A great deal of confusion still exists regarding metallized dielectric capacitors. This is unfortunate because this confusion has resulted in the exclusion of a most valuable tool from many circuit designs.

The electrodes in a non-metallized design are separate sheets of metal foil wound with sheets of dielectric material. These electrode sheets (foils) extend alternately out each end of the capacitor roll beyond the dielectric. This provides a mass of metallic material to which leads are attached by welding or soldering.

The metallized type of construction greatly reduces the physical size of the capacitor. The aluminum or tin foils are replaced with a thin layer of 99% pure aluminum vapor-deposited directly onto the dielectric. Provisions are made, by means of masking, to provide each dielectric with a margin. The two sheets of metallized dielectric are positioned properly relative to a right and left margin and wound into a roll. Since the dielectric material itself is present at each end of the wound capacitor along with the metal electrode material, direct attachment of the leads is not done.

The end terminations of the metallized unit are accomplished by application of a fine molten metal spray. The spray makes contact with the electrode material resulting in the plate contact. The lead wires are attached to this metal spray.

![Physical Construction](image)
VOLUMETRIC EFFICIENCY

The construction of the metallized design is quite similar to that of a non-metallized design except for the slight differences in the electrodes and end terminations. The volumetric advantage of the metallized design is self-evident due to the physical reduction of total electrode material. The advantage is more evident and becomes more pronounced as the capacitance value increases.

There is little volumetric advantage evident in smaller capacitance values because the end terminations, casings, and end seals, which are approximately the same for both types of units, form a disproportionate part of the total volume. Table 1 compares the approximate volumetric ratio for various values of capacitance between the metallized and non-metallized designs. All the example capacitors are wrap and fill style, 200 VDC rated, polyester dielectric.

<table>
<thead>
<tr>
<th>Capacitance (Mfd.)</th>
<th>Metallized Unit Volume (Unity)</th>
<th>Non-Metallized Volume - Ratio to Metallized Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>.001</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>.01</td>
<td>1</td>
<td>1.28 (28% larger)</td>
</tr>
<tr>
<td>.10</td>
<td>1</td>
<td>1.50 (50% larger)</td>
</tr>
<tr>
<td>.47</td>
<td>1</td>
<td>1.77 (77% larger)</td>
</tr>
<tr>
<td>1.0</td>
<td>1</td>
<td>1.88 (88% larger)</td>
</tr>
<tr>
<td>2.0</td>
<td>1</td>
<td>1.94 (94% larger)</td>
</tr>
<tr>
<td>10.0</td>
<td>1</td>
<td>2.33 (133% larger)</td>
</tr>
</tbody>
</table>

Table 1

The volume of the metallized design is set as unity, and the volume of the non-metallized design is then expressed as an equivalent ratio.

It should be noted that the metallized unit is not voltage stressed (volts per mil of dielectric) higher than the non-metallized version. The increasing nature of the percent volume difference with increasing microfarads is due to the difference in the total amount of electrode material wound into the units. The thickness of the electrodes in the metallized capacitor is approximately two millionths of an inch, or about 100 times thinner than the non-metallized designs.

SELF HEALING PROPERTY

The self-healing feature of the metallized capacitor offers a distinct advantage over the non-metallized unit. This self-healing feature is a result of the extreme thinness of the metallized electrode material. Whenever a flaw or weak spot in the dielectric results in a short condition, the stored electrons in the capacitor and the associated circuitry will immediately avalanche and cross at the shorted point. The electron density concentration results in an extremely high current condition which in turn provides sufficient energy in the form of heat to vaporize the thin metallic electrode. The vaporized electrode forms a fairly concentric pattern away from the point of the short. As a result of the vaporization, the short condition is removed and the capacitor is again operational. This is known as a “clearing” which is the self-healing process.

To illustrate this process Figure 2A represents a greatly enlarged section of a capacitor containing an extremely thin spot in one of the dielectric sheets. In this case, it is the result of two valleys on opposite sides of the dielectric surfaces coinciding at a point. This is an example of the distance between the electrodes at a thin spot that is not capable of withstanding the voltage stresses—thus a short develops. The “self-healing” or “clearing” action vaporizes the metal electrode sufficiently; therefore, the effective distance between the electrodes increases, the short is removed, and the capacitor is again a “good” unit (shown in Figure 2B).

There are two factors to be considered relative to a self-healing or clearing action. There must be sufficient energy present to accomplish this clearing action and during the process, the circuit will experience a small, short-duration, transient voltage drop.
ENERGY REQUIRED TO CLEAR

The energy required for an average or "normal" clearing is approximately 10 microwatt-seconds. This means that if energy is available only from the capacitor itself, there is a relationship between the capacitance rating and the magnitude of the charging voltage below which clearings may be questionable.

