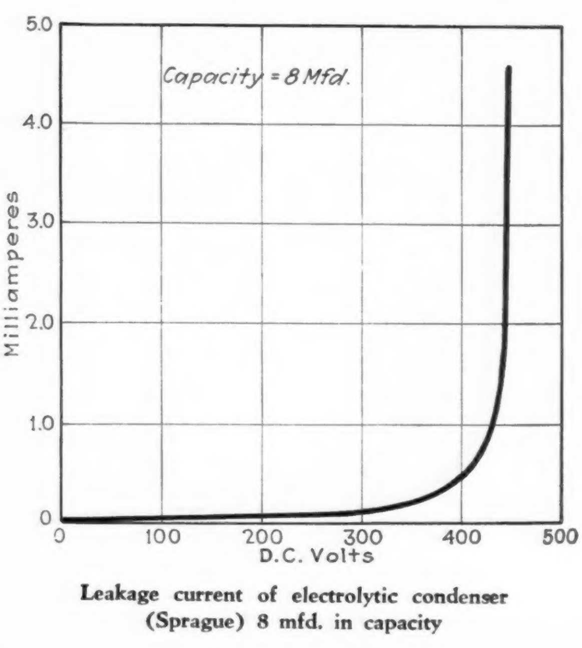
Electrolytic condensers for radio use

By F. W. GODSEY, JR.

THE aluminum electrolytic condenser dates back to 1853 when the peculiar behavior of an aluminum anode in an electrolytic cell was observed and commented upon by Wheatstone. Aluminum readily oxidizes when a freshly cut surface is exposed to the air, the property that keeps utensils made of aluminum clean and bright. The oxide formed adheres to the metal surface in a thin, transparent layer that is extremely tough and durable; and it is the durability and thinness of these films that make electrolytic condensers available for commercial use.

When a strip of aluminum is immersed in a suitable electrolyte and current is passed from the aluminum to the electrolyte, it is found that increasingly higher voltages are necessary to force the current through to the electrolyte as the quantity of current that has passed, or the coulombs passed, increases. This increase of resistance is such that an 8 mfd. unit with a total exposed area of 70 to 75 sq. inches of anode will increase

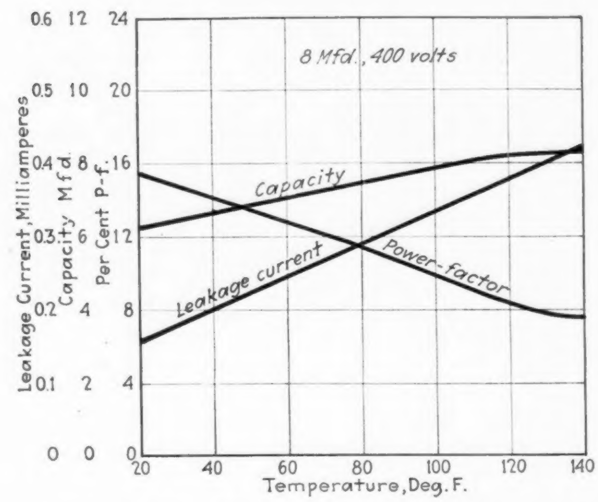


Leakage current of electrolytic condenser (Sprague) 8 mfd. in capacity

in resistance from a few ohms to a high enough value that less than one milliampere will flow when 400 volts are applied to the anode.

The increase in electrical resistance can be ascribed to the formation on the surface of the aluminum of a very thin film of aluminum oxide, mentioned above. The thickness of this film depends upon the quantity of current passed and the voltage applied, and is almost independent of the electrolyte except that some electrolytes will allow a thicker film to be formed ultimately than others, and hence the application of a higher voltage. The effective thickness of the film is almost exactly proportional to the voltage applied after the film has grown to its normal thickness for that voltage.

When a film has once been formed to a given voltage, it does not readily dissolve and the voltage may be lowered for some time before the thickness decreases to the new equilibrium value. The limiting voltage to which a film may be formed on an aluminum anode is controlled by the purity of the aluminum, the electrolyte used, and

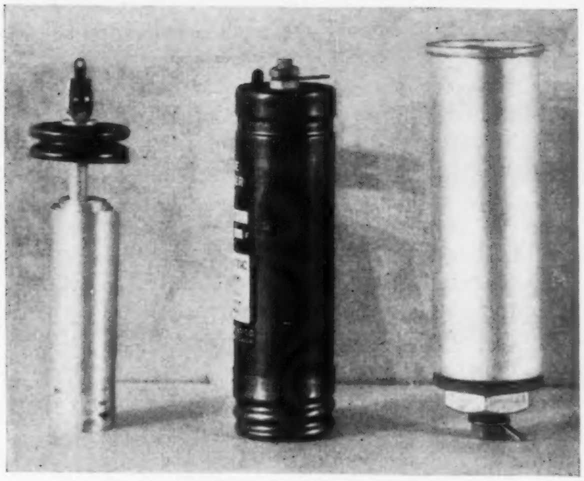


Power factor, leakage current and capacity as a function of temperature

the temperature of the electrolyte. Usual values are between 50 and 450 volts for most electrolytes; but in some electrolytes the dissolution of the film forming material is so rapid that it can be said that there is really no film formation.

The thickness of the film formed on the aluminum anode is found to vary from 5×10^{-6} to 5×10^{-4} cm. With such extremely thin films separating the aluminum and the electrolyte, there is a very high electrostatic capacity between the metal and the electrolyte with the oxide film acting as the dielectric. Since the thickness of the film is proportional to the formation voltage, the capacity is inversely proportional to the voltage of formation. As an example, if a condenser formed to 200 volts were reformed to 400 volts, the capacity will have been halved. Likewise, if a 400 volt condenser were operated on 200 volts, the film would gradually dissolve until the capacity were doubled. This transition from the high voltage of formation to a lower voltage is usually measured in days and weeks, while the reforming from a lower voltage to a higher may require minutes.

