately only one in 5,000 electrons resident in a conductor actually is used when a current is flowing through the conductor. In conductors the electrons are moving in all directions freely and wherever an electron dislodges another from an atom, the space left by the dislodged electron is filled by another electron from some other part of the conductor.

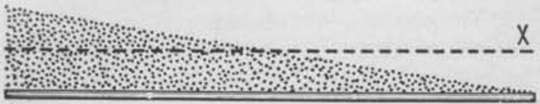


FIG. 3

Showing the gradient of current pressure (electron density) on a wire. At A the electrons are excessive and a current will flow to B until the common level is on line X. The density is obviously a "cone" field about the wire, but for purposes of simplicity it is shown only as a vertical plane above the wire

In non-conducting materials, so called, we have electrons which relatively are not free. They are so tightly bound to the neutral or centre of the atom that only extreme pressures can dislodge them. Such materials as hard rubber, air, Formica, Bakelite, etc. are of this type. There are no free electrons in insulators although electrical pressure can be applied and its effect noticed at a distance in the insulator, much in the same manner as a group of billiard balls may transmit the power of the impact of the cue ball providing a group of balls are already in physical contact. It is by forcing them out of their normal locations that we can make a condenser store electrical energy.

THE ACTION OF ELECTRONS AT CONDENSER PLATES

ASSUME that a potential of positive polarity is applied to one of the opposing plates. That means that one wall of the condenser will become crowded with free electrons and the other wall will be lacking in a sufficient number of electrons to satisfy the atoms in the conducting material (Fig. 4). Accordingly there will be an effect transferred to the dielectric between the plates which is an electrostatic strain or displacement. Although the electrons of the dielectric are not free to move permanently they can shift out of place. At the positive plate, they will be pushed back by the accumulation of electrons there. At the negative side they will be pulled toward the plate. Yet in neither case will they actually move out of the dielectric to the conductor or out of the conductor to the dielectric, otherwise the current would move immediately in one direction and not store up energy. This congestion or concentration of the electrostatic strains or lines of force exerted by the accumulation of electrons within a restricted area accounts for the term "condenser."

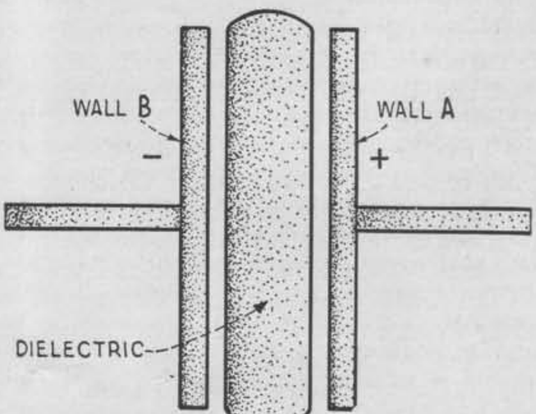


FIG. 4

Condition of electron congestion of a charged condenser. (The dielectric is shown as a separated "unit" in the centre, but actually is in contact with the wall surfaces A and B.) The stipling illustrates how the electrons crowd up on the inside wall of the A plate, thus pushing the dielectric electrons toward, *but not to*, the B plate, where the strain causes the electrons in the B plate to move away from the dielectric

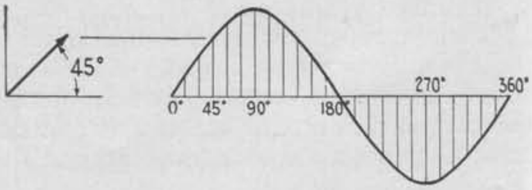


FIG. 5

Showing how a counter clockwise rotating voltage or current, or both, can be made to represent a "sine" curve when plotted against time. Each position on the curve thus has an "angular" value, used constantly in mathematical calculation

The closer the conducting walls and the greater the areas of their opposing surfaces, the greater their capacity to ho d electrical energy. A condenser cannot exist without a dielectric or insulating medium. If the opposing surfaces are separated by air, air is the dielectric. If separated by mica, then mica is the dielectric. The dielectric must necessarily be a non-conductor. This explains why the electron theory is vital to the proper understanding of condensers.

The dielectric, therefore, absorbs a certain amount of electricity and holds it in suspension until the potential used to move the free electrons is removed or reduced.

When the condenser walls are short circuited, the stored energy is permitted to discharge itself and a current is set up in an opposite direction to that of the original charge. Note that there are thus two currents: the current of free electrons in the conductor and the current of the movable but restricted electrons in the dielectric. The first is a conduction current and the second a displacement current. This distinction is fundamental.

If the impressing electromotive force (the push or pull of electrons along the circuit) is great, it may cause such a strain upon the electrons in the dielectric that the free electrons will break through the dielectric and flash as a spark discharge, in which case they pass physically through the dielectric whether it be glass, air, mica or what not and actually "puncture" the insulating medium. Thus storm clouds accumulate electric potentials which are built up until they are so great that they break down the insulation of the air and lightning is discharged from cloud to cloud or to the ground.

In radio receiving circuits we are dealing with extremely small voltages, so minute that it is practically impossible to construct a condenser with walls so close together that a spark could be passed by the voltage set up from a received signal. The "puncture voltage" of a receiving condenser is therefore not important. (Static charges, however, even on small aerials, will build up potentials of a thousand volts or more and cause considerable sparking across the condenser walls.) It is of vital importance, however, to preserve all the variations in voltage and current of the received signal regardless of how weak it may be. This involves certain resistance effects of high-frequency, alternating currents, and only by understanding them can we appreciate the importance of correct condenser design.

CAPACITY, INDUCTANCE, AND RESISTANCE

EVERY alternating current circuit exhibits three properties in variable proportions. There will be some capacity, some resistance and some inductance regardless of whether they are wanted or not. We find, also, that every circuit will respond or be most easily disturbed by an alternating current of one definite frequency more readily than by any other frequency. The frequency may be ten oscillations (charges and discharges) of the current through the circuit in one second, or it may be one million oscillations in one second.

An excellent anology may be drawn from the use of a tuning fork (Fig. 8). If struck, it vibrates and emits a note. The tines thus represent three physical effects: (1) the compression swing which we may call the condenser, (2) the inertia pull at the end of each swing which is typical of the inductance drag, and (3) the air resistance equal to the circuit resistance. If the fork is put in a sealed tube and the air pumped out, the fork will oscillate for a much

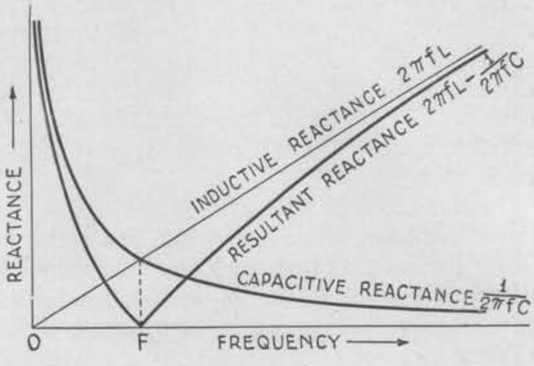


FIG. 6

Reactance curves, showing how the capacitative reactance and the inductive reactance are neutralized at resonance, shown at point F

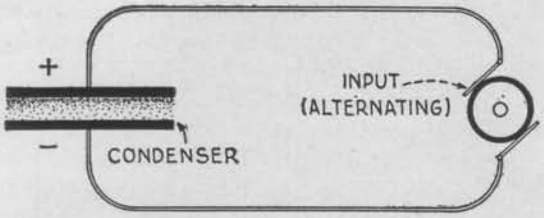


FIG. 7
Condition of electron displacement in the dielectric on one phase in an alternating current

longer period although no sound can be heard from it. The frequency with which the fork vibrates depends upon the length, weight and elasticity of the tines.

If we mount two tuning forks of the same frequency on a board, we can strike one and its vibrations carried through the air or along the board will cause the second fork to begin to vibrate. This is due to the fact that a slight disturbance of the same frequency as that of the fork causes it to vibrate and if the disturbance is prolonged, the two forks vibrate continuously for some time.

If, therefore, we wish to secure a signal from a certain station, we adjust our receiving circuit so that it will oscillate or alternate in potential and current with the exact frequency of the wave used by the transmitter. Then any variation in the amount of current sent from the transmitting antenna and to the receiving circuit is acting upon a highly sensitive mechanism which is so critically balanced that it will oscillate.

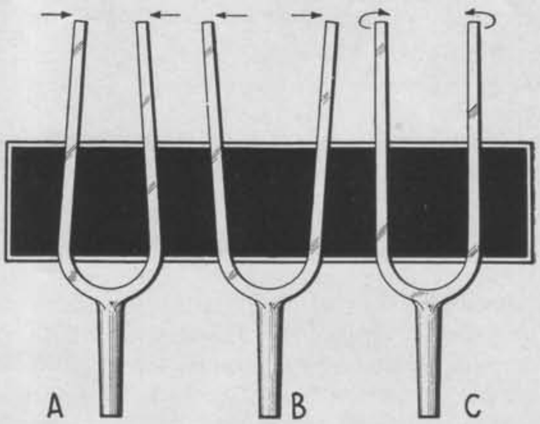
In this resonant circuit we must hold the resistances down in every way. Hence, we will return to the condenser part of the circuit and limit the discussion to a definite range of frequencies.

For wavelengths of 220 meters we are detecting currents that alternate at 1,363,500 alternations per second. For waves up to 700, the frequency is down to 428,600 alternations per second. For 350 meters our condenser must charge and discharge 857,100 times a second.

LOSSES IN CONDENSERS

THE first thing we observe when a condenser is used in a high-frequency circuit is that the current may be dissipated in the dielectric. Thus, if we force 1 ampere of current into a condenser and when it discharges we only get back .9 amperes, there has been a dielectric loss of .1 amperes due to the creepage across the space between the plates. Some of the current must have "leaked" through the dielectric or have been absorbed in the dielectric itself. These losses are normally too small to measure when the dielectric is only dry air, but under certain conditions the leakage can increase to an appreciable extent. In a solid dielectric, this loss is always appreciable and accounts in one way for the preference of radio engineers in using air as a dielectric wherever possible

FIG. 8
When the tuning fork is moving as in A, its spring is compressing, but its momentum is decreasing. In B, its spring is released and the momentum forces the lines to swing outward and accumulate an opposite spring tension. In C, the momentum and the spring effects are at the neutralized point where spring effect equals momentum, and the direction of motion changes with the spring effect inward exceeding the momentum outward. Any piece of steel or other springy material has a natural period of vibration just as an electrical circuit



The second and final part of this article will appear next month. It will deal with further kinds of losses in condensers, variable air condensers for radio use, disadvantages of the conventional form of condenser, the best materials for condensers, and condenser ratings.

What You Should Know About Condensers

Condenser Losses. Variable Air Condenser for Radio Use. Disadvantage of the Conventional Form of Condensers. What Materials Are Best for Condensers

By ALLEN D. CARDWELL

PART II

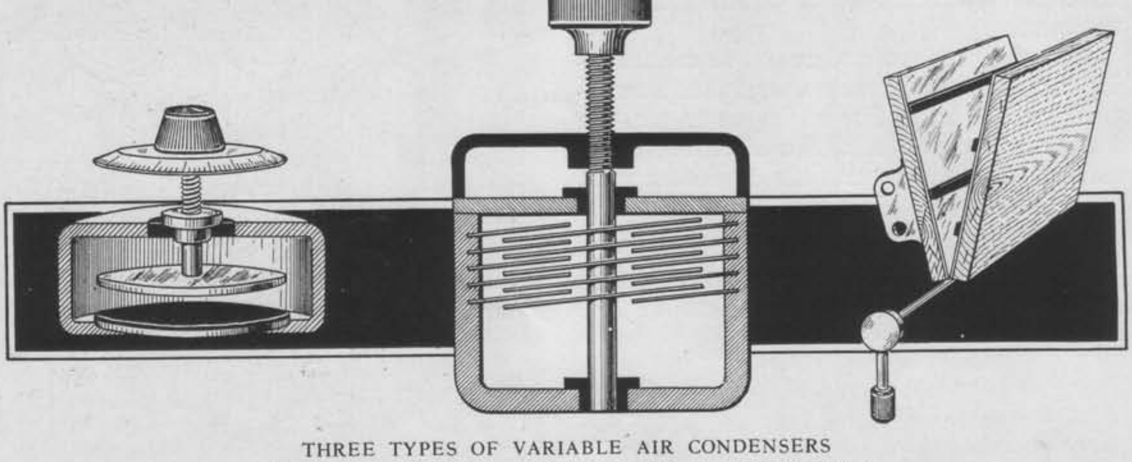
Last month Mr. Cardwell explained the theory underlying the construction of condensers and their function in electrical circuits. In this second and last part of his article, various practical considerations are taken up, with the purpose of showing the radio enthusiast how to select the best apparatus. As stated last month, "If receiving set owners would buy their variable condensers after a survey of the mechanical and electrical characteristics of the types on sale, rather than from a comparison merely of general appearance, hearsay, and price, there would be less trouble with thousands of receiving sets and less apparatus of inferior quality on the market . . . . A familiarity with good and bad condenser construction is worth any enthusiast's while to obtain."—The Editor.

LOSSES in the dielectric used in a condenser are one source of signal "damping" as pointed out at the conclusion of the last article. These losses are high in solid dielectrics and low with air dielectrics.

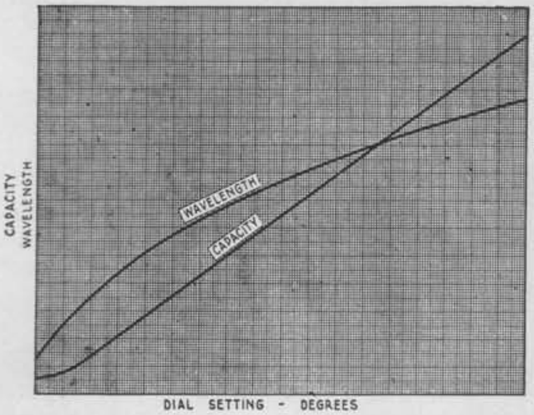
The first thing we observe when a condenser is used in a high-frequency circuit is that the current may be dissipated in the dielectric. Thus, if we force 1 ampere of current into a condenser and when it discharges we only get back .9 amperes, there has been a dielectric loss of .1 ampere due to the creepage across the space between the plates. Some of the current must have "leaked" through the dielectric or have been absorbed in the dielectric itself. These losses are normally too small to measure when the dielectric is only dry air, but under certain conditions the leakage can increase to an appreciable extent. In a solid dielectric, this loss is always appreciable and accounts in one way for the preference of radio engineers in using air as a dielectric wherever possible.

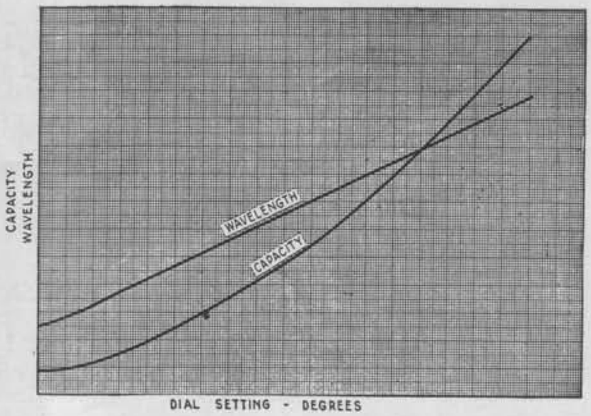
The next effect we observe is that some of the current may be dissipated in the conducting plates. If the different plates are so assembled that there are uneven pressures at supporting points or along the frame, we have loss from "contact resistance" aggregating a fairly high value.

Again we have condensive effects set up in any insulation used to support the condenser



THREE TYPES OF VARIABLE AIR CONDENSERS
"Up and Down" Motion—"Cork-Screw" Type—Book Leaf Type





CURVES FOR "STRAIGHT LINE" AND "DECREMETER" CAPACITY RANGES

The curve at the left shows how a condenser having a constant capacity increase varies for wavelength when used with a given coil. The curve at the right shows how an eccentric-shaped plate will correct this and give a constant increase in wavelength when used with the proper inductance

walls. Although these insulation pieces may not be intended as part of the dielectric, they are sometimes so placed as to be in the electrostatic field and some of the current works into this supporting insulation and causes losses from leakage, and from a source we call "dielectric hysteresis." Hysteresis losses are the result of impurities or cellular structure, as in wood, where the arteries of the grain may have innumerable moist passages to shunt the current from point to point. Thus the insulation may pass minute currents in and out internally and may refuse to yield up the current with a uniform speed—in any event less quickly than the dielectric proper and thus cause resistance effects merely by failing to discharge synchronously with the main dielectric. This reveals the important factor of time or rate of discharge in dielectrics. We can charge a dielectric material such as paper to a given potential and upon short circuiting get back most of the charged current, but if we short circuit it a second time (after a minute has elapsed) we may get back additional current which we did not think was still in the dielectric or paper.

