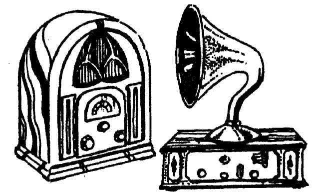
Vintage Radio

by PETER LANKSHEAR



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!

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

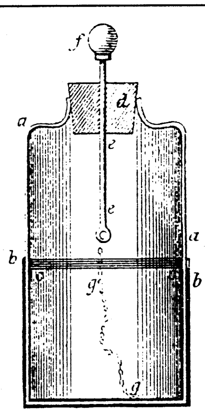


Fig.1: The Leyden jar capacitor, which has been around for well over 200 years, was one of the few types which successfully withstood the high voltages of spark transmitters. This 19th-century drawing shows the construction, with tinfoil extending halfway up the sides (inside and out) of a glass jar. 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...

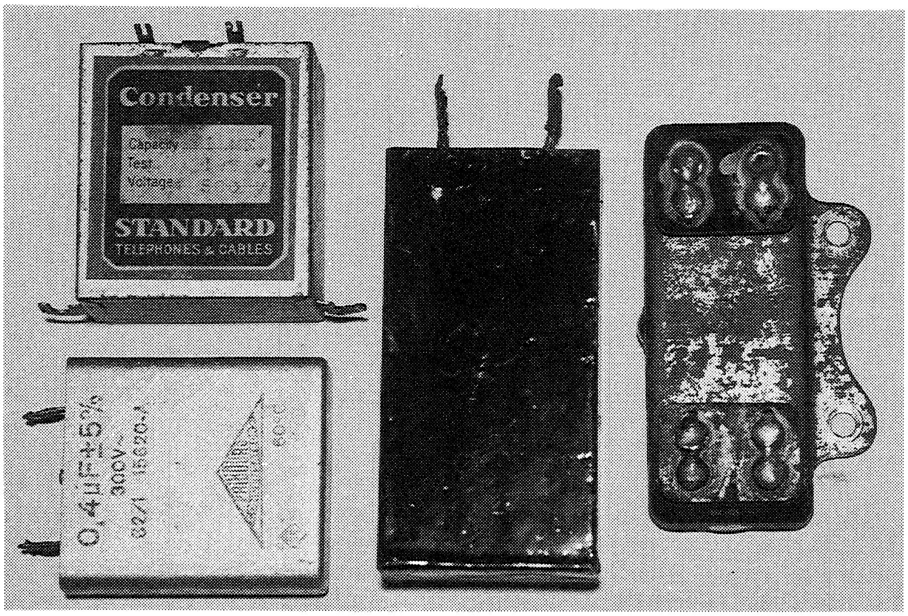


Fig.2: Early paper capacitors were generally sealed in metal cans, with varying degrees of success in keeping out moisture. Often several capacitors would be included in the one container, like the typical Atwater Kent unit on the right.

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.

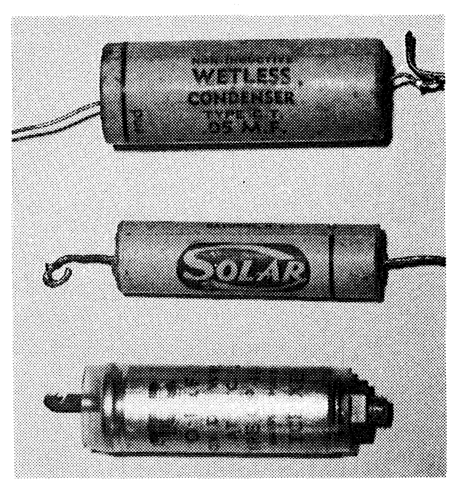


Fig.3: A selection of tubular paper capacitors, the most common type used in receivers from around 1930 to 1960. The top example is a waxed cardboard cased type, prone to leakage. Hard wax shells (centre) were a considerable improvement, but most reliable were the metal-cased type with plastic seals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

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.

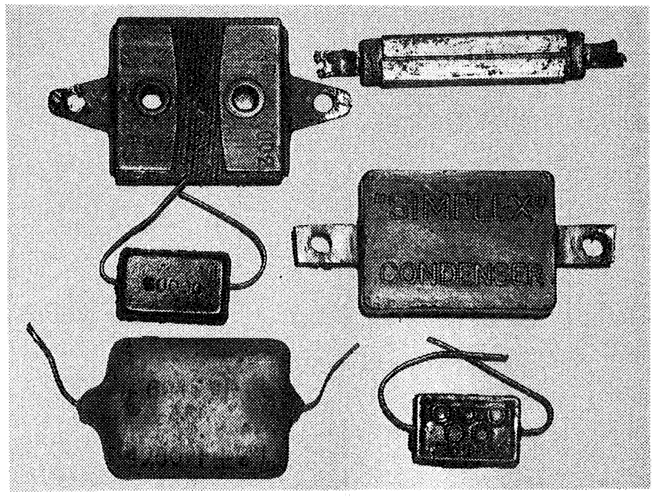


Fig.4: Some of the wide variety of mica capacitors. Two of the earliest types, simply unprotected sandwiches clamped together, are at the top. Bakelite and Micalex mouldings (centre) first appeared in the late 20's, and were a big improvement. The examples at the bottom are silvered mica, the one on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

Vintage Radio

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Capacitors in vintage radio — 2

Last month we looked at the evolution of the earliest types of capacitors, whose origins predated radio. These were adequate for pioneering radio equipment, which was very simple; but with the rapid progress in technology that came with the growth of the broadcasting industry, it was inevitable that new types of capacitors would be developed.

The *electrolytic* capacitor was the first to be evolved by the radio industry itself, rather than being adopted from earlier technologies. It was a case of the right component appearing at the right time.

