Vintage Radio

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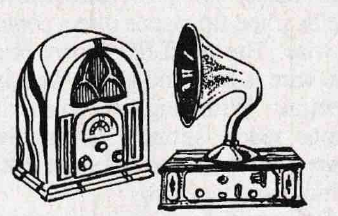


Capacitors in vintage radio — 1

The electronics industry is the major user of capacitors. For the earliest equipment existing types of capacitor were used, but in time the radio industry developed its own varieties, each with individual characteristics. In this article and those which follow, we will look at the different types found in vintage radios and suggest ways of dealing with faulty units in restoration projects.

Capacitors are indispensable components, performing a wide variety of functions including circuit tuning, DC blocking, bypassing and hum filtering. They are classified according to the dielectric used in their construction, the most commonly encountered in early receiving types being air; waxed, oiled or varnished paper; mica and ebonite. Glass and oil dielectric types were also used in early transmitters, but it may come as a surprise to realise that the types in regular use prior to 1930 are rarely found in modern equipment.

Capacitors can deteriorate or fail, and are the least reliable electronic components, with the situation aggravated by their being also probably the most prolific source of intermittent faults. Consequently, a sizable percentage of service and restoration work centres around capacitors.

Fortunately, modern replacement capacitors are significantly more reliable and stable than their predecessors. Each type has its own characteristics, and it is very important to select an appropriate substitute — not only for capacitance and working voltage, but also for its dielectric properties and behaviour.

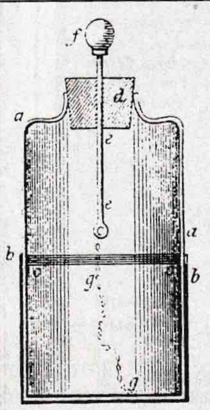
Around 1929 appeared the first of what was to eventually become an extremely important class, the *electrolytic* capacitor. Later in the decade came ceramic and polystyrene dielectrics. Without the multitude of types developed from these pioneers, electronic equipment would be very different today.

Postwar, other synthetics were developed and were found to have excellent performances. By the end of the valve era, capacitors with mylar, polyester, polythene and polycarbonate dielectric were coming into in common use.

Shocking event

The first capacitor, the glass Leyden jar, was invented about 250 years ago. This, by the way, is the origin of the obsolete unit of capacitance the 'Jar' — equal to 1.1 nanofarad — although one authority gives the capacitance of a one pint Leyden capacitor as 1.4 nanofarad. Credit for delivering the first ever man made electric shock is associated with the discovery of the Leyden jar. The story goes that a research group at Leyden University in Holland were using a static electricity machine connected to a glass jar with an external conductive coating and containing water. Electricity was then thought to be a 'fluid' and therefore it might be possible to store it in a container. Someone grabbed the connecting leads to the jar and discovered forcibly that it did indeed store electricity!

Fig.1: The Leyden jar capacitor, which has been around for well over 200 years, was one of the few types which successfully withstood the high voltages of spark transmitters. This 19th-century drawing shows the construction, with tinfoil extending halfway up the sides (inside and out) of a glass jar. A metal chain made contact with the internal foil. There is no explanation of how the foil was pasted inside a jar with such a narrow neck! Some versions solved this problem by half-filling the jar with fine metal shot, to form the inner 'plate' of the capacitor...



The classic Leyden jar consisted of a large glass jar, with the lower part of the exterior covered with tinfoil forming one electrode. The other electrode was a matching layer of foil inside the jar, with contact made by a metal chain suspended from the lid. Sometimes metal shot was used inside the jar instead of foil, to form the inner electrode.

Tradition has it that Hertz used Leyden jars for the capacitors in his experiments, to confirm James Clerk-Maxwell's predictions about the existence and behaviour of electromagnetic waves. Later, Sir Oliver Lodge used Leyden jars in his research into 'syntony', or tuning of electromagnetic radiations. Notwithstanding their bulk and difficulties in stowing, Leyden jars reliably handled very high voltages, and sets of them were often used in marine spark transmitters.

A more convenient capacitor for spark transmitters used flat glass photographic negative plates and tinfoil electrodes, often housed in an oil-filled container. Glass capacitors are still used for specialist equipment, but they are rarely found in vintage receivers.

