



Energy Storage Capacitors

Claude VINCENT



Power Electronics & Energy Storage event
27 juni 2023 | 1931 Congrescentrum 's-Hertogenbosch

ENERGY STORAGE



ELECTRONIC COMPONENTS

Ta / NbO / Polymer Capacitors	Interconnect	SuperCapacitors	Aluminum Capacitors	Power / Chip Film Capacitors	Circuit Protection	Ceramic Capacitors
<ul style="list-style-type: none"> Automotive General High CV Radial Leaded High Reliability Low ESR Low Profile High Temp DLA / MIL SPEC SMD Ta MnO₂ Polymer Space (TCH series) Wet Ta & Wet Ta modules 	<ul style="list-style-type: none"> Board to Board Wire to Board Wire to Wire IDC Medical I/O Battery Poke Home 	<ul style="list-style-type: none"> EDLC Capacitors Ultra Capacitors S-Capacitors Gold Capacitors 	<ul style="list-style-type: none"> Conductive Polymer: Solid Electrolyte Hybrid: Solid/Liquid Electrolyte Electrolytic: Liquid Electrolyte 	<ul style="list-style-type: none"> High Power Film Medium Power Film SMD Chip Film Energy Storage Discharge Automotive Film 	<ul style="list-style-type: none"> Automotive MLV Transient Voltage Suppressors Fuses Thermistors Varistors Diodes 	<ul style="list-style-type: none"> Low Inductance Discoidal Ceramics High Voltage Surface Mount EMI Filtering Feedthru SMD Leaded Medical Stacked DLA / MIL SPEC Automotive


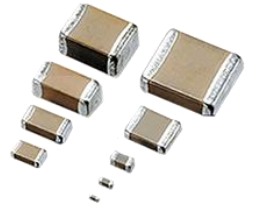

AUTOMOTIVE INTERCONNECT, SENSING and CONTROL

Connectors / Mechatronics	Pedals	Controls	Sensor
<ul style="list-style-type: none"> Custom Products Injection Molding Press-Fit Pin Mechatronic Solutions 	<ul style="list-style-type: none"> Active Passive Electronic Hand Throttle (EHT) 	<ul style="list-style-type: none"> Power Electric Motor Battery Management LED 	<ul style="list-style-type: none"> Temperature Position Proximity Quality Speed


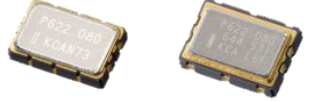
RF SOLUTIONS & SYSTEMS

RF / Microwave			
<ul style="list-style-type: none"> Filters Diplexers Couplers Attenuators 	<ul style="list-style-type: none"> Capacitors Inductors Hi-Q Capacitors SLC Capacitors 	<ul style="list-style-type: none"> RF Varistors Resistors RC Networks Fuses 	<ul style="list-style-type: none"> Active Antenna Systems Passive Antennas Test Measurement Test Services





ELECTRONIC COMPONENTS

Connectors	Crystal Devices	SAW Devices	Capacitors	Power Semiconductor Devices
<ul style="list-style-type: none"> • Board to Board Connectors • FPC/FFC Connectors • Wire to Wire / Board Connectors • Backplane Connectors • Shunt Connectors • Interface Connectors • Card Edge Connectors • Memory Card Connectors • Shield Locks • Power Terminals • Application Tools 	<ul style="list-style-type: none"> • Crystal Units • Clock Oscillators (SPXO) • Voltage Controlled Crystal Oscillators (VCXO) • Temperature Compensated Crystal Oscillators (TCXO) 	<ul style="list-style-type: none"> • SAW Filters • SAW Duplexers • SAW Quadplexers 	<ul style="list-style-type: none"> • Multilayer Ceramic Chip Capacitors (MLCC) 	<ul style="list-style-type: none"> • Discretes Diodes • Power Modules • High-power Devices • Stacks • Units 

AUTOMOBILE

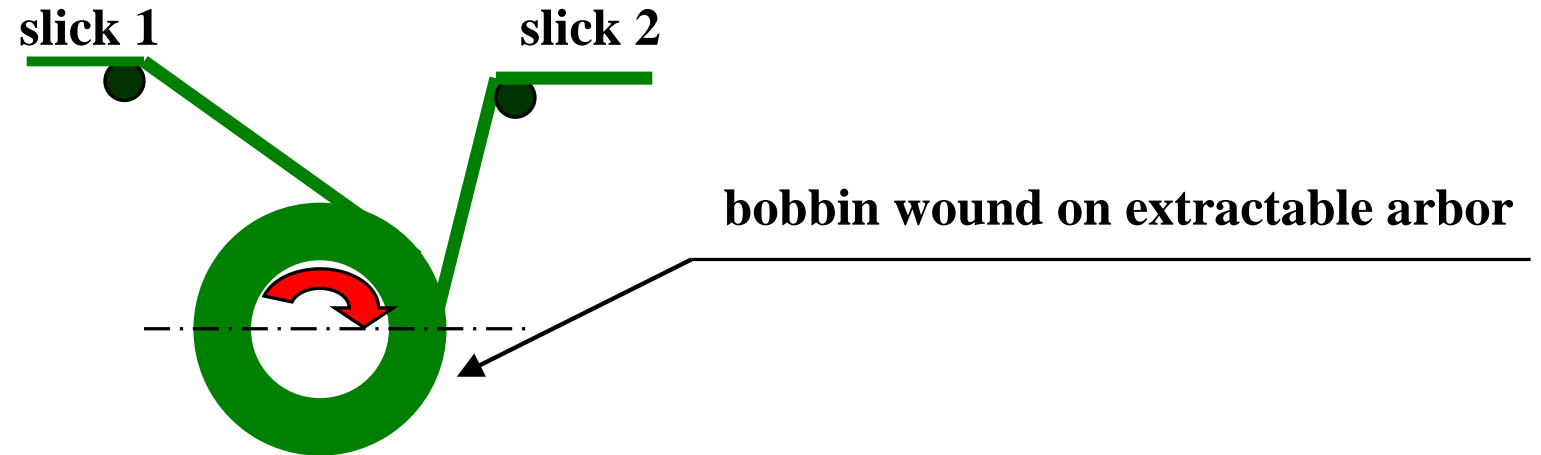
Connectors	Crystal Devices
<ul style="list-style-type: none"> • Floating structure • High heat resistance • High-speed transmission capability • Waterproof Branch Connector 	<ul style="list-style-type: none"> • Wide Temperature Range • High Reliability • CMOS Output Type for Automotive Applications • Small Size 

RF SOLUTIONS & SYSTEMS

Connectors	Crystal Devices	SAW Devices	Capacitors
<ul style="list-style-type: none"> • Space-saving • High-current • High durability • Low Profile 	<ul style="list-style-type: none"> • Ultra Small Size • Low Profile 	<ul style="list-style-type: none"> • Small size • Low insertion loss • High selectivity • High isolation 	<ul style="list-style-type: none"> • Ultra-compact size • High capacitance • Low loss characteristics 

Power Film Capacitors

The elementary capacitive bobbin is wound on extractable arbor before to be flattened