The capacity of a film formed to 400 volts is about 0.125 mfd. per square inch. The usual practice is to allow from 10 to 20 per cent excess capacity above the rated capacity so that about 75 square inches are required



Typical condensers showing anode construction, upright and inverted mounting

for a unit formed to 450 volts and rated at 8 mfd. for which a strip of aluminum $2\frac{1}{2}$ in. wide by 15 in. long securely fastened to an aluminum stem or riser is wound spirally about the stem until the entire assembly fits into a $1\frac{3}{4}$ in. diameter can. Sometimes a perforated spacer of celluloid sheet is placed around the anode to safeguard against contact with the container walls.

Usually, an aluminum condenser consists of an anode of aluminum, a suitable electrolyte, and means for obtaining electrical contact to the electrolyte, generally by the use of a metal container. In most commercial condensers the electrolyte is a saturated solution of borax and boric acid in water. The container is a metal can, and can be made either of copper or of aluminum. Present practice favors the aluminum container whenever constructional difficulties do not prevent. The anode is a spirally rolled sheet of aluminum; and for the standard 8 mfd. radio filter condenser rated at 430 volts, has an exposed area of 75 square inches.

Complete units are sealed to prevent leakage of electrolyte, and the escape of gas is allowed through a soft rubber valve. This valve consists of a suitably shaped rubber nipple pierced by a pin hole. When a slight pressure is exerted on the rubber, the pin hole opens and the gas escapes.

Electrical characteristics

The life of a condenser is limited by its construction and the service in which it is used. A well designed condenser will have an almost unlimited shelf life; and in continuous use will have under normal conditions, a life of twelve to fifty years, depending upon the actual conditions. When the condenser is over-rated by the manufacturer or abused by the user the life will be greatly shortened.

After a condenser has been on the shelf for several weeks, the oxide film will be found to have lost appreciably in thickness. Therefore, when the condenser first has voltage applied, there will be an initial current surge that lasts only a few moments. In the worst cases, the film reforms almost completely in less than five minutes in a radio set. Generally less than a minute is required to completely reform the film.

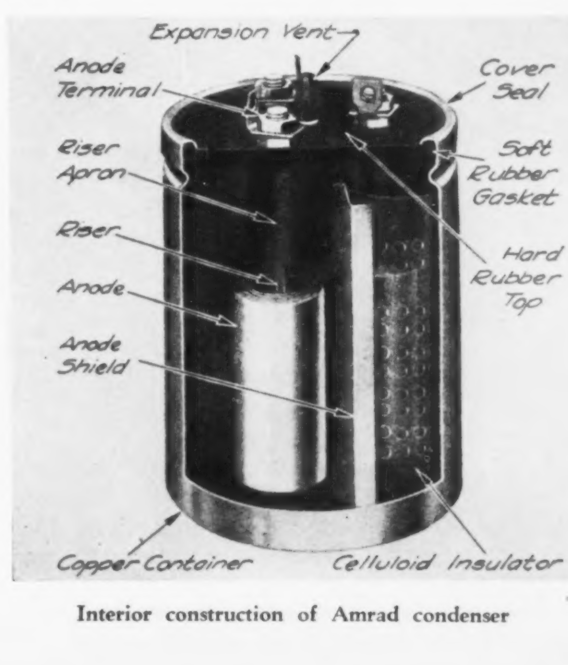
Electrolytic condensers have a poor power factor compared with paper dielectric condensers. Usually, the power factor is between 8 and 10 per cent in radio filter circuits. This high power factor must not only be considered when designing the power filters of radio sets and other applications, but should be made a consideration when estimating the operating temperature of the condenser.

High power factor is not much of a detriment in filter circuits for radio use, however, since the amplitudes of the higher harmonics in a full-wave rectifier are lower the higher the harmonic. The other consideration that must not be forgotten in calculating performance of an electrical filter is the equivalent series resistance of the condensers. Electrolytic condensers are obtainable in comparatively high capacities in very small spaces, and effects of high resistance can be overcome by increasing the values of capacity used over what would be used in a paper condenser. This is a factor which must not be forgotten when working close to the filter's limits. It is one of the points which must receive particular attention in the midget radio receivers.

Care must be used to so use electrolytic condensers that reversals of voltage across them never occur. As long as the formed anode is positive, leakage currents are negligible; but if the potential is reversed, heavy currents can flow with very little resistance to oppose them. However, it would be very unusual to find such a condition in the ordinary filter circuit for d.c. power supplies for radio use.

A very efficient filter for radio use is composed of two 30 henry chokes and a 24 mfd. condenser consisting of three 8 mfd. anodes. The voltage divider may take the customary form. For lower current requirements, it is possible to use only one choke of 40 to 60 henries, and 16 mfd. In the midget radio receiving sets, the magnetizing coil of the loudspeaker can be utilized as the choke when a dynamic speaker is used. In this case, it has been found necessary to use 12 mfd. per anode in the condensers where unusually severe operating conditions prevail. Input voltages to the filter are high for the condenser ratings, and fairly rapid deterioration of the condensers result. This abnormal condition can be readily corrected by limiting the input voltage.

Electrolytic condensers are particularly useful in filter circuits where the output ripple must be kept low with the lowest consistent cost of equipment. Voltage supply units for operating photo-electric relays, vacuum tube relays, etc., in industrial applications offer particularly advantageous opportunities for electrolytic condenser filters.



Interior construction of Amrad condenser