Battery powering of receivers was never popular with broadcast listeners. They were expensive, and filament battery acid was corrosive; so efforts were soon being made to use mains power.

Practical AC heated valves were available from 1927, and for a while there remained a demand for mains power supplies for existing battery receivers. High tension battery eliminators using paper filter capacitors were quite successful, but filament battery eliminators were a different proposition. For adequate filtering of the large currents involved, capacitors of hundreds of microfarads were necessary — completely impractical with paper types.

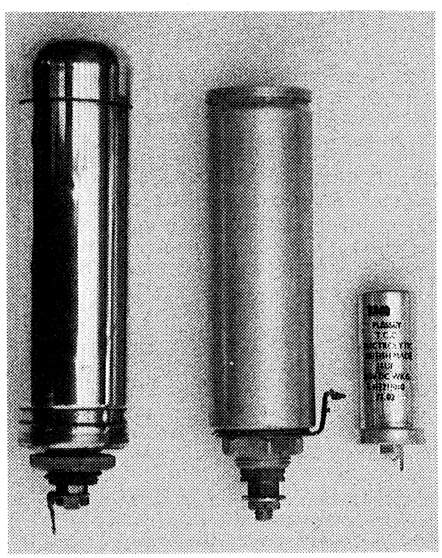
Filament battery eliminators did not achieve the same success as the high tension type, but from the search for a solution came the revolutionary electrolytic capacitor. This became an indispensable component for hum filtering and low frequency bypassing in valve receivers, and a generation later was to be essential in the new semiconductor equipment.

From rectifier to cap

The electrolytic capacitor actually evolved from the Noden valve electrolytic rectifier, a popular but messy type of rectifier for battery charging and eliminators. This device consisted of a container of electrolyte with a pair of electrodes, one of pure aluminium (or less commonly, of tantalum), the other an inert conductor, generally lead or carbon. A positive potential applied to the aluminium electrode builds up a molecularly-thin layer of aluminium oxide on its surface, effectively cutting off the current. As the polarity of the applied voltage is reversed, the oxide layer disappears, permitting current to flow.

Research during the mid 1920's showed that, provided the aluminium or tantalum electrode is maintained at a positive potential, the oxide layer is permanent and the same assembly can be used as a capacitor, with the oxide, the dielectric and the electrolyte functioning as the negative electrode. Aluminium and tantalum oxides are quite effective dielectrics, and the extremely thin layer provides a very high capacitance from a small electrode area.

The dielectric thickness is controlled by the initial 'forming' voltage, and governs both the breakdown voltage and the capacitance. A wide range of operating voltages is possible, in practice ranging from about three volts to a maximum of 600 volts. For a given electrode area, there is a relationship between capacitance and forming voltage.



A pair of cylindrical single-unit wet electrolytic capacitors became almost a standard for radio chassis of the 1930's. At left is an early Mershon copper-cased 10uF unit, while in the centre is an aluminium-cased Aerovox equivalent made in 1933, and still operational. At right is a Plessey 16uF dry electrolytic made 40 years later.

Conventional electrolytic capacitors have a wide capacitance tolerance, the nominal rating referring to the minimum capacitance. As with most components, electrolytic capacitors have steadily become much smaller.

'Mershons'

Electrolytic capacitors with tantalum electrodes and potassium hydroxide electrolyte were used for some filament supply eliminators, and it was necessary for the user to fill the capacitors with electrolyte during commissioning! Thereafter, the level had to maintained with distilled water, which was not much of an advance on the lead acid battery.

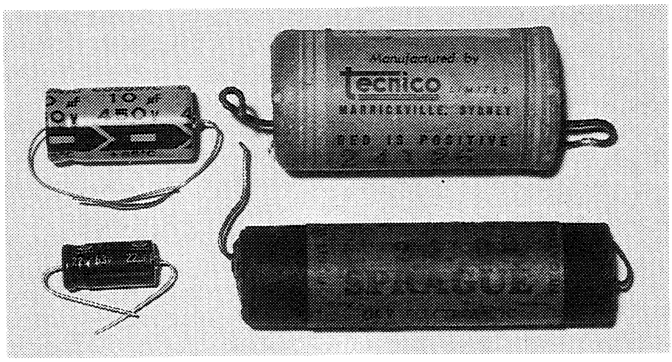
The demand for battery eliminators diminished with the advances in AC valve production, but the high tension supplies of the new receivers still needed hum filtering. Paper capacitors were satisfactory, but expensive and restricted to relatively low values of capacitance.

A common arrangement was to use two quite large chokes with paper filter capacitors, rarely larger than 4uF and frequently smaller. Low value capacitors had to be used with high inductance filter chokes.

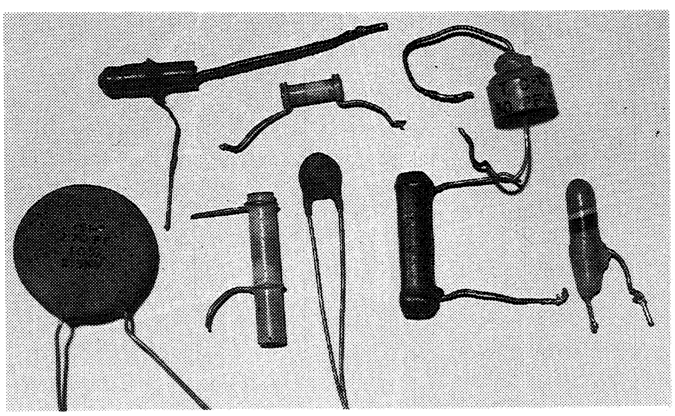
Alternatively, smaller and cheaper chokes needed larger capacitors to produce a tolerable hum level. Either solution occupied a lot of space, with attendant weight and cost. (An alternative way to minimise hum, frequently used in American receivers for a while, was the push-pull output stage.)

