Reforming and Testing High Voltage Electrolytic Capacitors

I have a number of old high voltage electrolytic capacitor and was interested in see if they were still good. Below are some of my observations. The intension was to reform them and test them for capacitance, leakage and effective series resistance (ESR). I also wanted to use some of my older test equipment I had available.

For the reforming, capacitance and leakage tests I used an EICO 650B resistance/capacitance bridge.* It is capable of producing over 500 VDC for the reforming and leakage test. To measure the leakage current a Motorola S1063A DC Multimeter was used. Its lowest current range is 1µa FS and this was more than adequate. To monitor the voltage while reforming and leakage tests I used a Triplett 630A VOM. If you try this remember the voltage is very high you need to be careful here. Another warning: Make sure the capacitor is completely discharged after the leakage test. It's not only dangerous but you could blow up some of your equipment when doing the other tests.

For the ESR tests the equipment was a little newer, a Krohn-Hite function generator and an INSTEK oscilloscope. The W2AEW method was use for the testing. **

To determine the acceptable amount of leakage current I used the formula I=.01 x C x V where I is in µa and C is in µf. For the ESR test I used a limit of 1.5 Ω. These seem to be generally accepted values. I am sure all would not agree.

For the reforming I slowly increased the voltage on the capacitor while monitoring the current until the capacitor's maximum working voltage was reached and then waited until the current no longer decreased. This could take a while. I did not want the capacitor to draw to much current while reforming although the EICO cannot source a lot of current. This reforming differs from the more conventional approach of supplying the capacitor its rated working voltage through a current limiting resistor.

The first capacitor tested was a NOS two section Mallory "can" type with a stated capacity of 100 µf at 500 working volts and 30 µf at 450 working volts. The date code indicated it is 1968 vintage. Both sections were charged up to their rated working voltage. Reforming of the 100 µf section took about 6 hours and the final leakage measured was 350 µa. According to the formula above the accepted leakage was 500 µa. The ESR was measured at 0.6Ω. The capacitance was measured at 95 µf.

The 30 µf section took about an hour to reform and the final leakage was 95 µa with an acceptable leakage of 135 µa. The ESR was measured at 1.17 Ω. The capacitance was measured at 30 µf.

A 40 µf dry electrolytic that has a rated working voltage of 450 was the next to be tested. It was removed from a 1950's vintage piece of test equipment because it was old. It did not need reforming. The capacitance was measured at 40 µf. The leakage was measured at 130 µa at 450 volts and the acceptable leakage according to the formula above is 180 µa. The ESR was measured at 0.86 Ω. These test results are not bad for a capacitor that is around 70 years old. If I knew these results before I replaced it, I probably would have left it in.

Next was another dry electrolytic capacitor manufactured by Sangamo. I don't know its manufacturing date but I think it may be 1960's vintage or before. It has two sections both 35 µf at 450 working volts. I don't know the chemistry behind the typical dry electrolytic capacitor but this one definitely benefited from reforming, however, it did not meet the objective. The goal for this one was to get the leakage below 157 µa. It was measured at about 190 µa at rated voltage although it may have gotten a little better if I let it reform longer. The ESR was measured at 1.02 Ω. I did not test the other half of this capacitor.

The last vintage electrolytic capacitor was an Aerovox dual 20 µf at 450 working volts. I don't know the manufacturing date but I have had it for many years. The goal for the leakage was less than 90µa. Neither section took very long to reform. The leakage for the first section was 15µa with a measured capacity of 20 µf and an ESR of 2.3 Ω. The leakage for the second section was 23µa with a measured capacity of 20µf. The ESR was measured at 2.24 Ω. These results were good except for the ESR.

As can be seen two of the four capacitors met the objectives. The dual Aerovox did not meet the ESR goal but it wasn't terrible. I would try it as a replacement capacitor. I'm guessing it would work fine.

There's still a lot more to be tested but it's time consuming so I'll wait until I need them to do that.

To get an idea what new capacitors would test like I tested a new Cornell Dubilier 476TTA450MRZ, 47 µf 450 working volts aluminium electrolytic. Its leakage was 211 µa at 450 volts and the ESR of 0.65 Ω. The capacitance measured was 47 µf. Of interest was the ESR specified in their spec sheet of 8.82 Ω. The test frequency they chose of 120 Hz is the result of the full wave rectification frequency in the North American power system. The high ESR seen in their spec sheet I assume is the result of the low test frequency used. Test frequency for the above tests I did was 200 kHz.

I tested one more new capacitor to see if the results were consistent. This one was a Cornell Dubilier 336TTA450M, 33µf 450 working volts aluminium electrolytic. Its leakage was 70 µa at 450 volts and the ESR of 0.27 Ω. The capacitance measured was 36 µf. The ESR specified in the spec sheet is 12.56 Ω. The ESR reading is consistent with the above CD capacitor.

While doing the above measurements I decided to replace the line cord on the EICO 950B with a three conductor. A fuse and holder was also added. For interest I checked the wax 0.01 µf "death" capacitor that was in it. It measured 0.015 µf and the leakage was 0.8 µa at its rated working voltage of 400.

Personally if I had the time and patience, I probably would test old electrolytic capacitor before blanket replacing them. This includes considering the cost and delivery time for new electrolytic capacitors, although, I can see why in many cases a blanket replacement is a good idea. If the equipment was recently in use reforming should not be required and this would save time.

* Note: This thing is a bit of a safety hazard for a number of reasons. Apparent safety wasn't a concern in the 1950's when this was built. Also, the critical internal parts used in the bridge circuit have been updated to provide the instrument with reasonable accuracy.

** Note: If you use a function generator to do the ESR tests you might want to consider confirming its output impedance. It really doesn't matter what it is (within limits) as long as you know what it is. Don't rely on the manual, I would check it. It could be out of spec and you wouldn't know it. This can easily be done with a decade resistance box that has good accuracy. Connect the resistance box to the generator and adjust the box until you get half the open circuit voltage and read the resistance indicated. Another easy way of testing and I think a better way is with an accurate 1 Ω resistor. This tests it with a practical load. Set the function generator and oscilloscope up like you would if you were testing a capacitor and see if you end up with 1 Ω. Also, you are dealing with low resistances, keep in mind lead resistance.

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