Although the vintage radio enthusiast will not encounter many glass capacitors, there is one type that may be found in very early home built receivers using neutralised triode RF amplifiers. One form of primitive neutralising capacitor consisted of a piece of thin glass tubing, wrapped with tinfoil forming one electrode. Inside the tubing was the other electrode, a piece of heavy gauge wire whose position could be adjusted to vary the capacitance.

Another pioneer capacitor, the air dielectric type, is the most efficient and

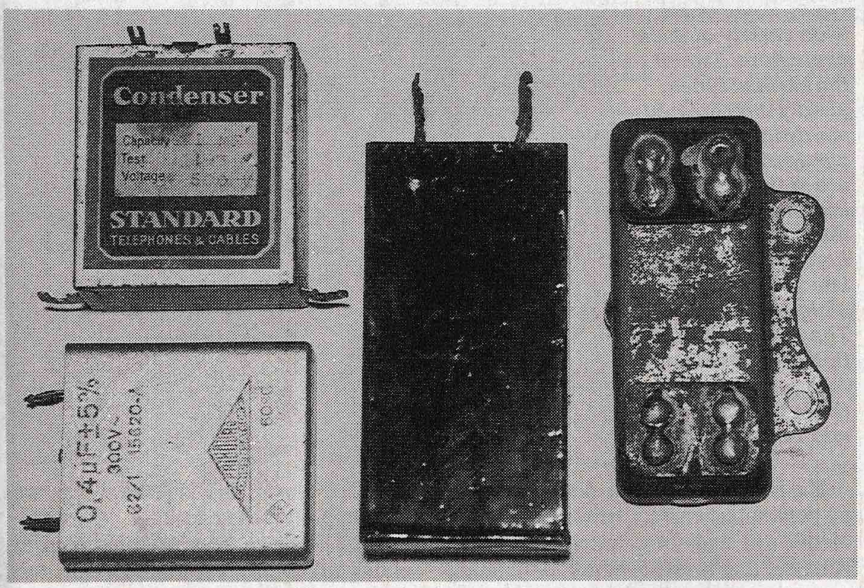


Fig.2: Early paper capacitors were generally sealed in metal cans, with varying degrees of success in keeping out moisture. Often several capacitors would be included in the one container, like the typical Atwater Kent unit on the right.

stable variety of all, and has of course been used extensively for variable tuning capacitors which hardly need any description. Air dielectric is ideal too for preset trimmers, one of the best known being the Philips 'beehive' type. Although used in some older test equipment, fixed air dielectric capacitors were not normally used in receivers.

What surely must have been physically the largest capacitor ever made had an air dielectric. This was the 1.8uF spark capacitor of the Marconi 300kW transmitter installed during 1906 at Clifden in Ireland, for the trans-Atlantic link to Glace Bay in Nova Scotia. Everything about this transmitter was awe-inspiring. Its capacitor, capable of handling 150,000 volts without flashing over, was assembled from 1800 galvanised steel sheets, each 30 feet by 12 feet and spaced 12" (300mm) apart. The array was housed in a shed the size of a warehouse, 350 feet long by 75 feet wide and reaching 33 feet at the eaves!

At the frequencies we use today, such large dimensions would make the capacitor useless; but Clifden transmitted on a wavelength of about 6.5km (i.e., about 46kHz). That enormous capacitor remained in service until 1920, when valves were installed in the transmitter.

The waxed-paper dielectric capacitor was used in telephone and telegraph equipment before the advent of radio. Paper's earliest use as a dielectric in radio was in the primary capacitors for induction coils, serving the same purpose that they still do in automotive ignition systems. As equipment became more complex, the paper capacitor was used increasingly wherever compactness with a high capacitance was required.

Impregnated paper is an inexpensive and reasonably effective material, but the dielectric constant is not constant at high frequencies, and it has some losses. Nonetheless, from the late 1920's until about 1960, paper capacitors were the most common type used in receivers. Various waxes and oils have been used, including paraffin wax, castor oil, mineral oil and petroleum jelly and later, some synthetic oils and plastics.

