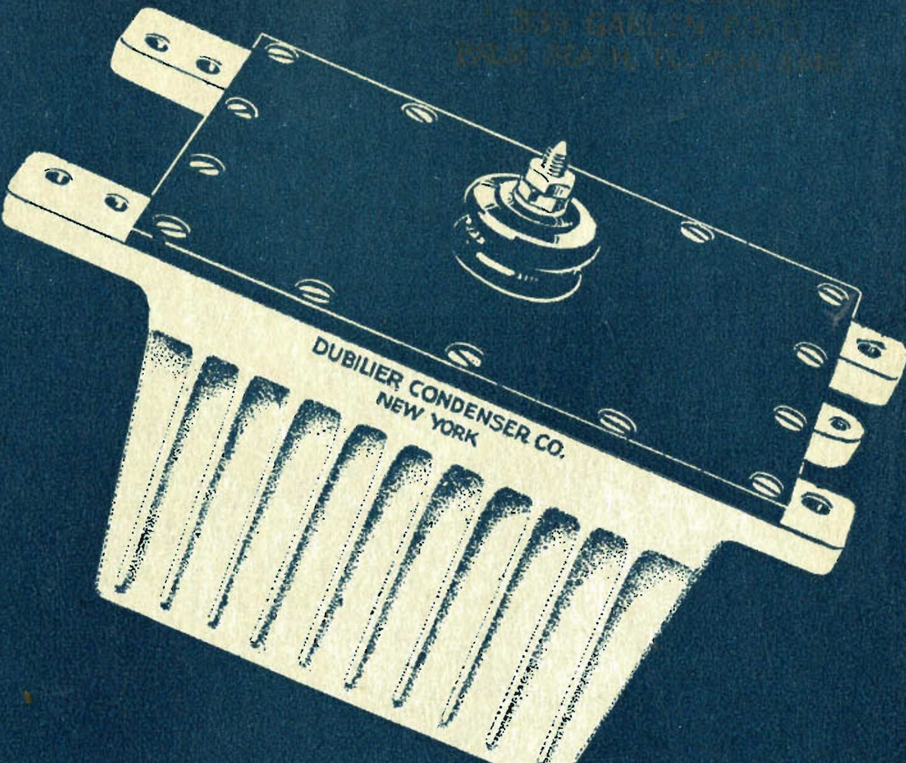

DUBILIER MICA CONDENSER

A RECORD OF THE
INVENTION, DEVELOPMENT
AND USES OF THE

DUBILIER MICA CONDENSER

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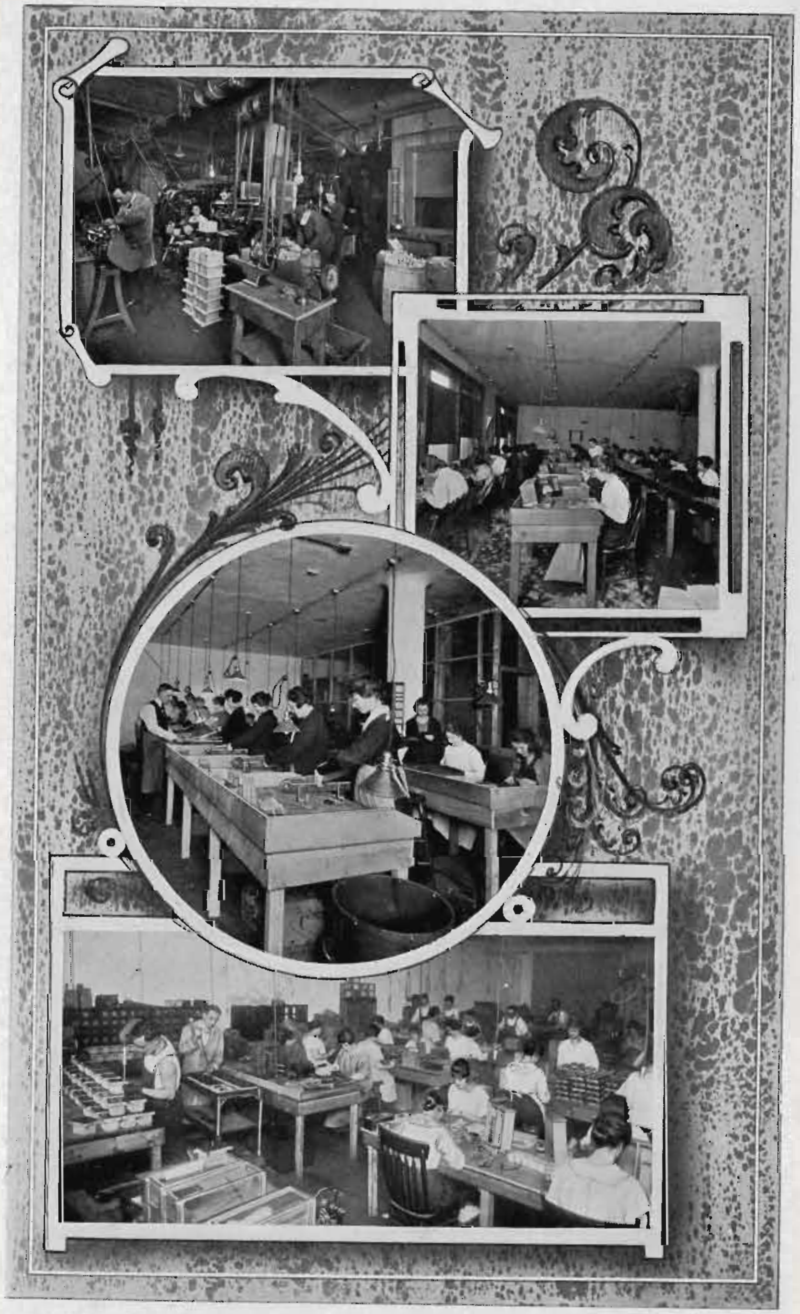


Metal Workings, Condenser Stacking, Mica Cutting and Assembling Departments

Introduction

OVER thirty years ago Hertz demonstrated that electromagnetic waves were propagated into space with the speed of light by discharges across a spark gap and in 1895 Marconi actually sent and received telegraph signals by means of these waves. Subsequently steady progress was made in the development of apparatus and their application in radiotelephony as well as in radiotelegraphy. After the outbreak of the World War the importance of radio communication was multiplied a hundredfold. In naval communication during the submarine peril and in engagements on the sea, in directing aerial flights, artillery fire and re-establishing contact between battalions after wires and cables were cut on land, the wireless "did its bit" in winning the war. Under the spur of the World War, the radio art was improved, adapted to new services and production was increased beyond expectation. This last was brought about largely by standardization. Perhaps the first single part of the radio set to be standardized and made a specialty in quantity production was the Dubilier mica condenser, which was specified in all contracts let by the government for radio sets.

One of the most necessary parts of a radio equipment is the condenser. Until Dubilier's invention was widely introduced by the United States and its Allies, the condenser was the most primitive of devices—a glass vessel which is called the Leyden jar for historical reasons and which is one of the oldest pieces of electrical apparatus.