An ideal dielectric is perfectly elastic electrically. It springs back to its normal condition of equalized potential of zero grade the instant it is short circuited.

Another consideration is the possibility of losing a certain amount of current by "stray field" or parasitic effects. If a body of metal is in or near the dielectric field, it will act as a supplementary condenser in interaction with one or the other sides of the condenser alternately. Thus, with many receiving sets, the panel is shielded. This means that the shield acts as part of the condenser and in doing so, a secondary condenser exists and losses may be caused since the shield may have conduction resistances as well as insulation hysterisis effects.

The losses in a condenser may thus be summarized as follows:

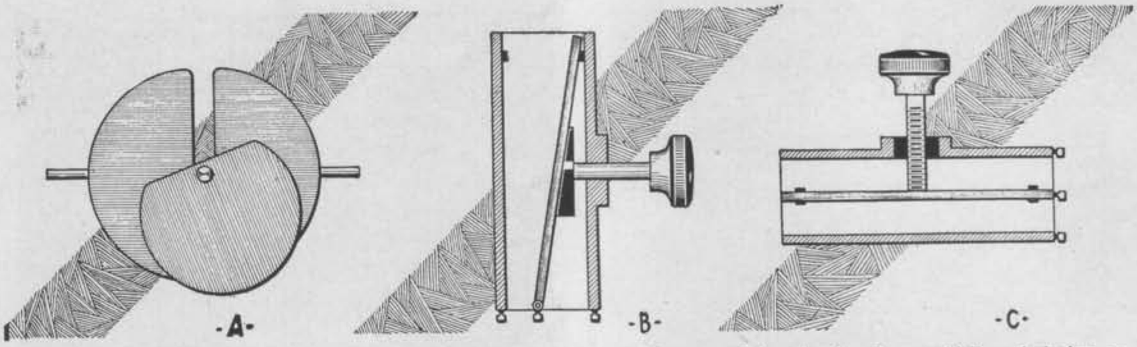
1 Dielectric leakage
2 Dielectric hysterisis
3 Insulation leakage
4 Direct-current resistance in plates
5 Stray field capacity
6 Insulation hysterisis

These losses can be reduced to such a point that the most sensitive instruments devised to measure resistances cannot accurately indicate or check any losses whatever. This is not an exaggeration. It does not mean, however, that there are no losses, but that the losses are so small that it is impossible, with unusually delicate equipment, to determine them.

Let us therefore consider various designs of variable air condensers (with which we are primarily concerned). Where do the various types of such condensers excel and where do they fail to secure proper efficiency?

A variable air condenser as generally designed consists of a series of fixed plates of semi-circular shape, so spaced that a second set of similar plates can intermesh between the fixed plates. The fixed plates are called the stator plates and the movable plates are called the rotor plates.

We can vary the capacity by the amount of

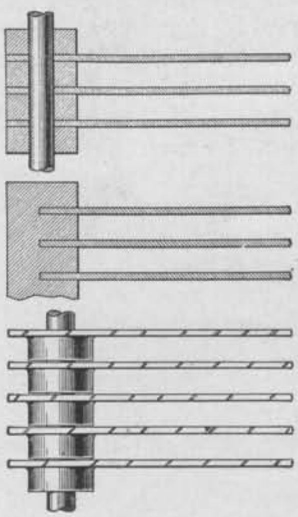


Three new types of coupling condensers: A—the Jones condenser used in neutralizing circuits; B—an old French design, revived recently by Allen D. Cardwell for use with the capacity-coupled, double-circuit tuner; C—a navy type coupling condenser

intermeshing of the rotor and stator plates. The variation of the intermeshing can be made to cause an equal increase of capacity for each degree of rotation. This may be an advantage in that it makes the controlling dial cause capacity changes directly proportional to the number of degrees through which the condenser dial is turned, but it does not increase wavelength uniformly. To do this, an eccentric shape is made for the rotor plates, and when used with a given coil the condenser changes cause a straight-line wavelength variation. In this case it is called "linear" because its wavelength variation, shown in a graph, would be a straight line. At the same time the advantages of the "straight line" or linear shape are relatively small for ordinary tuning, compared with the added cost of manufacture and the disadvantages of the extra cubic volume required for given capacity.

A variable condenser can also be constructed so that the plates (generally limited to two in practice) are moved closer or farther apart in a direction at right angles to the planes of their surfaces. Owing to the necessity of using a thin sheet of insulation between the plates to prevent short-circuiting, this type of condenser will not vary proportionately with the mechanical control variation. As the space or dielectric thickness decreases, the capacity increases more rapidly than the turns on the threads or knob-mechanism, because the amount of solid dielectric has become greater in proportion to the amount of air dielectric and most solid dielectrics have greater specific inductive capacity.

A third system for a variable condenser is to hinge two plates and vary the spacing by closing or opening the free ends, as a book cover is opened or closed. In this type of condenser the capacity also increases rapidly as the distance between plates is reduced beyond a certain point and, as in the reciprocating system, a good capacity rating is secured only by closing up the dielectric gap so closely that short circuiting would occur if solid insulation of some type is not placed in the electrostatic field. This means an air and solid dielectric are used so that what convenience is gained in higher capacity of the

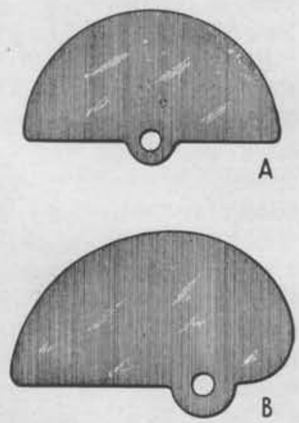


METHODS OF PLATE SPACING

The top system is most common—namely the use of washers

The second method is more accurate, but adds greatly to the cost. Each plate is hammered into the block and jammed tight

The third system is remarkably economical and is made by punching each plate to make a self-spacing collar



ROTOR PLATE SHAPES

A is the normal or standard shape, giving a "straight line" capacity increase

B is an eccentric shape to give a constant wavelength increase when used with the proper coil plates when close together is thus lost by the resistance of the solid dielectric.

A fourth style of condenser has occasionally been proposed—namely, a "screw type" in which the rotor plates are cast as a continuous "cork screw." Being a complete circle, the plates can double the capacity per plate area and increase the capacity at a very slow, constant rate.

Other rudimentary methods of varying capacity have been used—for example, a set of moving plates sliding along grooves into the fixed plates, or some with one tube telescoping over another. These designs have in general one or another of the following defects:

1 The increase in capacity is not linear
2 The cost of production is too high
3 The maximum capacity is either small or secured by high dielectric losses
4 The mechanical construction is not strong or is clumsy or bulky
5 Variable settings for given capacity

For tuning receiving circuits, a condenser should occupy small space, increase wavelength evenly with all changes of the dial, and have a large range of capacity from minimum to maximum.

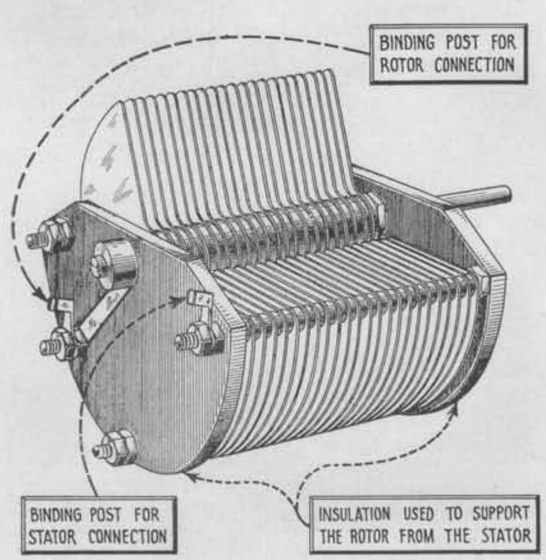
The intermeshing-rotor design has become the standard in radio practice.

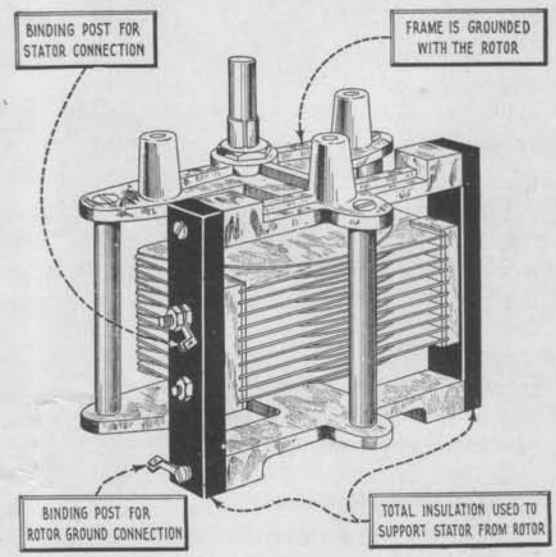
In the design of the standard variable air condenser a number of mechanical methods are followed. In spacing the plates of either rotor or stator, washers are often used. These are placed on supporting rods so that on assembly a plate is held in position by the flat faces of the alternating spacers.

This system has disadvantages. In the first place the spacers require tedious hand assembly. In a 43-plate condenser, for example, there would be three spacers per plate, or in all 129 spacers to be set as well as 22 plates of the stator and 21 plates of the rotor. Where the spacers are also used on the rotor, it would entail more than 256 distinct hand motions aside from locking the end plates and tightening all adjustments.

In itself, the labor is not as serious as the electrical inefficiency. A certain amount of oil, moisture, or surface unevenness is cumulative where each spacer touches a plate. The resistance is thus multiplied by the 256 or so contacts and aside from any other losses, the resistance may be considerable. Even soldering the joints does not satisfactorily overcome the mechanical weakness of the design. Fusing the metal would be the only way of assuring permanent low contact resistance.

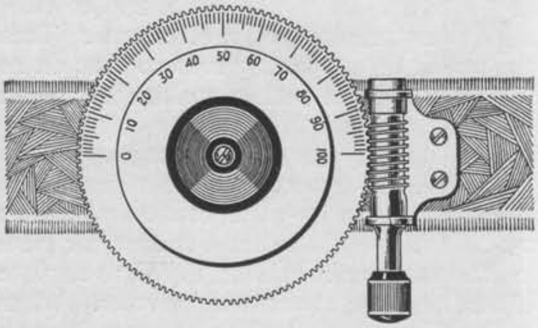
A better method of design is to cut a solid die by which the plates are cast as a solid part of the frame support—usually a flat semi-circular wall, thus supporting the plates by half of their circumference and having minimum resistance in the support. This type of condenser with





TWO WAYS OF INSULATING THE STATOR FROM THE ROTOR

At the left, the rotor is supported by end plates of insulation. Either rotor or stator can be grounded. The condenser on the right shows a design in which the rotor is part of the frame connection, permitting the use of less insulation. Only the rotor can be grounded



MECHANICAL VERNIER
This type gives a ratio of 256 to 1 which is truly a micrometer control

good bearings can be very closely spaced, that is, the dielectric thickness or clearance between stator and rotor can be extremely small. The cost however is high, due to the shape and accuracy required.

The surfaces of the plates cannot be smoothed down and are difficult to keep free from dust which will quickly cause minute short circuiting paths. Even when invisible to the eye, this dust will vary the capacity as it accumulates.

Again, the cast condenser requires a high degree of shielding, and its eddy current losses, due to so much metal serving only as support and not as true plate surface, add to the losses.

A third type of spacing can be used by cutting grooves into spacing pillars, or posts, into which the plates can be set with remarkably accurate spacing and with proper mechanical strength. This system is superior in its economy and efficiency *if the plates are properly fixed in the grooves*.

The proper design depends upon the method of fixing the contacts so positively that surface contact resistance is avoided.

For the rotor element, either die casting or washer spacing can be used. A few are made in which the rotor plates are set in position and the hot metal poured into a mould to form the center shaft.

In general, we may say that the conduction current losses due to washer spacing for either stator or rotor will be small, but the accuracy of the spacing will be difficult if washers are used for the stator. Every rotor shaft or bearing will eventually wear or have some parallel plate error, and an ordinary allowance can be made for this occurring on the rotor if the stator plates do not vary also. In short, by keeping the accuracy of spacing in the rotor, we could reduce the spacing to half of that required for washer spacing in both rotor and stator and hence secure high capacity for the amount of plate surface used.

The real difficulty in condenser design is in arranging the support of the rotor and stator and in insulating them from each other. This involves the utmost mechanical strength and is most commonly attained by making the frame a part of the stator system and insulating the rotor by means of a metal bushing set in an end plate of insulation.

Three standard ways of doing this are used, and in each case there are decided electrical disadvantages. In the first case, where the end plates are large insulating masses, the dielectric hysterisis losses are generally considerable. When the surface of the insulator is large, the possibility of conduction across the surface is greatly increased. In the second case, the bearings are supported in such a way that the bushing becomes part of the dielectric and suffers also by having a large metal-to-insulation contact surface, thus increasing the dielectric losses. In type three, the insulation design is good, but the mechanical ruggedness is low. But in all these types the capacity of the operator's hand is carried to the dial by the rotor shaft and is bound to cause some body capacity effects in tuning regardless of shielding.

It is therefore desirable to reverse the usual procedure and instead of "grounding" the stator, to ground the rotor. This means that the stator is insulated from the frame. The frame can then be attached to the panel and by grounding will not be influenced by any "body capacity" brought near the panel, This is a highly important feature in tuning long dis-

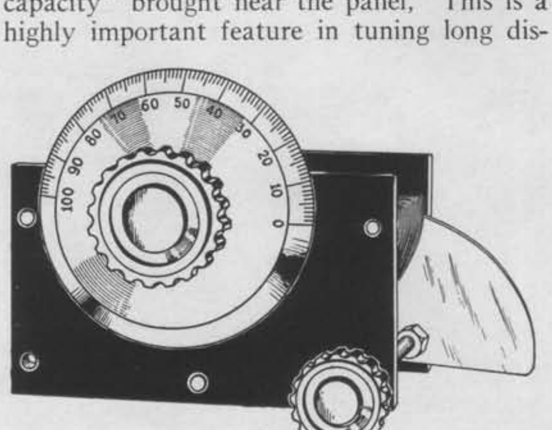


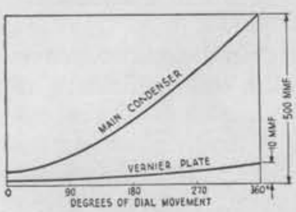
PLATE VERNIER
This design illustrates a simple method of getting a vernier effect by the use of a single plate on a second shaft

tance stations where the signal current is so weak that any variation of wavelength in the secondary or primary due to stray capacity fields will cause the desired station to fade out when the adjustment is fixed and the hand removed from the dial. To hold the station when the wavelength setting has been made it is therefore necessary to ground every part which may directly or indirectly be affected by body capacity. This can only be done by grounding the stator. Shielding does not entirely accomplish the desired end if the stator and frame are grounded, since the shaft of a rotor is part of the high potential side and passes through the shield and panel.

Another feature of design which is serious in the grounded stator type is the method of making contact with the moving rotor. If contact is made by friction, the amount of bearing surface is so small that a film of oil or dust or other foreign matter creeping into the bearing causes a high resistance. To avoid this unusually wide bearings must be used or a lead of flexible wire soldered to the rotor and carried to some connecting point.

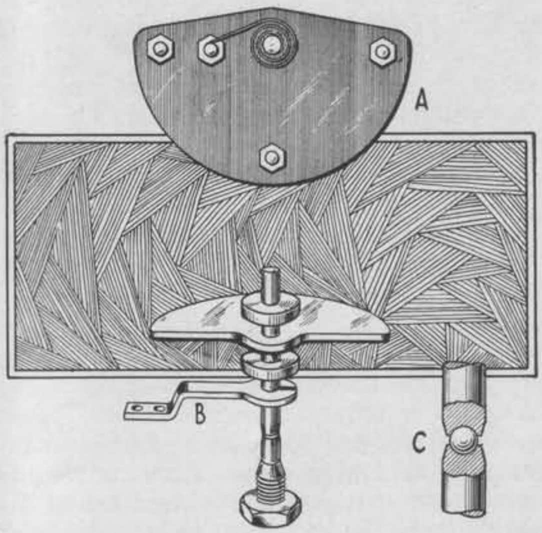
This point brings up the subject of counter balancing. A condenser bearing gradually loosens with wear and can eventually become so loose that the rotor will slip around due to its own weight when the semi-circular plates are not at perfect balance.

