Vintage Radio

by PETER LANKSHEAR

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.

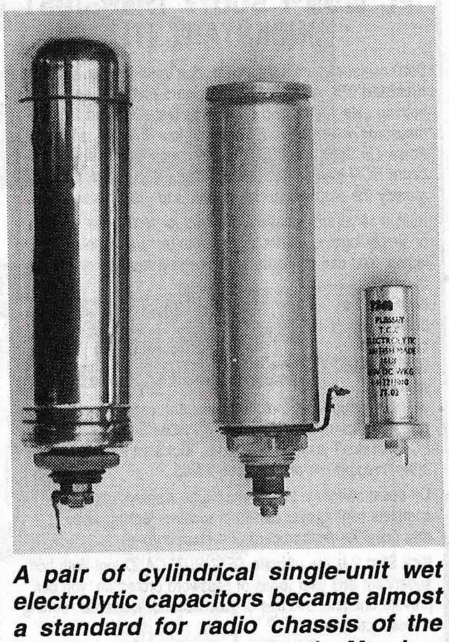
Filament battery eliminators did not achieve the same success as the high tension type, but from the search for a solution came the revolutionary electrolytic capacitor. This became an indispensable component for hum filtering and low frequency bypassing in valve receivers, and a generation later was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

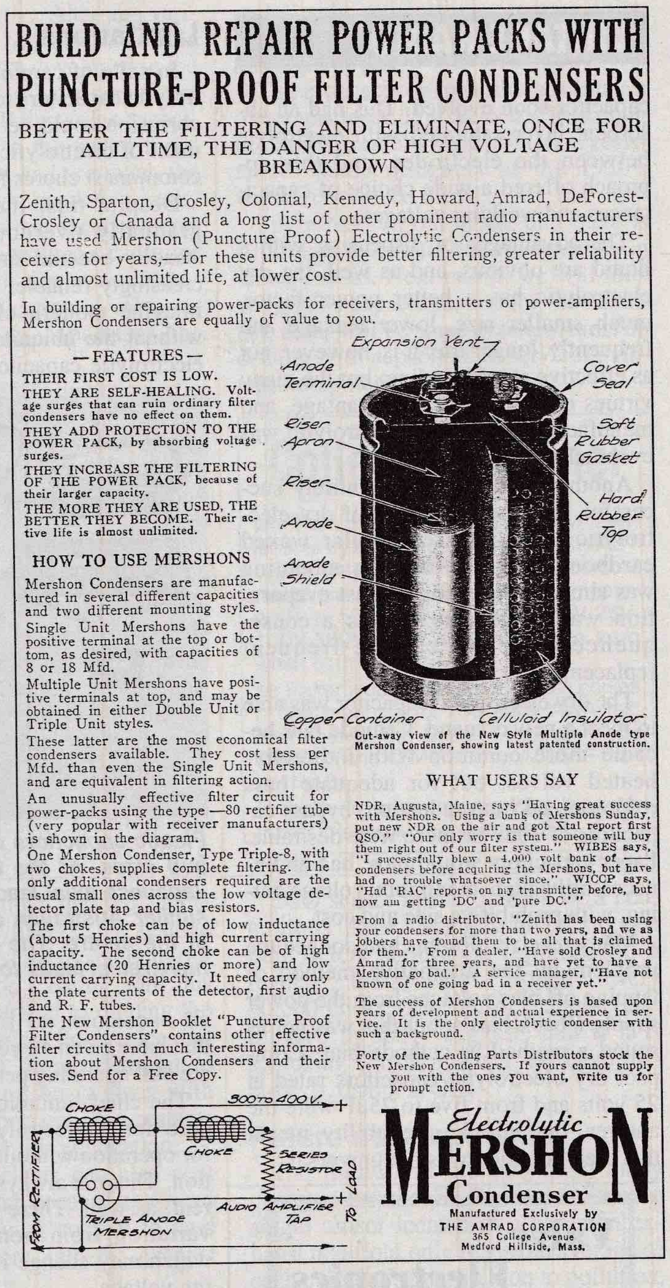
The demand for battery eliminators diminished with the advances in AC valve production, but the high tension supplies of the new receivers still needed hum filtering. Paper capacitors were satisfactory, but expensive and restricted to relatively low values of capacitance.

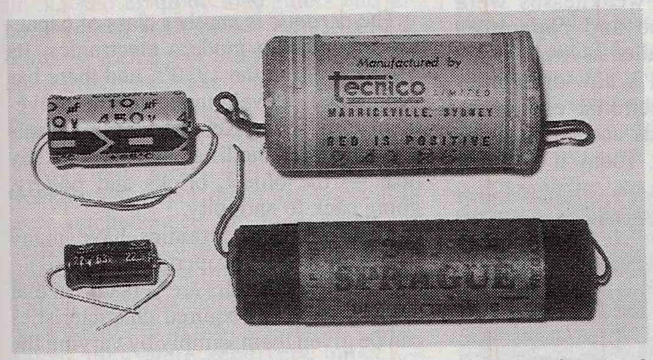
A common arrangement was to use two quite large chokes with paper filter capacitors, rarely larger than 4uF and frequently smaller. Low value capacitors had to be used with high inductance filter chokes.

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.)

