Lifetime expectation of Film Capacitors

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Content

- Temperature dependency
- Dielectric mixing
- Reliability
- Acceleration factors

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Polypropylene temperature characteristics

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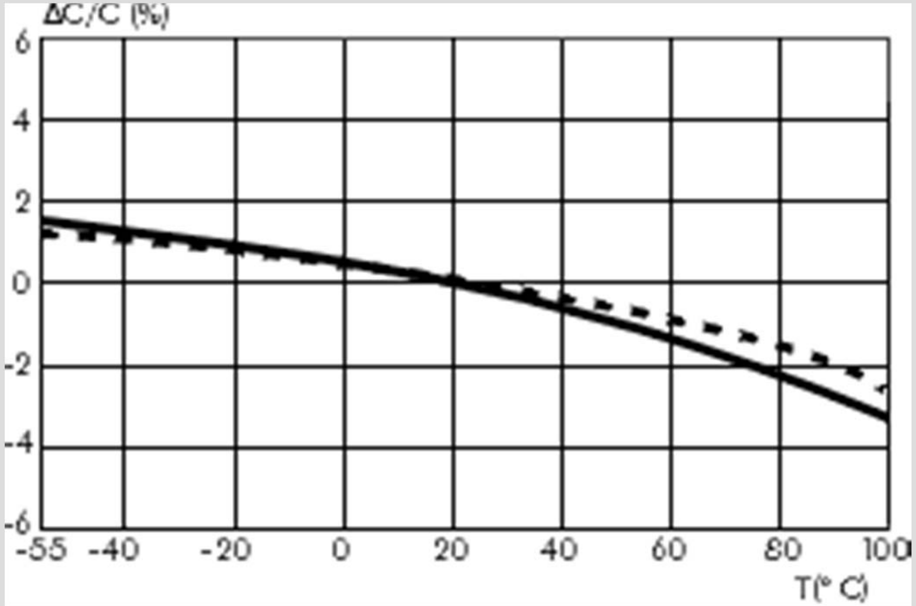
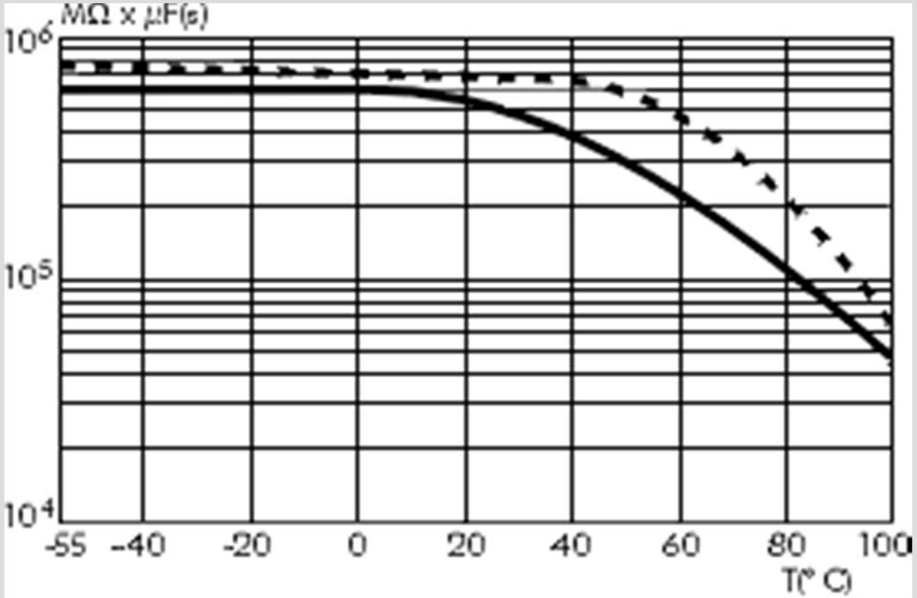
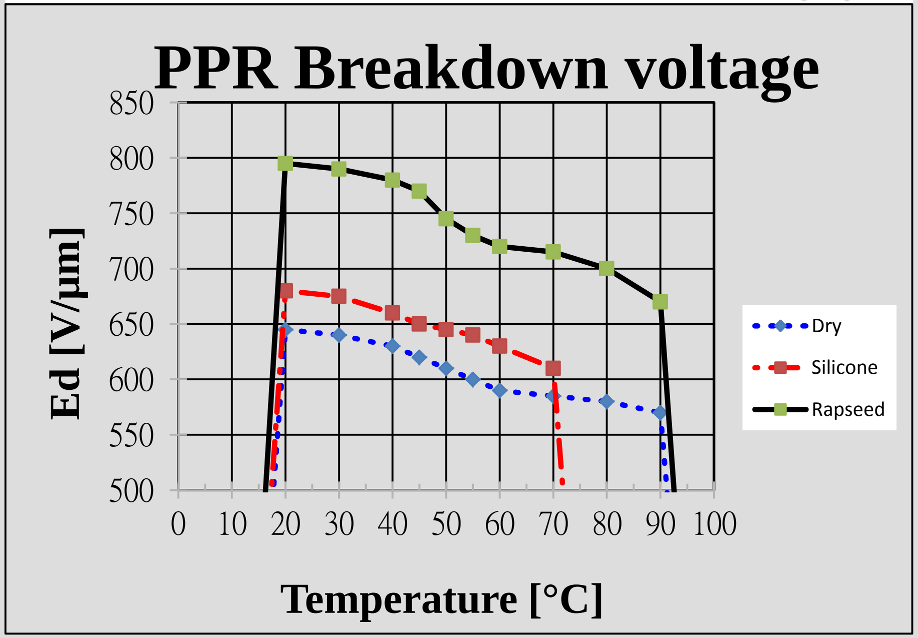