Thus, great difficulty is caused in using a loosened condenser mounted with the shaft



Note that although the ratio of the separate vernier plate to the main condenser is about 50 to 1 at maximum it is less than 4 to 1 at minimum settings, due to the high minimum capacity of this condenser design

horizontal on the panel as is generally the case. To overcome this objection some manufacturers place a counter-weight of moulded lead on the rotor so that even if the bearings loosen, the adjustments will not be altered by gravity. Other manufacturers resort to "two-side" construction, dividing half the rotor and half the stator plates symmetrically in opposite sides of the rotor shaft. Thus the same objective is attained. Both methods, however, add to the cost of the condenser, and its bulk, and make its minimum capacity high. Instead of three stator support rods as many as five or six



THREE TYPES OF ROTOR CONNECTIONS

A—Pig-tail connection used for many rotor contacts

B—A friction "pig-tail" spring which has a very good surface contact. The parts are moved open to show the relative positions

C—A ball bearing which can be used on rotor-grounded condensers. This affords a perfectly centered bearing not subject to end play

posts are required with the "two-side" construction, multiplying the spacing problem proportionately. The weight of the stator, when counter balanced, is nearly doubled. All this can be avoided by placing a friction sleeve on the rotor shaft. By using a slotted sleeve, practically even and permanent pressure is secured which avoids any possible slippage from gravity.

A debatable issue is involved when the question of verniers is brought up. An efficient condenser which has a firm, even bearing requires no vernier when used by an experienced operator. Because some types of receivers, such as regenerators, require very critical tuning, vernier devices are often used. The vernier may take the form of a second condenser of one or two rotor plates built on the frame with the main condenser. It may also take the form of a gear system attached between the rotor control and the rotor shaft.

With the separate condenser vernier there is introduced a double electrostatic field—such that when the main condenser is set the small condenser may do more than vernier—it may increase or decrease the first capacity far out of proportion. What is more serious is the necessity for a more complicated shielding and insulating system. The cost is considerably increased and the design mechanically less rugged in all cases, since one shaft must be contained inside the other shaft and must be fairly loose to operate at all. Possibility of wear or disalignment of plates can easily occur.

A mechanical vernier is preferable. By suitable gearing, a real vernier ratio is secured. A true micrometer effect is determined only by the gear ratio. With the separate condenser vernier, the ratio of increase is too low. Thus if the maximum capacity of the large condenser is 500 mmf. (micro-microfarads) and the maximum capacity of the vernier is 10 mmf., the ratio is 50 to 1, which is good. Usually, however, the interacting capacity of the vernier often runs up to 50 mmf. while in many condensers of this type the larger units hardly reach 400 mmf. Thus, in practice, the ratio becomes 400 to 50 or 8:1 which is not sufficiently large. By a mechanical vernier, such as a rubber roller on the edge of a 3-inch dial, the ratio is about 6:1 which is also too low. The best solution is by using a gear in which a single main condenser is varied by a ratio of turn of 50 to 1 or higher. This, however, is not altogether desirable for quick tuning and, in general, most experienced radio operators do not like verniers preferring to use a circuit in which a vernier is not required. This is worth careful study. Specially designed vernier dials are on the market which afford an 80:1 ratio, and, when mechanically rugged, they offer an ideal solution of vernier controls.

WHAT MATERIALS ARE BEST FOR CONDENSERS?

WE MAY now discuss the various types of materials used in the manufacture of the condenser. As the condenser should be light, some metal such as aluminum is almost universally used. The resistance of aluminum is almost as low as that of copper. Plates of aluminum, if more than .0025 inches thick, are reasonably strong and will not be easily bent. They are also springy enough to stay in shape even if accidentally pressed or hit, if made from hard stock. Aluminum also makes a good cast frame. Sheet aluminum is almost universally used for the plate material. It can be polished, and if made in constant thickness and of high purity it is satisfactory in all respects. Plates of brass and some other metals may be nickeled but this is not necessary if the spacing is greater than .05 inches as the possibility of dust short circuiting the plates is very small. Aluminum is not easily corroded under ordinary conditions, and the surface resistance is not an important factor. For the rotor shaft, a good grade of case-hardened steel is desirable. The end bearings should be of dissimilar metal from the shaft and preferably bronze or brass. Spacers should be about $\frac{3}{4}$ of an inch in diameter for the rotor. On the three-post types, used for stator spacing, washers of at least $\frac{3}{8}$-inch diameter are desirable. The bearings must always be made of the best steel and brass and where pressure is exerted, be so assembled that the wear is properly taken up by adjusting screws so that after long use the tension or position of the plates can be restored.

"Pig tail" connections for the moving element contact are generally made of braided copper wire of about twelve or more strands. If ribbon wire is used, it must be very flexible and not subject to twists when coiling or uncoiling; or a flat connector like a watch-spring may be used.

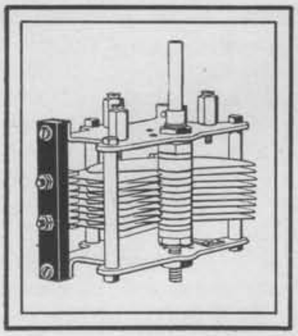
It is difficult to specify the best kinds of insulation without treading on trade names of different manufacturers. Phenol compositions have good insulation characteristics if not in the electrostatic field, but any solid material is bound to cause resistance in this respect. Fibrous materials rank somewhat below the phenolic compounds. Hard rubber of pure composition is particularly good for supports and insulation. A good design calls for the smallest possible contact with any solid insulation. On the other hand a fixed condenser uses a good deal of insulation, as the dielectric and the resistance characteristics then play an important part. Porcelain is electrically good but mechanically poor owing to its brittleness.

Back of all these factors in design, workmanship and materials is the basic efficiency of the condenser—resistance. No beauty of assembly, no perfection of material or convenience of design can offset resistance effects. Furthermore, if the condenser has only a low range of capacity variation it is inefficient and if it has proper maximum range but excessive bulk it is also undesirable.

The measurements of the resistance of a condenser are extremely difficult. The best way is by a comparison test, using as the standard a special condenser with plates suspended by silk threads and all stray field effects carefully isolated. Such a measurement involves very delicate and accurate devices and considerable engineering skill. The rating given must be based upon the reputation of a recognized authority.

CARDWELL CONDENSERS

THE Allen D. Cardwell Manufacturing Corporation was the first to adopt the now standard method of condenser construction: —the use of metal end-plates and grounded rotors, and the supporting of the stator by means of small insulation strips instead of bushings. The Cardwell Company produced the first "low loss" condenser over a year-and-a-half before the efficiencies which the Cardwell design afforded were sufficiently understood by others to suggest their following the same general design.



By this original construction, which was characterized by engineers as "low loss" to distinguish the Cardwell from ordinary varieties, the Cardwell Company was able to offer the public a laboratory-type condenser at a low price.

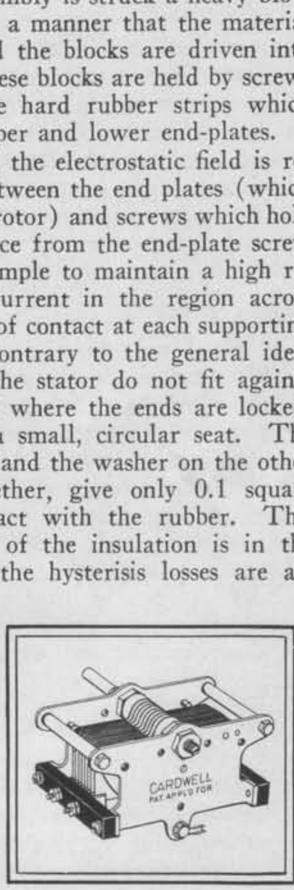
The general ideals of good condenser design are now fairly well understood by the advanced radio experimenters, but a brief review may not be amiss in pointing out the more refined details of construction. A condenser is a piece of machinery. It must be able to withstand rough usage, retain its rating under varied temperature conditions, give a permanent alignment of plates, have a proper bearing which will afford smooth, firm action, etc. Any condenser which can be set out of shape by pressure of panel screws so that the plates touch or which will become loosened or jammed by casual blows will never prove satisfactory.

In examining a condenser, therefore, see that it cannot be pressed at the opposite corners so that the shaft or plates will yield perceptibly. It should be possible to press the shaft in or pull outward on it without the condenser changing its calibration or "log" characteristics.

The Cardwell condenser is so strong mechanically that it will not suffer from rough usage. The bearings are accurately set and adjusted so that they will remain serviceable after years of constant use. The frame is so built that it takes a severe blow to make the slightest change in the alignment of the plates. The spacing of the plates is so arranged that they cannot become wide or narrow on one side due to the heat of the vacuum tubes inside the cabinet.

Since Cardwell inaugurated the present well-known principle of metal end-plates and a minimum of dielectric as a support for the stator, this construction has become almost standard. The plates of the stator, it will be noticed, are first pressed into slots in the brass blocks used as spacers and support and then the whole assembly is struck a heavy blow by a huge press in such a manner that the material of the stator plates and the blocks are driven into one compact mass. These blocks are held by screws which run through the hard rubber strips which are mounted on the upper and lower end-plates.

By this arrangement, the electrostatic field is reduced to a minimum between the end plates (which are connected with the rotor) and screws which hold the stator. The distance from the end-plate screw to the stator screw is ample to maintain a high resistance to any stray current in the region across these points. The area of contact at each supporting point is also small. Contrary to the general idea, the screw posts from the stator do not fit against the hard rubber except where the ends are locked. At each end there is a small, circular seat. The area of this on one side and the washer on the other end, when added together, give only 0.1 square inches of surface contact with the rubber. This means that very little of the insulation is in the condenser circuit and the hysterisis losses are accordingly low.



It will be noted also that the rubber is placed out at the edge of the end-plates so that it is in a relatively weak field between the end-plates and the stator plates at the points where the rubber is supported and is in an even weaker field where the stator strip is held to the hard rubber. Thus the insulation is held almost entirely outside of the electrostatic field where induced capacity effects will not cause losses in the rubber.

The arrangement of the insulation in the weakest part of the electrostatic field and the restriction of the surface area used in contact between the insulation and the stator screws are some of the most important elements of the Cardwell design. The blocks supporting the stator, being continuous and extending beyond the points of support, shield the insulation from all stray field. In this respect no type of construction has been found since, which can secure lower losses or better engineering than in the Cardwell.

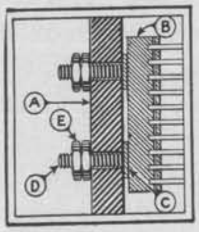


Figure 1
Stator Support

Obviously a variable condenser should be free of body capacity effects. Before the advent of the Cardwell condenser this difficulty in tuning was a common annoyance for most set operators as the rotor plates were then connected to the high potential side of the circuit (usually grid circuit), while the stator plates were grounded to filament circuit. Under this arrangement any movement of the hand in tuning reacted on the field of the condenser and changed the capacity of the circuit.

The Cardwell condenser ended this nuisance entirely. Because it used metal ends and permitted grounding the rotor to these metal ends, there was placed an efficient shield between the stator plates and any part of the external circuit, with the result that one could actually put his hands on the rotor or frame and still receive signals perfectly and without changes in the tuning.

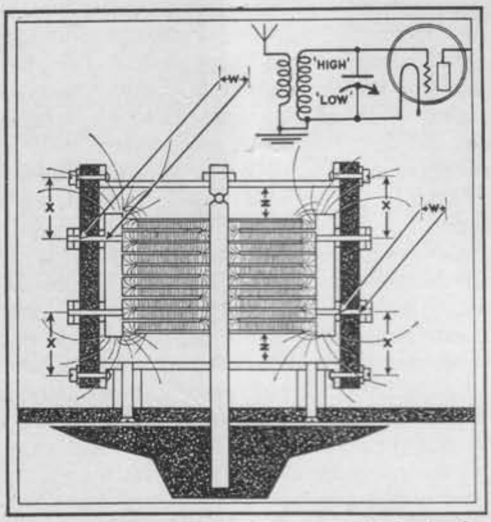


Figure 2. Theoretical Sketch (cross section), showing how losses are held low. Note that the shaft and rotor plates are one side of circuit and are grounded to end plates. The stator plates are supported by screws (refer to Fig. 1), which hold the blocks (B) into which the plates are swedged. These screws give no real contact to the rubber, but the inner seating washers (C) and the outer lock nuts (E) are relatively small in surface, resting against the rubber (A). In Figure 2, the distances (W) are practically air spaced from the rubber. This reduces the amount of surface of the high (stator) side to the rubber, thereby reducing hysterisis losses to a minimum. The intensity of the field is indicated by the fine lines between the plates and the stray field by the fine curved lines. Note that the blocks holding the stator plates act as shields to keep the stray fields out of the rubber. Also note that the distance (X) is relatively large and affords an extremely high resistance path to the currents which might tend to leak across the rubber. The distances (Z) permit a low minimum capacity as does also the plate spacing between rotor-shaft elements and stator plate edges.

This construction has now become the rule rather than the exception for condenser design but a careful comparison of the facts noted in this article will show that many condenser manufacturers fail to recognize the real necessities of "low loss" design to such an extent that, rather than increasing their efficiency, they have raised their losses and, in many cases, their design is not as good as some of the old "mud-end plate" variable condensers.

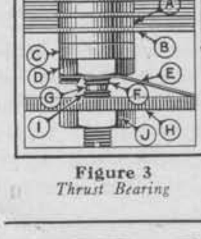


Figure 3
Thrust Bearing

This will be particularly noted to be a fact in many of the so-called straight frequency tuning condensers which, in order to secure straight frequency, have used very thin plates supported by insulation directly in the dielectric field.

Thus far we have dealt only with the broader considerations of good condenser design. In the succeeding paragraphs, we would point out a number of specific features of the Cardwell condenser which are not appreciated by many builders, but which have no small importance in the satisfactory operation of a receiver.

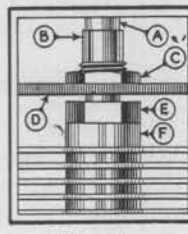


Figure 4
Panel Bearing

The first paragraphs which follow, refer to the design of the types B, C and D, and your particular attention is called to the departures from this, which are used in the type E, as described on Page 26.

1. The design is one which permits making up a number of different-sized condensers, but observing the same template for drill holes and the same width and depth and only varying the length back from the panel.

2. The connections to the stator and rotor can be made at either side and the condenser is accordingly an easy one to connect into a circuit without use of long leads.

3. The end bearing consists of a steel ball bearing *(See Fig. 3: G)* which is set in a cup at the end of the rotor shaft *(F)* and also set in a cup on the end adjusting-screw *(I)* which fixes the center of the shaft in perfect alignment and affords a smooth turning action. The shaft is of case-hardened steel and the end adjusting-screw is also of case-hardened steel. The bearing is practically immune from wear, as the case-hardened ball bearing revolves in a thin film of oil and is constantly keeping a fixed center and uniform pressure.

Figure 5
Auxiliary Contact

4. The end play of the shaft is adjusted at one end *(See Fig. 4)* by a broad hexagonal-headed brass bushing locked to end-plate *(D)* by lock nut *(E)*. A

steel spacer *(F)* rests against the hexagonal bushing *(E)* and thus two dissimilar metals afford a fine bearing which is not subject to wear or play.

5. The shaft bushing *(Fig. 4: E)* has a projecting split collar *(B)* which gives a firm even pressure against the shaft *(A)*, thereby insuring a good contact from rotor to shaft, but also avoiding any tendency of the rotor to turn due to its weight.

6. The condenser employs a special type of friction contact at the end bearing *(See Fig. 5)* which fits snug against the under side of the turned nut *(See Fig. 3: D)* and presents a broad surface for positive contact *(See Fig. 5: C)*. This special friction contact is not entirely needed, but doubly assures absolutely noiseless operation and is only added as a special precaution.

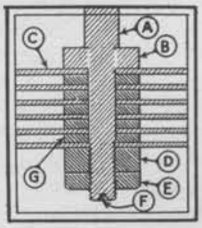
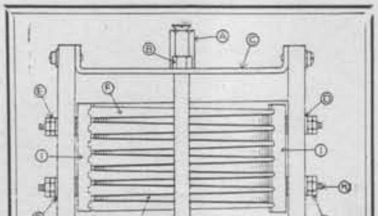


Figure 7
Rotor Elements

7. The stator plates *(See Fig. 1)* are swedged into grooves in brass blocks *(B)* by a special assembly process which insures unvarying pressure and avoids any risk of conductivity losses. The grooves in the blocks are sufficiently deep and long to afford a rigid alignment of the stator plates and also act to prevent any changes in the clearances at their centers.


