EMI Capacitor Design and Performance

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<u>**EMI capacitor, design and performance**</u>

Capacitors are normally classified by the dielectric used, tantalum, electrolytic, paper, ceramic and so on. However there is one particular capacitor identified by its application area. It is the capacitor for electromagnetic interference suppression or EMI capacitor. In the typical application the capacitor is a part of a simple L-C net work between the equipment and the main's power supply.

The standards for approval of EMI-capacitors are EN132400 or IEC 384-14 2nd edition. These standards set the minimum level for safety and performance. The design, material and production process, for such a capacitor is a matter for the capacitor industry to solve.

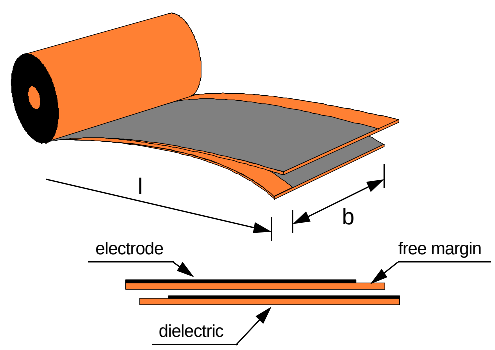
The most important decision in the design process is the choice of dielectric material.

Common dielectrics on the market for EMI-capacitors are

* ceramic
* metallized plastic film (polypropylene and polyester)
* metallized and impregnated paper

The discussion in this paper will concentrate on capacitors with metallized film.

The thickness of films in an EMI capacitor varies between 4 and 40 µm depending on class and rated voltage. The material in the metallized electrodes on the film is either Zinc, Aluminium or a combination of these materials. The thickness of the electrode varies between 80 to 300 Å (1Å = 10^{-10}m).



The films are wound to a capacitor element, namely a winding. To reduce the volume the winding is pressed flat. To obtain an electrical contact with the electrodes metal is sprayed on the end of windings.
Terminations are then welded to the sprayed contact and the finished windings are placed in a box. If the dielectric is metallized paper the winding is impregnated, in vacuum, with a special epoxy and becomes a solid capacitor element. All voids are filled with epoxy. If the dielectric is metallized plastic film, the volume between the box and the winding is filled with epoxy. The epoxy does not affect the hardness or the number of cavities in the winding.

The capacitor is now finished and its function, the reduction of interference signals, is the same for all technologies. The essential difference between technologies e. g. choice of dielectric, metallization, process parameters, impregnation or casting is the capacitor's safety performance when connected to the supply mains.

Safety performance relates to three incidents each of which could be catastrophic.

- ❑ **fire as a consequence of dielectric break-down**
- ❑ **fire as a consequence of bad contact between wire, endspraying and electrodes**

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- **short-circuit of Y-capacitor and a risk of exposing someone to dangerous electrical shock**

EMI-capacitors are connected to the mains supply and must be designed for the overvoltage, transients and high frequency signals that we all know exist on the mains supply. These requirements can be transformed into measurable design criteria.

* high resistance to current surges
* high resistance to voltages surges
* high resistance against ionisation

To design and produce a capacitor that complies with these requirements is a challenge for the capacitor industry.

<u>High resistance to surge current</u>

Peak current in a capacitor during a voltage surge is proportional to the rise-time of the voltage.

$$I_{peak} = C \times dV/dt$$

A typical capacitance value in application is C = 0.22 µF and a typical rise time for a transient is dV/dt = 2000 V/µs. This gives a peak current in the capacitor of 440 A. Even if the surge current lasts less than 1 µs it is obvious that there will be large stresses in contact areas and metallization. Performance depends on the thickness of metallization, metal and methods for spraying and welding of wire. A measure of a capacitor's ability to withstand current surge is the dV/dt value. Typical values for impregnated paper and metallized plastic film you can find in the table below. It is normal that the capacitor is tested with 10 000 pulses and du/dt value five times the specification.

dV/dt values in V/µs

Dielectric	Class					
	X1		X2		Y	
	spec	test	spec	test	spec	test
Impregnated paper	600	3000	600	3000	2000	10000
Plastic film	100	500	100	500	200	1000

You can see in the table that EMI-capacitors with impregnated paper as dielectric are tested with du/dt values well above the typical rise-time for transients.

<u>High resistance to voltage surges</u>

Several different studies show that frequently there are transients with an amplitude of several kilo-volts on the supply mains. In residential areas transients at 2.5 kV should be expected and in industrial areas between 3 - 6 kV. The frequency for the highest amplitudes is between 0.3 to 1 per year. Transients at the level of 2.5 kV can be expected 1 to 8 times per year.

