

Aluminium Electrolytic Capacitors

History, Components,
Applications

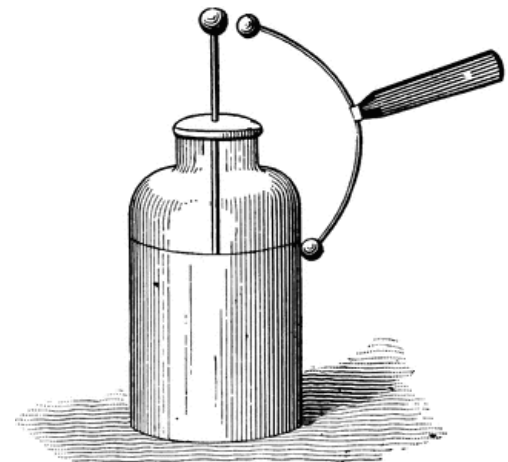
Luca Primavesi, Itelcond



6th Century BC - the charge by friction is described in a written record by Thales of Mileus. The Greek word for Amber is Elektron.



1745-46 - the Leyden Jar, the first device able to store energy, is independently discovered by two scientists, Ewald Jürgen Georg von Kleist and Pieter van Musschenbroeck.



1748 - the same magnitude and the opposite signs of the charge on the 2 conductors of a Leyden Jar, as well as the influence of jar shape on it is described on a letter by Benjamin Franklin.

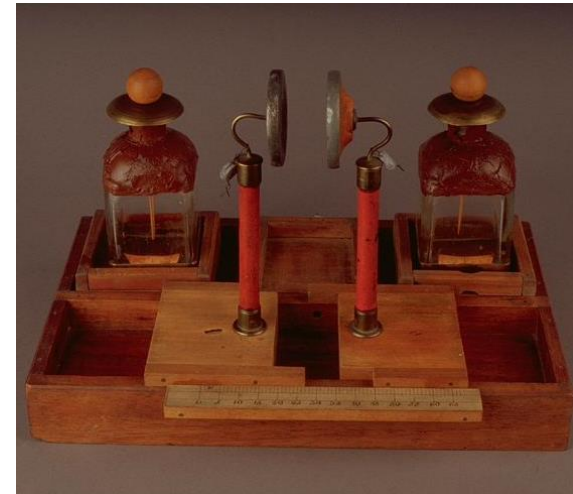
He also gave the name of Electrical Battery to a series of those elements, using what was then just a military term.



1775 – the Perpetual Electrophorus is described by Alessandro Volta in a letter.



1782 – the word Condenser (for the ability of the device to store a higher density of electric charge than an isolated conductor) is used for the first time by Volta during a reading at The Royal Academy of Science in London



1837 – the influence of different insulators in determining the capacitance to store electrical charge in an equipment is quantitatively measured by Faraday. The SI measure unit of capacitance is the Farad (one Coulomb per Volt).

1861 – the displacement current to describe how a change in electric field passing through a particular area can give rise to a magnetic field, as current does, is described by Maxwell



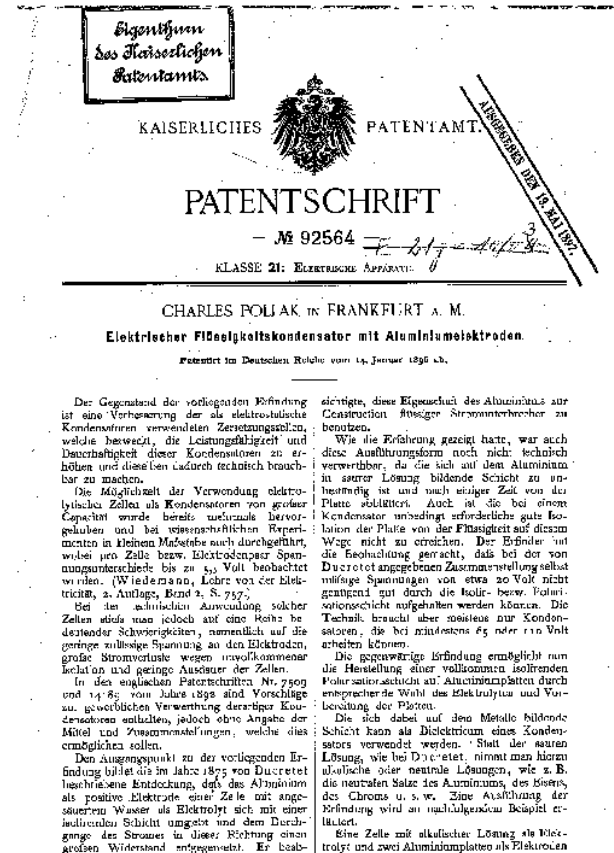
$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = - \frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