TYPE E
Showing taper plate construction

8. The rotor plates *(See Fig. 7)* are spaced by micrometer brass spacers *(G)*, which are very accurately finished. The surfaces are broad and afford ample area to maintain the rotor plates flat and in perfect parallel with the stator plates. The pressure on the rotor plates and spacers is very great, one end *(A)* being locked against the steel collar spacer *(B)*, which rides on the shaft *(A-F)*, and the other end being washer-locked by a thread on the shaft, and a hexagonal lock nut *(E)*, which is tightened by a heavy wrench. As the diameter across the washers is nine-sixteenths of an inch, it is practically impossible to get any of the rotor plates to turn on the shaft.

9. The dimensions of all rods, end-plates, shaft and supporting elements are amply designed to insure mechanical strength. By means of extra-heavy construction and the use of selected raw materials, the condenser has almost unbreakable characteristics. The Radion hard rubber supports *(See Fig. 1: A)* are also of great strength in proportion to the strains imposed on them, with the result that practically no failures result in use or in transit.

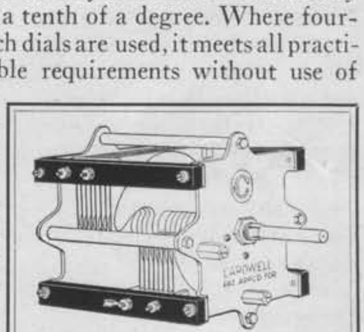
10. Every condenser must pass a severe breakdown test before it passes inspection. The condenser on reaching the testing room is placed in a circuit using a sufficiently high voltage to permit the current to arc across and to indicate any inaccurately-aligned plates.

11. The stator and rotor plates are of sufficient thickness (.0253 in.) to maintain permanent flatness. They are of a special grade of aluminum which will not react to extremes of temperature during assembly or during use.

12. The end-plates are drilled and tapped at each end, thus permitting assembly to panel, table mounting, or the addition of special coils at the ends of the condensers without the requirement of special tools to do this drilling and tapping.

13. Due to the excellent mechanical features involved, it will be found that when two or more Cardwell condensers of the same type are used in a tuning circuit, all the dials will log the same and thus afford great convenience in tuning in stations.

14. While vernier types are available, the Cardwell has such an even turning action that practically anyone can adjust a dial to an accuracy of a tenth of a degree. Where four-inch dials are used, it meets all practicable requirements without use of verniers. A good vernier dial, however, can be used to advantage as the Cardwell is very sharp in tuning, due to its low losses. This factor will be affected by the character of the coils used in conjunction with the condenser.


Showing dual end construction in multiple types B, C and D. Type B has semi-circular rotors and stators NOT cut away as illustrated

In getting a Cardwell variable condenser for your receiving set, it should be apparent that you are getting a number of advantages which are distinctive to this type. Briefly summarized, you have (1) lowest possible losses, (2) best mechanical design for long service, (3) absence of adjustment difficulties, (4) smooth, even turning action, (5) high capacity for overall size, (6) perfect workmanship, materials, and assembly.

From an operating point of view, Cardwell condensers assure longer distances (being non-absorbent of weak signals) and sharper tuning (not tending to damp the signal and allow other signals to energize the tuning system). These advantages are very real and are proven by the endorsements of thousands of users who have tried ordinary condensers and, for one reason or another, have found Cardwells superior. You cannot fully appreciate the value of

Cardwells until you have compared them, point for point, with other types that may appear to be similar. But if the judgment of the best engineers is worth something, you will find them universally recommending the Cardwell.

When building a receiver you may be sure that by getting the very best of parts throughout you are saving money. You may buy parts which are "almost as good," or "the same thing under a different trademark," and you may think you are getting very excellent results, but unless you use the proper material you are not getting the most possible from your set. This applies to every part you use. If you use rheostats and the wire gets loose it will give endless trouble. If you have a variometer in the circuit and the leads rub they may short-circuit and you will have much difficulty in finding out what has gone wrong. Sometimes the prongs on the bases of the tube will not make proper contact with the springs in the socket, and even though the tube may light it will fail to function. Perhaps your audio amplifier tends to distort or over-emphasize some notes and occasionally a binding post will be found which twists after being tightened on the wire. Such contingencies cause you endless difficulties when it comes to replacement. Or perhaps the troubles may be more insidious in character. For example, the set may work excellently over the whole wave band except a small sector in one part of the condenser where no distance will be obtainable or long wave stations will come in much more volume than short wave. Sometimes a set which operates wonderfully above 300 meters will emit unmerciful squeals every time it is tuned to higher frequency broadcasters. Sometimes a set will work wonderfully one night and very poorly another night—perhaps it is the condition of the atmosphere, on which it is undoubtedly blamed, but more than likely it is because of the effect the atmosphere has had on parts of the set—dampness may have penetrated some of the coils or effectively short-circuited some of the turns, or there may be leakage between the binding posts of instruments which use a poor grade of insulation. Such things as these are very difficult to discover and many a radio set user has been thoroughly satisfied with a set which, unknown to him, was only working about half as well as it might, if one instrument had been replaced.

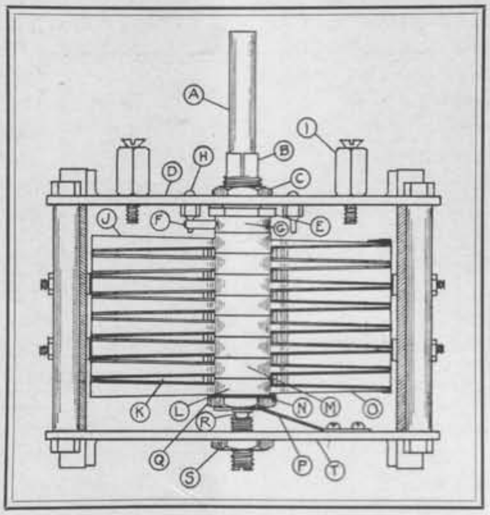


Figure 8. Conventional cross-section of taper plate type E design. Note the way the rotor plates (J) dovetail with the stator plates, giving variable spacing as the condenser is rotated. Shaft (A) passes through a projecting split collar (B) which gives a uniform even pressure. Attached to collar (B) is shoulder (E). This unit is threaded into end-plate (D) and locked in position by lock nut (C), thus determining the lateral distance of shoulder (D) attached to the rotor shaft (A). This assembly controls the adjustment of the condenser. The rotor plates are assembled on shaft (A), being automatically spaced by milled hubs (M) which are integral with the rotor plates. These plates are prevented from revolving too far by end-stop (F) which strikes spurs (H) which are threaded into end-plate. The whole condenser is supported at a proper distance back of the panel by mounting pillars (I). The plates are locked to shaft (A) by nut (Q) tightened against a special lock washer (N) and the whole unit is held up against shoulder bearing (E) by a ball-bearing socket socketed in an adjusting screw which is locked in position by lock nut (S) against end-plate (T). A self-cleaning brush contact (P) is riveted to end-plate (T), assuring positive contact, independent of bearings.

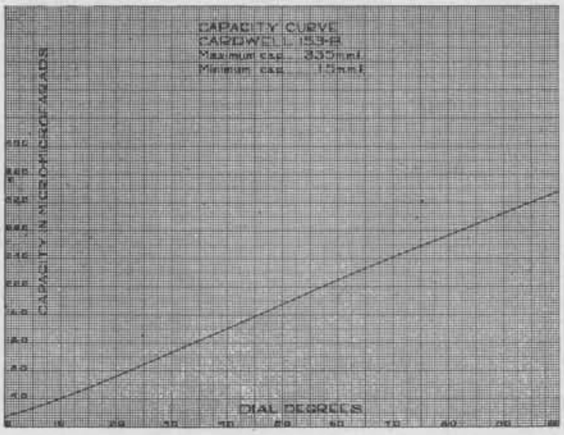
Even if the defective instrument can be located it may be necessary to tear the whole receiver apart to arrange for the changing of one unit in addition to the expense of replacing the offending unit. Hence, if you want to avoid difficulty in the end, exercise great caution in selecting your materials and do a real good job of assembly. The best of care and labor are none too good if you want your set to give you real entertainment.

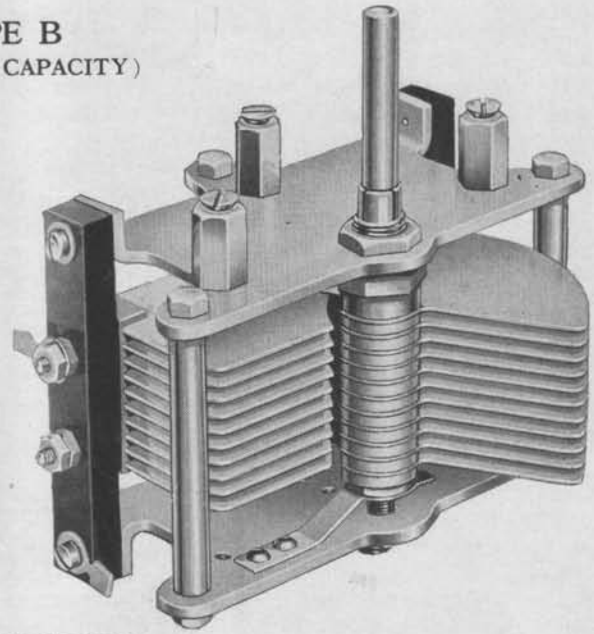
Cardwell instruments are all manufactured with the greatest attention to perfection in detail, and efficiency in every respect. They are fully guaranteed—but when you buy a Cardwell you don't expect to use the guarantee. It is right when it leaves the factory and, if given anything like reasonable treatment, will be right forever after.

There are nearly five hundred different types of Cardwell condensers manufactured as regular stock types and several hundred more which are made up against special order only, thus assuring anyone who wishes to secure a condenser, regardless of the types of tuning curve or capacity or special purpose desired, that it is a regular stock type of the Cardwell line and if it cannot be secured from the local dealer a letter to the factory will bring prompt and efficient service.

The Cardwell reputation is equally sustained in every other product, such as inductors, brackets, transformers, impedances, insulators and laboratory instruments. Every Cardwell unit is a pioneer—a part which determines the trend of design.

TYPE B
(STRAIGHT CAPACITY)





SPECIFICATIONS

Type	Code Word	Number of Plates	Maximum* Capacity (Rated)	Maximum† Capacity (Actual)	Minimum† Capacity	Depth (Back of Panel)	Price
159-B	DILSI	3	**.00005**	47	6.5	2⅜	**$4.00**
188-B	DUYHI	5	**.0001**	98	7	2⅜	**4.00**
154-B	DILRI	7	**.00015**	142	8	2⅜	**4.00**
141-B	DORDI	11	**.00025**	245	10	2⅜	**4.25**
153-B	DILNI	15	**.00035**	340	13	2⅞	**4.50**
152-B	DILKI	17	**.0004**	380	14	2⅞	**4.75**
123-B	DITNI	21	**.0005**	480	15	2⅞	**5.00**
137-B	DEYTI	41	**.001**	954	25	4	**6.00**
178-B	DOYHI	71	**.0017**	1684	43	5⅞	**15.00**

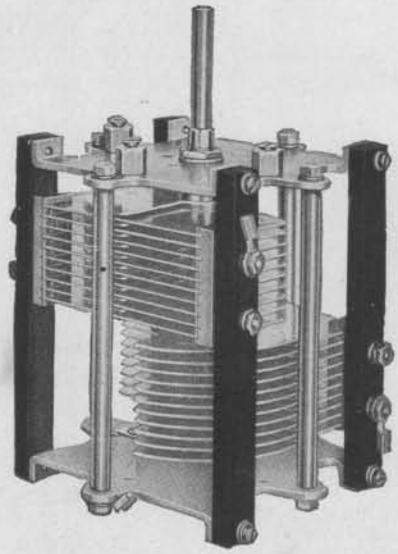
*Microfarads. †Picofarads.

GENERAL SPECIFICATIONS

Clearance of Plates, inches	.030
Overall mounting space, inches square	4.00
Radius of Rotor Plates, inches	1.437
Contact, Rotor to Frame	Friction
Voltage Breakdown	Approximately 1500
Stator Assembly Method	Pressed and swedged
Thickness of Plates, inches	.0253
Material of Plates	Aluminum
Area of Rotor Plates, in square inches	3.243
Area of Stator Plates, in square inches	3.819
Material of End Plates	Brass
Insulation	Hard rubber
Insulation Contact to Stator, in square inches	.4

For Template, see page 36.
For special end bearings, verniers and mounting brackets, see page 19.

CARDWELL CONDENSERS

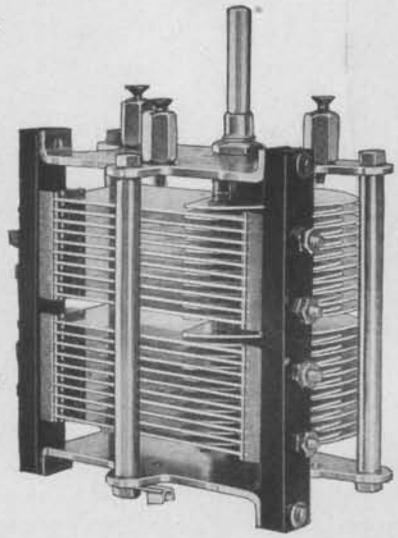


MULTIPLE TYPE "B"

(STRAIGHT CAPACITY)

With Balanced Rotor and opposite Stators

With Stators in Line Type 156-B only



SPECIFICATIONS

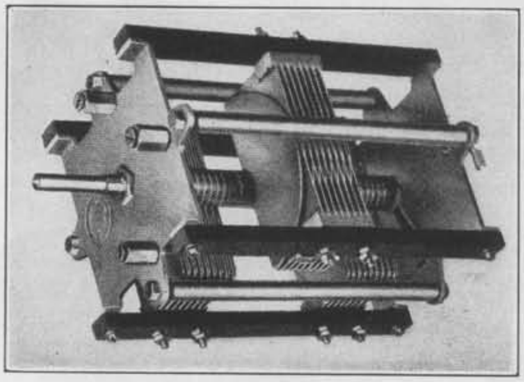
Type	Code word	Equivalent to	Depth Back of Panel	Price
156-B	DILWI	Two 123-Bs	4″	$7.00
203-B	KYONI	Two 159-Bs	2⅞	5.50
205-B	KYOLI	Two 188-Bs	2⅞	6.00
207-B	KYOTI	Two 154-Bs	2⅞	6.50
211-B	KAYDI	Two 141-Bs	2⅞	7.00
215-B	KAYLI	Two 153-Bs	4	7.50
217-B	KAYTI	Two 152-Bs	4	8.00
221-B	KITDI	Two 123-Bs	4	8.50
303-B	NYONI	Three 159-Bs	4	7.00
305-B	NYOLI	Three 188-Bs	4	8.00
307-B	NYOTI	Three 154-Bs	4	9.00
311-B	NAYDI	Three 141-Bs	4	10.00
315-B	NAYLI	Three 153-Bs	5⅞	11.00
317-B	NAYTI	Three 152-Bs	5⅞	12.00
321-B	NITDI	Three 123-Bs	5⅞	13.00

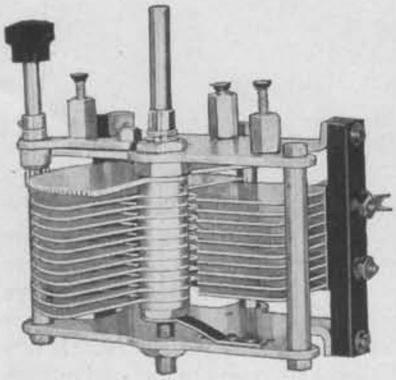
For General Specifications, see page 19.

Special Condensers in all the above types having grounded shields between the stator sections can be provided at an additional cost of $1.00 each.

Mounting Brackets for base or subpanel mounting—25c. per pair. See page 19.

Special Condensers in all the above types having shafts continuing through rear end-plates and fitted with coupling, can be provided at an additional cost of $1.50. See page 19.





Special Types

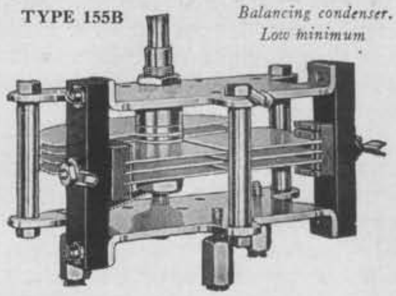
All types of condensers can be furnished with vernier built in as shown in this illustration. A solid gear is built into the rotor, and a pinion giving about a six-to-one reduction is mounted on the frame.