Early History of Condensers

On October 11, 1745, Dean von Kleist of the cathedral of Camin, Germany, made an experiment, the importance of which he himself did not grasp, but which was so strange that he thought it worth while to write about it to Dr. Leberkuhn. Said von Kleist:

"When a nail or a piece of brass wire is put into a small apothecaries' vial and electrified, remarkable effects follow; but the vial must be very dry and warm. I commonly rub it over beforehand with a finger on which I put some powdered chalk. If a little mercury or a few drops of spirits of wine can be put into it the experiment succeeds the better. As soon as this vial and nail are removed from the electrifying glass, or the prime conductor to which it hath been exposed is taken away, it throws out a pencil of flame so long that with this burning machine in my hand I have taken about sixty steps in walking about my room; when it is electrified strongly I can take it into another room, and then fire spirits of wine with it. If while it is electrifying I put my finger or a piece of gold which I hold in my hand to the nail, I receive a shock which stuns my arms and shoulders."

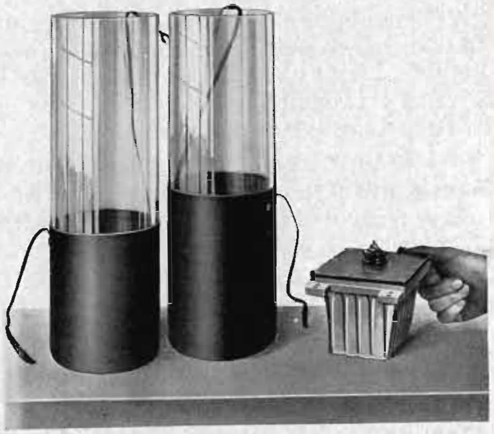
Thus was the Leyden jar invented.

In January, 1746, Peter van Musschenbroeck made the same discovery independently. Because van Musschenbroeck was a professor in the university of Leyden the apparatus came fittingly to be called a "Leyden jar."

The Leyden jar was a puzzle and a delight to polite society of the eighteenth century. Just as we talked about the X-ray and radium when they were discovered, so Paris and London in their time discussed the Leyden jar over the dinner table. But the old experimenters were unconscionable exaggerators. Gralath, one of them, maintained that the discharge gave some people the nose bleed. Even van Musschenbroeck, when he first wrote about his observations to Reaumur referred to "a new but terrible experiment," and said that his arm and body "were affected in a manner more terrible than I can express." The Abbe Nollet, in France, used to kill birds with the discharge to entertain the ladies of the court. Gralath tried to emulate him but succeeded in killing only beetles and worms. In his effort to obtain still stronger effects he hit on the plan of grouping several jars together and then succeeded in killing birds easily.

The most daring and imaginative of all these experimenters was certainly the Abbe Nollet. To amuse the French king he sent a discharge through one hundred and eighty soldiers and later through a line of Carthusian monks nine hundred feet long "by means of iron wires of proportionable length between every two, and consequently far exceeding the line of the one hundred and eighty guards. The effect was such that when the two extremities of this long line met in contact with the electrified vial, the whole company at the same instant gave a sudden spring, and all equally felt the shock." He electrified seeds, vegetables and animals, and noted the effect with painstaking accuracy and thus anticipated modern electroculture researches.

Even scientists were so entertained by such experiments that no one seemed to realize that here was an apparatus which actually stored up electric charges—still the only one of its kind, if we consider the so-called storage battery as a chemical rectifier, as we should. But as the novelty of electrically shocking unsuspecting innocents and of killing birds and insects wore off, serious study began. To Benjamin Franklin we owe the first scientific research that threw any light on the Leyden jar's strange properties. It was he who conceived the idea of connecting the outer coatings of a number of Leyden jars to produce his famous "cascade battery," in which the strength of the shock was enormously increased; and it was he who proved that the charges reside not on the surface of the glass but on the metallic coatings.



Comparative sizes of Dubilier Standard Mica Condenser and its equivalent, two Leyden jars, which it replaces with much greater efficiency and without the danger of breaking

In 1746 Dr. Bevis gave the jar its conventional modern form of a glass bottle which is coated part way up inside and outside with tinfoil and which has a metal chain suspended from its cover so as to touch the inner tinfoil coating. The only change made from that day to this is the employment of electrically deposited copper instead of tinfoil. It still remains primarily the old glass Leyden jar.

Glass is, however, fragile and therefore easily broken. The life of a glass condenser is scarcely a year. Its electrical capacity is dependent upon the thinness of the glass separating the two conductor coatings, so that for electrical reasons it cannot be made thicker and thus mechanically durable. There is the further objection that the Leyden jar cannot stand up under very high potentials.

When placed in the high tension, high frequency circuit, its hysteresis loss is large; it is electrically inefficient. The brush discharge is not only great but also objectionable because of the ozone generated, which necessitates the installation of cumbersome systems for exhausting the Leyden jar cases.

Development of the Dubilier Mica Condenser

Perhaps it was because the condenser is so very simple—merely two metal surfaces separated by a thin dielectric—that it seemed beyond further engineering development; perhaps it was the apparently insuperable difficulty of coping with the brush discharge and the heat generated by that discharge that checked the experimenter. At all events it was evident that the ideal condenser must be free from brush discharge and other losses, and therefore from heat, and that the enormous electrical strains imposed upon the widely adopted Leyden jar must be avoided. It was to the solution of this problem that William Dubilier, an American engineer, addressed himself.

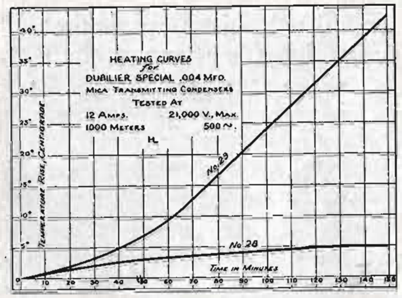
When Dubilier first began his researches, about ten years ago, his primary object was to design a radio set which would be so small, light and compact that it could readily be stowed away in an airplane. On a machine constantly shaken in flight by a powerful engine and subjected to severe shocks in landing at high speed, Leyden jars could not be used. A mica condenser suggested itself. In 1910 Dubilier made one which he tested with sufficient success to convince him that it could supplant Leyden jars for small powers. But he was still so far impressed by the brush discharges and strains to be overcome in large condensers that at first he thought it impracticable to substitute mica sheets for glass Leyden jars in large installations. In 1910, however, he did submit a mica condenser to the United States Government. After he was convinced that his conception was fundamentally sound, he took his invention to Europe.

On March 14, 1913, while in England, he was invited to testify before the British War Office Wireless Committee, which was composed of Sir Henry Norman, Capt. Louis Vaughn, Commander Silvertop, and others, and which was appointed to determine the status of radiotelegraphy. Dubilier's small mica condenser had attracted attention. In the presence of the committee he substituted his little portable condenser, made for airplane sets, for the Leyden jar condensers of a large radio set, with results that astonished everyone. It seemed incredible to these well-informed men that a little box should be able to take the place of a whole battery of Leyden jars. As a result of the demonstration, Dubilier was encouraged to begin the development and manufacture of mica condensers in England.