There was some economy in using input chokes tuned to ripple frequencies, but any system was complicated, and a capacitor failure could be very expen-

Right: Mershon's production of the electrolytic capacitor coincided with the demand for high capacitance filters for the new mains-powered receivers. This advertisement, from a 1930 copy of 'Radio News', gives detailed instructions for using the revolutionary multiple filter capacitor.



Above: One feature of electrolytic capacitor development over the years has been the reduction in size. Top right is a 1950's vintage 8uF HT filter capacitor, with its modern 10uF equivalent at its left. Even more striking is the comparison underneath between the old (right) and new (left) versions of a 25uF 40VW cathode bypass unit.



Above: A wide range of ceramic capacitors is available. Those in the top row are Dutch, American and English types dating from the late 1930's. Those underneath are more modern components.

BUILD AND REPAIR POWER PACKS WITH PUNCTURE-PROOF FILTER CONDENSERS

BETTER THE FILTERING AND ELIMINATE, ONCE FOR ALL TIME, THE DANGER OF HIGH VOLTAGE BREAKDOWN

Zenith, Sparton, Crosley, Colonial, Kennedy, Howard, Amrad, DeForest-Crosley or Canada and a long list of other prominent radio manufacturers have used Mershon (Puncture Proof) Electrolytic Condensers in their receivers for years,—for these units provide better filtering, greater reliability and almost unlimited life, at lower cost.

In building or repairing power-packs for receivers, transmitters or power-amplifiers, Mershon Condensers are equally of value to you.

— FEATURES —

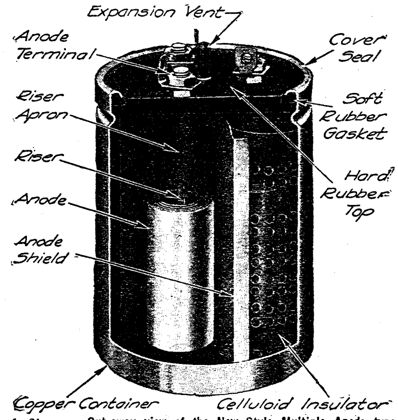
THEIR FIRST COST IS LOW.

THEY ARE SELF-HEALING. Voltage surges that can ruin ordinary filter condensers have no effect on them.

THEY ADD PROTECTION TO THE POWER PACK, by absorbing voltage surges.

THEY INCREASE THE FILTERING OF THE POWER PACK, because of their larger capacity.

THE MORE THEY ARE USED, THE BETTER THEY BECOME. Their active life is almost unlimited.



Cut-away view of the New Style Multiple Anode type Mershon Condenser, showing latest patented construction.

HOW TO USE MERSHONS

Mershon Condensers are manufactured in several different capacities and two different mounting styles.

Single Unit Mershons have the positive terminal at the top or bottom, as desired, with capacities of 8 or 18 Mfd.

Multiple Unit Mershons have positive terminals at top, and may be obtained in either Double Unit or Triple Unit styles.

These latter are the most economical filter condensers available. They cost less per Mfd. than even the Single Unit Mershons, and are equivalent in filtering action.

An unusually effective filter circuit for power-packs using the type —80 rectifier tube (very popular with receiver manufacturers) is shown in the diagram.

One Mershon Condenser, Type Triple-8, with two chokes, supplies complete filtering. The only additional condensers required are the usual small ones across the low voltage detector plate tap and bias resistors.

The first choke can be of low inductance (about 5 Henries) and high current carrying capacity. The second choke can be of high inductance (20 Henries or more) and low current carrying capacity. It need carry only the plate currents of the detector, first audio and R. F. tubes.

The New Mershon Booklet "Puncture Proof Filter Condensers" contains other effective filter circuits and much interesting information about Mershon Condensers and their uses. Send for a Free Copy.

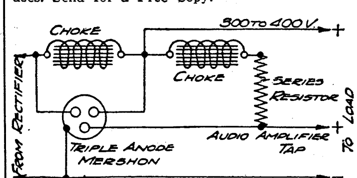
WHAT USERS SAY

NDR, Augusta, Maine, says "Having great success with Mershons. Using a bank of Mershons Sunday, put new NDR on the air and got Xtal report first QSO." "Our only worry is that someone will buy them right out of our filter system." WIBES says, "I successfully blew a 4,000 volt bank of —— condensers before acquiring the Mershons, but have had no trouble whatsoever since." WICCP says, "Had 'RAC' reports on my transmitter before, but now am getting 'DC' and 'pure DC.' "

From a radio distributor, "Zenith has been using your condensers for more than two years, and we as jobbers have found them to be all that is claimed for them." From a dealer, "Have sold Crosley and Amrad for three years, and have yet to have a Mershon go bad." A service manager, "Have not known of one going bad in a receiver yet."

The success of Mershon Condensers is based upon years of development and actual experience in service. It is the only electrolytic condenser with such a background.

Forty of the Leading Parts Distributors stock the New Mershon Condensers. If yours cannot supply you with the ones you want, write us for prompt action.



Electrolytic
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sive. What was needed was a compact, reliable and inexpensive capacitor of several microfarads capacity, capable of withstanding 500 volts or even more. High voltage electrolytics were the obvious answer.

The first of these electrolytic capacitors seems to have been made by the Mershon Company, which belonged successively to Amrad, Crosley, and then Magnavox. Until about 1930 (by which time well known brands including Ducon, Aerovox and Sprague were advertising the new filter capacitors), magazine articles often used the term 'Mershons' when referring to electrolytic capacitors.