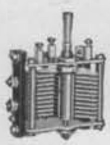
Type "B" condensers with vernier attached ..... $1.50 extra
All other types .... $2.50 extra

A special type of balancing condenser with a split stator of three plates on each side. This condenser is primarily intended for such circuits as the Pressley Super Heterodyne, Silver Autodyne, etc., but a variety of other uses suggest themselves.

Type 155B. Code word DILLI.................... $4.00
Maximum capacity—43 mmfd.
Minimum capacity—3 mmfd.

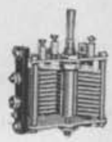
TYPE 155B *Balancing condenser. Low minimum*

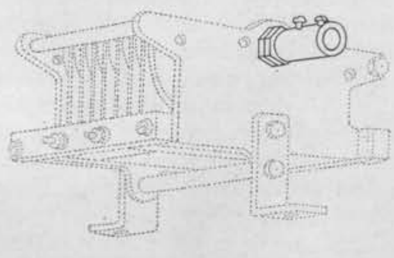




THE
ALLEN D. CARDWELL
MANUFACTURING CORPORATION
plans the
announcement of a superfine condenser of small size and capacity for balancing and similar uses.

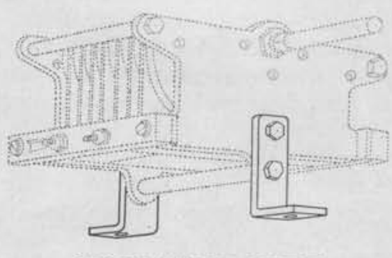
A supplementary page which can be pasted over this space will be mailed when this condenser is ready.





EXTENDED ROTOR SHAFT

continuing through rear end plate and terminating in Metal or insulated coupling.
Can be supplied on condensers of all types at
Extra $1.50



MOUNTING FEET

for Baseboard and Sub-Panel Mounting

Per pair .... $ .25

TYPE "C"

Modified Straight-Line Wave Length

In the construction of the type C condenser, almost all of the details just mentioned for the type B are followed, and the condenser is identical with the type B in every way, except that the rotor plates have a section cut out at the first entrance of the plates. This results in a tuning curve which approaches Straight Frequency at the lower settings of the condensers, and accordingly the lower wave lengths, and flattens out to a little greater separation than Straight Wave Length at the long waves. These tuning curves are shown in the graphs on the page opposite.

It is the belief of almost all of the prominent men of radio, that the ideal method of tuning is not Straight Frequency, as this concentrates the long wave and powerful stations within the upper 15 or 20 degrees of the dial, and spreads the short waves which are usually lower powered, and not as pleasant to listen to, over the major portion of the dial. This condition can best be avoided by a condenser with a tuning curve which gives a trifle more separation on the short waves than a Straight Wave Length curve, but which falls off a little above 300 meters and gives much greater separation on the higher waves. A recent wave length and power chart, published by the Department of Commerce showed 12 stations having more than 5,000 watts power above 300 meters and only 2 below. Drawn graphically by their separation on the dial and power-wave length curves all these stations would be almost symmetrical with a tuning curve of a Straight-Line Capacity condenser, such as the Cardwell type B. This condition will probably not remain quite as much accentuated as it is now, but there is no indication at the present of any probability of the allocation of higher power stations to the short waves. We therefore recommend the "Type C" as giving the best results in actual use.

All of these condensers are furnished with either anti-clockwise or clockwise rotation and with or without vernier. For clockwise rotation, specify type "CR," and for anti-clockwise, type "CL." For vernier add the letter "V" to the type number, and $1.50 each to the price.

TYPE "D"

Straight Frequency

The Cardwell type D condenser is built in two types, the single and balanced. Instead of using eccentrically-shaped rotor plates, with their accompanying faults of mechanical weakness, and large amount of panel space, Cardwell cut away the stator plates which keeps the construction of the condenser identical with the type C in every respect, excepting depth back from the panel. Owing to the much smaller amount of plate space available for tuning in these condensers, approximately double the number of plates are required to secure the same capacity as the corresponding type "C" or "B."

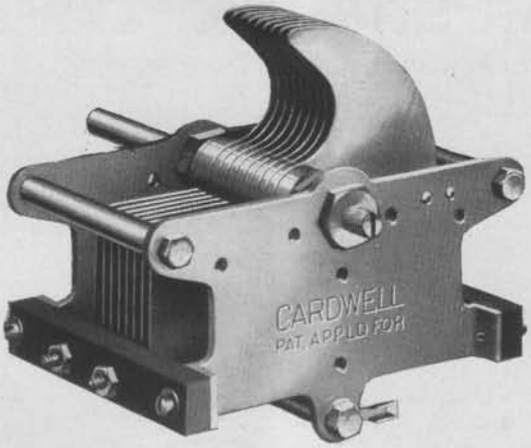
In order to counteract any possibility of excess weight on one side of the rotor shaft, the balanced construction was adopted in which the two stators of the condenser are connected by a strap in parallel, and in which the rotor, being divided in two sections on opposite sides of the shaft, is absolutely balanced. These condensers are designed to give absolutely Straight Frequency over their entire tuning range, when used with a coil of silk-covered wire wound on a Bakelite tube, and a tube such as UX-201-A, and wiring which with the tube includes a total circuit capacity of about 26 mmfd.

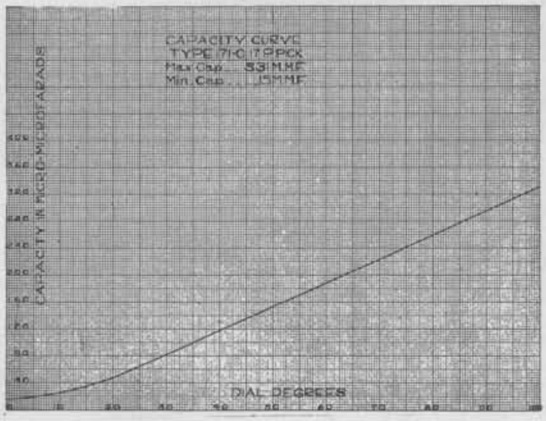
If absolute straight-line frequency is a necessity, no finer condenser with such a tuning characteristic can be found than the Cardwell Type D. The same substantial construction which has been outlined under type B was used in every respect, causing losses to be cut down to an absolute minimum. These condensers are used extensively in wave meters and laboratory oscillators where small size, particularly depth, is unnecessary and an instrument of the highest precision is desired.

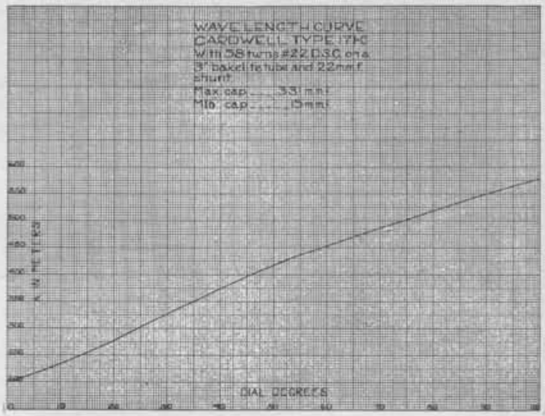
CARDWELL CONDENSERS

SERIES "C"

(SEMI-STRAIGHT WAVELENGTH)







SPECIFICATIONS

Type	Code Word	Number of Plates	Maximum* Capacity (Rated)	Maximum† Capacity (Actual)	Minimum† Capacity	Depth (Back of Panel)	Price
191-C	DUGDO	3	**.00005**	46	5	2⅜	**$3.75**
167-C	DYNTO	5	**.0001**	88.5	6	2⅜	**4.00**
168-C	DYNHO	7	**.00015**	131	6.5	2⅜	**4.00**
169-C	DYNSO	11	**.00022**	218.5	9.5	2⅜	**4.00**
170-C	DOYJO	13	**.00025**	260	11	2⅞	**4.25**
192-C	DUGKO	15	**.0003**	298	8	2⅞	**4.25**
171-C	DOYDO	17	**.00035**	340	12	2⅞	**4.50**
172-C	DOYKO	21	**.0004**	429	14	2⅞	**4.75**
173-C	DOYNO	25	**.0005**	517.5	15	4	**5.00**
174-C	DOYRO	33	**.0007**	697	18	4	**5.50**
194-C	DUGRO	41	**.0009**	867	21	4	**6.00**
175-C	DOYLO	47	**.001**	992	22	4⅝	**7.00**
176-C	DOYWO	71	**.0015**	1516	32	5⅞	**15.00**

For General Specifications, see page 19.

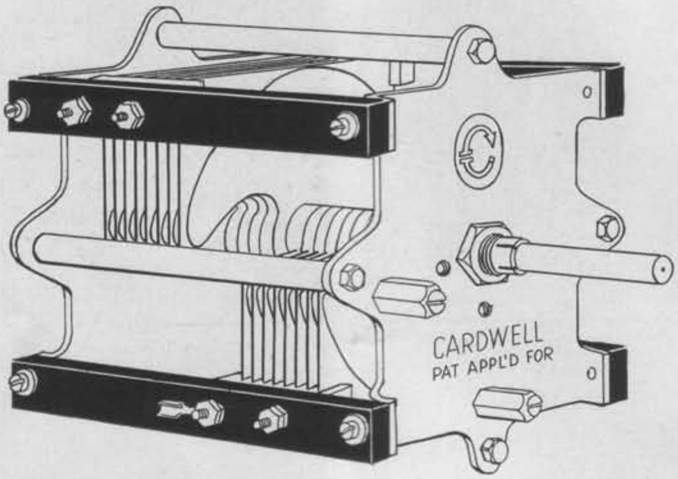
These condensers are made for both clockwise and counter-clockwise rotation. Please specify ". . . . CR" for clockwise, and ". . . . CL" for anti-clockwise when ordering.

*Microfarads. †Picofarads. (Micro-microfarads.)

For special end bearings, verniers and mounting brackets, see page 19.

MULTIPLE "C" TYPES

(SEMI-STRAIGHT WAVE LENGTH)



SPECIFICATIONS

Type	Code word	Equivalent to	Depth (Back of Panel)	Price
203-C	KYONO	Two 191-C	2⅞"	$5.50
205-C	KYOLO	Two 167-C	2⅞"	6.00
207-C	KYOTO	Two 168-C	2⅞"	6.50
211-C	KAYDO	Two 169-C	2⅞"	7.00
215-C	KAYLO	Two 192-C	4 "	7.50
217-C	KAYTO	Two 171-C	4 "	8.00
221-C	KITDO	Two 172-C	4⅝"	8.50
225-C	KITLO	Two 173-C	4⅝"	9.00
303-C	NYONO	Three 191-C	4 "	7.00
305-C	NYOLO	Three 167-C	4 "	8.00
307-C	NYOTO	Three 168-C	4 "	9.00
311-C	NAYDO	Three 169-C	4 "	10.00
315-C	NAYLO	Three 192-C	5⅞"	11.00
317-C	NAYTO	Three 171-C	5⅞"	12.00
325-C	NITLO	Three 172-C	5⅞"	13.00

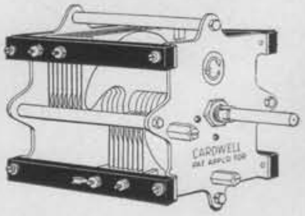
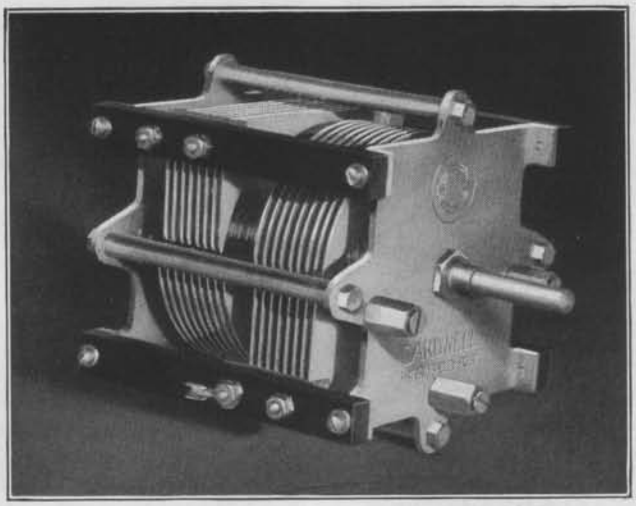
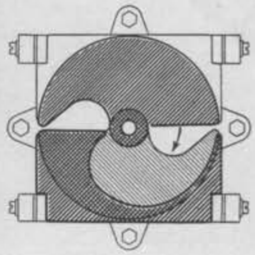
For General Specifications, see page 19.

Special condensers in all the above types having grounded shields between the stator sections can be provided at an additional cost of $1.00 each.

For other special types, such as verniers, continuous shafts, mounting brackets, etc., see page 19.

These condensers are made for both clockwise and counter-clockwise rotators. Please specify "....CR" for clockwise, and "....CL" for anti-clockwise when ordering.

TYPE "D"
(STRAIGHT FREQUENCY)

SPECIFICATIONS

Type	Code word	Number of Plates	Maximum* Capacity (Rated)	(Single End) Maximum† Capacity (Actual)	Minimum† Capacity	Depth (Back of Panel)	Price
191-D	DUGDU	3	**.000025**	22	3	2⅜	**$4.00**
168-D	DYNHU	7	**.000075**	65	5.5	2⅜	**4.00**
169-D	DYNSU	11	**.0001**	109	6	2⅜	**4.25**
192-D	DUGKU	15	**.00015**	157	7	2⅞	**4.25**
173-D	DOYNU	15	**.00025**	250	11	2⅞	**5.00**
174-D	DOYRU	33	**.00035**	336	12	4	**5.50**
175-D	DOYLU	47	**.0005**	490	16	4⅝	**7.00**
176-D	DOYWU	71	**.0007**	705	25	5⅞	**15.00**
				(Balanced Type)**			
211-D	KAYDU	22	**.00022**	210	16	2⅞	**$7.00**
217-D	KAYTU	34	**.00035**	323	19	4	**8.00**
221-D	KITDU	42	**.0004**	400	24	4⅝	**8.50**
225-D	KITLU	50	**.0005**	475	25	4⅝	**9.00**

*Microfarads. †Picofarads. (Micro-microfarads.)

**Capacity shown is for two stators connected in parallel.

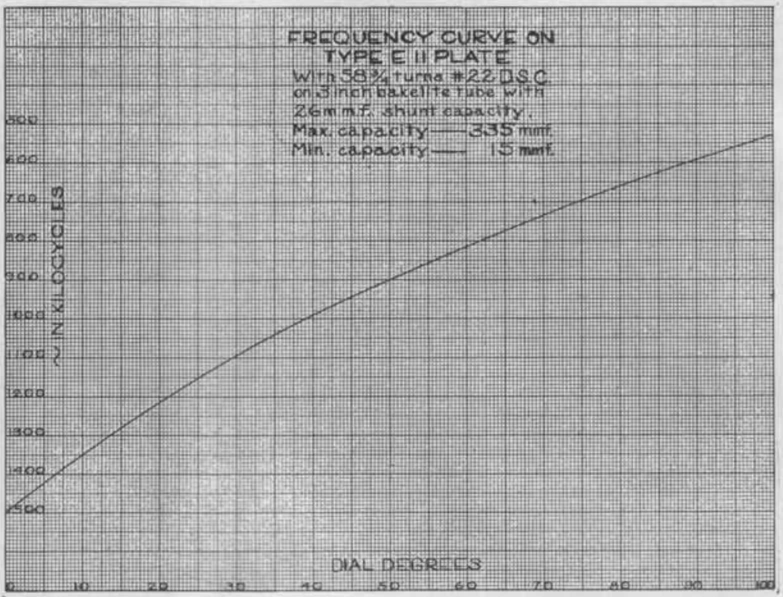
For General Specifications, see page 19.

These condensers are made for both clockwise and counter-clockwise rotation. Please specify "...DR" for clockwise, and "...DL" for anti-clockwise when ordering.

For special end bearings, verniers, and mounting brackets, see page 19.