In 1915, Dubilier went to Europe again for the purpose of intensively studying the part that radiotelegraphy was playing in the war. As a consulting radio adviser of officials of the Allied governments he spent eight months in an exhaustive investigation which convinced him that the Leyden jar needlessly restricted the military applications of radiotelegraphy, because of its fragility and clumsiness.

However, at the request of the United States Navy Department, a number of mica condensers were made and subjected to test at the Brooklyn Navy Yard. The result was an order for condensers to form part of 5-kw Lowenstein service sets. The Dubilier Condenser Company has every reason to believe that these first sets are still in use; for all broken condensers are returned to the company in accordance with its guarantee of performance. Since then over 50,000 Dubilier Mica Condensers have been installed and are being used.

A Dubilier condenser is composed of several sections or units enclosed in a common casing of aluminum. Each of these sections



Comparative heat rises using poor Mica, and using good Mica as is selected for our Condensers

or units comprises alternating sheets of mica and foil, over a thousand in number. The sections or units thus constituted are piled on top of one another in the aluminum casing, and each section or unit is separated from the next by a sheet of mica. The sheets of mica are larger than the sheets of foil so as to avoid any brush discharge at the edges.

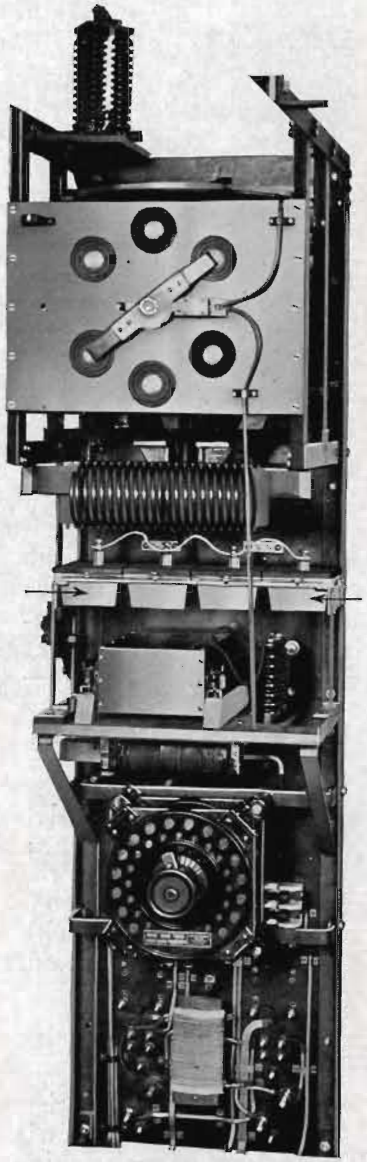
Air, moisture and small vacuum pockets must be eliminated from each section or unit. Hence an insulating adhesive of special composition, having the required dielectric properties is forced through the entire condenser. The moisture and air are expelled, and the vacuum pockets are filled with this adhesive, which is deposited in a thin layer on each of the thousands of sheets of mica. Next a melted wax compound, discovered by Dubilier after much experimenting, is poured into the aluminum casing, so as to fill any empty spaces between the condenser sections or units and the aluminum case.

Before the wax has hardened a pressure plate is placed on the topmost section or unit. After the cover is screwed on, this plate presses all the sections together. Because they are pressed together, the sections cannot move about. It is highly important that the spacing between the metal foil and the mica be kept constant—an end secured by the use of the pressure-plate. A post passes up through the cover of the aluminum case and serves as one terminal, the aluminum case serving as the other.

The efficient use of the space inside the condenser—the active surfaces taking up the larger part of this volume—is, of course, a big factor in making the Dubilier condenser a fractional part of the size of Leyden jars of an equal capacity. Yet the Dubilier condenser has 2,000 square inches of active surface as compared with 175 square inches for a Leyden jar of equivalent capacity and voltage.

Since it consists of over a thousand sheets of mica and foil, the full voltage across the transformer is minutely subdivided. Hence the potential that does act across a single unit is so very small that there is no destructive brush discharge. The losses in the dielectric increase greatly with the voltage. Hence if the voltage of each section in the condenser is reduced markedly the problem of preventing the brush discharge is met. It is better to control seven hundred volts in this manner than twenty thousand volts individually.

No electrical instrument has been subjected to severer tests during the past three years than the Dubilier Condenser—the dampness and moisture of the trenches, the salt air and rough usage on the seas, and the dry and freezing conditions above the clouds on airplanes. They have gone through all these tests in perfect working order, ready for years of further service.



Arrows indicate set of Dubilier Mica Condensers installed in Bureau of Standards 2 kw Radio Equipment

These mica condensers are suitable for Radio Installations; Medical Apparatus; Ignition Systems; Artificial Lines; Submarine Cables; Transmission, Telephone and Telegraph Line Protection; Motor, Generator and Instrument Protection; Power Plant Phase Shifting; Laboratories; Colleges and Other Purposes. Dubilier Mica Condensers are patented in almost every civilized country in the world. U. S. Patent Nos. 1,229,914 (1917); 1,229,-915 (1917) and 1,281,309 (1918). Many other patents pending.

The advantages of the Dubilier Mica Condenser may thus be summarized:

1. Its life with ordinary care is almost indefinite.
2. Its efficiency is astonishingly great, being ordinarily over 99%.
3. It saves from 75 to 90% of condenser space.
4. It is self-healing.
5. It reduces brush discharge to a negligible quantity.
6. It avoids the generation of ozone.
7. It is simple and thereby reduces the cost of the equipment of which it is a part.

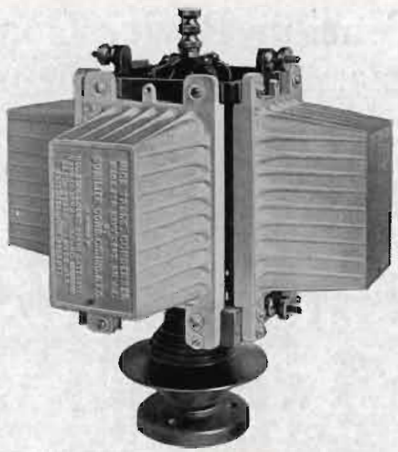
High Tension Power Condensers

DESIGNED FOR RADIO EQUIPMENTS

This illustration represents a standard type of condenser now used in practically every government wireless installation for producing high frequency oscillations. Each condenser is built up of more than a thousand units of foil and carefully selected mica films. The sheets are tested by specially devised methods to insure freedom from pin holes, air bubbles, moisture and other defects. After assembling in aluminum casing, the remaining air and moisture are exhausted and a special wax compound forced in, hermetically sealing the condenser. The result is a compact, rugged condenser that can be overloaded 100% without danger and which, when operating in a standard radio set at 500 cycles and 12,500 volts effective has an efficiency of over 99%.

The ruggedness of the condenser makes it suitable for use in the open air and other dangerous places as well as on portable outfits for laboratories and for field work. Its design is such as to make it easy to handle and to install in inaccessible places, where it can be fastened down securely.