capacitive bobbin winding



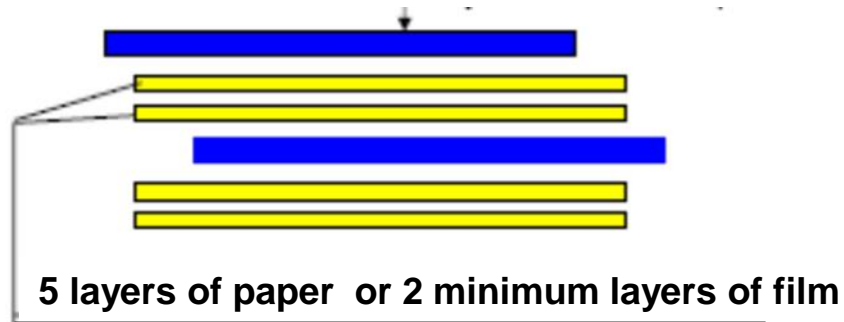
flattened bobbin



The 2 film technologies : FOIL vs METALLIZED

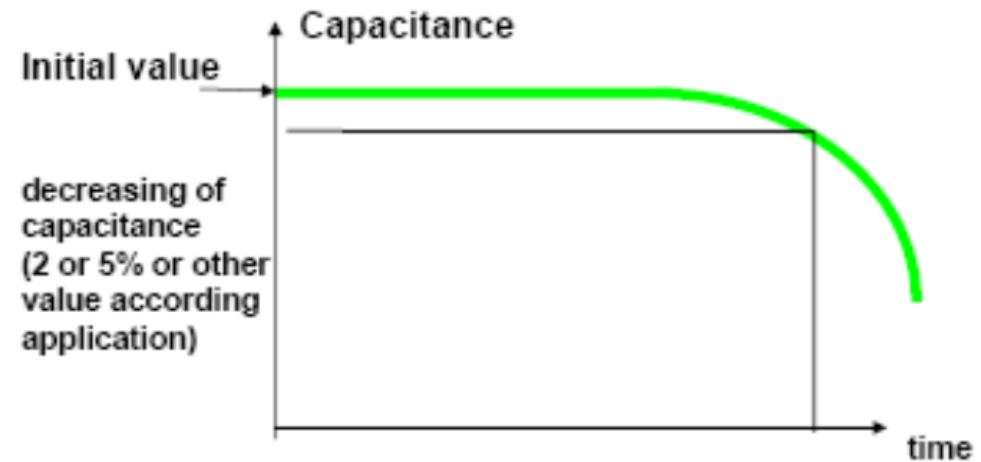
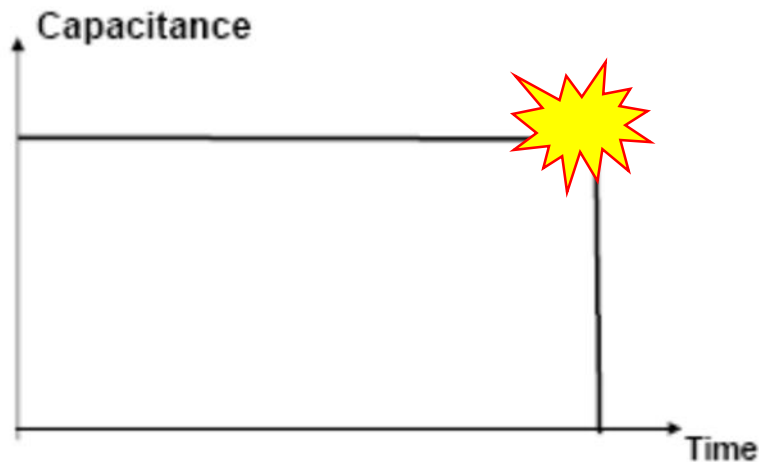
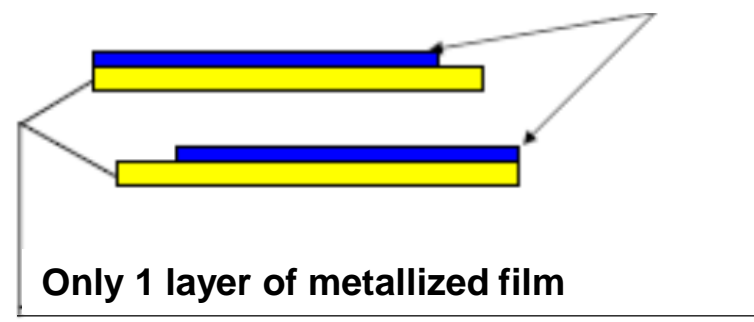
FOIL