SERIES "E"

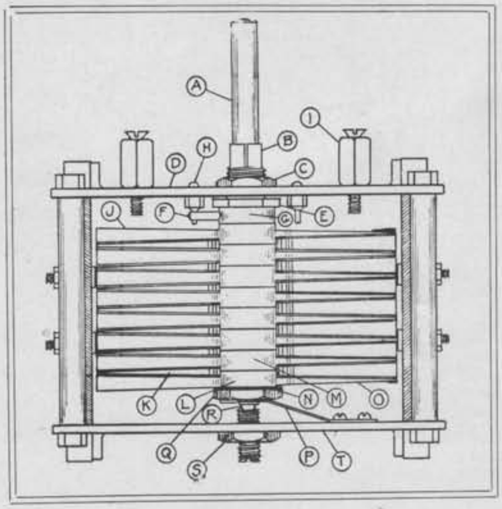
The Taper Plate Type "E" - - - -



The taper plate type E Cardwell condenser is the first logical answer to the demand for a condenser which will give more separation on the shorter waves than the type C condenser. It has a tuning characteristic which approximates Straight Frequency over the lower part of the dial, but the curve falls off sufficiently to give a slightly greater separation on the longer waves than absolute Straight Frequency would secure. This results in complete freedom from crowding on any part of the dial and the electrical efficiency of this condenser, which affords somewhat lower losses than is possible with even other type Cardwells, assures the user of maximum selectivity.

When the crowding of broadcasting stations made it evident that a straight frequency tuning curve would be popular, many condensers were rushed on the market with flimsy plates, and weak over-balanced construction. Electrical efficiency and mechanical strength were sacrificed in order to approach straight frequency by the shaped plate method. Large panel space was required and accurate logging was impossible.

Meanwhile Cardwell engineers were perfecting a new condenser in which a straight frequency tuning curve is secured by a regular variation of the thickness of the air-dialectric, with a pronounced gain in compactness, efficiency and mechanical strength.

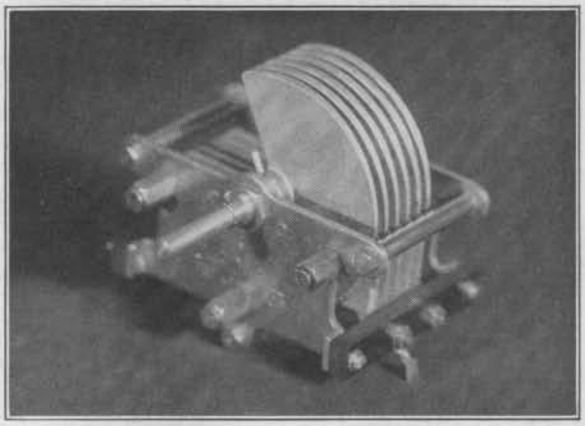


CROSS SECTION

Of taper plate type E condensers shows the design which assures the lowest possible losses, and at the same time the greatest possible mechanical strength. Note how rotor plates (M) (L) dovetail into stator in such a way that the spacing varies as the dial is rotated. End stops (F) (H) prevent condenser from turning too far. Rotor plates are made integral with machined hubs, assuring positive alignment. Dial shaft (A) passes through slotted sleeve (B) which gives a smooth even turning motion. This sleeve is threaded into end plate (D) and terminates in shoulder bearing (E). The whole unit is locked into position by lock nut (C). Bearing (G) against shoulder (E) controls the adjustment of rotor plates. At the back end of the condenser, shaft (A) terminates in a cup in which ball bearing (R) is socketed, giving an absolute concentric bearing which can be adjusted by (S). Rotor plates are locked in position by nut (Q) and lock washer (N). Contact independent of bearings is obtained by self-cleaning brush (P) which is riveted to end plate (T). Note that whole stator is supported and makes contact with the insulation only at four points.

SERIES "E"

. . . a condenser
you can
depend on



The type E condenser is built into the same frame which is familiar to almost all radio builders as the ultimate in strength and compactness. In depth back of the panel, it is almost identical with type B condensers of corresponding capacity, and the fact that it will mount entirely behind a 4″ dial proves a tremendous advantage over eccentric types which require anywhere from 6 linear inches up, of panel space, when the plates are open.

Another advantage given by this method of construction is that the weight of the rotor plates is concentrated close to the rotor shaft, where it exerts but a short leverage. Eccentrically shaped plates with a good deal of weight in the rotor, several inches from the rotor shaft, will invariably cause the rotor to move easily in one direction or stiffly in the other, or sometimes actually fall until the rotor assumes a position where it can go no further.

Due both to the short radius and unusual thickness of plates in the type E condenser, a stiffness is obtained which has been heretofore unequaled. It is almost impossible to bend the plates even by rough treatment, and calibration or the log of a set using these condensers will remain absolutely the same for all time.

800
160
6.40

SPECIFICATIONS

Type	Code Word	Maximum* Capacity	Minimum† Capacity	Depth Back of Panel	Price
191-E	DUGDE	**.000075**	5	2⅜″	**$4.00**
167-E	DYNTE	**.000150**	7	2⅜″	**4.00**
168-E	DYNHE	**.000250**	8	2⅜″	**4.25**
169-E	DYNSE	**.000350**	13	2⅞″	**4.75**
192-E	DUGKE	**.000500**	15	3¼″	**5.00**

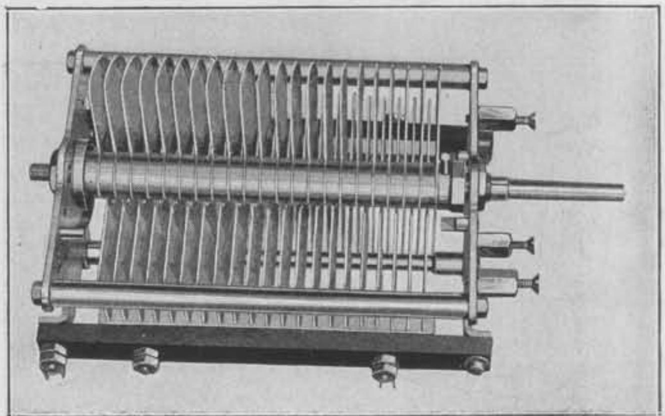
*Microfarads. †Picofarads. (Micro-microfarads.)

For special types, such as verniers, continuous shafts, mounting brackets, etc., see page 19.

These condensers are made for clockwise, or right-handed rotation, only.

CARDWELL CONDENSERS

TRANSMITTING TYPES



Type 147-B

Cardwell Transmitting Condensers use the same basic construction as the type "B." All the parts, however, are much heavier, and the contact system employed is a flat ribbon pigtail in some models, and a self-cleaning brush in others.

While public opinion for some time has favored the use of pigtails, it now appears that many of the largest users of condensers in commercial, military and naval equipment find the pigtail to be a disadvantage rather than a help. Variance in inductance and capacity caused by the movement of the pigtail as the rotor revolves very frequently make a great deal of trouble on the short waves, and accordingly Cardwell Transmitting Condensers are being made to a great extent with a self-cleaning brush contact which gets rid of most of the difficulties which are inherent in pigtail construction.

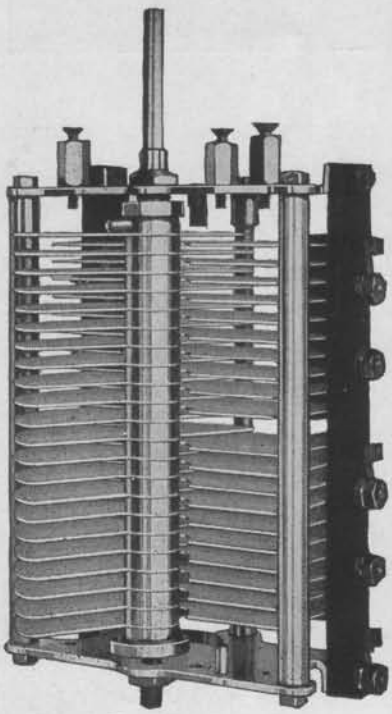
Cardwell condensers are so ruggedly constructed that they will maintain exact calibration through any atmospheric conditions. This assures the user of freedom from variation of wave length, and it will be found that once the transmitter has been tuned by means of a wave meter of standard signal, you can depend on your QRH remaining constant night after night, and month after month.

A number of different types are made for the varied kinds of service which result from the use of different sized tubes and circuits. For example, either the 164 and 147, or the 157 can be used anywhere in a circuit of one or two 50-watt tubes. For quarter Kw. tubes the 183-B is a necessity, unless only a few turns of the inductance are tuned. For even higher powered work the type 166-B, displayed on the following page, is recommended.

Attention is called to the type 157-B which has two stators, each having a capacity the same as the 164-B, with a common rotor. This condenser may be used to secure a variety of capacities with the two sections in series, one alone or in parallel, or for simultaneous tuning of two Oscillating circuits.

We will be glad to cooperate with anyone who plans to build a transmitting station and make suggestions as to the best parts to be used. Send us your hook-up and the parts you have and we will be glad to make recommendations for the approval of your set.

Always give your call letters.



Type 157-B

SPECIFICATIONS AND PRICES OF TRANSMITTING CONDENSERS

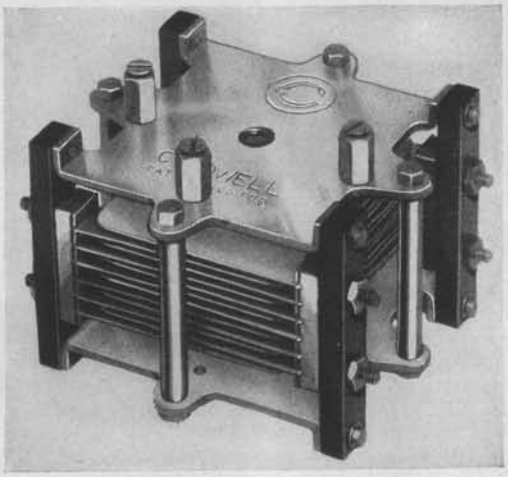
Type Number	List Price	Number Plates	Capacity Minimum MMF.	Capacity Maximum MMF.	Plate Spacing Inches	Breakdown Voltage (1)	Shaft Diam. Inches	Shaft Length (2) Inches	Overall Length (3) Inches	Code word
164-B	$ 7.00	21	13	217	.070	3,000	.250	1.000	4.000	DYRNI
147-B	10.00	43	35	440	.070	3,000	.250	1.000	5.875	DORTI
197-B	8.50	9(4)	10(4)	80(4)	.070	3,000	.250	1.000	4.000	DUGTI
157-B	12.00	21(4)	16	217(4)	.070	3,000	.250	1.000	5.875	DILTI
183-B	15.00	31	33	156	.153	5,250	.250	1.000	7.500	DUYNI
166-B	70.00	23	38	297	.219	7,600	.375	2.125	10.250	DYNWI

(1) At 600 meters using 500-cycle generator. (2) From inside surface of mounting panel (or top of post) to end. (3) Length from back of panel, as mounted. (4) Double stator of 21 plates each.

ALL TRANSMITTING CONDENSERS SOLD DIRECT TO USER ONLY

THE STANDARD OF COMPARISON

Fixed Air Condensers



The Cardwell Fixed Air Condenser is the result of a quite apparent need for such a condenser in modern transmitting equipment. This condenser is a highly efficient and permanent capacity condenser designed especially for use as a tuning, blocking, or coupling condenser in vacuum tube transmitters or oscillators of all powers. The construction of these condensers in most respects follows that of the standard Cardwell Variable Air Transmitting Condensers listed in this book, the same low loss construction being used throughout. In this respect particularly it is far superior to the mica condensers ordinarily used for such purposes. For example, when tuning the antenna circuit a much sharper resonance point is secured, permitting the use of closer coupling with consequent greater energy transfer, and retaining at the same time as sharp tuning as was the case when looser coupling was used with a mica condenser. The plates on both sides of the circuit are insulated from the frame, making it possible to mount the condensers on wooden frames or baseboards without danger of losses through conductivity of the support.

Probably the greatest practicable advantage in the use of this condenser is the fact that in the event of an unusually high potential being placed across the plates of the condenser momentarily, a spark may jump, but the condenser immediately returns to its former condition and can be used indefinitely under conditions where mica condensers, once broken down, would have to be replaced frequently.

For C.W. sets using powers up to an overloaded quarter KW Tube, any the first three types illustrated below will give very satisfactory service. For phone sets of 250 Watts or over the Type 504 is recommended.

In accordance with the regular Cardwell policy, these condensers are sold direct to the amateur from the factory at the lowest possible prices. When ordering give your call letters.

SPECIFICATIONS

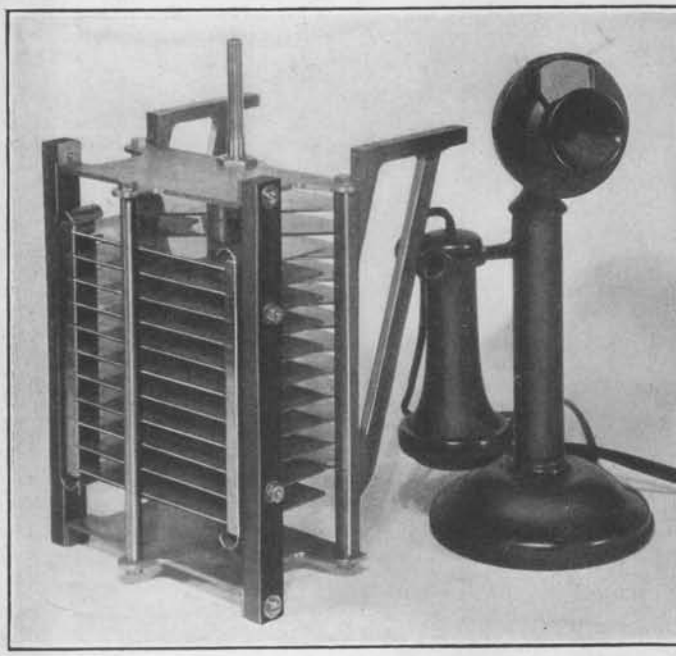
Type Number	List Price	Number of Plates	Capacity MMF	Plate Spacing	Breakdown Voltage	Depth Inches	Code word
501	$4.50	12	250	.070″	3,000	2.500	LYODA
502	7.00	20	440	.070″	3,000	3.625	LYOKA
503	10.00	42	966	.070″	3,000	5.500	LYONA
504	15.00	22	250	.153″	5,250	5.500	LYORA

CARDWELL CONDENSERS

Transmitting Type 166-B

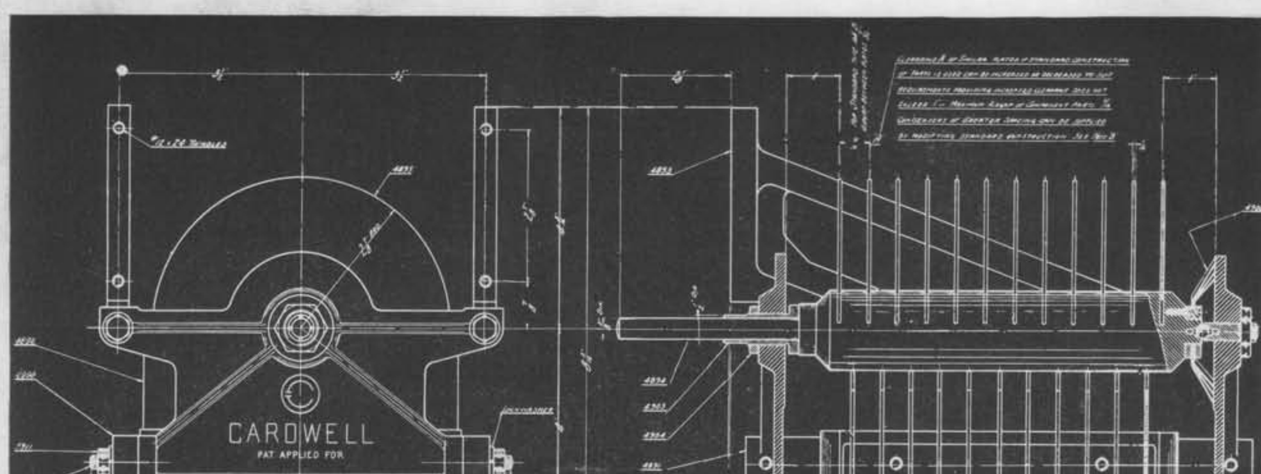
This condenser is designed especially for use in laboratories where a precision instrument of permanent calibration and extremely low losses is a necessity, and also for high-powered transmitting stations using power of 500 watts or more in the output circuit, and it has been made in sufficiently generous proportions to accommodate the very large currents which are handled under such conditions. In general appearance, it follows the same design as the receiving condensers, but a close examination shows a number of departures from the regular design which are necessary to assure perfection in a condenser of this type. The insulation is made from the best grade of hard rubber obtainable and is of sufficiently heavy stock to guarantee immunity from mechanical strains. The insulation strips measure 50″ x 1.00″ in section and at the same time, due to careful design, there is less than one square inch of contact surface between the stator shields and the insulation.