1875 – the possibility of using aluminium plates immersed in a proper electrolyte as a substitute for a static condenser is offered by Ducretet



1896 – the first Electrolytic Capacitor is patented by Charles (Karol Franciszek) Pollak, it comprises an oxide and a slightly alkaline electrolyte (Borax)

1931 – the Electrolytic Capacitor, as we know it, is finally patented by Julius Edgar Lilienfeld.

It is made of a film-forming metal such as aluminium with a retiform or textural material for retaining the electrolyte. This latter is a mixture of polyhydric alcohols, such as glycol, and boric acid, recognised to be a forming electrolyte.

Patented Sept. 3, 1935

2,013,564

UNITED STATES PATENT OFFICE

1,812,264

ELECTROLYTIC CONDENSER

Julius Edgar Lilienfeld, Winchester, Mass., assignor to Evans Research Laboratories, Inc., a corporation of Delaware

Application August 23, 1931, Serial No. 566,148

5 Claims. (Cl. 175-315)

The invention relates to an electrolyte for use with thinning metals or electrodes, as in electrolytic condensers, and lending itself for use in liquid, semi-liquid or paste condition.

The invention has for an object the provision of an electrolyte in which electrodes may be formed and in which their behavior with respect to pass, deterioration, etc. will be far superior to their behavior in the usual known electrolytes used in electrolytic condensers. For example, in such electrolytes as borax and boric acid, boric acid with small amount of borax, etc. The novel electrolyte is thus particularly suitable for such use, as well as in the preparation of insulation layers generally.

A further object of the invention resides in the provision of an electrolyte having a low freezing point, which property is of especial value where an electrolytic condenser is to be used under low temperature conditions of the surrounding atmosphere.

A still further object of the invention resides in the provision of a novel electrolyte composition which is of a highly viscous and hygroscopic (non-drying) nature and suitable for use, furthermore, with or without separator elements between electrodes inasmuch as, in the case of narrowly spaced plates, its viscosity is sufficient to prevent a short-circuiting contact between the plates. Another object is to maintain the electrolyte composition at the desired degree of saturation.

Electrolytes of a more or less viscous nature have heretofore been employed, for example, glycerine which is a trihydric alcohol. Such electrolytes are objectionable for various reasons, among which is the fact that they do not possess to a sufficient degree forming properties, and, therefore, when utilized in a condenser they naturally reduce, if not totally suppress, the highly desirable self-healing property of the electrolytic condenser.

Furthermore, the use of these electrolytes does not admit of the application of as high voltage to the condensers as in the case of condensers utilizing the novel electrolyte.

I have found, however, that certain condensation products of polyhydric alcohols with, preferably, a weak acid and particularly compounds of dihydric alcohols with a weak mineral or organic acid afford a particularly satisfactory electrolyte, the latter being both of a highly viscous nature and possessing forming properties so that in the use of the same leaks are extremely small and the deterioration rate of the film or electrode layer very low.

A further object of the invention resides in the provision of a paste involving the addition of a very finely divided filler such as metallic dust, lamp black, graphite, starch, distillaceous earth, the dust of regenerated or not regenerated cellulose, etc., to a viscous electrolyte in desired amounts for increasing its conductivity.

