Part 1 - Condenser Construction and Failure Modes

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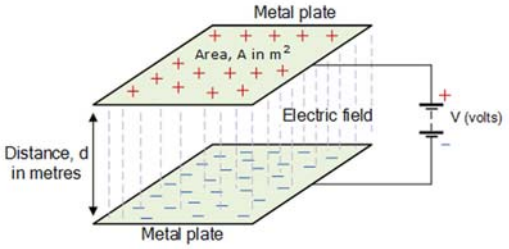
Anyone that has repaired a number of old outboards will know that when you are doing a complete “rebuild” of an old motor, you almost always have to replace the condensers. They are a VERY high failure rate part! And, if the manufacturer of your motor went out of business 40 years ago or more, you might have serious problems finding functional replacements. (Just be cause an old condenser was never used, that doesn’t mean it’s good! Finding old condensers that are GOOD is a challenge!) So, I’ve written a four-part series on Condensers, to help you understand these failures, and what you can do about them! This series will include the following sections:

Part 1 - Condenser Construction, and Failure Modes
Part 2 - Condenser Testers, and Testing Condensers Correctly
Part 3 - Sizing Condensers Correctly (When The Original Value Isn’t Known)
Part 4 - Repairing Broken Condensers (Yes, it CAN be done, even the tiny ones!)

SO! Here we go with Part 1 – in which I will attempt to describe WHAT condensers are, HOW we wound up with these high-failure-rate devices, and WHY their failure rates are so high. (Don't worry, the later chapters will give you good solutions!)

First of all, what is a “condenser”? Well, a “condenser" is just an old-fashioned name for a CAPACITOR, which is a small electronic component that can store an electric CHARGE on a couple of metal plates, that are insulated from each other. In the simplest arrangement, you can build a capacitor with two flat metal plates separated by air. If you connect a battery to these two plates, it will drive electrons onto one plate of the condenser. Since **like charges repel** each other, this will push some electrons off of the other plate, into the other side of the battery. Unlike your battery (where the charge is created by a chemical reaction), in a condenser, the charge is created by the Electric Field between the two plates. (See Fig. 1 below for details).

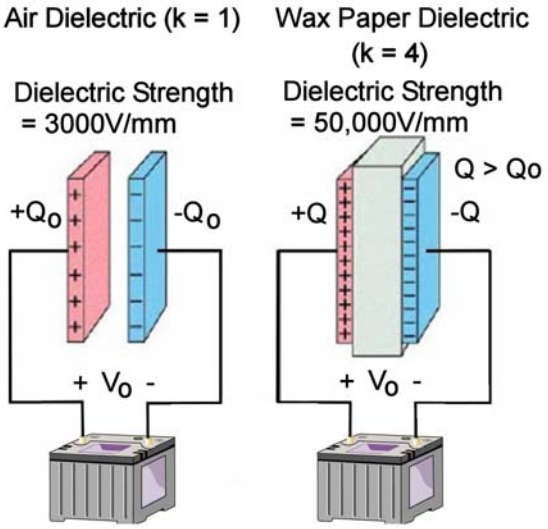


$$C = E^*K^*\frac{A}{d}$$

Where C is in Farads,
E is 8.85 pF/meter
K (dielectric constant) of air is 1.0
A (area) is in meters ^{2}
d (distance between the plates)
in meters

Fig. 1 - Parallel Plate Capacitor

However, this simple “parallel plate” capacitor isn't very practical. Yes, you COULD make one large enough to work on an outboard motor magneto, **but to build one large enough to measure 0.22uF (the standard condenser size for 1930s and newer outboards), a parallel plate capacitor would have to be 6.78 square feet (31 inches by 31 inches) in size. This wouldn’t fit inside a typical outboard very well, to say the least.** And, the reason why is that air isn’t a particularly good insulator. MANY different insulating materials could be put between those two metal plates, and would keep electrons from jumping between the plates much better. And, as a bonus, some of these insulators (also known as "dielectrics)", actually make the capacitor work BETTER and store more charge for a given plate size, than they could if you just had air separating the plates. Let’s take a closer look at why Wax Paper was often used to separate the metal plates in outboard condensers. See Fig. 2, below:



Adding an insulator between the plates:

1) Allows the plates to be placed 10 times closer without arcing between the plates. With "d" 10 times smaller, C can now be 10 times larger, for a smaller capacitor physical case size.
2) The insulator has a "K" factor larger than 1.0 (air), so this directly multiplies the capacitance value by 4.00, in this example.