A very important feature with metallized film capacitors is their ability to self-heal. When the dielectric breaks down there is, in principle, a channel between the electrodes that can be seen as a short circuit. The current or energy, increases very quickly, ~10 ns, from zero to a very high value, 100 - 200 mJ. The temperature in the channel increases to a point where the dielectric material near the channel and the electrodes evaporate.

The effect of this process is that the dielectric break-down insulates itself i.e. self-heals. The self-healing process depends on several factors such as electrode thickness chemical composition of dielectric and process parameters during manufacturing. It is verified in several investigations that impregnated metallized paper is the best qualified dielectric to self-heal.

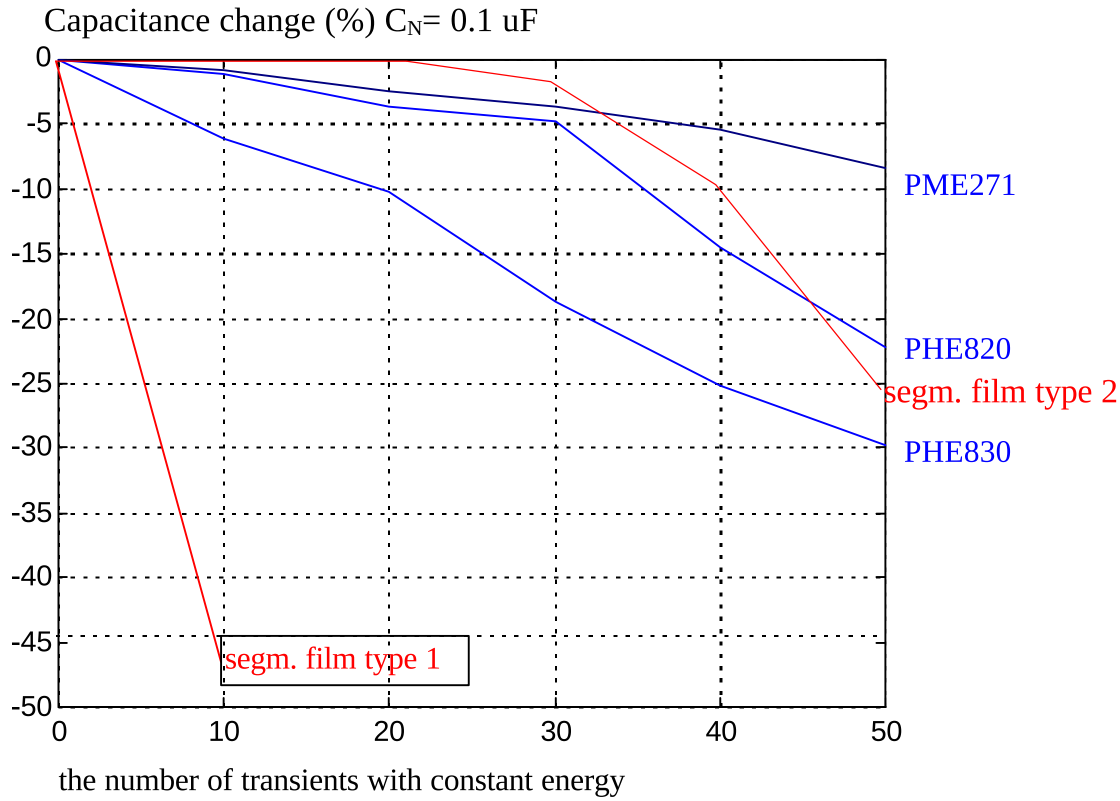
One way to improve the metallized plastic film capacitor's capability to self heal is to divide the electrodes into segments, encl.1 type 1 and 2. The intention is that when there is a dielectric break down in a segment the weak point will be insulated by breaking the connections to the adjacent segments. The technology is interesting and Rifa´s R&D department are investigating the performance of capacitors with segmented metallization.

There are several questions:

Shape of segments and connections
Capacitance stability as a function of the number of self-healings
Surface resistivity as a function of the number of selfhealings, e.g. low insulation across the winding

There are many questions but they can all be formulated into one single phrase **“is the design safe”?**

To investigate the capacitance stability the winding structures in encl.1 was tested with transients at 4-5 kV superimposed on the mains supply, result according to figure.



The test result clearly shows that after 50 transients the decrease in capacitance value in metallized paper capacitors is less than in the other designs. Design of segments and connection between them are important and can be seen by comparing the result for the different types of segmented film. None of the capacitors start to burn during the test.