Aluminium foil : $5\mu\text{m}$



METALLIZED

Aluminium metallization $\approx 100 \text{ \AA}$

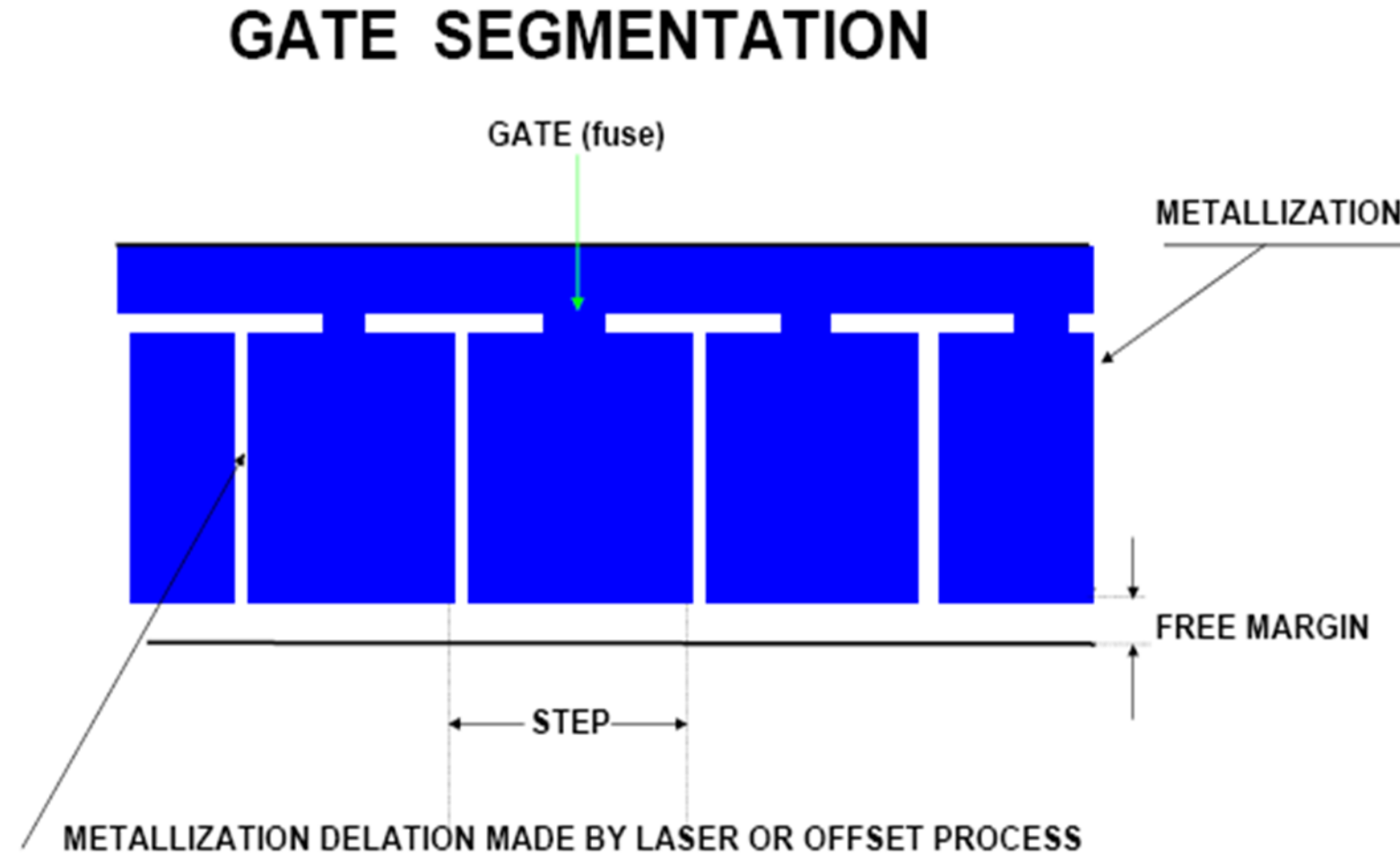


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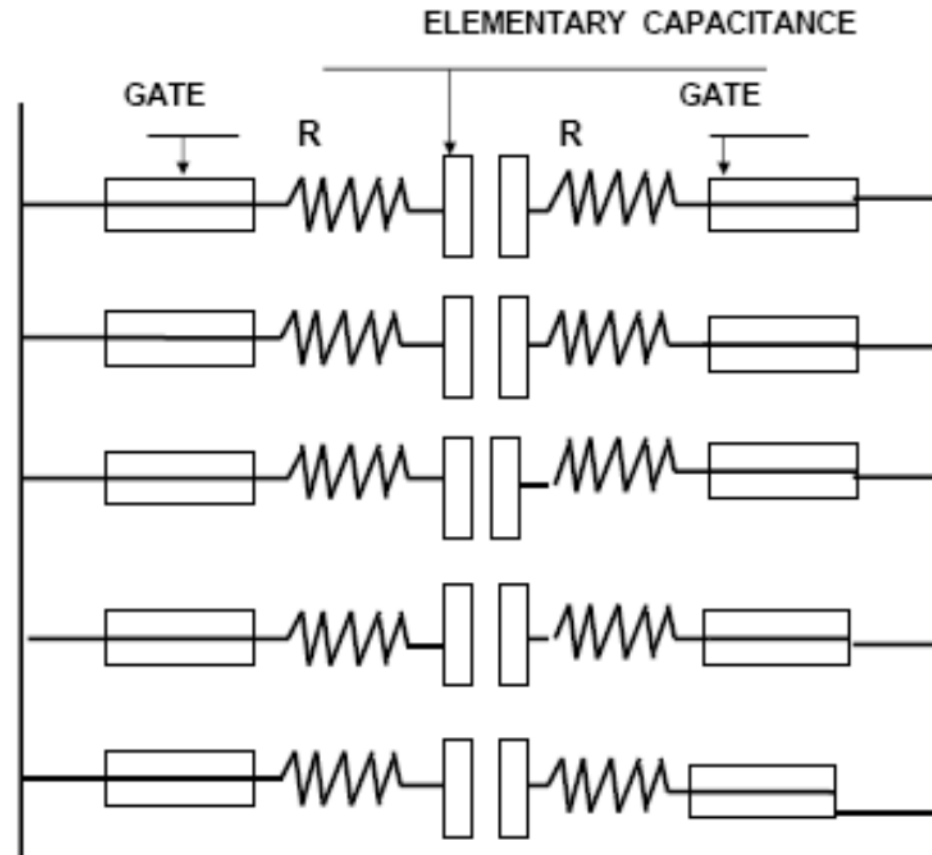
The Controlled Self-Healing by segmentation : KAVX patent on 1976



➤ **The Gate Segmentation limits the Self Healing Energy**

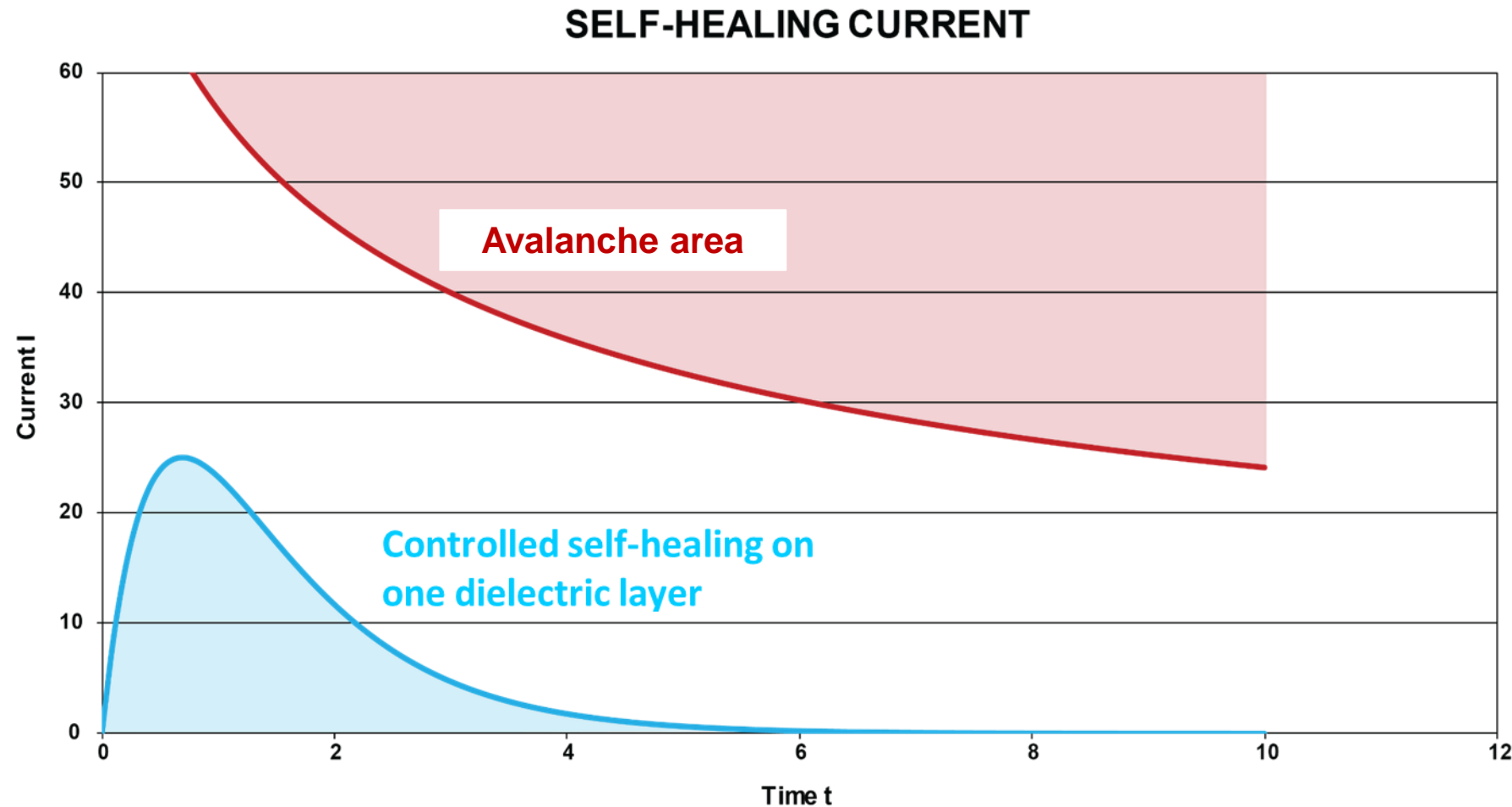
The Controlled Self-Healing by segmentation : KAVX patent on 1976

EQUIVALENT CIRCUIT DRAWING FOR A GATE SEGMENTATION



- The Gate is acting as a fuse, the self-healing energy is limited by the sensitivity of fuse gate

The Controlled Self-Healing by segmentation : KAVX patent on 1976



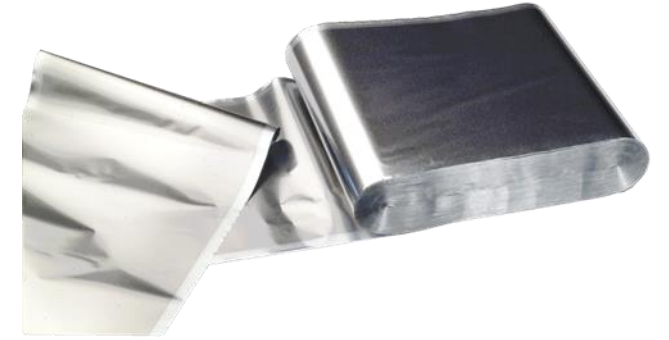
- **The Gate is designed to have no risk to reach the avalanche area inducing potential destruction**

FIM TECHNOLOGY with Controlled Self-Healing

Film

Impregnated

Metallized



Elementary flat bobbin

Film : High Crystallinity rough polypropylene (95°Cmax)