Fig. 2 - Adding an Insulator (Dielectric)

As you can see, by putting wax paper in between the plates of a condenser, you get the following advantages:

1) You can put the plates 10 times closer without electricity jumping across the plates. With the plates 10 times closer, you can make the condenser 10 times SMALLER than a condenser made with air as the insulator, and get the same capacitance value.
2) With wax paper in between the plates, the electrons in the one plate "push against" electrons in the wax paper, and those (in turn) push against the electrons in the other

metal plate. As a result of this, the presence of an insulator between the plates INCREASES the capacitance of the condenser, by a factor known as "K"….also known as the "dielectric constant" of a given material. In this example, just switching from air to wax paper multiplied the capacitance of our condenser by a factor of four. (OR, it would allow us to make the same VALUE of condenser, and make it ¼ the SIZE of the original!)

3) By making your condenser out of wax paper and tin foil (which are both FLEXIBLE), the condensers can now be built as a ROLLED-UP COIL, making it VERY COMPACT compared to your simple "air insulator" condenser. This is a huge advantage.

Historically, there have been three generations of condensers used in outboard motors. In the very earliest outboards, some condensers were made from Mica insulators (dielectrics) and tin plates. By the 1910s, much thinner tin foil was used, separated by wax paper. And, ever since the 1950s, almost all condensers have been made with Mylar (polypropylene and other plastic films) with aluminum foil used in the metal plates. (Fig. 3, below, shows these different construction techniques.)

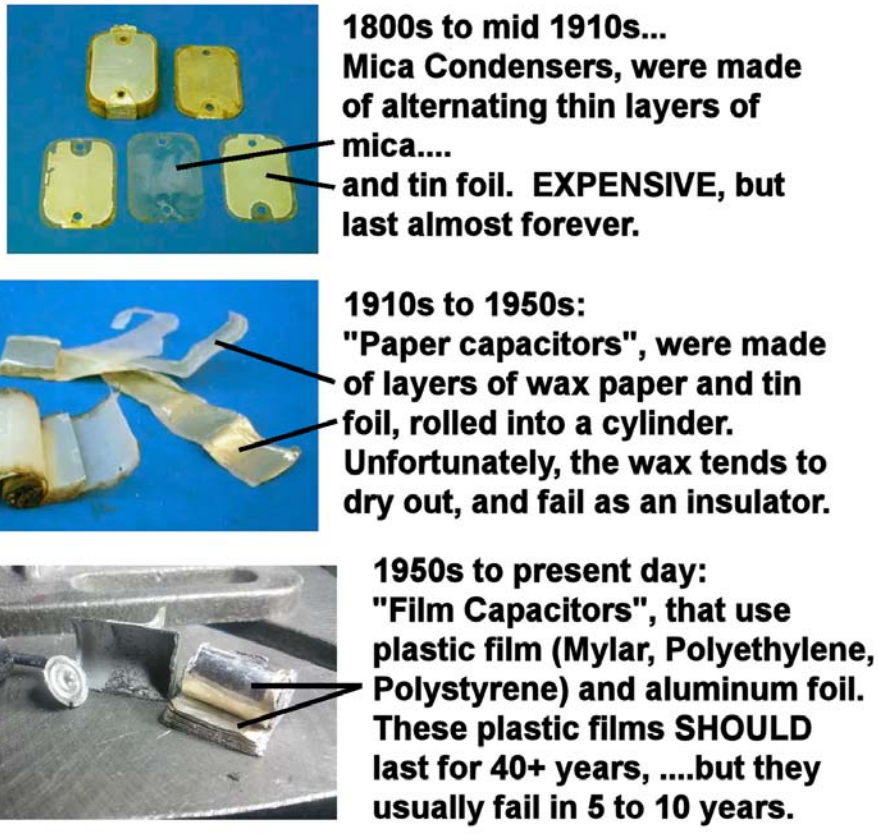


Fig. 3 - History of Condenser Construction

Mica-based capacitors were extremely reliable, but also extremely EXPENSIVE to manufacture, and were somewhat mechanically fragile. From the 1910s on for several

decades, condensers were built with layers of wax paper as the insulator (dielectric), wound in a tight coil with thin layers of tin foil. These were very inexpensive to build. However, the wax in the wax paper tended to dry out, and when it did, it would fail to work as an insulator, allowing electricity to "arc" through it between the plates, and the condenser would fail. And, the wax tended to dry out very quickly, often in just 2 or 3 years. See Fig. 4, below, for details on how these metal foil / mylar condensers are constructed:

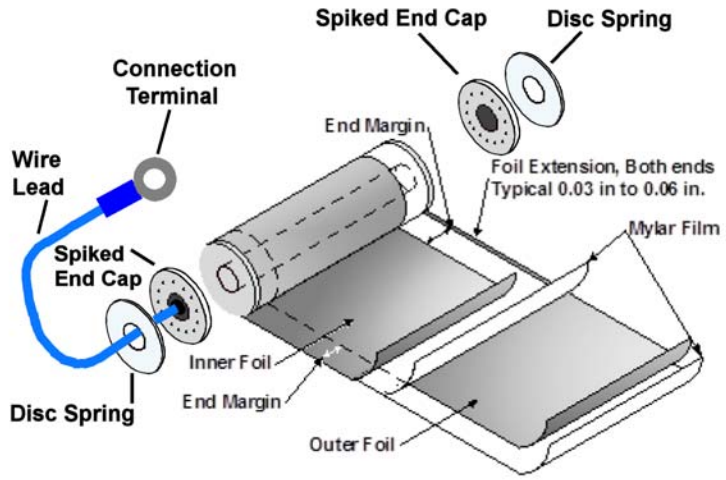


Fig. 4 - Construction of "Metal Foil Mylar Condenser"

Ever since the 1950s, though, condensers have been built with aluminum foil, with some type of plastic film between the plates. (Polypropylene, polystyrene, polyethylene, and several other compounds…..many under the generic name "Mylar film"). And, almost all condensers manufactured today are built with very similar construction techniques. See Fig. 4, below, for details on Mylar Foil Condenser construction:

Split apart almost any condenser today, and this is what you will find. (Well, that is, unless you cut open one of the really cheap units built in India and China. Many of those don't have the springs or spiked end caps, and because of this their electrical connections are very "iffy", to say the least.) But, QUALITY condensers will almost all be built like the picture above.

Now, compared to Wax Paper (that dries out in just a couple of years, and fails)….Mylar film is **really stable.** *Theoretically*, Mylar film condensers should have a service life of about 40 to 50 years…....and yet, they often only have a service lifetime of 4 to 5 years, and a shelf life of only about 10. Why is this? What could possibly cause a mylar-film condenser to fail, in $1/10^{th}$ it's expected lifetime? (See Fig. 5 for details.)

Failure Modes of Metal Foil Plates (RARE!)

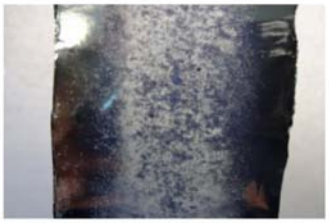
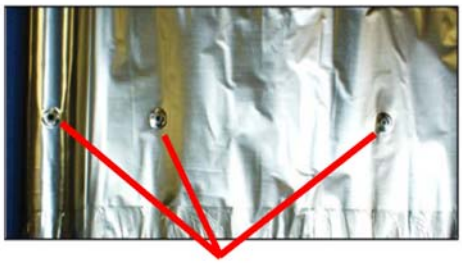


Plate failure due to corrosion.

Plate failure due to corona discharge (high voltage + air gaps in the windings)

Dielectric Punch-Through Failures in Film Condensers (VERY common!)



Pinholes / arcing through the film insulation. (75X magnification).