Following on from rectifier practice, they were at first constructed in glass jars, but metal cans were soon found to be more suitable, copper and aluminium being popular. As well as being less fragile, metal had the advantage of making good contact with the electrolyte.

As these capacitors contained a liquid, they had to be mounted vertically; but major advantages were a significant reduction in size, and the fact that they were self repairing in the event of a breakdown! If the dielectric punctured from a voltage surge, as it did especially during warm up of valve cathodes, there was merely a short period of sizzling and bubbling as the oxide layer reformed, restoring normal operation.

By 1930, the single unit electrolytic filter capacitor had been standardised as a metal cylinder about 30mm in diameter and 120 - 150mm tall, rated at 8 - 10uF and 450 volts working. Before long, improvements had doubled the capacitance for the same working voltage and size of container and after 1932, paper filter capacitors were used in few new receiver designs.

Early in the evolution of the electrolytic capacitor, it was realised that as the electrolyte could be common to two or more capacitors. Thus it was practical to make multiple units in the one can, as shown in the Mershon advertisement.

Just as the liquid-filled Leclanche cell was adapted to become the dry cell, so the more convenient 'dry' electrolytic capacitor soon evolved. This had an absorbent layer saturated with electrolyte between the electrodes, and this approach offered a wide choice of capacitances and working voltages.

The advantages of dispensing with a liquid are obvious, and as well, the dry electrolytic has a better power factor, much smaller size, lower leakage and frequently, longer life. It is, however, not as effective at self-healing; but the many virtues outweigh this disadvantage, and manufacture of the wet electrolytic was eventually phased out.

Another innovation, not entirely successful, was the packaging of dry electrolytic units into rectangular waxed cardboard boxes. Although mounting was simplified, sealing against evaporation was inadequate and as a consequence there were more frequent replacements.

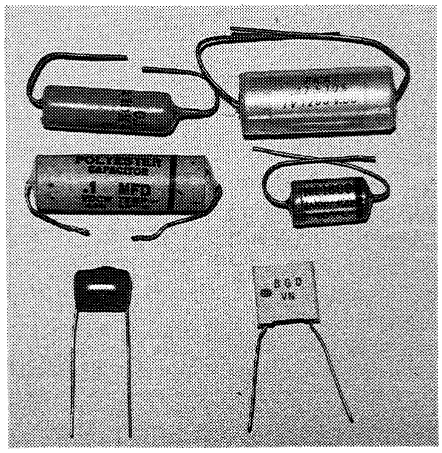
The dry electrolytic capacitor was able to meet a new demand. Cathode bias became more common with indirectly-heated valves, but for adequate bass response and hum reduction, bypass capacitors of 10uF or more were desirable. Paper capacitors would have had an unnecessarily high maximum voltage rating, with prohibitive size and cost.

Many receiver designs had dodged the problem by the alternative method of tapping off bias voltages from the power supply ('back bias'), but this was not as sound a method as cathode bias. Compact dry electrolytic capacitors rated at 25 volts and from five to 25uF were the answer, but initial unreliability meant that their adoption was not universal.

Limitations

In spite of careful sealing, early electrolytic capacitors tended to dry out, and corrosion could be a problem. Replacement of electrolytics became one of the commonest chores for radio servicemen.

Despite this, the weaknesses were gradually overcome and capacitors steadily became smaller as well as increasingly reliable. It is now difficult to imagine modern electronic equipment without the ubiquitous and inexpensive electrolytic capacitor. Today it is not at



Plastic capacitors come in all shapes and sizes. At the top are Dutch and Japanese axial leaded examples, with similar Australian and German types in the centre. The two at the bottom have radial leads for PCB mounting.

all uncommon to find filter capacitors that have given 40 years' service and that are still operating perfectly.

The chief limitations are that in standard form, electrolytics are unsuitable for operation without some DC polarisation. There is always some leakage current, as well. There can also be a wide variation from nominal capacitance, which may change in time with operating voltage.

A major advance was made possible with 'etched foil' construction. By giving the positive electrode a matt finish, the active surface area was increased, significantly reducing the physical size of the capacitor. Note, however that etched foil capacitors have to be used with care when high ripple currents are present, or heating may occur.

Tantalum was originally used to a very limited extent for low voltage wet capacitors, but in recent years the tantalum electrolytic capacitor has become important in semiconductor equipment. These capacitors are very compact and have long and stable lives. However not having any self-healing properties, they are destroyed by voltage spikes and are intolerant of any voltage overloads. Such conditions are likely to be encountered in vintage receivers and consequently, tantalum capacitors have no place in valve equipment.

Ceramic capacitors

The *ceramic* is another class of capacitor essential to modern electronics. Its origins were in the 1930's, and there has been steady development and improvement ever since. Ceramics are minerals that have been modified and hardened by heat — the oldest, bricks and pottery, going back to antiquity.

As dielectrics, ceramics have many varied and useful properties.

Ceramic capacitors are versatile in that a wide range of required characteristics can be given them, simply by varying the mixture of materials in the dielectric. Some are similar in many ways to mica types, which they have largely superseded — but with the added advantages of very small size, a greater range of capacitances and working voltages.

One especially significant property which can be varied is the way capacitance changes with temperature. The temperature coefficient can be varied anywhere from negative through zero to positive. Negative coefficient capacitors are especially useful in stabilising oscillators against drift created by heat from valves and resistors, which can affect tuned circuits.

Increasingly popular after the mid 1950's, two main groups of ceramic capacitors were used in valve receivers. Most common are the general purpose high temperature coefficient ('high-K') types, which combine high capacitance with low inductance and are made in a wide range of working voltages and capacitance values.