Metallization : Al and Zn reinforced edge

Elementary cap : soft flat bobbin

Impregnation : rapeseed oil

Voltage range : 1800Vdc up to 100kVdc

Electrical field : 288V/ μ (264V/ μ) - 100000h - 70°C(80°C) Hot Spot



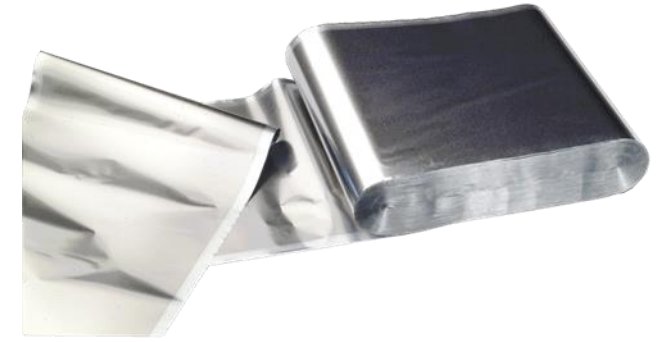
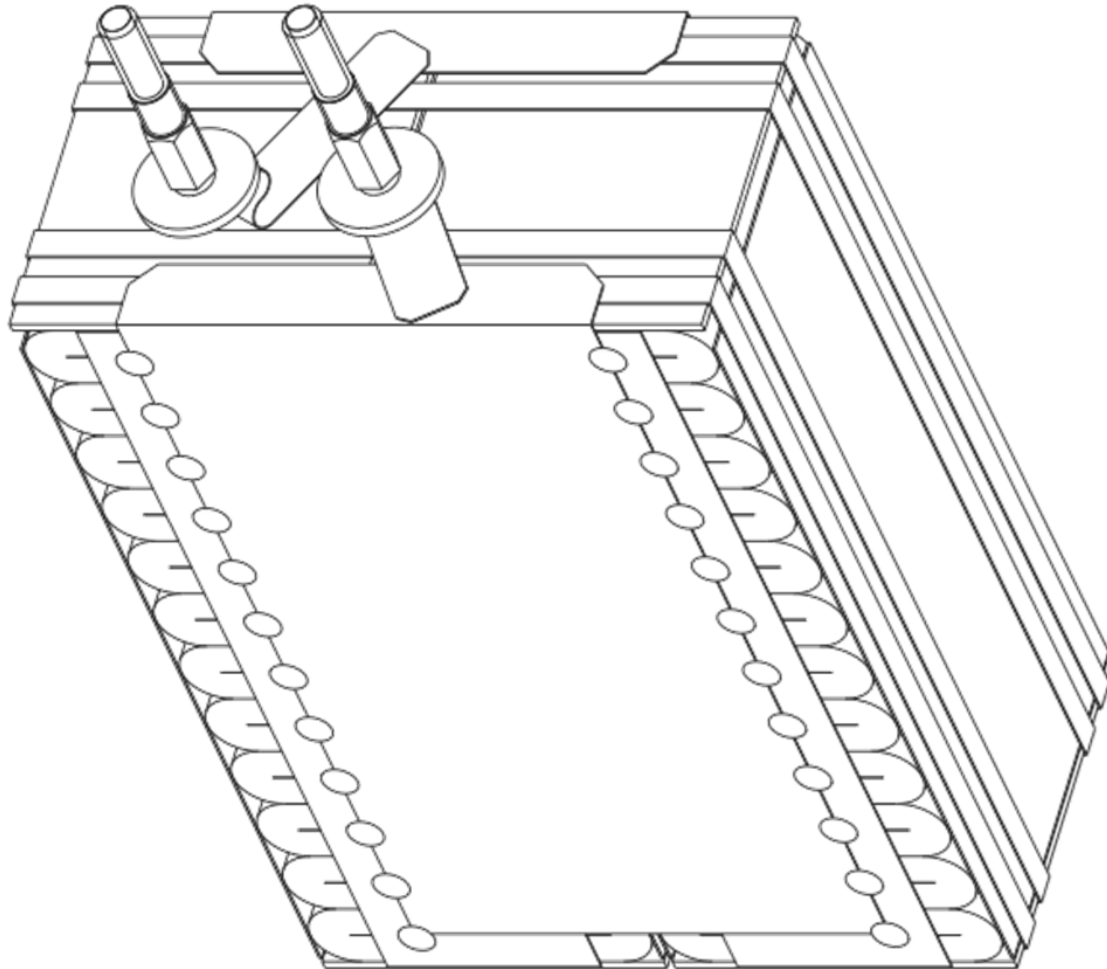
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FIM TECHNOLOGY with Controlled Self-Healing

Internal design



Elementary flat bobbin



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FIM TECHNOLOGY with Controlled Self-Healing

DC Applications

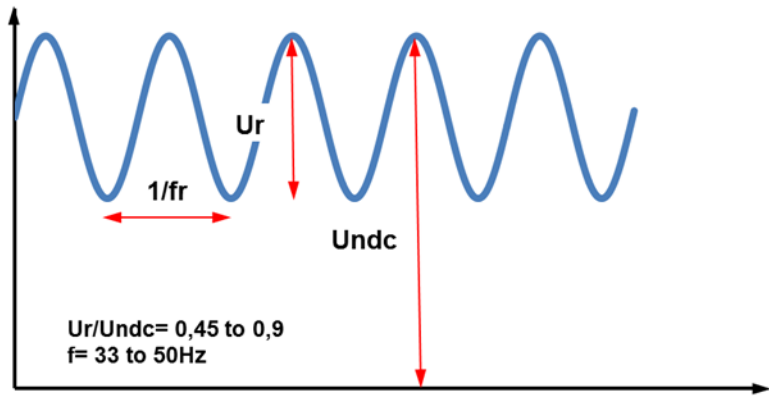


TRAFIM products
1,8kV - 6kV

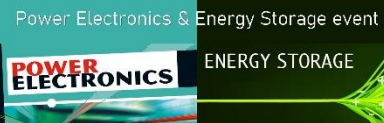
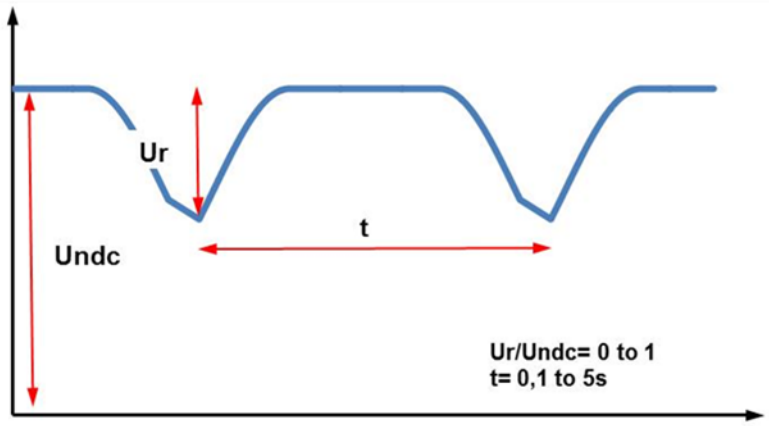


FILFIM products
6kV - 100kV

DC Link and Resonant Filter



Energy Bank for Power Supply



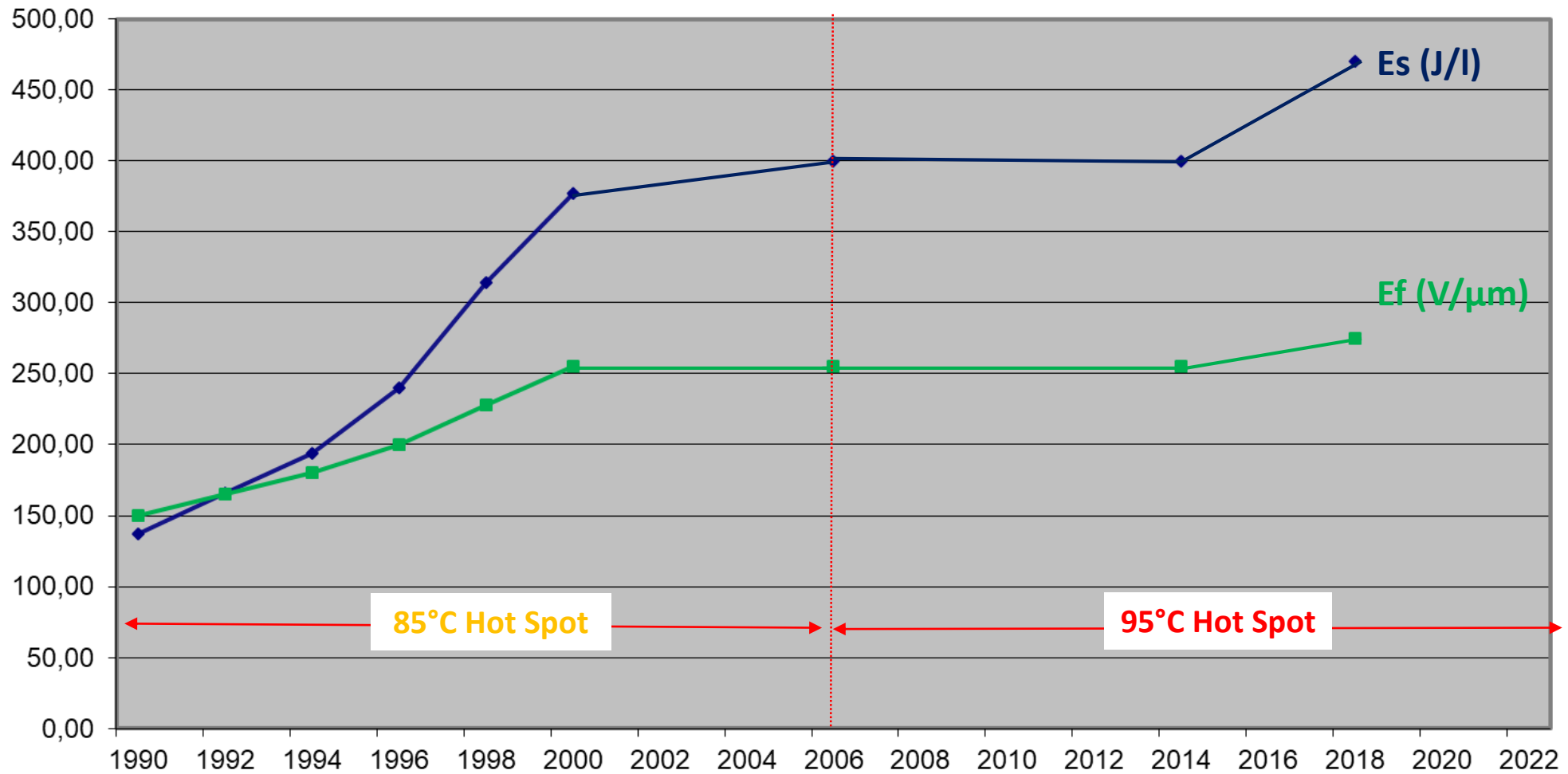
FIM TECHNOLOGY with Controlled Self-Healing