The most effective of all synthetics has created a serious environmental problem. Polychlorbiphenol (PCB) is the ideal insulating and impregnating oil, and was used extensively in capacitors, transformers and switch gear. Unfortunately the characteristics of extreme stability and indestructibility, which made it such an excellent dielectric, have also made it a toxic ecological disaster. The use of PCB is now illegal and any supplies have to be destroyed under controlled conditions. About the only way to deal with it is by burning in very high temperature kilns. Australia and New Zealand recently found it necessary to export their stocks to France for destruction in a specially built plant.

Fortunately PCB is not likely to be encountered in receiver components, but Australian manufacturer Ducon did use it in some of their metal-cased industrial grade capacitors.

Paper can exhibit fairly serious dielectric absorption losses, a phenomenon in which it takes time to accept or release a charge. This has the effect of reducing apparent capacity at high frequencies, and for this reason paper capacitors should not be used in tuned circuits. This trait works in reverse, sometimes causing a disconnected capacitor to apparently recharge itself. Consequently, to avoid nasty shocks, out of service filter capacitors from high powered valve transmitters were stored with a length of wire connected between their terminals.

The earliest method of paper capacitor construction was in the form of a multilayer sandwich, built up with alternate layers of paper and tinfoil. By 1910, the modern form of construction was common. Long sheets of thin paper and tin or aluminium foil are forced into close contact by rollers and the required lengths are rolled tightly to form the familiar general purpose tubular paper capacitor.

Voltage ratings are raised by increasing the number of layers of paper between foils. High capacitance units are wound flat, much like a bolt of cloth, often with several sections connected in parallel to achieve the required capacitance. After winding they may be then sealed in metal boxes.

Pinhole problems

One problem with paper as a dielectric material is that it is apt to have random pinholes which can lead to a rapid failure. On the assumption that two holes in adjacent sheets are unlikely to coincide, an extra ply is included to reduce the chances of breakdown, but increasing the finished size of the capacitor.

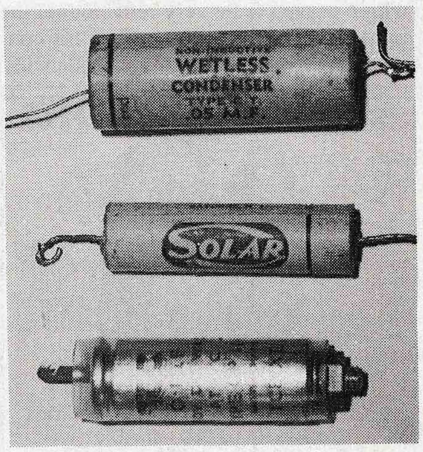


Fig.3: A selection of tubular paper capacitors, the most common type used in receivers from around 1930 to 1960. The top example is a waxed cardboard cased type, prone to leakage. Hard wax shells (centre) were a considerable improvement, but most reliable were the metal-cased type with plastic seals (bottom).

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In the late 1930's, German and English research developed the space saving *metallised paper* capacitor. Finely divided aluminium or zinc was deposited directly onto the paper, and there was no safety ply. Instead a voltage, applied after metallising, effectively vapourised any metal film at weak spots or holes in the paper, where there was a breakdown. The result was a capacitor significantly smaller than its multi-ply equivalent.

Metallised paper capacitors have proved often to have had lower insulation resistance than the conventional variety but are immune to voltage spikes that would ruin a conventional capacitor.

The biggest problem with paper dielectric capacitors in service is effective sealing against moisture. Unless they are extremely well sealed, moisture will penetrate the layers, seriously reducing insulation resistance. Initial specifications were typically for resistances of hundreds of megohms per microfarad, but it is not uncommon for this to drop to a few thousands of ohms.

Various casings, including waxed cardboard, hard wax, plastic, aluminium and steel have been used, with varying degrees of success. Least effective was probably the most common — the waxed cardboard tube; but other types of casing are not immune from trouble either.

Another problem with tubular paper capacitors was lead termination. Rolled capacitors originally had thin metal strips wound in with the foils, a method which proved to be very reliable; but the inductance of the strips makes this construction unsuitable for high frequencies.