As with electrolytic capacitors, the high-K types have a wide tolerance range and in valve receivers were used mainly for bypassing and audio coupling — applications taken over from paper capacitors. Generally in the form of round or square plates, 'blobs' and tubes, they have a very high insulation resistance, a wide range of working voltages and with capacitances up to about 0.25uF.

However with their high dielectric losses, high-K ceramics are unsuitable for tuned circuits. For this purpose, close tolerance, high stability ceramic capacitors, generally made in values below 1000pF are used in much the same way as the mica variety. Negative and zero temperature coefficient ceramic trimmers have been used for critical applications such as oscillator trimmers in communications receivers, where frequency drift with heat must be minimal.

A specialised type of ceramic capacitor may be found in the detector area of valve receivers and can be a puzzle to the uninitiated in having three leads, one earthed. These are convenient composite units, used as diode load filters and incorporate a resistor — typically 47k ohms — with a pair of bypass capacitors connected, one at each end.

Fantastic plastics

For many years, although they had weaknesses, paper dielectric capacitors were unchallenged for applications requiring a non-polarised medium capacitance combined with relative cheapness, a good life expectancy, low leakage and reasonable efficiency. By today's standards, they were relatively bulky — mainly the consequence of unavoidable pinholes requiring the use of multiple plies of paper.

Another problem was susceptibility to moisture, and to achieve a long and stable life, elaborate impregnation and sealing was necessary. Although still made, paper capacitors have largely been displaced by the various *plastic* dielectric capacitors.

The first plastic dielectric did not challenge paper directly. Although various plastic materials had been available previously, *polystyrene*, developed in the 1930's, was the first to have significant value as a dielectric. Polystyrene capacitors are constructed in the rolled form, similar to paper types and are much the same size. With high insulation resistance, very low losses and excellent temperature stability, polystyrene capacitor applications are much like mica capacitors. Their chief application in valve radios was as padding capacitors for oscillator tracking.

It was in the late 1950's that the plastic dielectric revolution began, and various dielectrics including *polycarbonate*, *polyester* and *mylar* appeared concurrently with the emergence of semiconductor technology.

Today often known as 'greencaps', polyester dielectric capacitors were used to great advantage in the later generation of valve receivers. At that time they looked much like paper capacitors, with tubular shells and axial leads; but as the printed circuit increased in popularity, radial leads became more common.

As there is not the same problem of pinholes, multiple layers of dielectric are not essential. Plastic capacitors can be rolled or layered; some have metallising rather than separate foils, and applications are similar to the various paper types.

These capacitors have the advantages of compactness, low dielectric loss, long life and extremely high insulation resistance. Radio designers of the 1930's would have loved them!

Space has run out again, and there is still much to be said about capacitors in vintage radio. Next month we will look at variable capacitors, and for the beginner, there will be some practical hints on dealing with capacitors in servicing vintage equipment. ❖

Vintage Radio

by PETER LANKSHEAR

Capacitors in vintage radio — 3

Lately we have been looking at the various types of capacitors used in vintage equipment. Such is their importance, and their range so comprehensive, that, to provide even a superficial coverage of the subject we have run into an unprecedented third section. This time we look at semi-variable or 'trimmer and padder' capacitors, and then at the practicalities of capacitor repairs and replacement.

This month we provide some capacitor restoration hints for inexperienced readers. But first, left over from last month are some comments about the all important semi-variable preset *padders* and *trimmers*, essential for receiver alignment. (By the way, a *padder* is a preset variable capacitor with a relatively high value, used mostly to achieve the tuning offset for the local oscillator section of a superhet receiver. *Trimmers* are preset variables of lower value, used for fine adjustment of tuning and tracking.)

Several representative types are shown in Fig.1, but it should be realised that these are only a fraction of the number of patterns likely to be encountered. In the top row are two varieties of the superior air dielectric trimmers found in the highest grade equipment, especially test and military equipment and communication receivers. The trimmer at the top left is in reality a small conventional variable air spaced capacitor with a screwdriver slot and locknut instead of a knob. These will often be found in the coil boxes and IF transformers of the classic communications receivers.

One of the most successful air trimmer designs was the remarkable concentric 'Beehive', illustrated in the top centre and right in Fig.1 and produced by Philips over a period of at least 40 years — and possibly longer. They consisted of two sets of concentric mating cylinders, with one mounted on a coarse threaded centre rod so that its cylinders could move between the fixed set. The only insulation necessary was a ceramic sleeve section on the rod.

With air dielectric, and ceramic insulation, concentric air dielectric trimmers were very efficient and stable. Other manufacturers appreciated their worth, two diverse examples being Britain's Eddystone in their communication receivers and New Zealand's Radio Corporation in some 'Columbus' and 'Courtenay' models. Philips at one stage even scaled up the concentric capacitor to make full scale three-ganged tuning capacitors!

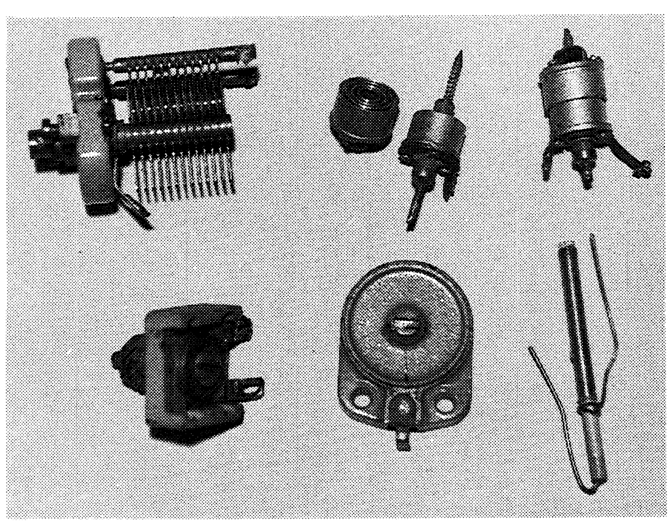
Very familiar are the compression preset capacitors, and a typical padder of this type is shown at the bottom left of Fig.1. Most have a ceramic body, with electrodes and dielectric, usually mica, interleaved like the pages of a book. A simple screw adjustment controls the pressure on the plates. Many tuning capacitors have integral compression trimmers of this type. This class of capacitor is generally satisfactory for medium waveband receivers, but for good shortwave performance, trimmers with better temperature stability are desirable.