The condenser is made almost entirely of brass. Massive end plates support an eleven-plate stator which is constructed of plates 1/16″ in thickness, soldered into brass blocks on each side. The edges and corners of the plates are all carefully rounded in order to minimize brush discharge, and the ends of the supporting blocks are shielded with a curved strip for the same purpose.



Type 166-B
"The Standard of Comparison"

Extreme care is used all the way through the condenser to assure that no sharp corners exist to encourage stray discharges.



THE STANDARD OF COMPARISON

Transmitting Type 166-B

All parts of both stator and rotor are buffed in order to assure an absolutely smooth polished surface.

The rotor is assembled on a shaft of solid brass one and one-half inches in diameter, which is carefully turned to exact dimension. The rotor plates are soldered into slots machined in this shaft, which passes through a monel metal sleeve bearing at the panel end of the condenser very similar to the one used in smaller types, except that it is of much more generous proportions.

The same steel ball-bearing construction is used at the back end of the condenser, also much heavier, and a special form of phosphor bronze self-cleaning brush contact is used in order that there may be no possible loss at this point.

The dial shaft is ⅜″ in diameter and extends 2⅛″ in front of the back of the panel when the condenser is mounted.

A condenser having this construction can be relied on to hold its calibration under any circumstances whatever and is probably the finest condenser obtainable today from any source whatever. Cost has not been made a factor in the production of this condenser, and as each one is practically hand-made by master artisans who have been specializing in this work for many years, the user can be assured of the nearest thing to perfection in the condenser line that has ever been manufactured—truly a "Standard of Comparison."

SPECIFICATIONS

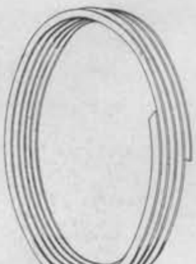
Type number	166-B
Price	$70.00
Number of plates	23
Maximum capacity	.297 Mmfd.
Minimum capacity	38 Mmfd.
Plate spacing	.5″
Overall depth, panel to end	10 7/32
Overall panel space	8 3/16″ x 8″
Contact	Self-cleaning brush
Radius of rotor plates	2 ⅞″
Rotor construction	Pressed & soldered
Stator construction	Pressed & soldered
Material of plates	Brass
Thickness of plates	.0625″
Material of insulation	Hard rubber
Insulation contact with stator	Less than 1 square inch
Code word	DYNWI

Blueprints furnished on request.

PRICE - - - - - - - - - - - - $70.00

Transmitting Inductance

Edgewise Wound Copper Ribbon



Copper ribbon .0625″ x .25″, edgewise, wound into turns 5¼″ in outside diameter. Sold by the turn in helices of up to 30 turns.

Price, per turn .... **$ .10**

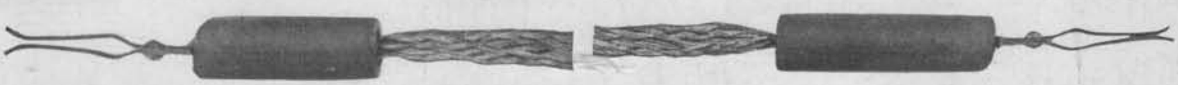
Same as above, but wound to 9″ diameter.

Price, per turn .... **$ .15**

Flat Copper Ribbon

Copper strip as above, suitable for winding inductances, use as Busbar, lead-in, or other connections.

Price, per foot .... **$ .08**

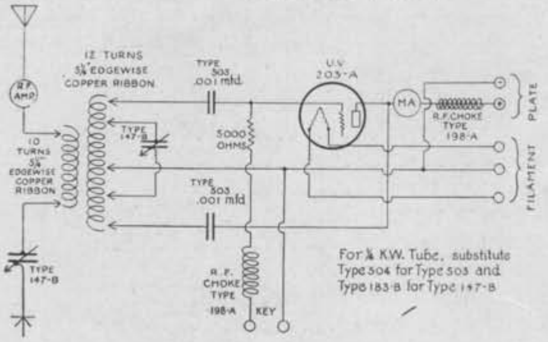


SPRING CLIPS for tapping Inductors, each .... $ .10
BELDEN BRAID for connections, per foot .... $ .15
CONNECTORS, 18″ long, complete with two clips and ferrules .... $ .50

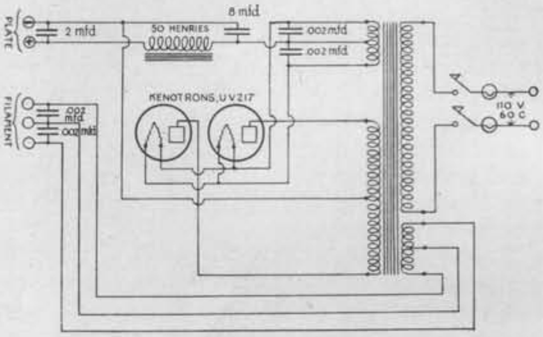
Standard Transmitting Circuits

HARTLEY

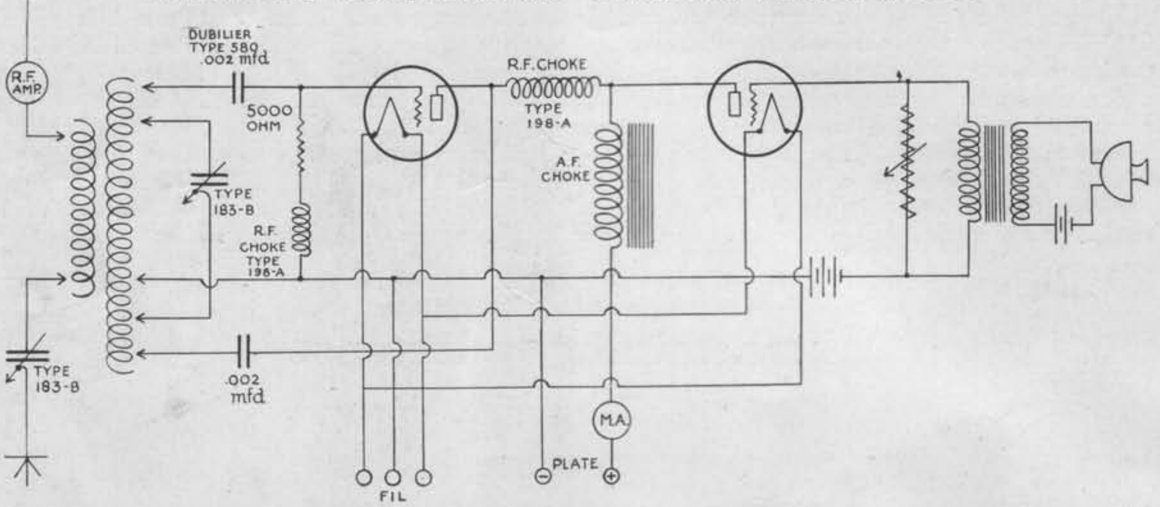
OSCILLATOR



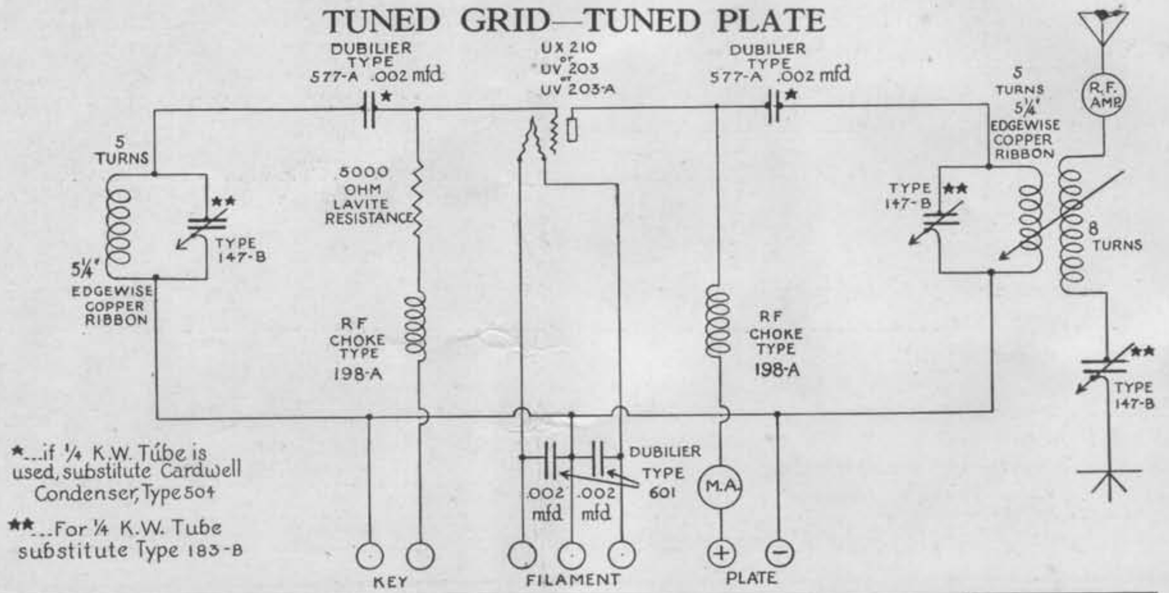
POWER



HARTLEY OSCILLATOR—HEISING MODULATOR



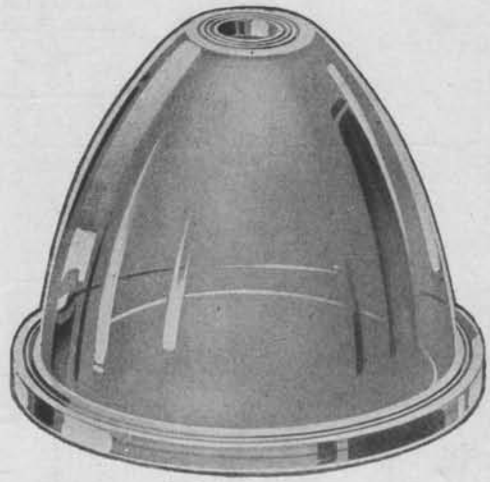
TUNED GRID—TUNED PLATE



*...if ¼ K.W. Tube is used, substitute Cardwell Condenser, Type 504

**...For ¼ K.W. Tube substitute Type 183-B

Pyrex Insulators



Lead-in Insulator

A fundamental fact, not always recognized, is that the insulation of a broadcast reception antenna has a definite bearing on reception results, and is just as important as the proper insulation of the antenna of a broadcasting station.

The reception antenna collects radio energy which is transferred through the lead-in to the receiving set. The total energy collected by an antenna under the best conditions is small, and perfection in reception can only be secured by feeding the maximum received energy to the detector or R. F. amplifier. Using a sieve to gather rain water is equivalent to employing an antenna with "leaky" insulators to gather radio energy.

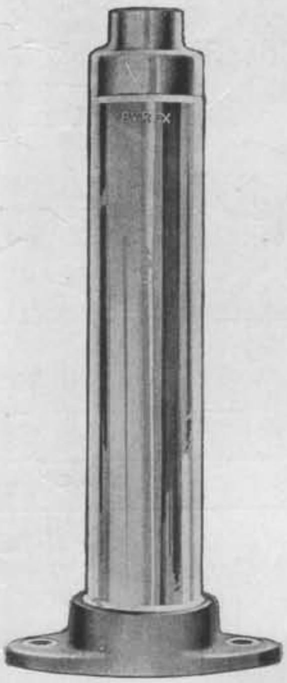
Strain Insulator

Antenna insulators must be permanent and unchanging in their electrical characteristics. They must have a super-smooth surface to prevent collection of soot, dust, etc., and to allow rain to wash them off thoroughly. They must possess sufficient mechanical strength to permit the use of relatively small sections, thus keeping insulator bulk and weight to a minimum. As a measure of insulating value the material should have a small phase angle difference which does not change appreciably with increase in frequency.

Phase angle is assuming great importance at the present time through the growth of interest in transmission and reception at high frequencies. "Low Loss" tuners coupled to antennas with poor insulators are not unusual, and the tuner generally gets the blame.

Pyrex is an ideal material for the construction of antenna insulators and other parts of radio equipment where permanent high insulating values are desired. It is homogeneous and of a continuous uniform structure, and so does not depend for its insulating properties on a surface glaze.

Pyrex does not absorb water or attract moisture, and its smooth permanent surface prevents the collection of dust. It is mechanically strong and light in weight, thus enabling even high-power transmitting insulators to be made with reasonable dimensions.



Stand-Off

The electrical properties of pyrex which interest the user of radio equipment are as follows:

Phase Angle Difference—0.25°.

Dielectric Constant—5.4.

Volume Resistivity—10^{14} ohm-cms.

Surface Resistivity, 34% Humidity —10^{14} ohm-cms.

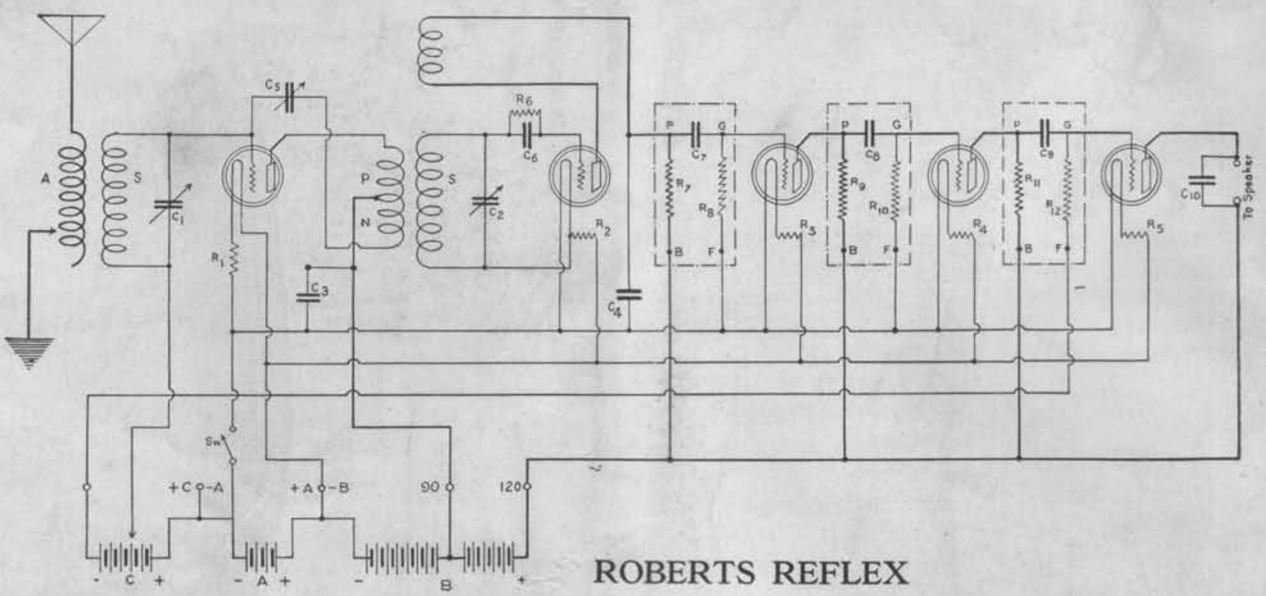
Surface Resistivity, 34% Humidity —14×10^{8} ohms.

The Broadcast Reception Insulators have a strain resistance of over 450 pounds.

