Aluminium Electrolytic Capacitors

History, Components, Applications

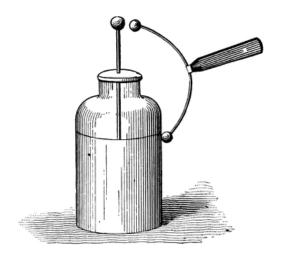
Luca Primavesi, Itelcond



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)



CHARLES POLIAK IN FRANKFURT A. M.

Elektrischer Filleeigkeitskondensator mit Aluminiumeiektroden.

Feienfirt im Deutschen Reiche vom 14. Januar 1836 ab.

ist eine Verheserung der als elektrostulische Construction flüssiger Strommterbrecher zu Kondensafuren verwendeten Zersetzungsstollen, benutzen. welche bezweckt, die Leistungefähigkeit und Dauerhaftigkeit dieser Kondensuteren 20 erhöhen und diese ben dadurch technisch brauch-

Die Möglichzelt der Verwendung elektrolytischer Zeller als Kondensatoren von grafust Copacitati wurde bereits meintunk bervorgehuben und bei wiesenschaftlichen Reperimenten in Bleinem Madeinbe auch durchgeführt, wybei pro Zelle bzzw. Elextrodenpest Spannungsunterschiede bis zu 5,5 Volt beobachtet wirden. (Wiedernann, Lohre von der Elek-

tricitat, 2. Auflage, Bend 2. S. 757.)
Bei der gedreischim Anwendung sokher Zellen stiefs man jedoch auf eine Reihe be deutender Schwierigkeiten, nomentlich auf die geringe zullissige Spannung an den Elektroden, große Stromvertusie wegen myolikommener kelation und geringe Ausäsuer der Zellen.

In der englischen Patentschriften Nr. 7509 und 14:85 vom Juhrs 1892 sind Vorschläge zu. geworblichen Verwerthung derartiger Kou-densotoren entlichten, jedoch ohne Angabe der Mittel and Zussammenstellungen, welche dies ermöglichen sollen.

Den Ausgangspunkt zu der vortlegenden Er-findung bildet die im Jahre 1875 von Ducrettet heschriebene Entdockung, daß des Altminium als positive Elektrode einer Zelle mit angesauertem Wasser als Elektrolyt sich mit einer isolitenden Schicht umgebt und dem Derch-

Der Gegenstend der vorliegenden Erfindung sichtigte, diese Eigenschuft des Aluminitates auf

Wie die Erfshrung gezeigt hatte, war auch diese Ausführungsform noch nicht technisch verwerthbor, da die sich auf dem Aluminium in saurer Lösung bildende Schicht zu unheatendig ist und much einiger Zeit von der Platte sobilitieri. Auch ist die bei einem Printe solution. And a de los ones of the following the fo militage Spanningen von etwa 20 Volt nicht gentigent gut durch die Isolit- bezw. Polinisotionsschicht aufgehalten werden können. Die Technili, brought uber meistens nur Kondon saloren, die bei mittdestens ég nder in Volt arheiten können.

Die gegenwärtige Erfindung ermöglicht num die Herstellung einer vollkommen isolirenden Polar sation-schicht au. Aluctiniumplatten durch entsprechende With) des Elektrolyton aud Vor

bereitung der Plotten. Die sich dabei auf dem Metalle bildende Schicht kann als Dielektrieum eines Kondensators verwendet werden. Statt der asuren Lösung, wie bei Dochetet, nimmt men hierzu ukulische oder neutrale Lösungen, wie z.B. die neutralen Salze des Aluminiums, des Bisens, des Chroms u. s. w. Zine Ausfilheung der Erfindung wird an nachfulgendem Beispiel erlikulert.

Eine Zelle mit alkulischer Lönneg als Meicgange des Stromes in dieses Richtung einen Sine Zelle mit alkalischer Lösung sie blet-großen Widerstand entgegenselnt. Er beab- trolys und zwei Aluminiumplatten als Elektroden



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

3.012.564

REACTROLYTIC CONDENSER.

plips Edgar Lifeticidi, Winobster, Mass. a
pignor to Ergun Hentarch Laboratorica, Inc.,

pplication August 29, 1931, Serial No. 566,168 5 Claims, (Cl. 175—315)

The invention relates to an electrolyte for use with firming metals or electrodes, as in electrolytic contracts, and lending ideal for use in

- liquid, semi-liquid of pearly continuou.