The relationship is illustrated below for both normal clearing (10 microwatt seconds) and clearing requiring 10 times the energy (100 microwatt seconds).

\[ W_o = \frac{C E_o^2}{2} \]

(Clearing energy available from the capacitor)

\[ E_o = 1.414 \sqrt{\frac{W_o}{C}} \]

where:
- \( W_o \) = Energy to clear (microwatt-seconds)
- \( C \) = Capacitance (microfarads)
- \( E_o \) = Charging voltage (volts)

<table>
<thead>
<tr>
<th>Capacitance (Microfarads)</th>
<th>( E_o ) (Charging Voltage) For ( W_o = 10 )</th>
<th>( E_o ) (Charging Voltage) For ( W_o = 100 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>1.4</td>
<td>4.5</td>
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<tr>
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<td>4.5</td>
<td>14.1</td>
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<tr>
<td>.1</td>
<td>14.1</td>
<td>44.7</td>
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<td>.01</td>
<td>44.7</td>
<td>141.1</td>
</tr>
<tr>
<td>.001</td>
<td>141.4</td>
<td>447.2</td>
</tr>
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</table>

Capacitor Voltage Drop During Clearing

Given:
- \( C \) = Capacitance
- \( E_o \) = Capacitor voltage before clearing
- \( E_d \) = Voltage drop during clearing
- \( E_f \) = Capacitor voltage after clearing
- \( W_o \) = Energy required to clear

And we note:
- \( \frac{C E_o^2}{2} \) = capacitor energy before clearing
- \( \frac{C E_f^2}{2} \) = capacitor energy after clearing
- \( E_f = E_o - E_d \)
The energy required to clear the capacitor will be the difference between the energy before and after the clearing:

\[ W_o = \frac{CE_o^2}{2} - \frac{CE_d^2}{2} = \frac{C}{2} (E_o^2 - E_d^2) \]

and, since \( E_d = E_o - E_d \):

\[ W_o = \frac{C}{2} (E_o + E_d) (E_o - E_d) \]

\[ W_o = \frac{C}{2} (2E_o - E_d) (E_d) = \frac{C}{2} (2E_oE_d - E_d^2) \]

rearranging: \( E_d^2 - (2E_o) E_d + \frac{2W_o}{C} = 0 \)

we note that \( E_d \) can be derived from the quadratic formula:

\[ E_d = \frac{2E_o \pm \sqrt{4E_o^2 - 8W_o}}{2} \]

\[ E_d = E_o - \sqrt{E_o^2 - \frac{2W_o}{C}} \]

(since the positive root is not applicable)

Assuming a normal clearing energy requirement of 10 microwatt-seconds, our formula reduces to:

\[ E_d = E_o - \sqrt{E_o^2 - \frac{20}{C}} \]

and, substituting values for \( E_o \) and \( C \), we chart the voltage drop as follows:

<table>
<thead>
<tr>
<th>Capacitance (Microfarads)</th>
<th>100 VDC</th>
<th>200 VDC</th>
<th>400 VDC</th>
<th>600 VDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>.01</td>
<td>10.56</td>
<td>5.07</td>
<td>2.51</td>
<td>1.7</td>
</tr>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>.65</td>
<td>.25</td>
<td>.17</td>
</tr>
<tr>
<td>10.0</td>
<td>.01</td>
<td>.05</td>
<td>.025</td>
<td>.017</td>
</tr>
</tbody>
</table>

* Stored energy not sufficient to clear

years without clearings during its service life. This is because both voltage and temperature derating will tend to minimize the short producing condition necessary for the initiation of the self-clearing process.

The dielectric itself will have a strong controlling effect on these self-healing occurrences. For instance, under accelerated life test conditions, a metallized polyester dielectric unit will exhibit considerably less clearings than a metallized polycarbonate device.

**SUMMARY**

**Disadvantages of a Metallized Capacitor:**

1. The dissipation factor is slightly higher than that of a non-metallized unit.
2. The insulation resistance is slightly lower than a non-metallized unit.
3. The metallized unit maximum current limitation is lower than its non-metallized equivalent unit.
4. The maximum AC voltage-frequency capability of a metallized unit is slightly less than its non-metallized equivalent unit.

**Limitations of a Metallized Unit:**

1. Under a clearing operation situation, sufficient energy must be present to accomplish this function.
2. During a clearing operation, the resulting transient drop in voltage must be considered in the application.

**Advantages of a Metallized Unit:**

1. The self-healing feature of a metallized design enables the metallized unit to remain operational after a short condition develops. In a non-metallized unit, the short condition results in a catastrophic permanent failure.
2. The volumetric efficiency of a metallized unit is higher than its non-metallized equivalent unit.
3. In direct proportion to the volumetric efficiency is the weight savings realized with a metallized unit.
4. The cost of a metallized unit in the higher microfarad ratings (above 0.1 Mfd) is less than its nonmetallized equivalent unit.