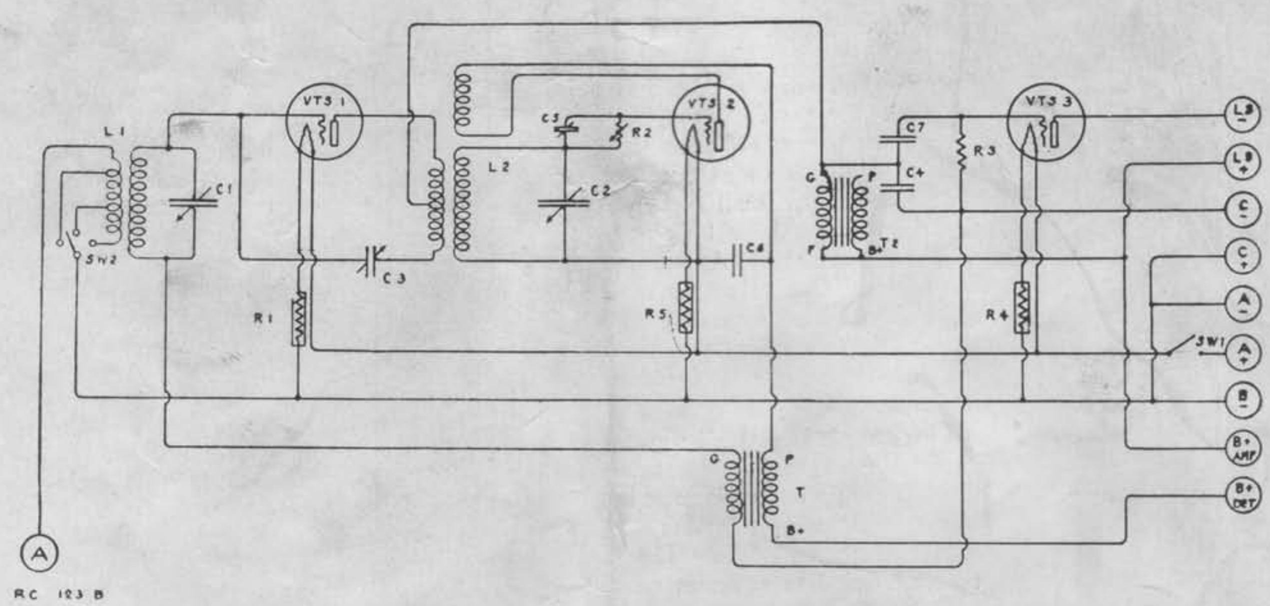
Type		*Size*	*Price*
Strain Insulator	67077	3½″	$ .45
	67017	7¼″	1.50
	67021	12¼″	3.50
Broadcast		30″	On application
Stand-off Insulator	67018	3″	$2.75
	67019	7″	3.00
Lead-in bowl	67009	each	1.50
Special Lead-in equipment (2 bowls and complete hardware)			4.00

CARDWELL RADIO INSTRUMENTS

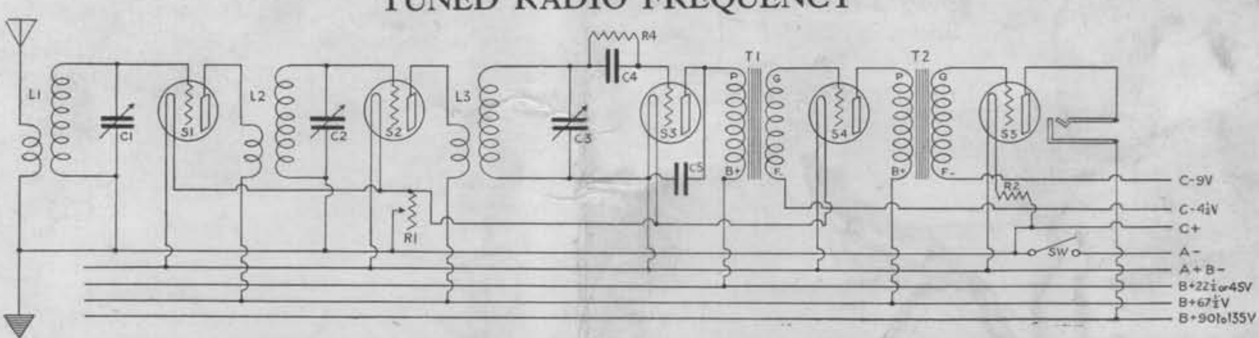
THE "RADIO BROADCAST ARISTOCRAT"



ROBERTS REFLEX



TUNED RADIO FREQUENCY



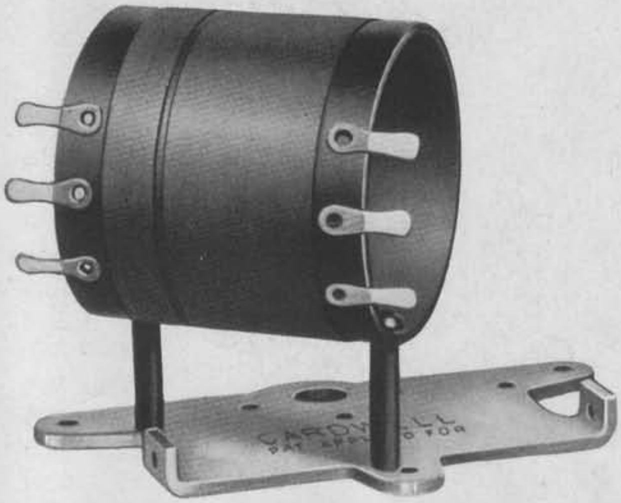
THE STANDARD OF COMPARISON

Inductors

During the past two years a great amount of publicity and advertising have attended the "invention" of various new types of Coils wound crosswise, sidewise, lengthwise, alligator-backwise and a great many other wise. It was claimed for these coils that they were panaceas for almost every ill which attacked the home-built radio set, and undoubtedly some of them had their advantages. In the meantime, however, to those who investigated textbooks and other scientific works, one fact presented itself with startling clearness—no other form of coil even closely approached the single layer solenoid for efficiency, provided the proportions were proper.

Cardwell Inductors are single layer solenoid coils wound on hard rubber in such shape and with such constants that maximum efficiency consistent with the limitations of broadcast reception is secured. The use of comparatively fine wire reduces the grid-plate capacity of the windings as well as the distributed capacity of the windings, making for a decided increase in the efficiency of the transformer from several standpoints. The terminals are so arranged that the Inductors can be used for almost any of the popular circuits. Center taps on the windings allow the tuning of one-half the coil only to reach shorter wave lengths than could be done with the whole coil.

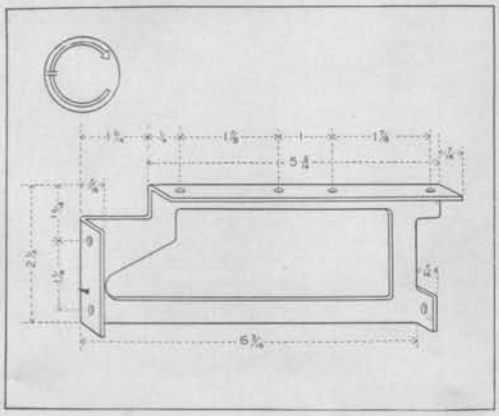
These Inductors are manufactured in a size which permit of their covering the full broadcast band when tuned with a condenser of approximately 340 mmfds maximum capacity, such as Cardwell Type 153-B, 215-B, 315-B, or 171-C, 217-C, 317-C, or 167-E. Cardwell Inductors have mounting arrangements which will permit of their being attached to the rear end plates of Cardwell Condensers, to Cardwell Sub-Panel Brackets, Panels, or Sub-Panels.



Type 198-B, R.F. Choke, for transmitters on wave length of 150 meters or longer, complete with tips and tip jacks...... 4.50
Type 198-C, R.F. Choke, for receivers, all waves 1.50

Type 196-A $1.50
Type 196-A2 (Set of 2 Inductors)........ 2.75
Type 196-A3 (Set of 3 Inductors)........ 4.00
Type 198-A, R.F. Choke, for 20, 40 and 80 meter transmitters, complete with tips and tip jacks 3.00

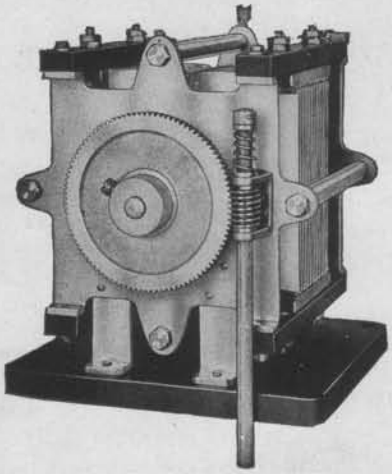
Sub Panel Brackets



These are the original subpanel brackets, on which the first subpanelled sets were built years ago. They are, we believe, the only subpanel bracket of sufficient height to *enable the user to mount audio frequency transformers beneath the subpanel.* Made of heavy brass, nickeled, extending 6⅝″ back of panel and 2½″ high.

No. 195. Code word DUGLA..................................**Price, per pair $. 75**

Properties of Magnet Wire

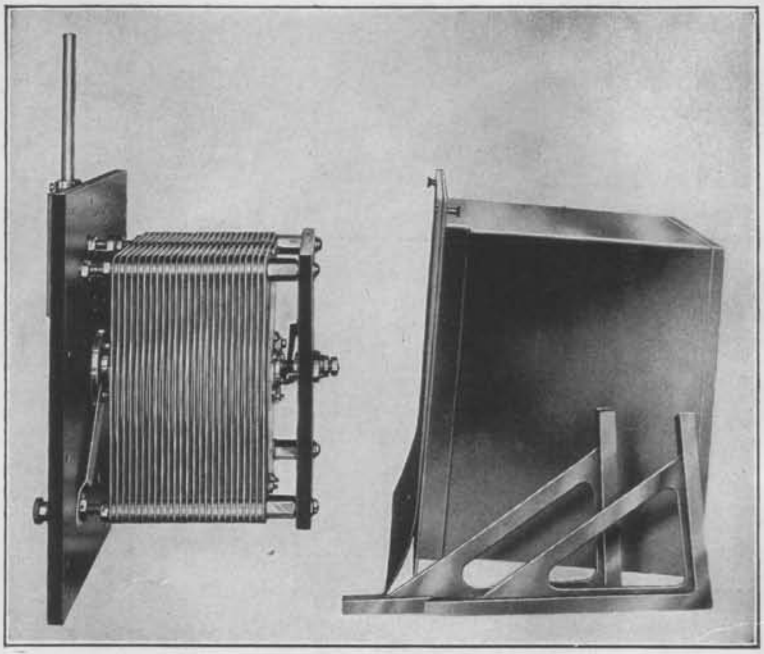


Special Laboratory Balancing Type

SIZE B & S Gauge	Enamel	TURNS PER INCH Single Silk	Double Silk	Single Cotton	Double Cotton	RESISTANCE Ohms per 1,000 ft. D. C.	200 λ
10	9.6			9.3	8.8	1.02	12.25
12	12.0			11.5	11.0	1.62	15.50
14	15.0			14.0	13.5	2.60	19.75
16	19.0	18.8	18.2	18.0	16.6	4.10	25.00
18	23.8	23.6	22.8	22.0	20.5	6.50	32.00
20	30.0	29.5	28.0	27.0	24.5	10.40	41.00
22	37.0	36.5	34.5	34.0	30.0	16.50	52.50
24	46.5	45.2	42.0	41.5	35.5	26.20	67.75
26	58.5	56.0	51.0	50.0	42.0	41.60	88.00
28	74.0	69.0	61.0	60.0	50.6	66.20	114.00
30	92.0	83.0	73.0	70.0	56.0	105.00	148.00
32	115.0	101.0	85.0	83.0	63.0	167.00	200.00
34	145.0	121.0	100.0	98.0	70.0	266.00	285.00
36	180.0	143.0	114.0	111.0	77.0	423.00	430.00
38	227.0	167.0	128.0	125.0	84.0	673.00	675.00
40	285.0	195.0	145.0	142.0	91.0	1,000.00	1,000.00

Dielectric Constants of Insulators

Material	Specific Inductive Capacity
Air	1
Bakelite	4 to 8
Celluloid	4 to 16
Glass	4 to 10
Mica	3 to 7
Oil, Castor	4.7
Oil, Transformer	2.2
Paper	2 to 4
Paraffin	2
Porcelain	5 to 6
Rubber	2 to 3½
Pyrex	5.4
Shellac	3.5
Varnished Cambric	4
Wood	2 to 8



Special Oil Type for high capacity

Some Useful Information

There are times when, for various reasons, the experimenter will not wish to purchase all the parts necessary for a set, but prefers to make such parts as he can himself. In order to make this as easy as possible, we are giving below a few formulæ:

To find the wave length of a coil and condenser:

(1) $\lambda = 1884\sqrt{LC}$

For L in microhenries
C in microfarads

(2) $f = \frac{159.2}{\sqrt{LC}}$

Where f = Frequency in kilocycles

Capacity of a condenser:

(3) $C = .0000000885 \frac{SA}{t}$

Where S = Specific inductive capacity or dielectric constant of the dielectric. (See page 30).
A = Surface area of one plate in sq. cm.
t = Thickness of dielectric in cm.

For a condenser of "N" interleaving plates:

(4) $C = .0000000885 \frac{(N\text{-}1)\ SA}{t}$

To calculate inductance of a single layer solenoid:

(5) $L = \frac{.03948\, r^2 n^2}{l} K$

Where n = Number of turns
r = Radius of tube on which coil was wound
l = Length along winding
K = A constant determined by $\frac{2r}{l}$

To calculate the inductance of a toroid (doughnut coil):

(6) $L = .01257N^2 \left(R - \sqrt{R^2 - A^2}\right)$

Where R = Radius of toroid from center of doughnut to center of winding
A = Radius of turns of winding

To calculate the radio frequency resistance of a coil shunted by a condenser the following procedure, while not absolutely accurate, will give a sufficiently close result for ordinary usage:

Place a thermo-galvanometer in series with the condenser. Using an oscillator as a source of power note the galvanometer reading at the frequency desired. Then insert a rheostat which has been calibrated in ohms in series with the condenser and galvanometer. Retune very carefully and adjust the rheostat until the galvanometer reading is just half its previous reading.

The amount of resistance used in the rheostat, less the known resistance of the galvanometer, will equal the resistance of the coil and condenser.

To find the phase angle:

(7) $\text{Tangent } \theta = \frac{2\pi fL - \frac{1}{2\pi fC}}{R}$

To find the impedance of a tuned circuit:

(8) $Z = \sqrt{R^2 + \left\{2\pi fL - \frac{1}{2\pi fC}\right\}^2}$

Where Z = Impedance in ohms.

Values of "K" for use in Formula 5

Diam. Length	K	Diameter Length	K	Diameter Length	K
0.00	1.0000	2.00	0.5255	7.00	0.2584
.10	.9588	2.20	.5025	7.40	.2491
.20	.9201	2.40	.4816	7.80	.2406
.30	.8838	2.60	.4626	8.50	.2272
.40	.8499	2.80	.4452	9.50	.2106
.50	.8181	3.00	.4292	10.00	.2033
.60	.7885	3.20	.4145	12.00	.1790
.70	.7609	3.40	.4008	14.00	.1605
.80	.7351	3.60	.3882	16.00	.1457
.90	.7110	3.80	.3764	18.00	.1336
1.00	.6884	4.00	.3654	20.00	.1236
1.10	.6673	4.20	.3551	24.00	.1078
1.20	.6475	4.40	.3455	28.00	.0959
1.30	.6290	4.60	.3364	35.00	.0808
1.40	.6115	4.80	.3279	45.00	.0664
1.50	.5950	5.00	.3198	60.00	.0528
1.60	.5795	5.40	.3050	80.00	.0419
1.70	.5649	5.80	.2916	100.00	.0350
1.80	.5511	6.20	.2795	.....	.....
1.90	.5379	6.60	.2685	.....	.....

ALL DIMENSIONS IN CENTIMETERS

Mounting Pillars

Nickeled, Brass, 1/4" diameter, tapped for 6:32 screw

Part No.	Length	Price, each
4735	1 5/16"	.10
4548	1 7/8"	.10
4616	3"	.15

Hexagonal, 1/2" long, 5/16" across, untapped hole large enough to pass 8:32 machine screw.

Part No. 4741 **each 2 1/2c**

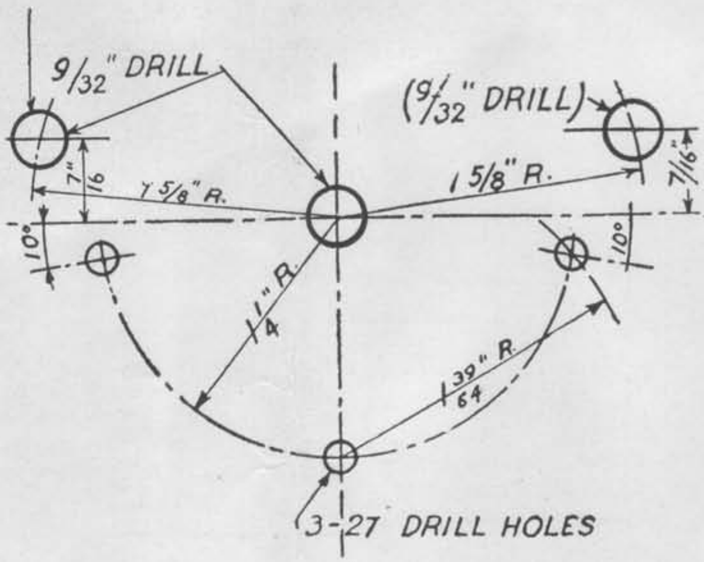
Template

For all Condensers

(Except Type 166-B)

Drill this hole for mounting B V L Vernier Type Condenser only

DRILLING LAYOUT for Variable Condenser All types



Drill this hole for mounting Vernier Type Condenser only

7½ x 10½

192 Wale