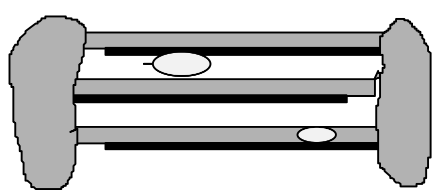
Clearly there has been a number of selfhealings in the plastic film capacitors during the test. It is also verified that the "fuse" between the segments in film of type 2 do not always function.

High resistance to ionisation

Ionisation is normally a destructive process and EMI capacitors should not operate in that condition.

There are three areas in a capacitor where ionisation is likely to take place:

1) air pockets in dielectric
2) air pockets between films
3) air pockets at the end spraying



When the field-strength in a cavity reaches a critical value there will be an electric break-down. The break-down voltage is called "Discharge inception voltage" and is a function of the gas pressure in the cavity and the size of the cavity, "Paschens law". In general the break-down voltage increases when the pressure in the cavity increases. Dielectric material responds differently to this.

Polypropylene is sensitive to ionisation. It is a soft material and it is difficult to build up a pressure to reduce the discharge inception voltage. The melting point is relatively low and there is a clear risk that the material could begin to melt and the capacitor becomes a short circuit.

Polyester is more resistant to ionisation. It is possible to build up the pressure required to suppress the ionisation.

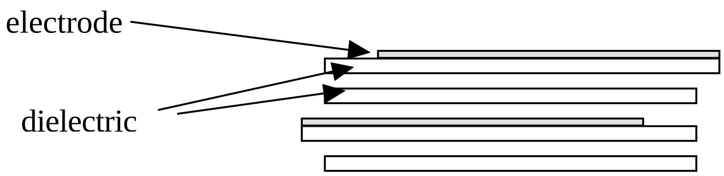
Impregnated paper contains, if properly impregnated, no cavities, - they are completely filled with epoxy. The capacitor is therefore very resistant to ionisation.

Conclusion

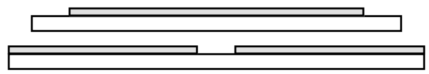
The test we discussed above is to complement the tests required by the standards EN132400 and IEC 384-14 (1993). Rifa believes that high resistance to surges and ionisation are important for the safety of a component that is connected to the mains supply.
The new design with segmented metallization is interesting. Rifa has the opinion that there should be further investigations regarding design rules before the technology can be used on the market place. It is absolutely necessary that the weak point in a segment is isolated by breaking the connections to the adjacent segments.

The capacitor on the market that fulfil all safety requirements in standards and application is a modern **impregnated metallized paper capacitor**.

Typical winding structures

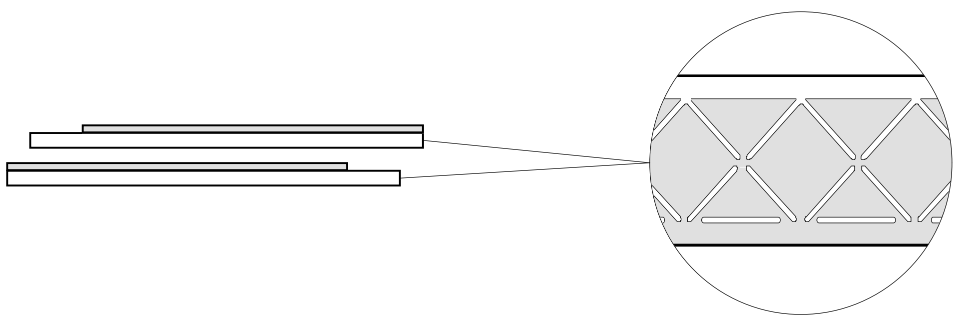


impregnated metallized paper (PME271)

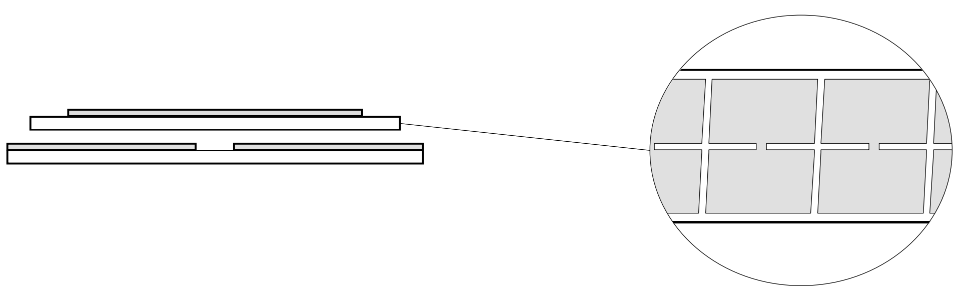


series-design metallized plastic film.
(PHE820 alt PHE 830)

Design with segmented metallization



Type 1



Type 2

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