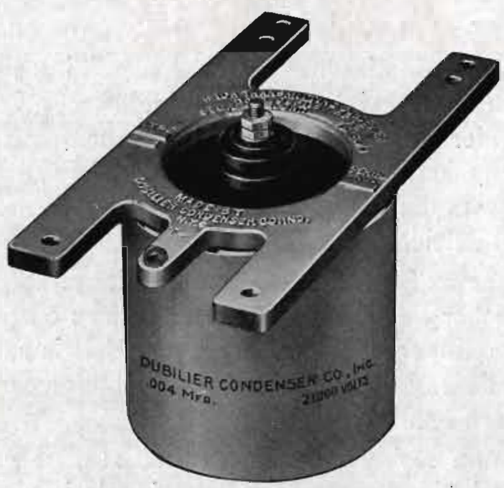
The aluminum casing forms one terminal of the condenser and the second terminal projects through an insulating knob at the top and in the center of the bakelite dilecto cover.



Four Units Mounted on a Single Insulated Base

The condensers illustrated on these and the following pages are made in standard capacities with a safety factor of 100%.

Provided the voltage applied across these terminals is not allowed to exceed the safety value with damped oscillations, the condensers will last almost indefinitely.



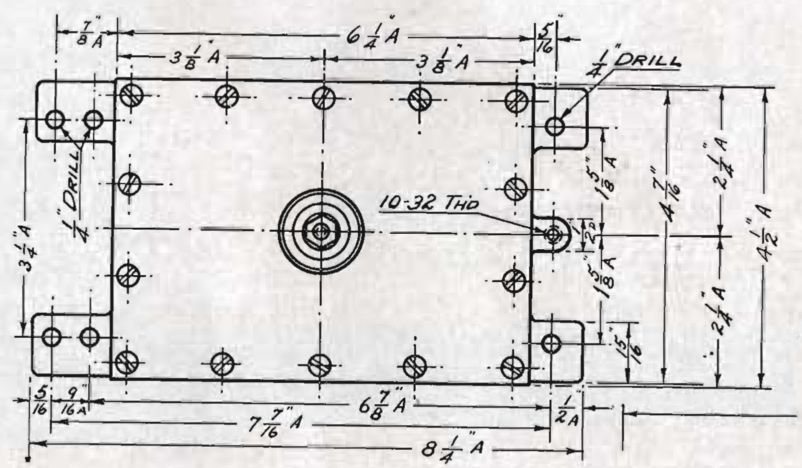
Standard Condenser Mounted in a Cylindrical Container

The flat form of types 192 allow them to fit into shallow places

Types	Volts (max.)	Cap. (mfd.)	Watts	Price
AM 158	18,000	.004	500	$22.00
CD 158 (Navy Standard)	21,000	.004	500	35.00
AM 192	15,000	.002	250	12.00
CD 192 (Navy Standard)	21,000	.002	250	20.00
AM 201	15,000	.001	125	7.00
AM 200	21,000	.001	125	11.00

Unless otherwise ordered, the standard mounting will be supplied.

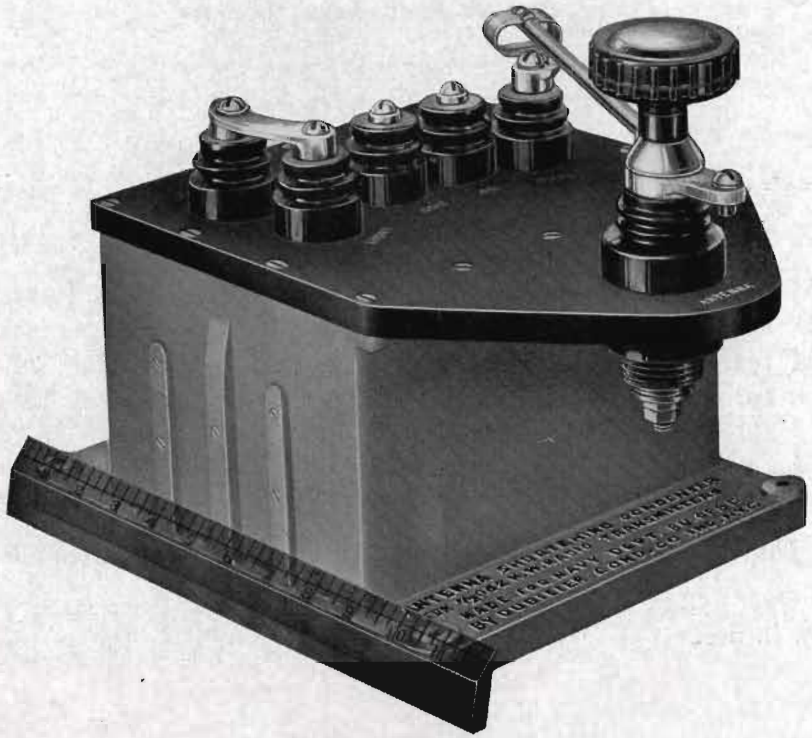
Over 25,000 of the above types of Transmitting Condensers are now in use.



Dimensions between Standard Mounting Lugs, Types CD-158 and AM-158

Antenna Shortening Condensers

SUITABLE ALSO FOR USE AS
ARTIFICIAL ANTENNAS



Type CD 1448 Condenser

Considerable difficulty had been experienced in generating short wavelengths with high powers from large antennas. The aerials of almost every ship installation, and especially of the land stations, have a natural wavelength about three hundred meters. In order to transmit at this wave length, antenna shortening condensers must be employed. Ordinarily Leyden jars are not suitable unless a number of them are placed in series and even then the losses in the jars due to the high potential directly across them make the set very inefficient.

The potential across the terminals of the Dubilier Antenna Shortening Condenser, however, is minutely subdivided, so that

brush discharge losses are reduced to an exceptionally low value. In comparative unofficial tests made by the Navy Department two standard Leyden jars connected in series in a radiating circuit showed a current of 8½ amperes; but a single Dubilier Antenna Shortening Condenser of the same capacity produced 15.4 amperes in the aerial, all the other conditions being the same.

The illustration on the opposite page shows type CD-1448 Antenna Shortening Condenser suited for quenched spark installations up to 2 kw. It can withstand 40,000 volts effective across. Its capacity is adjustable in three steps; namely, .0008, .0012, and .001 mfds. Price, $120.00. Other capacities can be supplied.

Antenna Shortening Condenser of smaller capacity for small equipments, maximum amperes 8, maximum voltage 30,000, capacity .0006 and .0008, $45.00. Without insulated base, $35.00

Standard and Laboratory Condensers

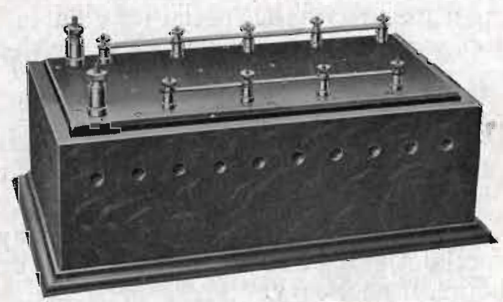
Here we have a form of condenser which is useful in laboratories and schools and wherever an adjustable capacity is required. The particular one shown has a capacity of ten mfds. and can be varied from 1–100 mfd. to the full value; though any capacity with any adjustment can be supplied. The mounting is a mahogany or oak case with bakelite dilecto top. The condenser shown is rated for pressures up to 1,000 volts. Price, $350.00.