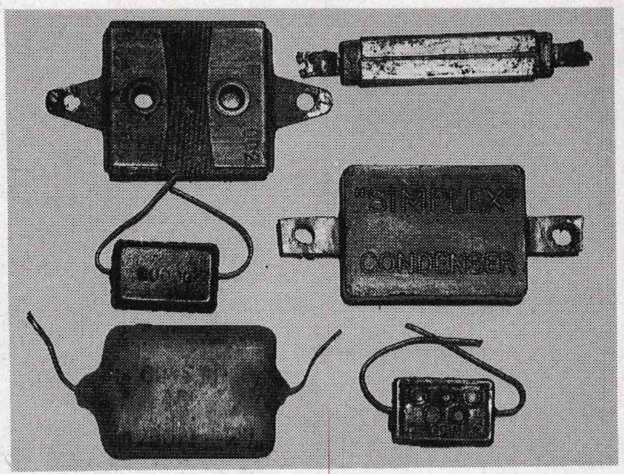

Fig.4: Some of the wide variety of mica capacitors. Two of the earliest types, simply unprotected sandwiches clamped together, are at the top. Bakelite and Micalex mouldings (centre) first appeared in the late 20's, and were a big improvement. The examples at the bottom are silvered mica, the one on the left having a wax coating.

The inductance can be eliminated only by continuous contact between the edge of the foil and its connecting lead. In practice, this is achieved by terminating the lead in a flat spiral or metal cap and securing it in close contact with the projecting foil edges.

Tinfoil can be soldered, but contact to aluminium foils is difficult and often is dependent on pressure provided by the crimped edges of the protective sleeve or a wax or composition plug. Poor contact can of course, produce sporadic behaviour and the all too-familiar-complaint of an intermittent fault.

A natural dielectric

The use of mica capacitors also predates the beginnings of radio communication, and for a long period these were regarded as premium components. Mica is one of the most efficient and effective dielectrics, with a high dielectric constant and extremely high electrical resistance. It is also temperature stable and has very low losses even at microwaves.

Mica is also unusual in that it is a naturally occurring material. Unlike paper, dielectric absorption is negligible and efficiency is very high. Finely laminated, it can be readily split to any required thickness — although brittleness and the relatively small size of the sheets limits methods of construction.

Mica capacitors are constructed by the traditional stacking of metal foil and mica plates not more than a few centimetres square, to provide capacitances ranging from 5pF or so to 0.1uF. Of course, the thinner the mica sheets, the greater is the capacitance — but the lower the voltage that the capacitor will handle. The assembly is clamped together between two pieces of fibre, and leads or tags are connected to the foil.

Initially, mica capacitors were often left unprotected. But from about 1930, moulded plastic and later hard wax was used to protect the capacitor.

Mica has long been used between the plates of compact variable capacitors, and will be frequently found in semi-variable trimmers and padders.

A problem is encountered with the sandwich method of mica capacitor construction. No matter how carefully they are assembled, minute quantities of air become trapped between the foil and mica. This air reduces the capacitance, and can become ionised if more than about 500 volts is applied, leading to rapid failure. To reduce this possibility, high voltage mica capacitors were frequently assembled in a series-parallel arrangement to reduce the voltage handled by individual sections.

The *silvered mica* capacitor is one solution to the problem of trapped air. Instead of using foil electrodes, a thin coating of silver is deposited on the mica, much as with the metallised paper capacitor, effectively eliminating any air.

Silvering reduces the physical size and improves stability. However silvered mica capacitors have their own breakdown problems. After a period of time, which may be only a few hours or in some cases many years, a silvered mica capacitor connected across a DC potential may suddenly develop a short circuit. The problem is the result of what is known as *ion migration*, whereby a microscopic branched growth or 'dendrite' of silver penetrates the mica and bridges the electrodes. As we shall see when we cover servicing of capacitor faults, receiver manufacturers were not always aware of this possibility.

The capacitor types that we have covered so far had their origins in the 19th century and earlier, well before the development of radio. But next month we look at electrolytic, ceramic and polystyrene capacitors, which were developments of the radio industry itself. ❖