For critical applications, especially oscillator tracking, ceramic trimmers with a negative temperature characteristic are preferable. One common pattern is the rotary type shown in the lower centre of Fig.1. At the bottom right is an earlier type used by Philips in the 1930's. It consists of a thin ceramic tube, with a coating of silver on the inside. The other electrode is a single layer of tinned soft wire wound on the outside and cemented. Adjustment procedure is simple: the wire is unwound until the correct capacitance is reached. Of course, what happens in real life is that the unwinding goes past the optimum point, and some of the wire then has to be rewound and fastened in position! For production alignment these trimmers were satisfactory enough, but over-enthusiastic experimenters can get into bother with repeatedly adjusting them.

Renew or repair?

A significant part of restoration work involves capacitors. There are several philosophies as to the best approach, but if you have any doubts about your ability to restore a valuable receiver, remember that it is all too easy to devalue equipment by thoughtless servicing. If there is any doubt or difficulty, my advice is — don't do *anything*. An inoperative veteran receiver in original condition is more valuable than one made workable by ill-considered substitution of irreplaceable components. Generally, the

Fig.1: A selection of small variable 'trimmers' and 'padders'. At top left is a high grade air-spaced type, with examples of Philips' very successful 'beehive' concentric air trimmer at top centre and right. A mica compression padder is at lower left, then a ceramic trimmer and finally a tubular ceramic type.



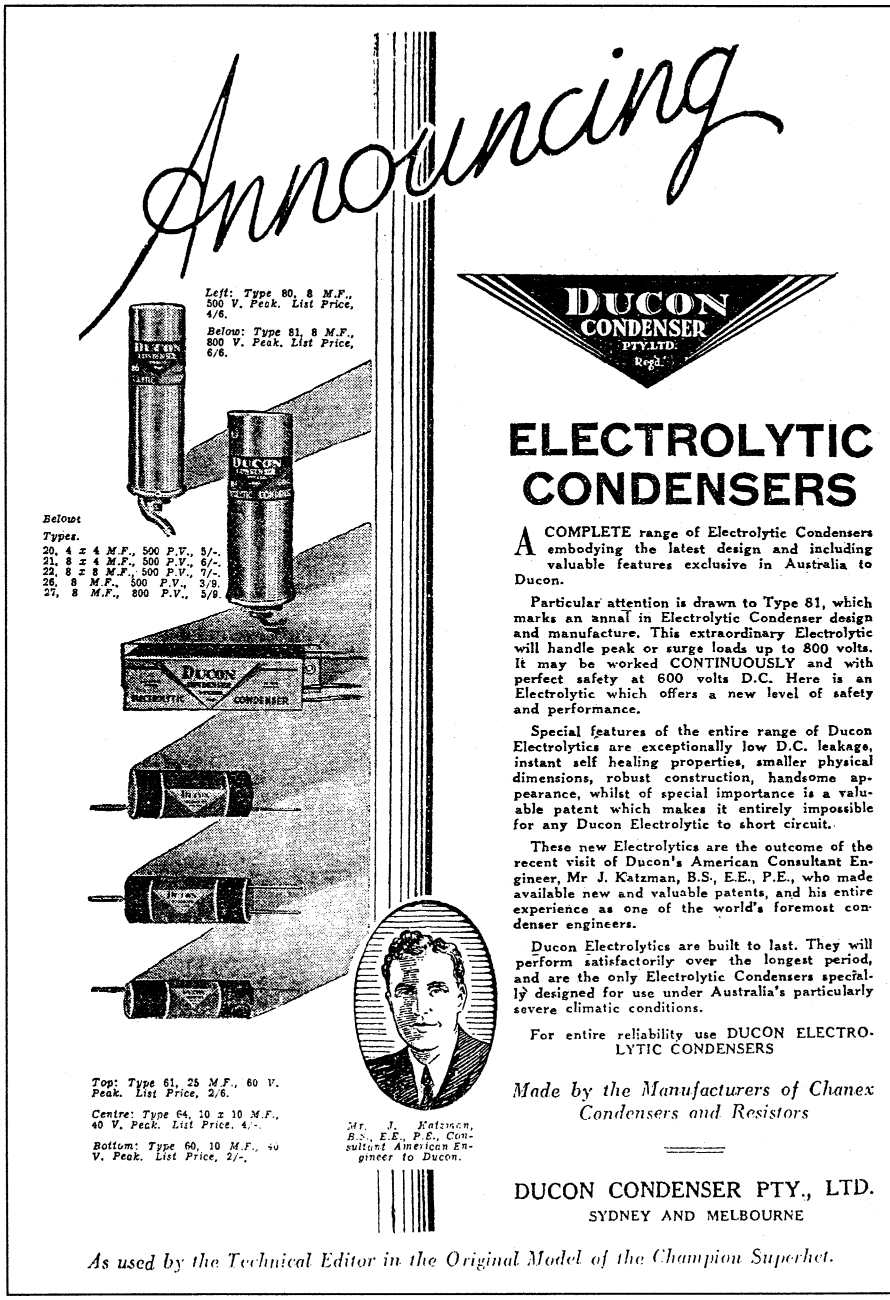
older the equipment, the greater the importance in maintaining originality.