Similar condensers are made with many units mounted each with separate posts, as shown on page 15, so that connections between the units can be made both in series and in parallel, thus allowing a greater variation in capacity and voltage to be applied.

These standard condensers are also built in circular metal or wooden cases and are hermetically sealed. Their capacities range from .0002 to 10 mfds., their accuracy recommending their use as standards and for checking purposes.

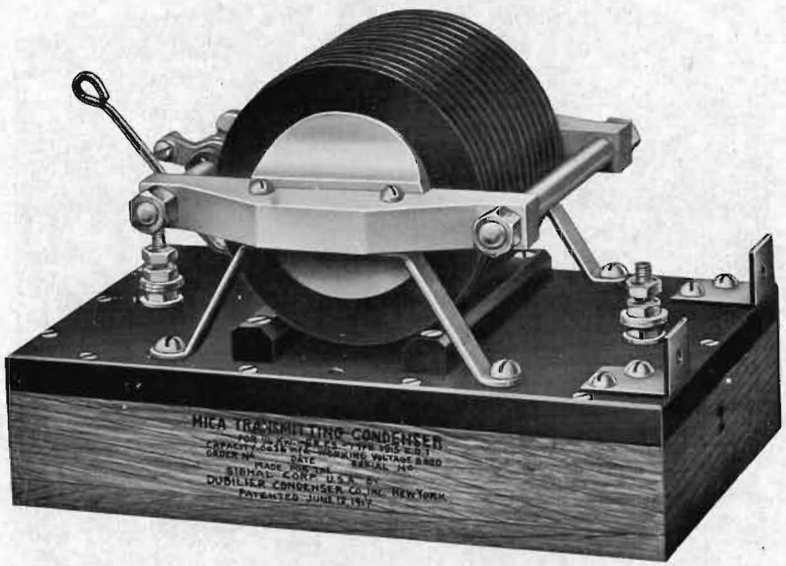
Capacity is guaranteed to remain constant within ½ of 1%. Each condenser will have a Bureau of Steam Engineering's certificate of value, if required. Prices upon application.

The Phantom Antenna System shown above was especially designed for the U. S. Signal Corps and consists of a condenser of .00035 mfd. for 40,000 volts with a 10 ohm resistance unit mounted in a wooden box. It is useful for making double voltage tests in radio laboratories. Any capacity can be supplied from .0002 to .001 mfd.; voltage up to 100,000.



Laboratory Type of Mica Condenser. Consists of many units that can be connected in series or parallel for various capacities and for voltages up to 50,000

Special Types of Transmitting Condensers



Wherever metal containers are not suitable the condensers can be mounted in wooden or other insulating boxes, or the metal case can be insulated from the condenser itself and the condenser terminals mounted independently on two insulated posts. In many cases where space is the prime consideration, it is advisable and convenient to make the condenser in this way so that spark gaps, transformers or other parts can be mounted on the condenser, thereby forming a single compact unit.

The condenser above illustrated was designed with this object in view and was used in large numbers by the United States Signal Corps and the Navy Department in their standard pack sets. The condensers, with the special terminal mountings on a bakelite dilecto top, were supplied by us ready for the quenched spark gap units to be mounted directly upon them.

This type and method of construction is both useful and economical in the designing of compact equipments such as high power portable transmitting and testing outfits, field receiving sets, wavemeters and similar devices.

The Dubilier Condenser Company is prepared to construct special types of condensers for any capacities within twenty-four hours, if necessary.

Protection Devices

For Power, Telephone, Telegraph and Cable Plants and Lines

and

For Motors, Generators and Instruments in or near Radio and Other High Frequency and High Tension Systems

SURGES

Surges and Resonance Effects in Plants and Lines are dangerous unless the proper provision is made to prevent the potentials from rising above certain definite limits. The study of the whole subject from the standpoint of prevention of damage to apparatus and lines, though complicated in part by a mass of formulas and other scientific claims to our notice, can be boiled down to a few fairly simple problems, the solutions of which can be made easy to apply and extremely practical for the protection of overhead and underground A. C. and D. C. systems.

High tensions which develop in a system may be caused by the following:

External Conditions

(1) Direct Strokes of Lightning.

(2) Induced Potentials from Lightning.

(3) Proximity to Radio or Other High Frequency Systems.

(4) Atmospheric Charges.

Internal Conditions

(1) Operating of Circuit Breakers, Switches, Fuses, etc.

(2) Harmonic Alternator EMF's in Resonance.

(3) Low Proportioned Capacity of Alternators.

Overhead Line Protection

Direct Strokes of Lightning

At the outset we will state we cannot completely guard against the effects of direct lightning strokes on overhead lines because no such protection exists. Fortunately, the effects of such strokes are almost always only local, insulators are shattered and poles, if wooden, are knocked down. Obviously, to place a spark gap (Horn Arrester) from the line to the ground is a dangerous practice in power systems since during such times as the spark is passing, we will produce a circuit which will immediately be brought into resonance by the power house generators, which action itself will give rise to dangerous surge tensions.

It is evident, therefore, that we cannot use a Horn Arrester without resistance. On the other hand if we use resistance enough to preclude resonance oscillations, that resistance would have to satisfy the well-known formula of Thomson:

$$R > 2\sqrt{\frac{L}{C}},$$

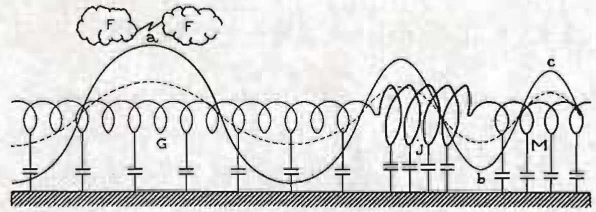
where L and C are the inductance and capacity per unit length, respectively.

The radical has the nearly constant value for all transmission lines of 600 ohms, so that R would have to be, at the very least, 1,200 ohms. Obviously with a resistance as large as this, the Horn Arrester arrangement would be of little or no protection against direct lightning.

That part of a direct lightning discharge, however, which would travel for any distance along the transmission line can be dissipated into the earth in the manner employed for the Induced Potentials from Lightning, described below.

Induced Potentials from Lightning

It is not enough to prevent surges *above* the rated voltage from entering into a plant. Lightning discharges several miles away are known to induce potentials in a transmission line insulated for 3,000 to 5,000 volts, which though not high enough to break down the line insulators, would burn out the transformers or generators in the plant. Before considering the nature of the proper protective appliance, let us investigate the cause for this phenomenon, which strange as it is, so often happens.



The diagram represents the electrical configuration of a line G, a choke coil J, the winding of either a transformer or a machine M. Each portion has inductance and capacity uniformly distributed, although their constants per unit length vary. F and F represent two clouds between which an electric discharge is taking place. It is evident that the clouds simulate a two-plate Hertz oscillator, but on a huge scale, and they therefore send out high frequency waves, whose periods are in the order of some hundreds of thousands of cycles per second. The transmission line is nothing more than an insulated wireless antenna, so that the line receives these waves just as a radio antenna would. As it is further true in a radio antenna, the received lightning waves seldom, if ever, induce potentials great enough to disrupt the insulators, so in the transmission line they seldom rise above several thousands of volts and, accordingly, do no damage here.