Fig. 5 - Failure Modes of Condensers

So: Here are the failure modes you typically encounter:

1) **Simple corrosion.** While many condensers have rubber plugs to keep moisture out, many don't, and none of them are hermetically sealed. Eventually water gets into the condenser, and the metal elements can simply corrode apart. This is a RARE failure mode, though, as aluminum doesn't rust.
2) **Corona discharge.** This is an oddball effect, caused by air trapped around the mylar film, in the presence of very high voltages. This can cause arcing and 'corona discharge' on the edges of the foil, causing the foil to recede. However, in outboard magnetos, the voltages are usually far too low for this to be much of an effect. (I've NEVER seen this kind of failure in an outboard application.)
3) **"Dielectric punch-through".** Theoretically, the mylar film in a condenser should last 40 to 50 years. **However, if they make the film VERY THIN,** and then stretch or "kink" or bend it tightly, it can cause mechanical stresses in the film. These stresses, combined with water vapor and high electric fields, can cause de-polymerization of the mylar file. (That is, the plastic just chemically "breaks down" under these conditions.) Now note, the bend radius of the mylar film is TIGHTER near the center of the condenser, compared to the outside edges. As a result, the windings of the condenser near the center are under more mechanical stresses than the outside windings…and so THIS is typically where the "punch-through" occurs**. It doesn't take much mechanical stress and voltage combined over much time for the plastic to fail…..and then, just like a Wax Paper condenser, the electrons just start "jumping through the holes",**

and your engine's ignition starts to become "erratic" and fail in very mysterious ways.

About 99+% of your outboard condenser failures will be of this type, where the mylar insulation has broken down over time, and electricity is "arcing" between the metal plates. **This is a serious problem, because most capacitor testers will say that your condenser is good (and give you the capacitance VALUE in microfarads of your condenser), when the condenser is actually BAD.** The reason why is because most capacitor testers only test with 1 or 2 volts across your condenser during the test. In your outboard motor, it's not unusual to find 400 volts peak-to-peak across your condenser, or even slightly higher when your engine is running. **So, in order to certify that a condenser is "good", you not only have to measure it's CAPACITANCE, you also have to test it for insulation breakdown at high voltages.** (In Part 2 of this Condenser series, I'll explain how to test condensers correctly, and the types of test equipment needed to do this.)

Well, now THIS is annoying. Condenser manufacturers *could* just use film that's 2 or 3 times thicker to begin with, and NOT wind the condenser so tightly in the middle. The condenser would wind up being 2 times normal size, and would cost a bit more to manufacture, and it would likely last a good 40 or 50 years. Just one problem…..there aren't many condenser manufacturers around anymore, and there just isn't any financial motive for them to make any manufacturing changes at THIS late date, for this small of a market.

So, like it or not, if you want to get an old motor to run, you'll have to find condensers of the correct size AND VALUE that will fit your old motor…...and these condensers also have to be GOOD. And, therein lies another hidden problem; finding good (old) condensers. You'll find that about half or more of the old condensers you buy on e-bay (or other surplus outlets) will NOT pass an insulation breakdown test, and won't work well in your motor, if at all. There are only two solutions to this:

1) Find a REPUTABLE supplier of old-style condensers that can be trusted.
2) REBUILD your old condensers.

In the AOMCI, there are many people that sell used condensers. I don't know the history of all of these people, and whether they sell tested, good condensers (or untested units, likely to be "duds".) What I can tell you is that many of us in the AOMCI Western Reserve Chapter often turn to one of the only remaining manufacturers of QUALITY condensers in the world, which is Standard Magneto out in Wood Dale, Illinois. Phone number for them is: 1-800-MAGNETO (1-800-624-6386). Standard Magneto purchased Weico Condensers years ago, and still manufactures many of their old parts. So, if you want NEW condensers for your old outboards, this is one really good resource to look at. (By the way, Weico was formerly Prestolite, that you might remember was the company that manufactured many of the highest-quality condensers for old Mercurys

back in the day). If you call Standard Magneto, ask to speak with Rich Malin. Rich is a good friend of the AOMCI, and he's one of the best resources for old magneto parts you can find…..(not just condensers, he can get you replacement coils and other really hard to find parts as well. Ask him; you'll be surprised at what he can find for you!)

If Rich at Standard Magneto can't help you, then you will have to turn to e-bay and the surplus market. If you do, though, the old saying "caveat emptor" (let the buyer beware) certainly applies. This is the principle that says that the buyer alone is responsible for checking the quality and suitability of goods before a purchase is made. And so, in Part 2 of this Condenser Series, I'll explain exactly that: WHAT types of test equipment are needed to test condensers correctly, and HOW to correctly perform these tests.

See you soon for **Part 2** - **Condenser Testers, and Testing Condensers Correctly!**

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