2000 μ F-1800Vdc – 200Arms – 100,000h Evolution

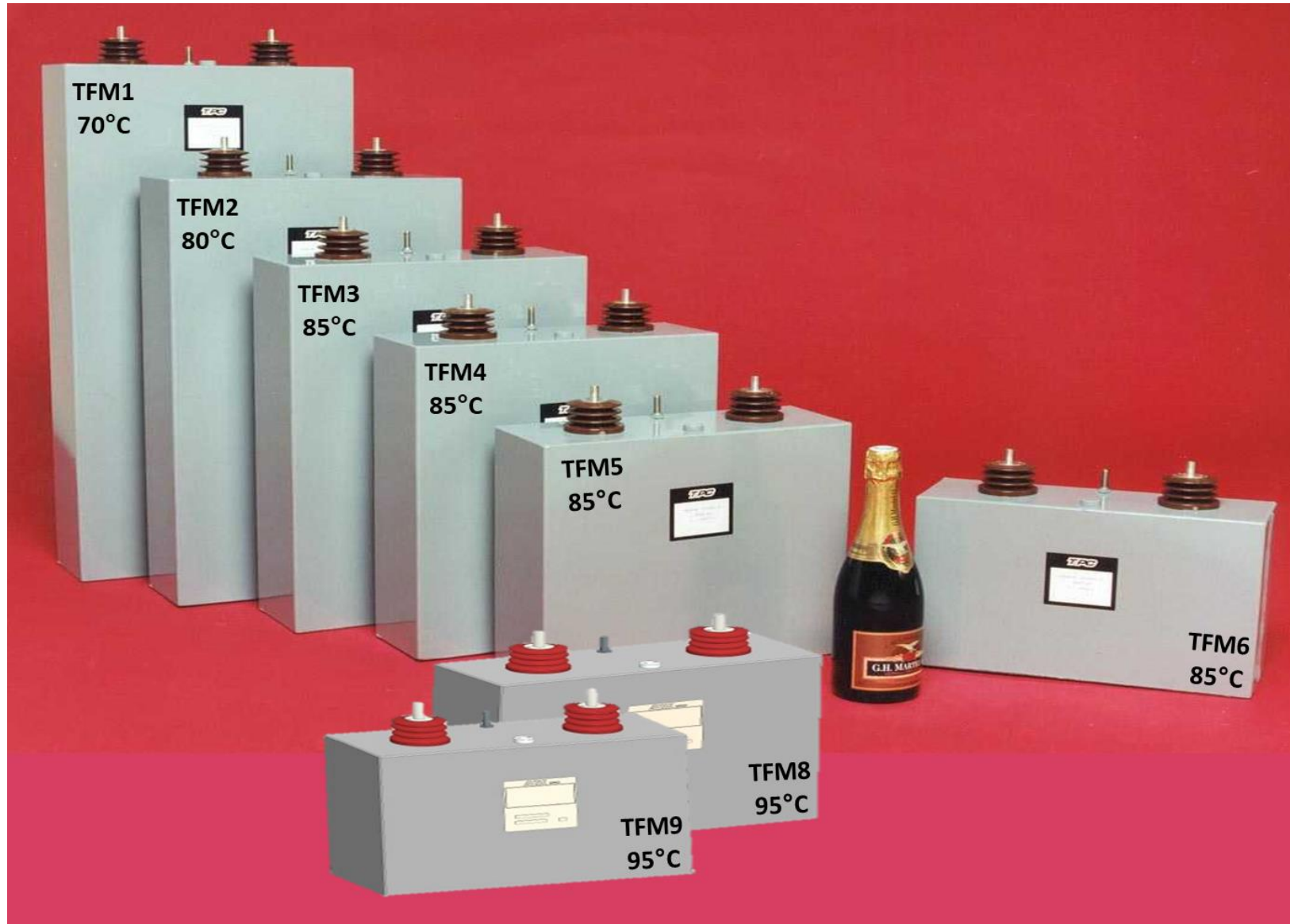
TFM1	TFM2	TFM3	TFM4	TFM5	TFM6	TFM7	TFM8	TFM9
1990	1992	1993	1995	1997	2000	2006	2015	2017
Hazy PP	Hazy PP	Hazy PP	Hazy PP	Hazy PP	Hazy PP	Smooth HC PP	Hazy HC PP	Hazy HC PP
150V/ μ	165V/ μ	180V/ μ	200V/ μ	228/ μ	255V/ μ	255V/ μ	255V/ μ	275V/ μ
2-3 Ω ■	2-3 Ω ■	2-3 Ω ■	2-3 Ω ■	4-8 Ω ■	10-20 Ω ■	10-20 Ω ■	10-20 Ω ■	10-20 Ω ■
T segment	T segment	Mosaic 4 segment	Mosaic 4 segment	T segment	No segment	No segment	No segment	No segment
70°C Hot Spot	80°C Hot Spot	85°C Hot Spot	85°C Hot Spot	85°C Hot Spot	85°C Hot Spot	85/95°C Hot Spot	95°C Hot Spot	95°C Hot Spot
V=100	V= 82	V=67,5	V=55	V=45	V=37	V=34	V=37	V=30,5



U_n DC Specific Energy (E_s) & Electrical Field (E_f) evolution for 100,000h at Hot Spot Temperature



FIM TECHNOLOGY with Controlled Self-Healing



2000 μ F-1800Vdc – 200Arms – 100,000h Evolution



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FIM TECHNOLOGY with Controlled Self-Healing