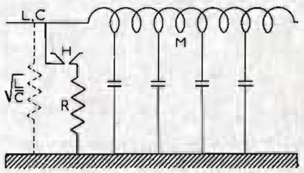
However, the waves are propagated along the line with the speed of light, their potentials being greatest at "a" where they enter the line and where they start with a wavelength equal to that radiated from the lightning discharge and so continue until they reach the choke coil J. Here a wave passes through the concentrated inductance but its length is abruptly shortened. It arrives at the machine M with its wavelength further modified and continues to the end of the winding, from which it is reflected backward as shown by the broken line. The wave travels as shown to the other end of the transmission line and is then reflected backward and forward until all its energy is consumed by the ohmic resistance of the circuit.

Between "b" and "c", respectively the points of maximum negative and maximum positive potential, the greatest potential difference exists. With high frequencies of several hundred thousand to a million cycles, such as lightning discharges have, it is quite possible for this whole potential difference to be concentrated between the first few wires in the transformer or electric machine. Since the enamel and cotton insulation between these even in high voltage apparatus could hardly be made to withstand a thousand volts or more pressure, the transformer or machine is simply burnt out.

We thus come to the important conclusion that if the proper protection is not afforded, *High Frequency Line Surges even of a few thousand volts are able to burn out a 50,000 or more volt Transformer or Alternator.*

Effect of the Horn Arrester

In the annexed diagram we have a transmission line and the winding of the alternator protected by a spark gap having the regular horn-shaped electrodes. The necessity for having a resistance in series with the gap has already been dwelt upon. The resistance must be at least large enough to allow only a non-oscillatory current to flow after the breaking of a spark. The value of such a resistance as we have seen must be at least 1200 ohms. In practice, however, it would not be safe to employ less than a 2,000 ohm resistance, R in the above diagram.



The maximum theoretical surge E_s if there were no resistance whatever in the Arrester across the line has the value of

$$E_s = I_s \sqrt{\frac{L}{C}},$$

I_s being the short-circuit current and the radical as before.

The maximum surge potential E_s' which could be obtained in the above illustrated system when a spark which is discharging across the Horn Arrester is broken, as found by Ivan Dory, equals

$$E_s' = I_s \frac{R \times \sqrt{\frac{L}{C}}}{R + \sqrt{\frac{L}{C}}}$$

Comparing the two surge potentials

$$\frac{E_s'}{E_s} = \frac{R}{R + \sqrt{\frac{L}{C}}}$$

Substituting the value of these constants,

$$\frac{E_s'}{E_s} = \frac{2{,}000}{2{,}000 + 600} = 77\%$$

and hence, the reduction in potential rise which can be brought about by the Horn Arrester is 23%. If we should substitute a resistance

R of 5,000 or 10,000 ohms instead of that of 2,000 we will find that the reduction is still less, being 10% in the one case and 6% in the other.

From the foregoing it is to be concluded that it is inadmissable to use a spark gap and resistance for protection from induced lightning effects, since to employ the amount of resistance necessary to prevent dangerous resonance surges from the Horn Arrester itself, allows only a small and insufficient reduction in the theoretical surge resulting from the breaking of a dead short circuit. Especially is this true of large capacity power stations where I_s is very appreciable.

Another very serious drawback of the Horn Arrester that we ought to keep in mind is its inability to prevent induced currents of high frequency, but of a voltage less than that for which the Arrester is set, from burning out the plant machines and measuring instruments. A high tension power system is likely to be the bigger sufferer from this condition.

Protection by Condensers

The effect of employing different sizes of an Inductance L_1, a Condenser C_D, and a resistance R_1, in place of the Horn Arrester and resistance, is shown in the following table. Here the reduction ratio with respect to the maximum surge tension produced by the abrupt opening of a short circuit is again determined by calculations somewhat different from those preceding, but ones which are often used in telephone and telegraph work. The value of the capacity C_D need be only slightly greater than that corresponding to one-half a wavelength of the line which it protects, and for these computations a standard Dubilier Battery was assumed.

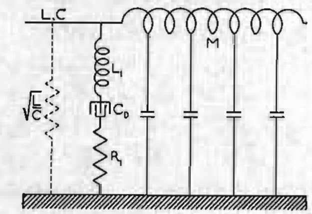


Table Showing Reduction Ratio of Surge Tensions where Condensers are used

R (ohms)	L (henries)	FREQUENCY 10,000	250,000	500,000	1,000,000
0	0	0.067	0.027	0.013	0.007
5	2×10^{-6}	0.065	0.024	0.009	0.016
5	2×10^{-5}	0.041	0.028	0.092	0.205
50	2×10^{-5}	0.093	0.087	0.128	0.225

It is now seen that instead of reductions of only 23%, those of 77% in the poorest case and of 99% in the best are obtained. But by the simple expedient of minimizing the resistance of the ground connection and of bringing the wires from a transmission line through the Condensers in as short and straight a line as possible, it is possible in practically every case to obtain a reduction of over 90% by means of the Condenser Batteries.

Since the current taken by the condensers is wattless, and the hysteresis and leakage losses in Dubilier Mica Condensers are extremely low, it is evident that they afford an efficient means of protection.

Proximity of Radio and Other High Frequency Systems

It makes no essential difference, of course, whether a high frequency current is induced by lightning or by the nearness of radio or similar systems, the phenomena are exactly the same. Practically, while the potential induced in this case is likely to be less than before, the fact that the frequencies are higher makes the possibility of these tensions being applied across the first two or three windings of the apparatus at the end of the line even more certain. Especially if any air is left in the insulation between these windings, only a few hundred volts would gradually oxidize this insulation and ultimately cause the rupture. Protection against high frequency currents such as these is again obtained with Dubilier Condenser Batteries, and are generally required for underground cable systems as well as those overhead.

Atmospheric Charges

Charges which develop from changing electrical conditions in the atmosphere, such as are caused by the passing of charged clouds, by rain and hail, and by electric storms, are by their very nature alternating in intensity. They, therefore, can largely be included among the causes of producing high frequency currents, even though the currents are erratic; and the protection against them is again a properly designed battery of condensers.

Overhead and Underground Systems

Operating of Fuses, Circuit Breakers, Switches, etc.

The problem caused by the opening of switches and the operating of similar protective apparatus reduces itself to much the same difficulty produced by the breaking of the spark discharge when lightning strikes a line fitted out with an Horn Arrester. When

protection is not afforded, a surge current I_s is developed from the short circuit and this creates a maximum rise in the potential of

$$E_s = I_s \sqrt{\frac{L}{C}}$$

A well designed condenser battery will prevent the maximum rise in potential being effected by dissipating the surge potentials as they arise.

It has previously been intimated that transmission line surges which do not give rise to potentials high enough to burn out the transformer in a power station are nevertheless often sufficiently large to rupture the weaker insulation in the alternator. This danger manifests itself also during the normal operation of a high tension power system, in radio, medical and similar installations. All that is required to adequately protect the generator from such "kick-back" surges are two low capacity condensers shunted across the machine with the center point between them grounded. This device is described more fully on pages 25 to 30.