 The invention has for an object the provision of an electrodyte in which electrodes hay be formed and in which their behavior with respect to leak, deterioration, siz. will be far superior to their behavior; in the usual known electropies when the pearly of the pearly of the continuous descriptions.
- 10 used in electrolytic confidences, for example, in such electrolytes as borns and borte acid, bords acid with small amount of borns, size. The novel electrolyte is thus particularly equiphed for the lower servers.
- A further object of the invention resides in the provision of an electrolyte having a low freezing point, which properly it of especial value when an electrolytic occusioner is to be used index for temperature conditions of the surrounding at
- mosphere.
 A still further object of the invention radios
 in the provision of a novel electrolyte composition which is of a highly viscous and hyprocoult
- Structuring mature and cuttable for use, furthermore, with an without separatin elements between selectrode insample; as, in the case of narroosty spaced pistes, its viscosity is nufficient to provent a chort-circuiting contacts between the plants. Another object is to maintain the circle and the control of the control of the control of the plants.
- ration.

 Richtrolytes of a more or less viscous nature
 have heretafure been surplayed, for example,
 a threating which is a trinydric shooks. Such
- observolytes are objectionable for visitosis reasons, among which is the fast that they do not peasess to a sufficient degree forming properties, and, therefore, when utilized in a continues they mandet tensity resiste. If not totally suppress, the highly describes actification remonerty of the sketchylde
- Purthermore, the use of these electrolytes does not admit of the application of as high voltages to the conference us in the uses of conference
- I have found, nevert, that certain comments time products of polytomic alcohols with, person as ably, a weak acid and particularly compounds of thirdits alcohols with a weak pinneral or or gane acid afford a particularly ministratory weatrolyte, the latter being both of a highly vascou
- By In the cas of the below jorger are expansely most nature and homostick toronic brobactus to rue

- The invention relates to an electrode and the determination rate of the film or electrode
 - any the determinant war or the num or electrons in given very law. A grather object of the invendent resides in the previous of a paste involving the addition of a previous of a paste involving the addition of a law or the state of the second of the second law or the second of the second of the law or the second of the second of the law of responsization from responsively of the second of the second of the second law, etc. to a viscous section of the second amount for increasing its consistency.
 - amounts for miniesting its outsidency.

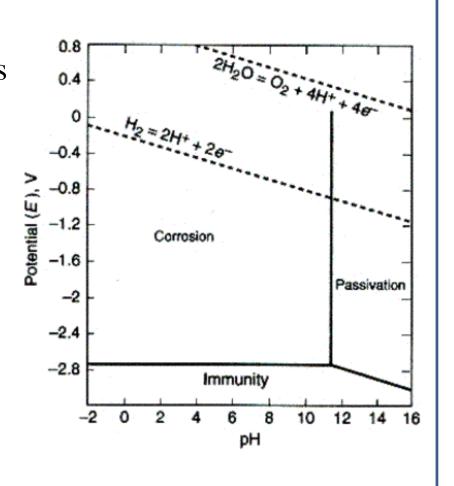
 The foregoing objects are attained in the use of a mere or less siguid composition comprising condensation promets of polyhydric alcoholas such as a grood trinchtylene glycol), or compounts of the season of the sea
 - pounds thereof, with a weak minoral or organic and, such as bords sold, the polymerazion being effected preferably in the presence of a catalyra, is such as size schooleds. Such condensation produels are of a highly viscous, sticky, non-drying making, spible, in water, I have discovered that they possess to a marked degree forming progerties to provide an implicing layer on a filming 8
 - erties to provide an imagining sayer on a filming imetal such as significant, smalldum, etc., a property that runders the said condensation product missible for use as a furning electrolyse. Ricetrodes may be formed in sith when this composition is utilized as the electrolyte therefor.
 - While those products afford a satisfactory shelt, where per m, in such cases it may be advantageous to change their viscosity and/or their specific resistance by adding a small smoothst of deathed water with the possible further addit, being of boric acid, borns or other tenongen discussed when the said, borns or other tenongen discussed their said.
 - Furthermore, in order to serior the proper consistency and enherance of said theritarys, compounds of the character described may be 35 strong therwith, a more liquid can being added to a brighty viscous or said electroyle. There, also may be added a filter to said so that a pickey, non-flowing, pasty roses is obtained which may
 - ner. For example, it may be sprayed, bristled, or spread thereon to provide for a superating or spacing medium as well at the electralyte. The mainte of the investica, however, will best
 - the secure of the presenting in which:

 Fig. 1 is a presentive view fineling one ap-
 - electrodes of a flat plate condenser.