The foregoing objects are attained in the use of a more or less liquid composition comprising condensation products of polyhydric alcohols such as a glycol (ethylene glycol), or compounds thereof, with a weak mineral or organic acid, such as boric acid, the polymerization being effected preferably in the presence of a catalyst, such as zinc chloride. Such condensation products are of a highly viscous, sticky, non-drying nature, soluble in water. I have discovered that they possess to a marked degree forming properties to provide an insulating layer on a filming metal such as aluminum, tantalum, etc., a property that renders the said condensation product suitable for use as a forming electrolyte. Electrodes may be formed *in situ* when this composition is utilized as the electrolyte therefore.

While these products afford a satisfactory electrolyte per se, in some cases it may be advantageous to change their viscosity and/or their specific resistance by adding a small amount of distilled water with the possible further addition of boric acid, borax or other known substances therein.

Furthermore, in order to secure the proper consistency and coherence of said electrolyte, compounds of the character described may be mixed therewith, a more liquid one being added to a highly viscous or solid electrolyte. There also may be added a filler to put up that a sticky, non-flowing, paste mass is obtained which may be applied to an electrode in any suitable manner. For example, it may be sprayed, brushed, or spread thereon to provide for a separating or spacing medium as well as the electrolyte.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawing, in which:

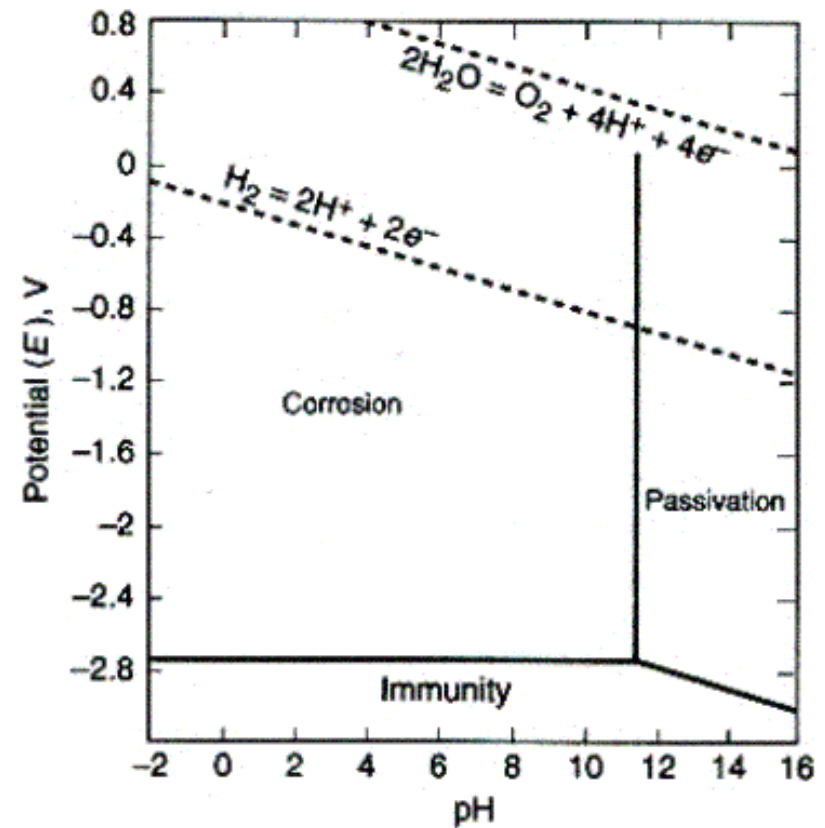
Fig. 1 is a perspective view illustrating one application of the novel electrolyte, as between the electrodes of a flat plate condenser.

Fig. 2 is a similar view illustrating a modification.