DC voltage lifetime expectancy typical curve



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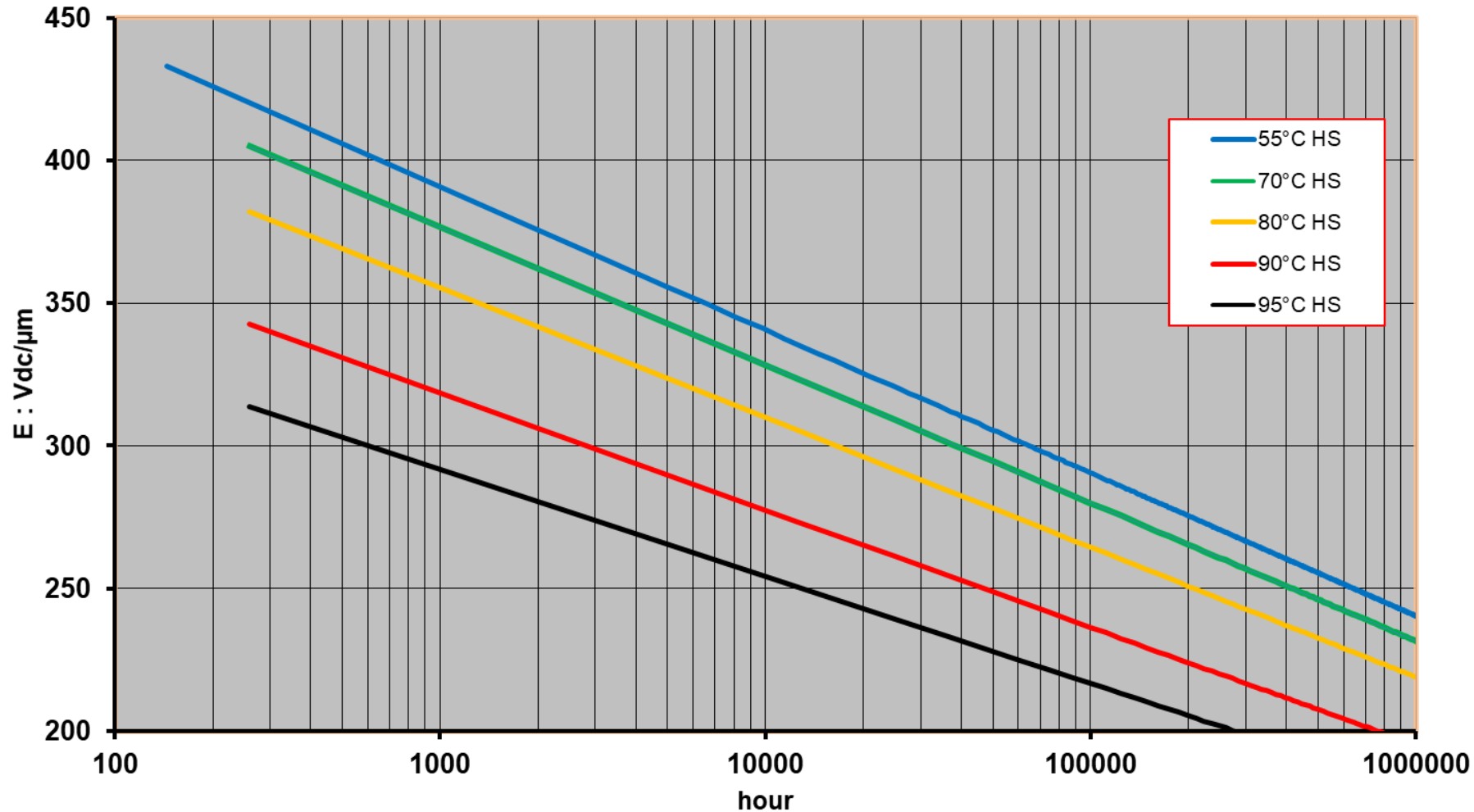
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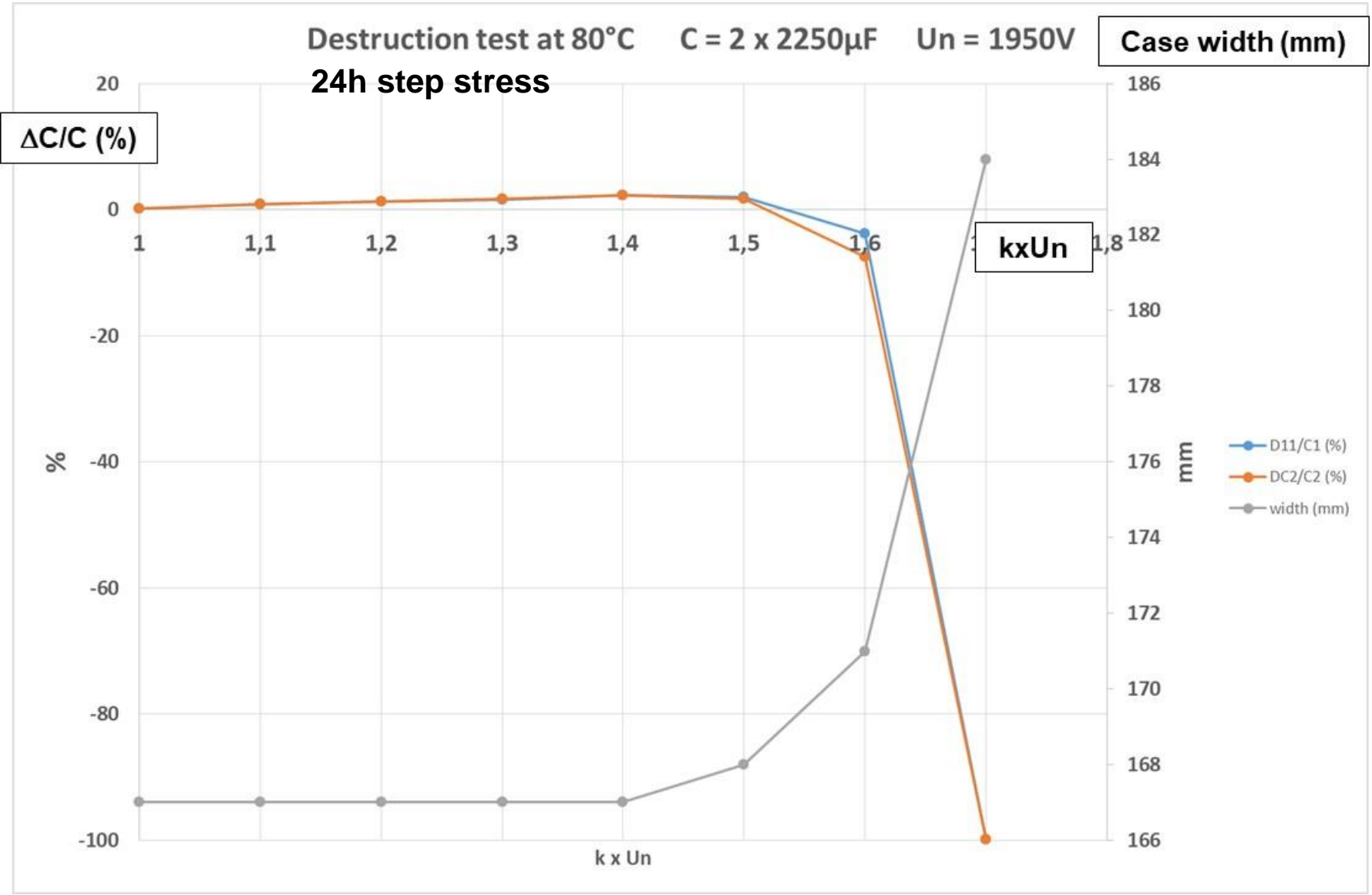
FIM TECHNOLOGY with Controlled Self-Healing

DC voltage lifetime expectancy typical curve

TFM9 Lifetime expectancy ($\Delta DC/C = -2\%$)



Destruction tests on FIM Capacitors



DC voltage energy bank

Flicker smoothing in ESRF Grenoble



9x(0,2F / 1650V-1500kg)



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DC voltage energy bank

50Hz/60Hz Converter fo NATO warships : 7,4MJ



12x(0,07F / 4200V - 2100kg)



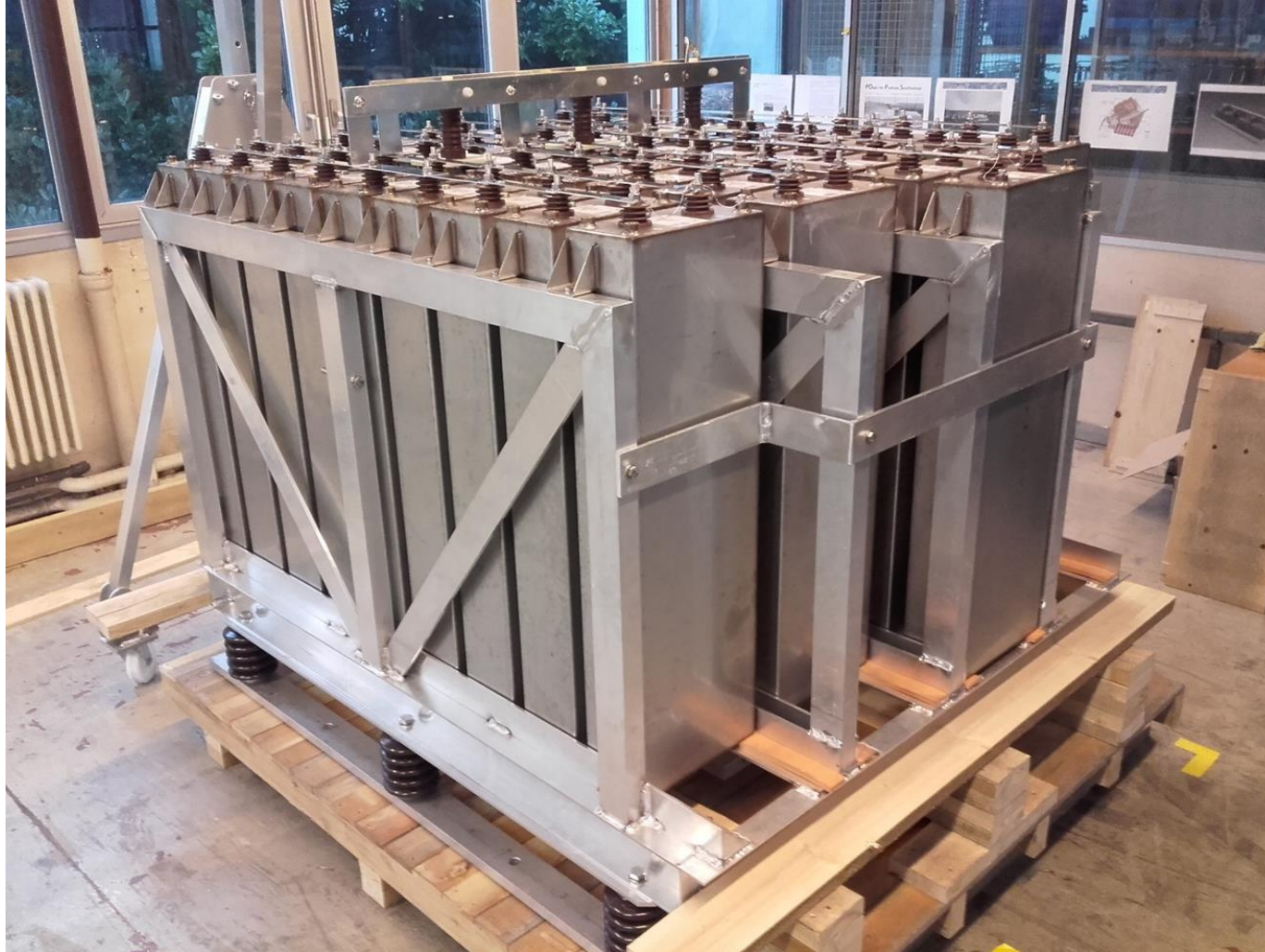
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DC voltage energy bank