 Fig. 2 is a similar view illustrating a modifica-
 - Fig. 5 is a perspective view, with portion trains wear, of a perspective embadying the navel size training and postelled with resource for majorish

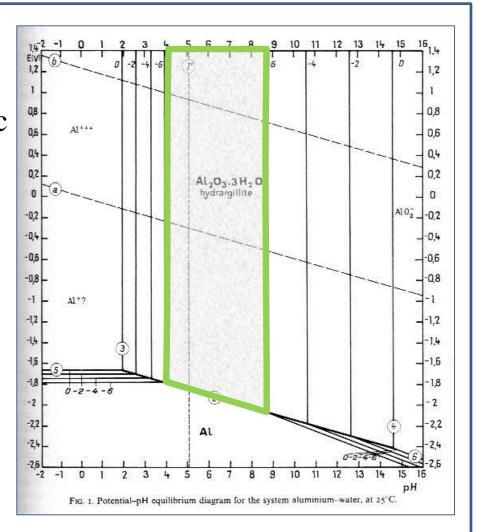
1945 – the possible stable phases of an aqueous electrochemical system are mapped by Marcel Pourbaix on diagrams helding his name.

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

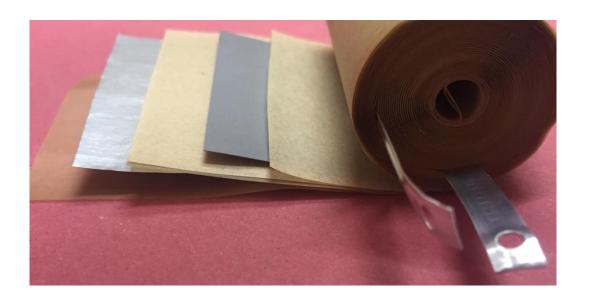


In green the passivation area of the γ -alumina, the dielectric of a capacitor, the element between the 2 plates that accumulate (condense, remember Volta) electrostatic energy.

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

Components

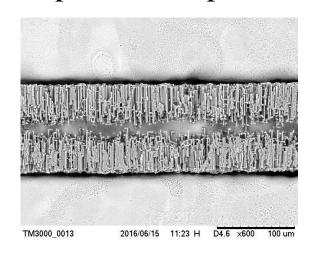
The most relevant difference between an "antique" capacitor and an actual one is most probably lying in the way the raw materials are treated than in themselves.

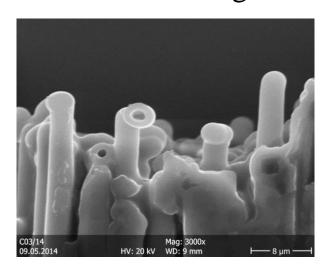
This is done to assure a stable behaviour during the whole lifetime of the capacitor and involves:

- 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!

Components

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.

Components

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.



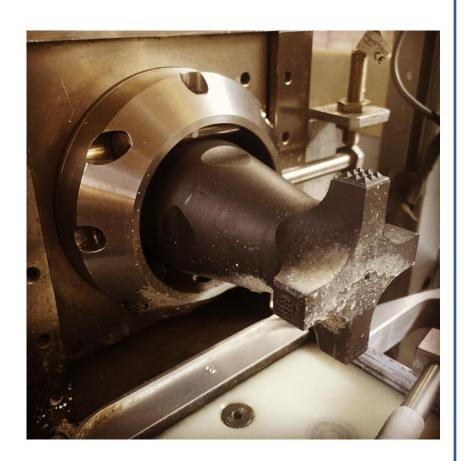
Capacitance dependence on surface and distance (and electrolyte) makes the rolling operation a very delicate step when building a capacitor.

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

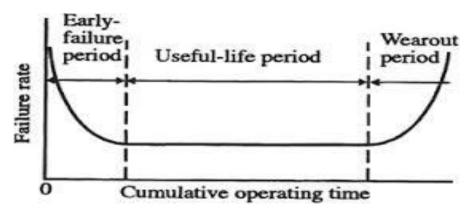


Components

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

•...

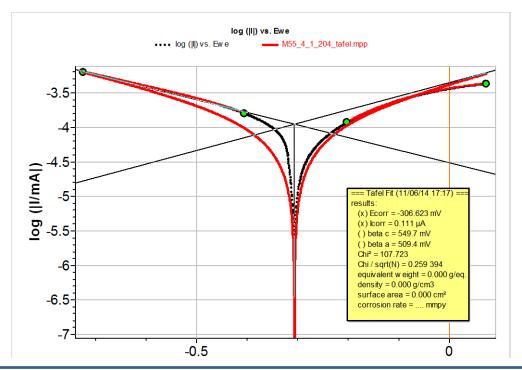
Major drivers on the market are:

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

As a term of comparison, consider:

- •our first ever design, a 2200μF 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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