Fig. 3 is a perspective view, with portion broken away, of a condenser embodying the novel electrolyte, and provided with means for maintaining

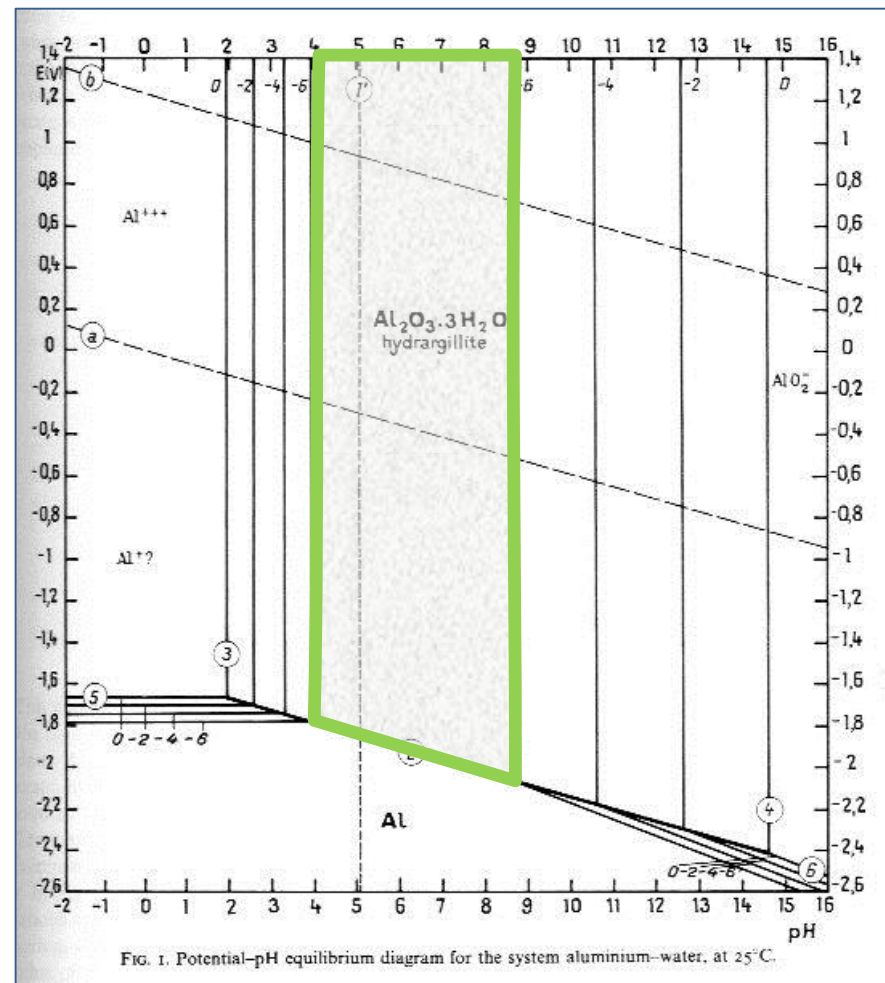
1945 – the possible stable phases of an aqueous electrochemical system are mapped by Marcel Pourbaix on diagrams holding his name.

This work answers the increasing demand for more reliability and durability of the Aluminium Capacitors.