POPS A & B in CERN : 20MJ + 15,2MJ



Energy DC storage bank : 0,65F/5000V/3600kg : 815kJ



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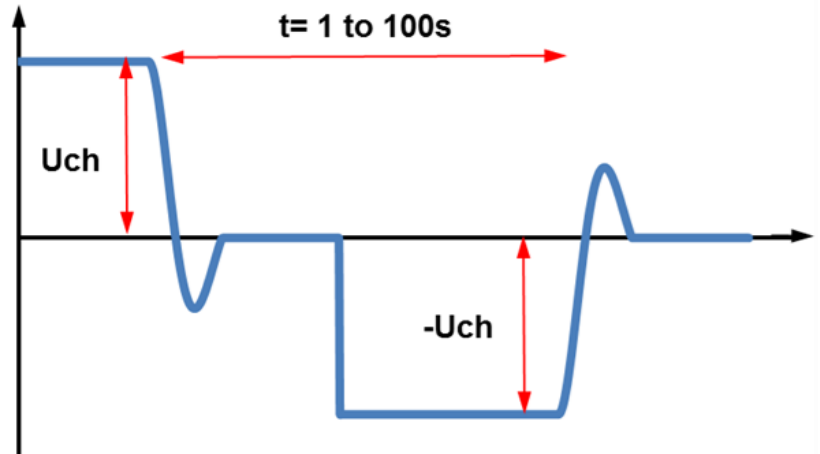
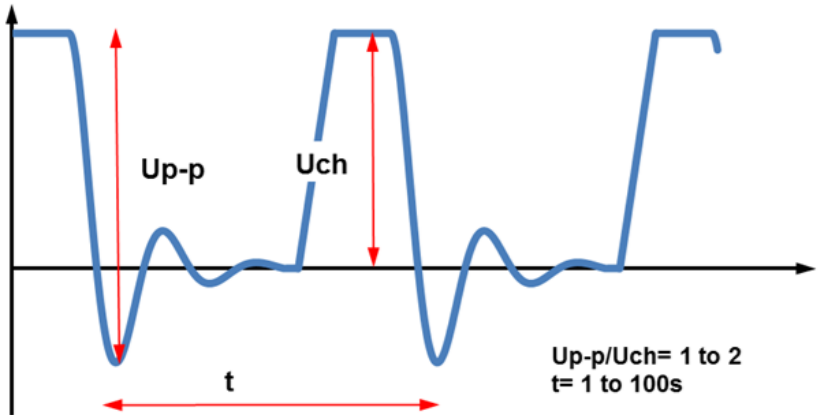
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FIM TECHNOLOGY : Controlled Self-Healing