Harmonic Alternator EMF's in Resonance

The alternator harmonics which are known to most often cause trouble by their resonance effects are those whose frequencies are 3, 5 and 7 times the fundamental. At the points the inductance and capacity of the alternator enter into resonance with the inductance and capacity of the line, very high tensions have been produced. Obviously, the first means of preventing this from occurring is to use only such generators whose no-load EMF curve as described by an Oscillograph turns out to be practically a sine curve. Where temporary resonance takes place notwithstanding, a liberally designed condenser set will be found effective.

Low Capacity of Alternators

Resonance of the fundamental frequency will be brought about when the size of an alternator is too low in proportion to the length and electrical constants of the line which it feeds. In general no difficulty is experienced with overhead transmission lines, but for underground cables where the capacity per unit length is considerably greater, trouble may ensue. If K is the output of the generator which feeds a cable of length G at a line potential of E between wires, then the proportion should be

$$K > \left(\frac{E}{400}\right)^2 G$$

where K is in KVA, G is in kilometers and E is in volts.

However, the greater danger in underground cables especially lies in their bringing the frequencies higher than the fundamental into resonance, thus making the installation of protective condensers a direct necessity.

Recapitulation

Our remarks may be summarized as follows:

(a) A. C. Power Plants having Overhead Lines and using Transformers are subject to all the dangers we have mentioned;

(b) A. C. Power Plants using Transformers but with Underground Distribution Systems are subject to disturbances from Inherent Conditions largely;

(c) D. C. Power Plants having Overhead Lines are subject to all the dangers mentioned excepting, of course, those resulting from generator harmonics in resonance;

(d) D. C. Power Plants with Underground Distribution are subject to disturbances from Inherent Conditions excepting those from generator harmonics being in resonance;

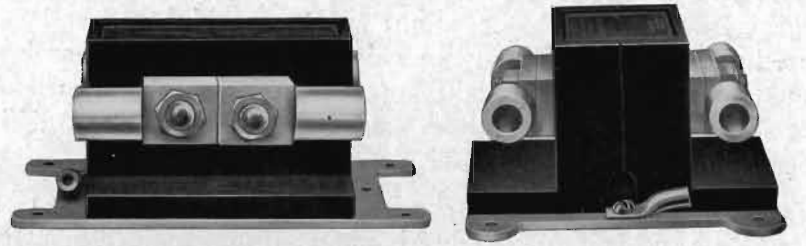
(e) Telephone and Telegraph Systems may or may not be subject to dangers from Internal Conditions, although those with Overhead Lines are all decidedly affected by the External Effects enumerated;

(f) Protection from "kick-backs" from secondary circuits in any system is afforded by a two-condenser arrangement of low capacity in which the condensers have their common terminal grounded.

Condensers are effective for protection from all the above causes and Dubilier Mica Condensers, being extremely efficient, durable and simple in construction, are peculiarly suited for the work.

We are ready to build on short notice any special capacities, for any voltage, in any container to meet your particular needs.

Protective Devices Suitable for Instruments, Motors, Generators, etc.



Type CD872 Standard Protective Device, for Installations up to 10kw

In practically all of our protective devices installed across instruments, motors, generators, etc., bus-bars and lugs form part of our device, as shown in the above illustration. This patented feature makes it impossible for any of the appliances to be left unprotected. If the condenser becomes defective—which rarely occurs—and is removed, a new device must be installed; whereas if the protective device were merely connected across the terminals without our lugs, there is the possibility of the appliance being injured. When a mica sheet burns out it ceases to be a dielectric and becomes a conductor. A hole is left, and there is nothing to fill it. The spark jumps through the hole. Wax cannot be relied on to seal the hole; for but an imperceptible amount of wax can be utilized to fill the space between the metal surface, if an efficient condenser is to be produced. Finally, Dubilier devised a condenser of such construction that, after a breakdown, there will always be a space between the mica and the metal foil. The condenser is truly self-healing, and there is rarely a short circuit. It is no longer necessary to run the risk formerly incurred when a burnt-out paper condenser was left in a line for lack of time to replace it. The adoption of the Dubilier condenser as a protector of generators effected an enormous saving on shipboard and prevented the burning of many machines. In practice it has been found that condensers will heal themselves over a dozen times before becoming useless. This is another feature covered by the Dubilier patents.

Type 872 consists of two condensers in series, each .05 mfd., tested for 3,500 volts A. C., and is mounted in a molded insulated container with a metal base. The lugs and bus-bars are suitable up to 150 amperes, and it is usually connected across lines with voltages up to 500. Many thousands of these now form part of Standard Navy Radio Equipments.

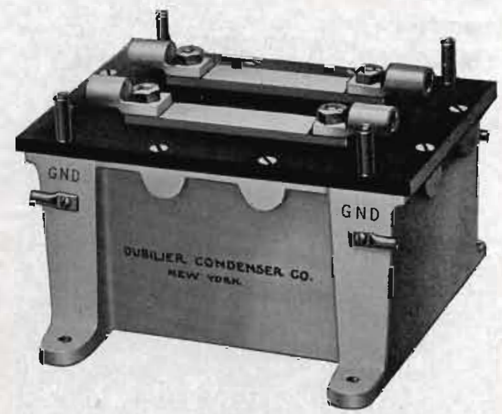
Type CD-872, tested voltage 3,500.......................... $8.50
Type AM-872, tested voltage 2,500.......................... 7.00

The photograph herewith shows our larger type CD-53 Protective Device where a current greater than 150 amperes is carried in the lines and is known as type CD-588, designed especially for undamped oscillation radio equipments, but suitable for connecting across generators up to 10 kw. The individual condensers have a capacity of 0.05 mfds. and both are tested at the pressures of 3,500 volts. Price, $12.00.

Type CD-53 made into type CD-588 condenser

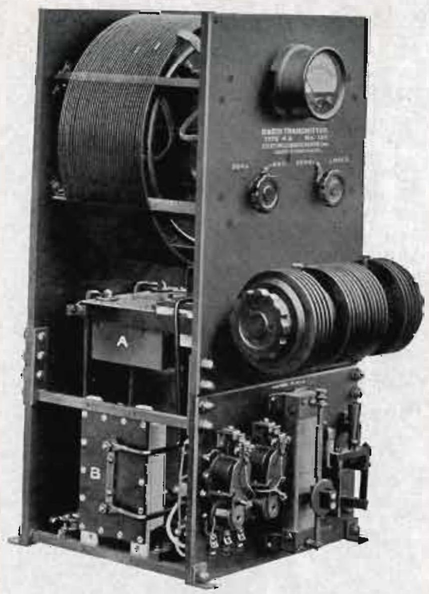
Protective Device for Arc Transmitters and Other Undamped, High Frequency Generators

For purposes of protecting generators from surges of high potential from the secondary circuits of large arc and other undamped wave generators the Protective Device above is especially well suited. Its two condensers have a capacity of .1 mfd., each, and are tested at 5,000 volts A. C.