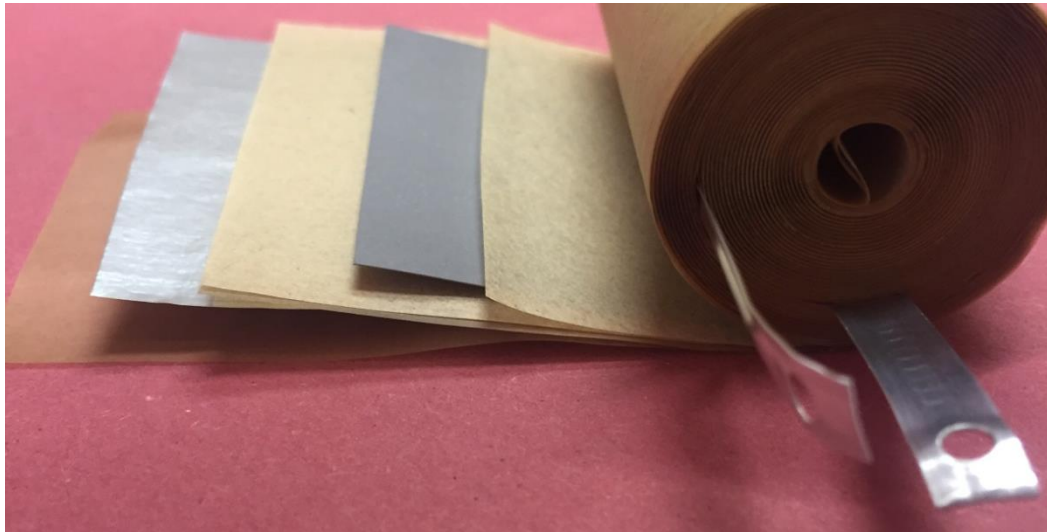


In green the passivation area of the γ -alumina, the dielectric of a capacitor, the element between the 2 plates that accumulate (condense, remember Volta) electrostatic energy.

If the dielectric breaks, or deteriorates, the condensation decreases and the capacitor wears out.



The basic components inside an Aluminium Electrolytic Capacitor are aluminium, paper and electrolyte.



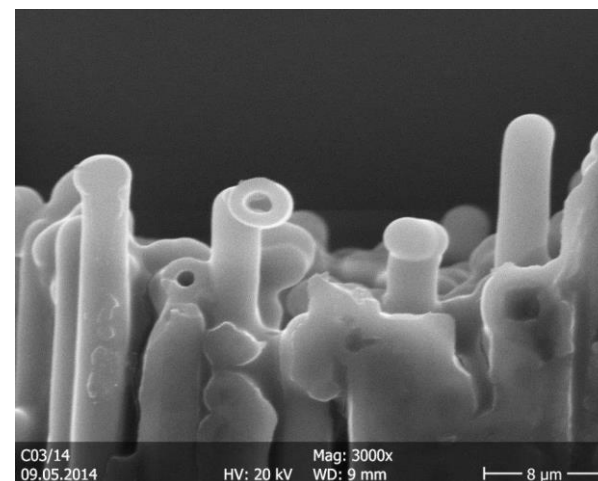
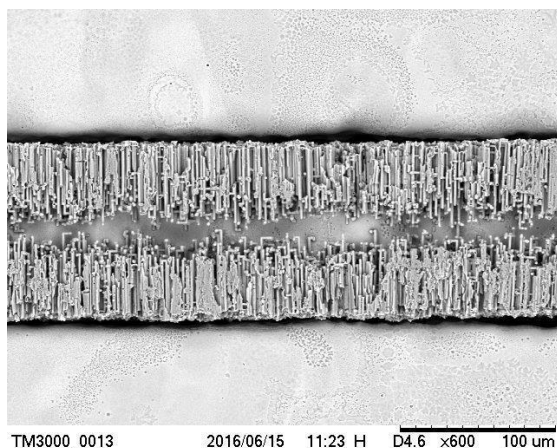
All the components and all the technologies applied to manufacturing must focus on keeping the whole assembly in the passivation area the longest time possible

The most relevant difference between an “antique” capacitor and an actual one is most probably lying in the way the raw materials are treated than in themselves.

This is done to assure a stable behaviour during the whole lifetime of the capacitor and involves:

- a more accurate preparation of the material itself prior to its use,
- highly supervised operations to produce the capacitor, including various check on connections and quality
- final burn-in
- a lot of R&D!

High purity aluminium foil (99,99%) etched then passivated. Etching is a controlled process that increase enormously the surface per square meter of foil and purifies the surface where, during the passivation process, the aluminium oxide grows.



Those processes increase the overall capacitance and the durability of the capacitor by decreasing the amount of electrolyte needed to keep the passivation stable.

Paper spacer are specially crafted to avoid any halogen (mainly chlorine) or metal presence, and to maximise the absorption and retention of the electrolyte. This grants the minimisation of polluting agents that could cause different potential areas between the plates of the capacitors or move the system out of the passivation area.

Electrolyte is designed to keep the dielectric passivated all capacitor's life long. It has to show good electrical properties, low resistance, high sparking voltage, high electrochemical stability.