The hints that follow do not apply to very old receivers — which used very few fixed capacitors anyway — but are intended for those made after about 1930 when standardised proprietary components came into common use. A complicating factor is that previous servicing work may have to be remedied.

Several philosophies...

There are several philosophies in dealing with small components. At one end of the scale, the attitude is that, as they are out of sight under the chassis, all electrolytic and paper capacitors, regardless of condition, should be replaced with modern equivalents.

Probably the majority of restorers work on the less extreme principle of replacing only those capacitors which have failed, or are in critical locations. Some are content to use replacements 'as is'. Sticklers for originality and correctness go to considerable lengths to obtain genuine replacements, and in some instances, repair faulty capacitors, or renew the contents of the original cases. Especially distinctive components may be left in position, with a modern replacement, which is invariably smaller, placed alongside. Meticulous conservators will carefully document all work.



Sixty years ago, Australia had a thriving capacitor industry, as shown by this advertisement from the July 13, 1934 issue of 'Wireless Weekly'. Ducon and Chanex capacitors can still be found in many receivers from this period.

A good place to start is with the electrolytic capacitors. Vintage electrolytic capacitors had a limited life expectancy, and there may have been several generations used in a veteran receiver during its life. Ascertaining their exact condition can be a problem. They can dry out and lose capacitance, and consequently some method of measuring them is desirable.

For the old-time serviceman, who regarded even a good test meter as a luxury, a capacitor tester was but a dream. Consequently, rough and ready empirical methods of testing were developed. Capacitance could be estimated by the size of the 'splat' when a charged capacitance was short circuited, and leakage was judged by the length of time a charge was held after the power was turned off!

Many digital test meters have a useful capacitance measuring facility, but as many cannot measure a very wide range, a capacitance bridge is a valuable tool for the serious restorer. This does not need to be an elaborate instrument, and a suitable home-built unit was described in *Electronics Australia* for February 1991.

A most critical capacitor application is that of the filter immediately following the rectifier. In earlier receivers this was often a chassis-mounting wet type which is likely to have long since dried up, and in all probability there is now a tubular dry type already fitted as a replacement. Repairs are impractical, and the positive terminal may have been used as a tie point for several other components.

Normally, unused wet electrolytics are disconnected and left in position for appearance. The simple approach is to connect the leads to an insulated tie point mounted on the capacitor's terminal and substitute a dry electrolytic capacitor. In many circuits, to provide a bias supply, the negative terminal of the capacitor is insulated from chassis.

Some enthusiasts use skill and ingenuity in enclosing the replacement capacitor inside the old can. One method that may work is to uncrimp or grind down the swaging around the base. Another method is to cut the can in two near the base, remove the contents and with the replacement capacitor installed inside, turn up a wooden mandrel the diameter of the original can. The mandrel, with a suitable hole for the leads, is then used as a sort of splint to rejoin the two sections of the can. A paper sleeve or the original label can hide the join.

There are some important points to note in selection of replacement capacitors. Do not be tempted to use extra large filter input capacitances, or valve rectifiers may be damaged by peak currents. Several interdependant factors are involved in individual cases, but as a general rule, don't use more than twice the original value, and then with a top limit of about 40uF.

Failure to observe this rule could result in a damaged rectifier valve, excess HT voltage developed and an overheated power transformer. I have encountered instances where the substitution of a 100uF TV type filter capacitor connected to the rectifier cathode has resulted in a burnt out power transformer. Large values at the *output* of the hum filtering system do not create the same problems.

There are two characteristics of electrolytic capacitors that are of special importance in hum filtering service. The first is the peak voltage at switch on. Although valve receivers commonly operate with 250 volts of high tension, the no-load voltage at the cathode of the rectifier can be considerably higher, especially if the filter system includes a speaker field.

When the set is first switched on, a filamentary type rectifier such as a 80 or 5Y3 will conduct within a few seconds — but the indirectly heated valves take a half minute or so to warm up. During this period, the voltage can rise to something like 40% more than the rated voltage of the power transformer. Many power transformers had a secondary voltage of 385 volts, giving an initial peak voltage at the input capacitor of more than 500 volts.

The label on some filter capacitors gives a peak or surge rating, as well as a working voltage. Another parameter often provided on filter capacitors is the maximum current rating. In some applications, this can be an appreciable fraction of an ampere, but it is impossible to give specific figures and not all capacitors are provided with a rating.

Check for heating

As many technicians and experimenters have discovered, electrolytic capacitors can object to voltage and current overload in a most spectacular manner! They may overheat and explode with considerable force, and there are tales of damage to wiring and components, and of the remnants of capacitors being left on ceilings. Therefore, after replacing a filter capacitor, keep a close watch

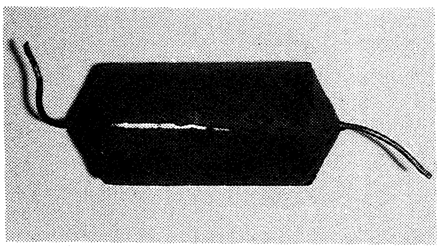


Fig.2: The cases of hard wax and composition jacketed paper capacitors frequently shrink and split, letting in moisture. Replacement is the only remedy.

on its temperature for the first 10 minutes or so of operation. If the capacitor feels to be getting warm, the chances are it is not suitable.