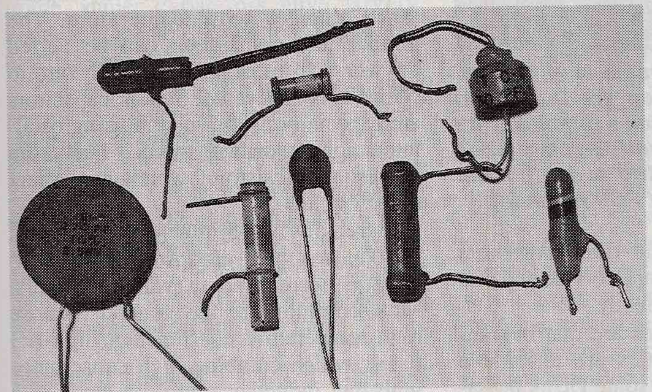
There was some economy in using input chokes tuned to ripple frequencies, but any system was complicated, and a capacitor failure could be very expen-

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.

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.

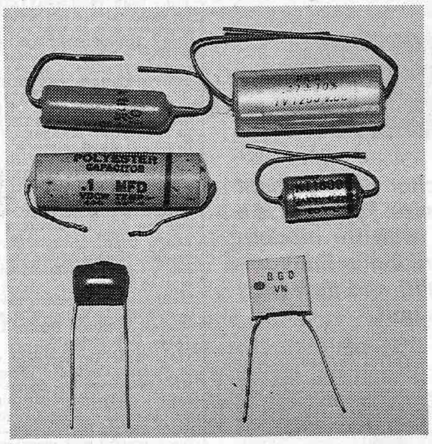
The dry electrolytic capacitor was able to meet a new demand. Cathode bias became more common with indirectly-heated valves, but for adequate bass response and hum reduction, bypass capacitors of 10uF or more were desirable. Paper capacitors would have had an unnecessarily high maximum voltage rating, 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 all uncommon to find filter capacitors that have given 40 years' service and that are still operating perfectly.



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.

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. ❖

Collector's Corner

Mr Brian Baker, of Russell, New Zealand, is trying to restore a University AST Signal Tracer, and needs a replacement meter movement. The meter is apparently a 500uA type, reading 5V-25V-100V-500V each side of centre zero when correctly set.

Mr Baker would also like to obtain copies of the manuals for two early AWA test instruments: the Signal Generator type 2R/7003 and Q Meter type A50589 (Serial No.8).

If there is anyone who can help Mr Baker, please write to him c/- *EA*.

Ego Tester

Continued from page 50

remains *high*, this indicates a rich mixture that is possibly caused by excess fuel pressure — or by the ECU again, as a result of either incorrect input sensor information or an ECU fault.

Sensor faults

There are two main causes of EGO sensor failure. These are by contamination, or physical damage. There are several ways that sensors can become contaminated, mostly from carbon, lead or silicone. Short runs on rich mixtures where the EGO does not reach its self-cleaning temperature (around 450°C) will cause carbon to build up in the sensor, making it ineffective. A good hard run should heat it up and burn off any built-up carbon.

Lead 'poisoning' of the EGO occurs when leaded fuel is used instead of ULP (unleaded petrol). Minor contamination can be removed by reverting to ULP use, followed by another 'good hard run'. Continued use of leaded fuel will eventually coat the sensor with lead, which will be impossible to remove.

When certain silicone sealants are curing, they release vapours (say from a manifold or rocker cover gasket). If these vapours are drawn into the engine and burnt in the cylinders, the residue flows out the exhaust valve and onto our waiting EGO sensor. Coating with this residue can be compared to dipping the sensor into molten glass (looks nice, but won't work again). It is important to practice safe sealing on engines with these types of sensors; use only sealants that are specified for this application.

Glycol-based coolants can also coat the sensor. This can occur if the head gasket blows, allowing coolant to pass through the cylinders, into the exhaust — you know the rest.

Turning now to physical damage, hard knocks to the engine or exhaust system both carry the potential to crack the zirconia thimble. Be careful if air chisels and the like are used to remove exhaust system components. Ensure that the sensor is clean externally, with no mud or paint etc., blocking the atmospheric vent. Another one to watch is damage from an ohmmeter. One sensor manufacturer tells me that a current flow of only 10uA (0.00001 amp) flowing through the EGO sensor will 'blacken' (that's another word for stuff-up) the zirconia, which causes it to lose its 'ion gathering' properties. This much current is easily supplied by most multimeters when they're set for the 'ohms' ranges.

EGO sensor ageing is a bit of a contentious issue. Many sources suggest that EGOs should be replaced on a regular basis, say around every 80,000 clicks. The sensor manufacturer referred to above suggests that if it is switching (in the manner we have discussed), then it is OK.

Future developments

The future will probably hold many changes for the EGO sensor. Since a single sensor located in a common exhaust manifold only reads the average of each cylinder's contribution to pollution, it cannot possibly compensate for the individual needs of each cylinder. As emission restrictions tighten up in the short years ahead, individual cylinder sensing of some kind is inevitable.

Another area of obvious change will be the development of sensors which can successfully measure leaner mixtures, for the coming generation of lean-burn engines.

I guess there is a lot more that could be said for this little device, but that is all I have for now.

I hope this subject has been of interest to those involved in the 'more traditional areas of electronics'. Incidentally, did you know that automotive engines still use valves? ❖