Aluminium, paper and electrolyte are assembled altogether only after incoming quality approval, which involves many tests for polluting agents, as well for electrochemical parameters that are demonstrated to have such a great influence on the final quality of the product.



Capacitance dependence on surface and distance (and electrolyte) makes the rolling operation a very delicate step when building a capacitor.

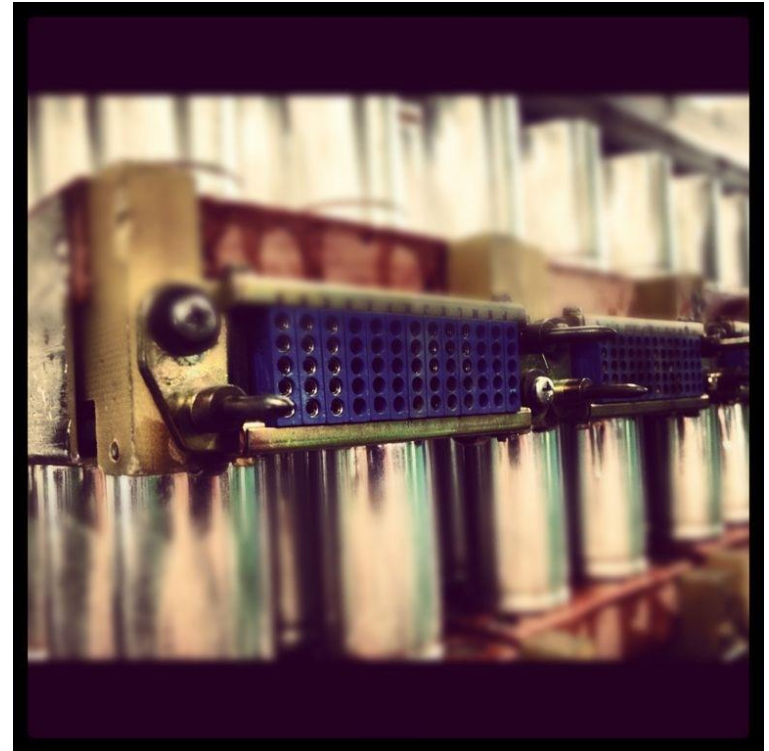
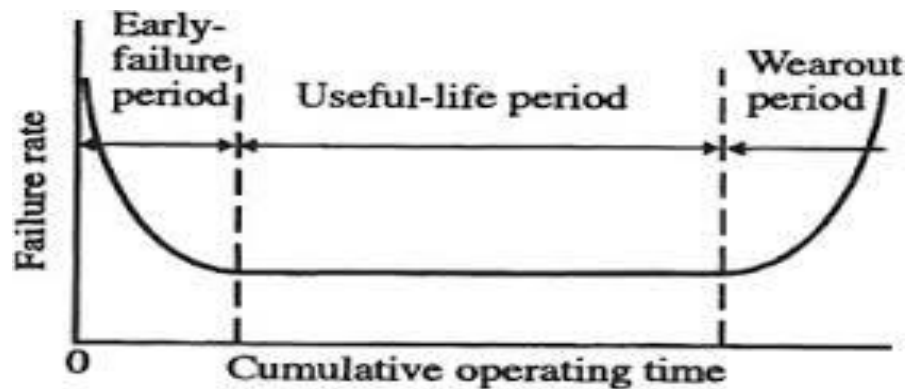
$$C = \varepsilon \frac{S}{d}$$



Another critical point during assembly is to avoid bad connections that cause current densities that the construction isn't designed to withstand.



Burn-in is the last critical step before a capacitor assembly is completed. It avoids infant failures to happen at the user's site. If all operations are correctly done, it will not exceed 0,8% of the produced quantity.



All operations needed to get a finished capacitor are held in different ways following the requirements of the market **X** on its different niches such as:

- Industrial
- UPS
- Inverter, including regenerative
- Traction
- Automotive
- Medical
- Military
- ...