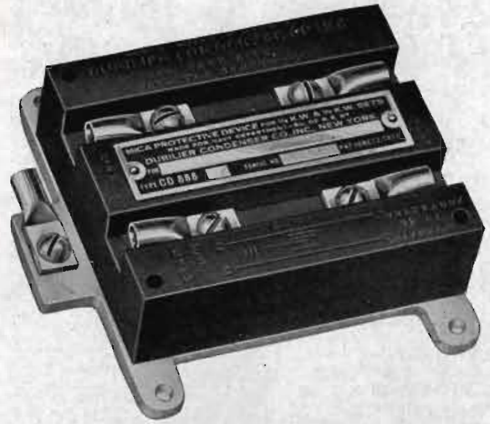
Type CD-130 Protective Device for Arc Generators

An insulating cover can be mounted on the four posts shown, if desired. Price, type CD-130, $50.00.



Type CD-130, as shown in the annexed illustration, is also suitable for radio telegraph installations of the impact type. This equipment was manufactured by Cutting and Washington. Large capacities and comparatively low potentials are used.

A shows the Dubilier tone circuit condenser and B the oscillation circuit condensers.



Standard Protective Device

The protection of instruments and small motors and generators up to 1 kw. can be accomplished by the device shown in the above illustration. Bus-bars and lugs are standard 25 ampere type and are so molded in the insulated container as to be slightly below the surface, affording protection from pieces of metal.

A wiring diagram showing methods of connection is impressed in the container.

The capacity of each unit is .02 mfds.

Type CD-888, tested voltage 3,000, price $6.00.

Type AM-888, tested voltage 2,000, price $4.00.

Condensers Suitable for Radio Telephone Bulb Generators and Small Spark Coil Sets

The photograph above, on the left, shows a Dubilier condenser designed for protection purposes on the Standard Radio Telephone Airplane Sets. It is adaptable to all undamped bulb sets for protecting the D. C. generators and eliminating the hum. Capacity .25 mfd., tested voltage 1800 D. C., price $5.00.

The photograph on the right illustrates a bulb generating condenser, also suitable for spark coil or vibrator sets. Any capacity up to .004, volts 8,000, price $5.00.

Special Condensers

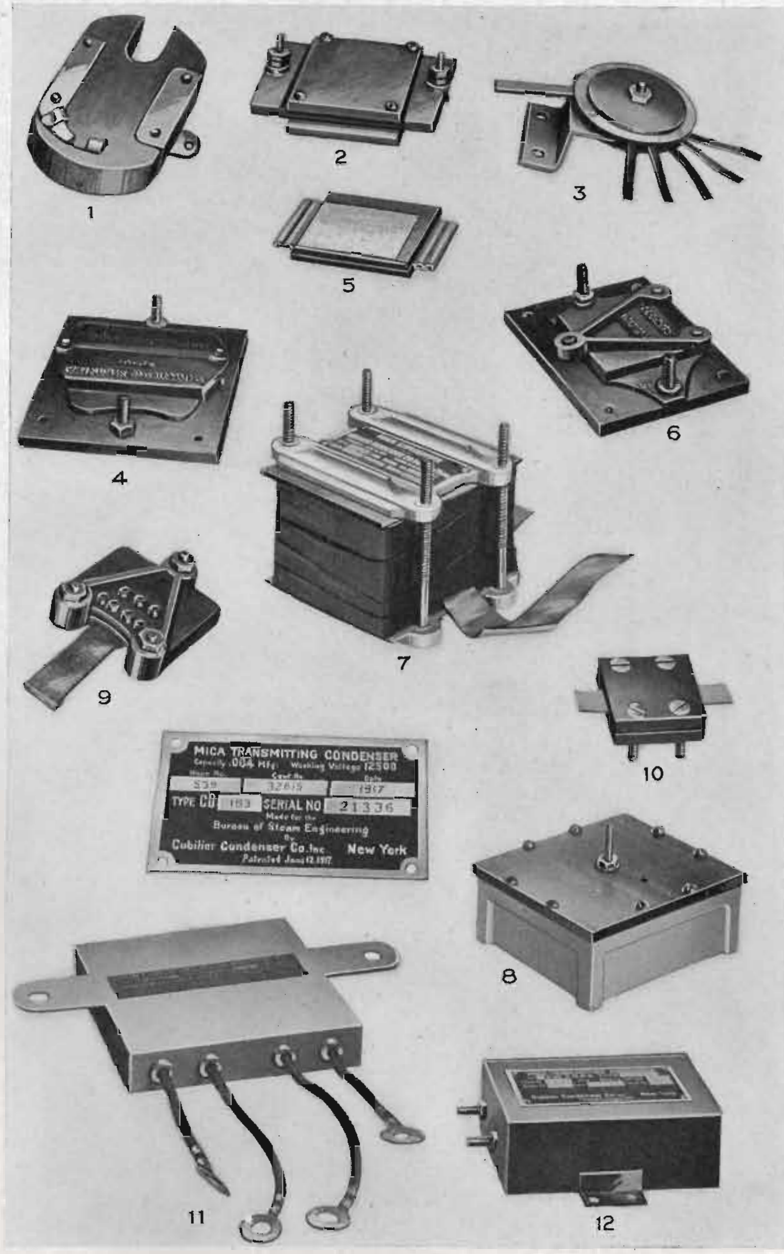
We have in stock mica varying in size up to 6 by 8 inches, from which condensers will be made upon order in any size and shape, as well as in any capacity.

Such special condensers will be made up within 24 hours time, if necessary.

On the following page are some of the special condensers we have supplied. They represent according to their numbers:

1. Magneto type.
2. Standard made in capacities from .0001 up to .5 mfd.
3. Winged type with five taps suitable for receiving sets.
4. and 6. Small condenser made up to .2 mfd. capacity with insulated base.
5. Small grid condenser for bulb sets.
7. Airplane type of transmitting condensers.
8. Airplane high tension transmitting condenser, small space and light weight.
9. and 10. Small standard for constant capacity.
11. Double protective device.
12. Hermetically sealed type in metal container.

When ordering please mention number.



Some Representative Users of Dubilier Condensers

United States Navy.
United States Army.
British Government.
French Government.
Russian Government.
Spanish Government.
Japanese Government.
Marconi Wireless Telegraph Co. of America.
General Electric Co.
The Westinghouse Electric & Mfg. Co.
Lowenstein Radio Co., Inc.
Liberty Electric Co.
Kilbourne & Clark Mfg. Co.
International Radio Telegraph Co.
Federal Telegraph Co.
Cutting & Washington, Inc.
Crocker-Wheeler Co.
American Radio & Research Corp.
Manhattan Electrical Supply Co.
National Electrical Supply Co.
Western Electric Co.
Wireless Improvment Co.
Wireless Specialty Apparatus Co.
Sperry Gyroscope Co.
E. J. Simon Co.
Radio Materials Corp.
Compagnie Generale de Radiotelegraphie.
Compagnie Universellie de Telegraphie.
Societe Francoise Radio Electrique.
Thompson Houston Co., London.
Rouzet, France.
University of California.
University of Nebraska.
Oregon Agricultural College.
Tulane University.
West Virginia University.
University of Wisconsin.
Ohio State University.
College of the City of New York.
Purdue University.
Texas A. & M. College.
University of Vermont.
Cornell University, Sibley College.
Harvard University.
Columbia University.