Discharge Applications

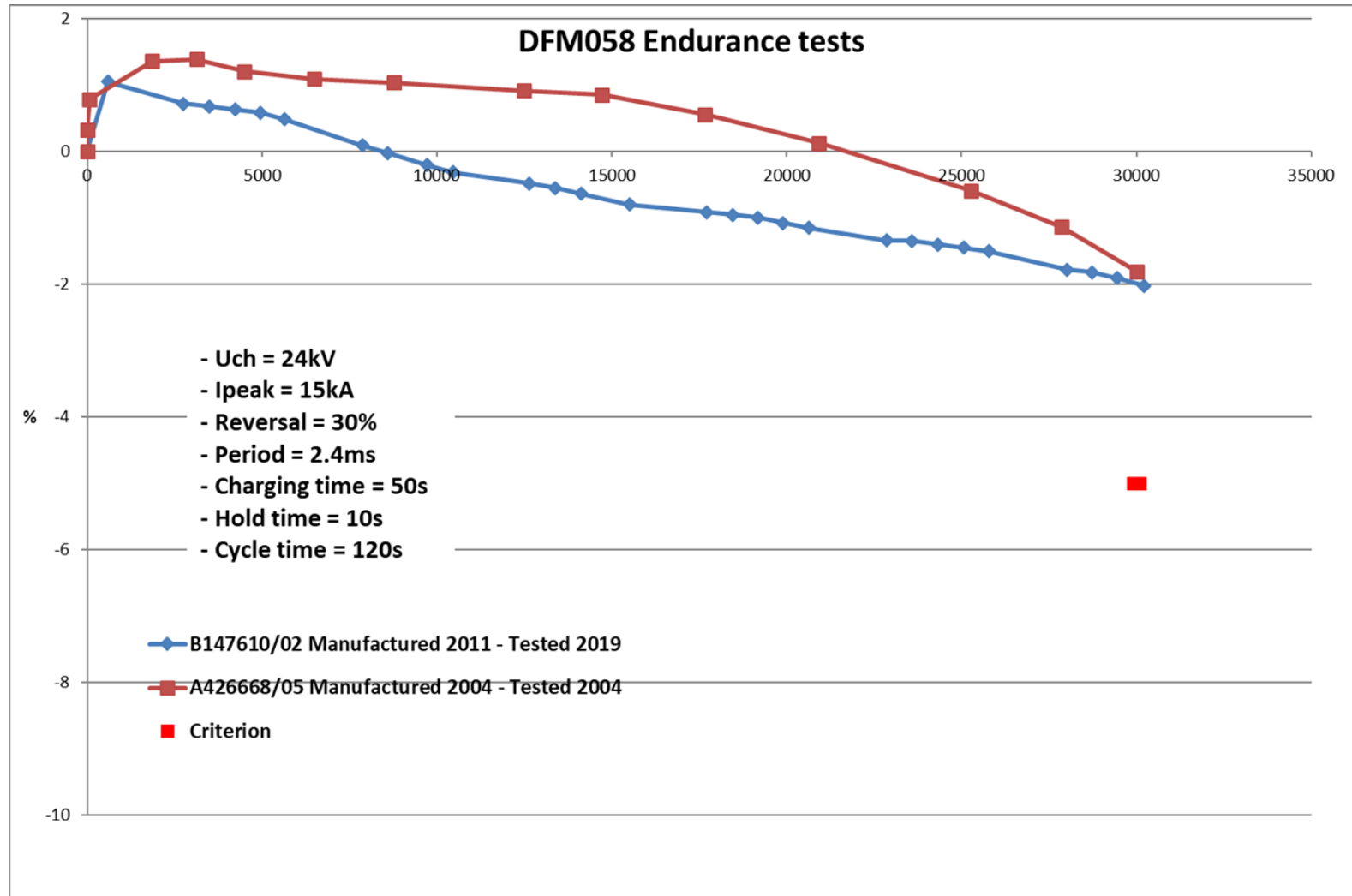


DISFIM products
1,8kV - 100kV



FIM TECHNOLOGY : Controlled Self-Healing

Discharge Applications



Discharge capacitors for Electromagnetic guns

$C=865\mu\text{F}$ - $U_{ch}= 10.75\text{kV}$ - $I^2t= 500\text{kA}^2\text{s}$

Foil technology : paper + castor oil



Metallized technology : polypropylene + rape seed oil



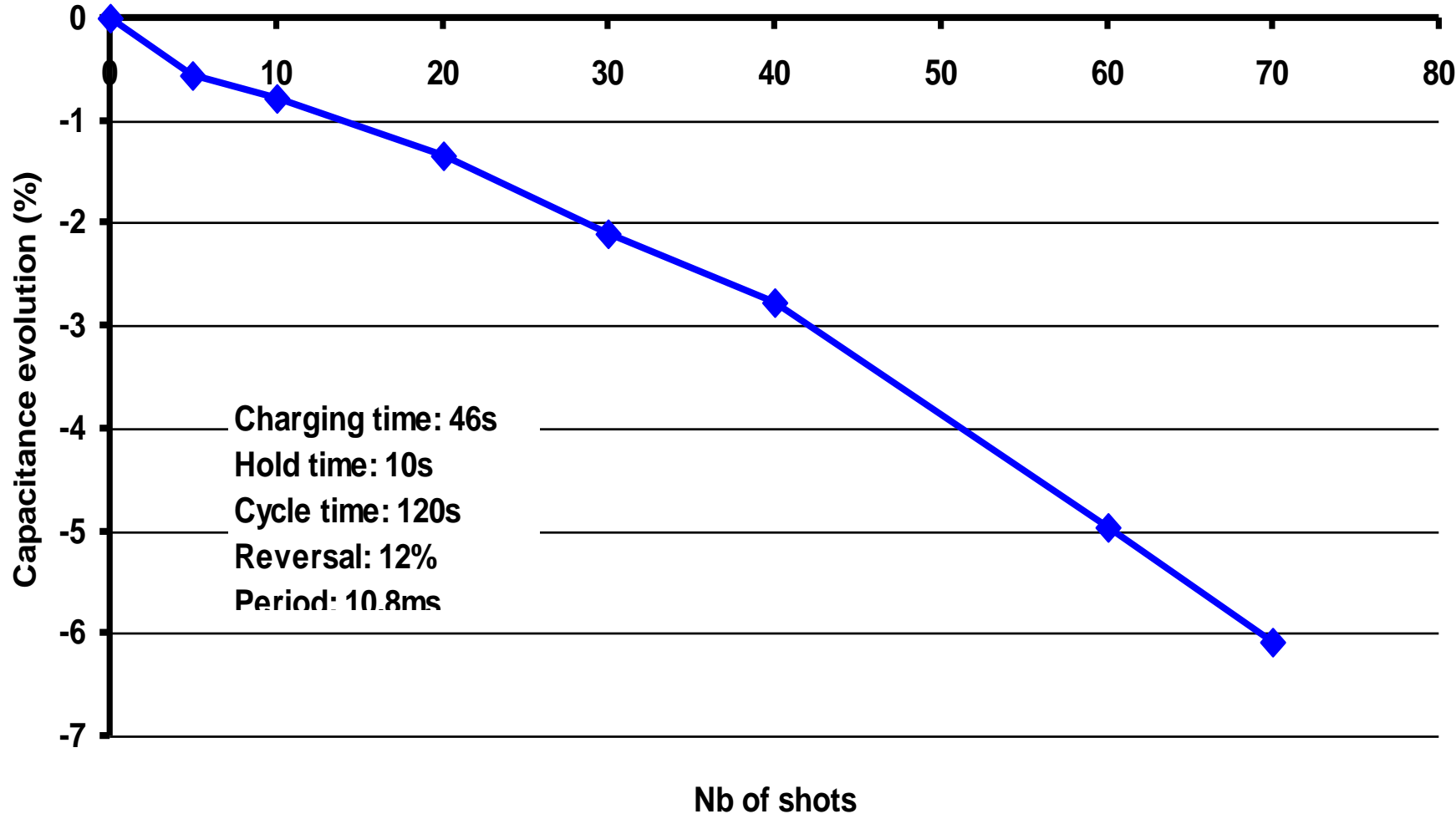
 KYOCERA
AVX

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Discharge capacitors for Electromagnetic guns



Discharge capacitors for Power Fusion Laser in CEA

DFM3 technology – 445V/ μm – 15,000 shots – 10% reversal - 900J/l



300 μF / 24kV
445V/ μm – 900J/l



➤ 3520 caps (300 μF - 24kV – 87kJ – 111kg) = 306MJ – 390,000kg

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FILM FOIL TECHNOLOGY : discharge capacitors :

Discharge Applications for HV Marx generator :

Typical characteristics :

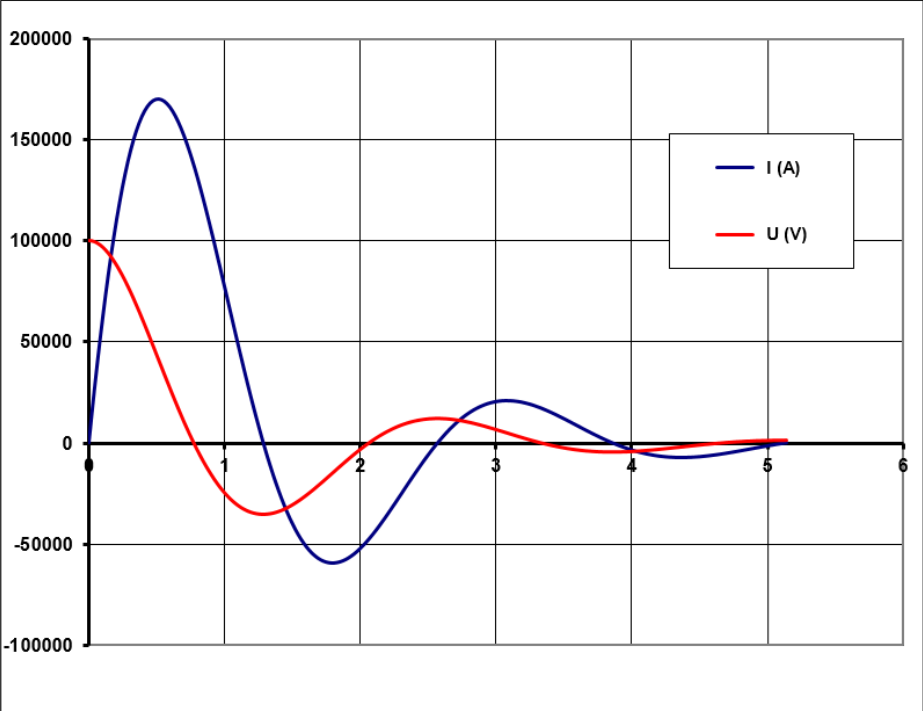
- C=1μF
- Uch = 100kV
- Ip = 100kA
- Ls <50nH

Paper + aluminium foil + castor oil : obsolete technology due to poor quality of paper

Tension de charge (V)	100000
Capacité (μF)	1
Résistance (ohms)	0,246
Self (μH)	0,150
Période (μs)	3
Temps pour I max (μs)	0,5
Inversion (%)	35
Courant crête (A)	170000

Récurrence de tir (s)	10
Longueur shoopée (m)	1000
Courant efficace (A)	45,11
I ² t/m ² (A ² s/m ²)	2,04E-02
I ² t (A ² s)	2,04E+04

Régime oscillant amorti



The 2 film technologies : FOIL vs METALLIZED

Technology	FOIL	METALLIZED
Electrode	20µm aluminium	100Å aluminium vacuum spraid
Dielectric	Paper or Paper + film	Polypropylene
Oil impregnation	Castor oil	Rape seed oil
Density of energy	Up to 500J/l	Up to 2200J/l
Peak current	« no limitation » (*)	Limited by metal spraying length
I ² t	« no limitation » (*)	Limited by metal spraying length
Serial resistance	Not relevant	mΩ scale
Serial inductance	<50nH « up to 100kV » (*)	Depending of voltage « 50nH/10kV »
End of lifetime	Not predictable	Capacitance measurement
Main failure mode	Short-circuit (explosion)	Capacitance lost
Future	Paper obsolescence	Mature phase

Polypropylene is and stays the best dielectric compromise : performance vs quality vs cost

No better film on the market



QUESTIONS & ANSWERS



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