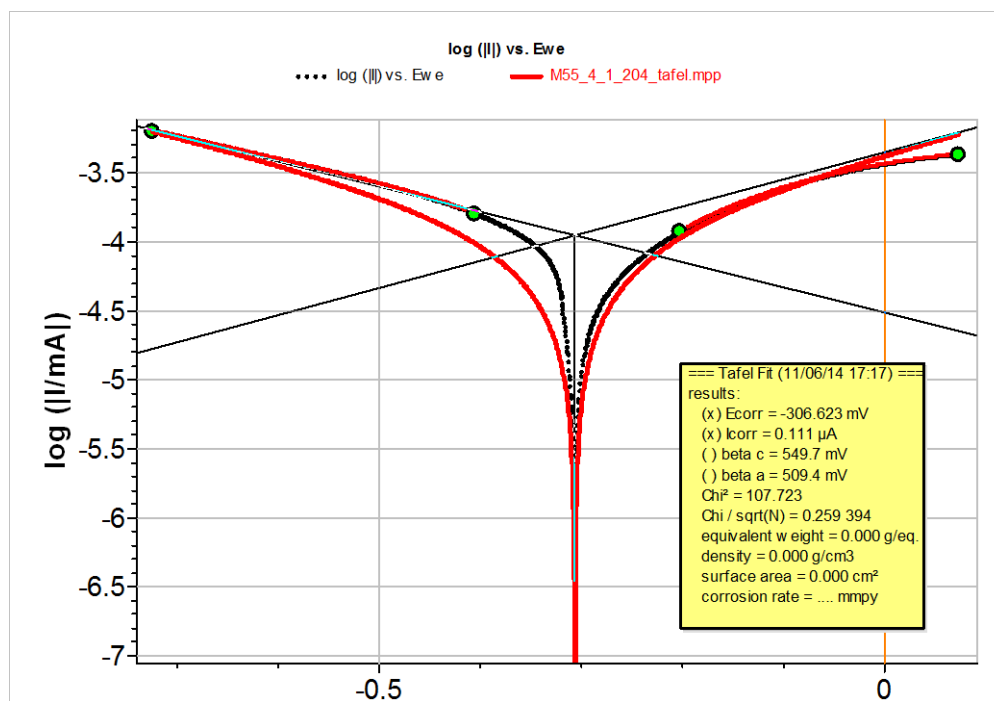
Major drivers on the market are:

- Size
- Capacitance
- Voltage
- Reliability
- Time To Market (TTM)

As a term of comparison, consider:

- our first ever design, a 2200 μ F 450V dated 1976, now occupies 23% of the former volume
- in 1976 450V was highest voltage whilst today 600V is the highest commercial voltage, and 700V is appearing on catalogues.
- 0 fail is required
- TTM is 6 months, not years

Following, or better anticipating, such a demanding market involves strategies based upon the principle of Potentiodynamic Polarisation, applied to different extent, from material scale to finished product scale.

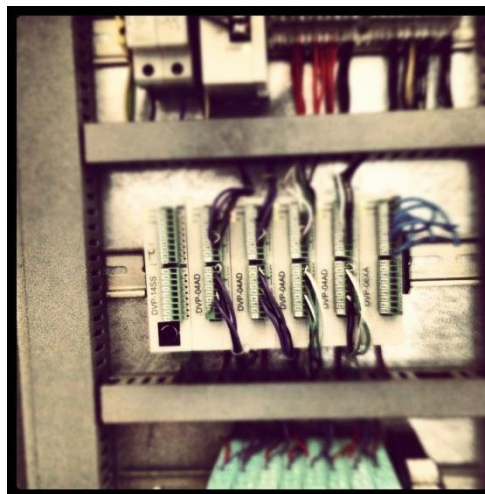


Cell test, full Lifetime test and predictive tests on corrosion are amongst the used techniques.

5000 single tests/year

3500000 hrs extensive tests/year

Corrosion models: Tafel Plot, Hysteresis Cycles,...



Thanks for your attention

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