There is a further aspect of electrolytic capacitor replacement which should be mentioned. Capacitors stored over a period of years may need dielectric reforming. Some testers have this facility, but a simple method is to connect the capacitor via a current-limiting resistor across a voltage source comparable with the rated voltage. A value of 1k ohms per volt is suitable for the resistor, and progress is readily monitored with a voltmeter. Initially, the reading may be low, but when reforming is complete, there will be practically full voltage across the terminals.

Many vintage receivers had only two electrolytic capacitors, both used for HT filtering. More elaborate sets had others for additional filtering and for stabilising oscillator and screen supplies. Cathode bias for audio valves was avoided by many designers — in many instances, I suspect, because of the poor reliability of early low voltage electrolytic capacitors. This is no longer a problem, as with the large range of low voltage electrolytics now available, suitable replacements for sets that do use them are cheap and readily obtainable.

High voltage medium capacity electrolytics are a different story. They are becoming harder to find, especially in the range 8 - 20uF which was commonly used in older valve receivers. The reason for this is limited demand, but some manufacturers will make a special run if sufficient numbers are ordered.

Recently, one enterprising New Zealand vintage radio group was quoted a very competitive unit price for a special run of 10uF 450 volt capacitors from a Japanese manufacturer. Although the minimum order required appeared at first to be large, the attractive price encouraged plenty of sizable individual purchases and the venture proved to be quite viable. Incidently, this same group, in a similar manner, managed to organise a supply of the old style textile covered hookup wire.

Paper replacements

Paper dielectric capacitors are the most commonly found variety in vintage sets, and their condition today varies considerably. The chief problem is leakage, and this can be attributable to the difficulty of sealing against moisture. Insulation resistances, even in identical capacitors from the same chassis may vary considerably. Those with waxed cardboard sleeves are the most likely to have deteriorated, but, as illustrated in Fig.2, capacitors with thin hard wax or composition coatings can develop cracks, with disastrous results.

Leakage is equivalent to a resistor in parallel with the capacitor, and its effect varies with the position in the circuit. In the case of, for example, a bypass across a cathode resistor of a few hundred ohms, an insulation resistance of one megohm is obviously not very significant. But that same capacitor coupling the anode of the audio amplifier to the grid of the output valve, using a grid resistor of a half megohm, would have serious consequences. Similarly, this same leaking capacitor connected to an AGC line could halve the RF control bias.

My own rule is to replace paper capacitors in control grid circuits, or which are bypassing high value resistors, if their leakage is worse (i.e., lower) than 100 megohms.

Paper capacitors have been, as noted previously, largely superseded by plastic dielectric capacitors, and provided that the working voltage of the replacement is adequate, substitution presents no

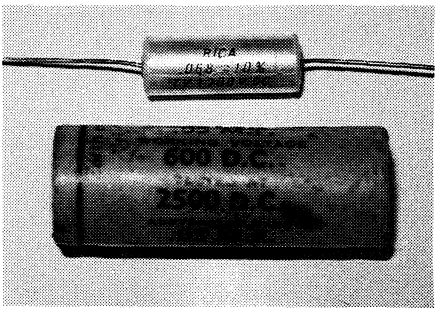


Fig.3: A modern polyester capacitor can be fitted into the tubular sleeve of an old paper type with room to spare. This provides a practical compromise between originality and using modern components in old receivers.

problems. Just remember that any capacitor connected to the HT line, even through a resistor, may have a high voltage present during warm up and the voltage rating of the replacement should be adequate. If authenticity is not a problem, for general receiver applications, high-K ceramics — provided that their working voltage is adequate — make compact replacements in most paper capacitor applications.

Frequently, tubular capacitors have one end marked with a band. This indicates the lead to the outside foil, which is normally connected to the lowest impedance side of the circuit; for example, earth in the case of bypasses, and the anode in resistance coupled amplifiers.

Repair or renew?

In the case of older equipment, the question arises as to the possibility of restoring paper capacitors or at least, the best method of retaining their original appearance. Most deterioration is from moisture absorption and it is possible in many cases to drive it out.

In a practical exercise, I tested several 60 year old cardboard cased 0.05uF tubular paper capacitors, and none had an insulation resistance better than two megohms. They were then immersed in molten paraffin wax held at 120°C in an electric oven. After about half an hour, when the seething and bubbling had ceased, they were drained and allowed to cool. Finally, the ends of the cases were sealed with wax. Their resistances are now all greater than 200 megohms.

These capacitors are now serviceable, but this process may not always be successful, and of course, it's no good for composition or hard wax coatings. How long they will remain in good order will be very dependent on their environment. Given similar conditions and effective sealing, their life expectancy could possibly be as good as it was when they were new, and for some restorers this may be sufficient.

A compromise is to insert a modern capacitor in the original casing. This is generally quite easy, Fig.3 giving an idea of the relative sizes. If the old capacitor is first immersed in hot wax, the contents can be readily pulled out of the sleeve. Replacement plastic capacitors can also be fitted into the metal boxes used in the very early receivers, and of course, smaller value capacitors can be connected in parallel to make up high capacitance units.

Mica replacements

The remaining type of capacitor found in vintage radios is the mica dielectric. Mica capacitors are generally reliable and rarely develop leakage. Nevertheless, they can have some problems. A serious tendency mentioned previously is for silvered mica capacitors, when connected across a high potential, to develop a short circuit from metallic bridges growing through the mica.

An often unsuspected, but annoying fault in mica capacitors can be an intermittent open circuit when some of the electrode foils do not make proper contact with the terminal leads. This fault can be especially frustrating in the fixed tuning capacitors for permeability tuned IF transformers.

Like the paper capacitor, mica capacitors are now practically unprocurable. However in most cases, polystyrene and low-K ceramics, provided that they have an adequate working voltage, can be used as satisfactory replacements. ❖