- C temp variation
- Insulation résistance
- Dielectric resistance



Electrical field on the electrode edges

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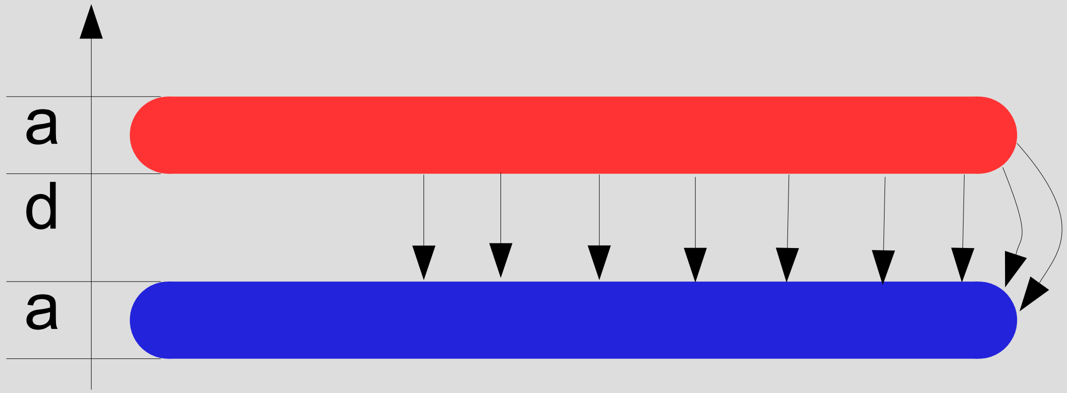
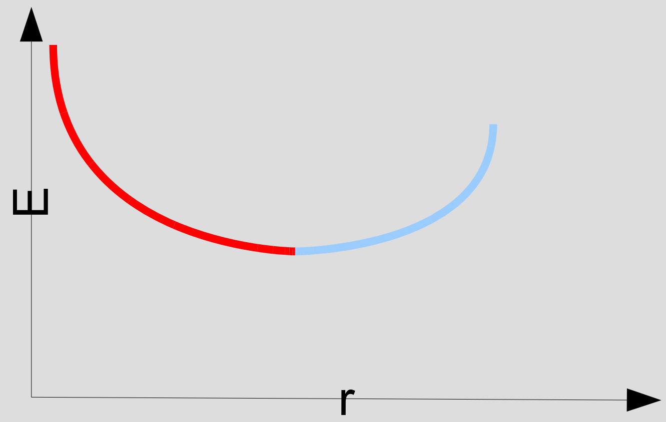
$$U = \int \vec{E}\, d\vec{r}$$

The field intensity is maximum close to the edges





- a= electrode thickness
- d = dielectric film thickness

Electrical field repartition

- DC with parallel resistances

$$E_1 = \frac{\sigma_2}{\sigma_1 d_2 + \sigma_2 d_1} U$$

- AC with the dielectric number

$$\varepsilon_1 E_1 = \varepsilon_2 E_2$$

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Electrical field in a capacitor

Dry

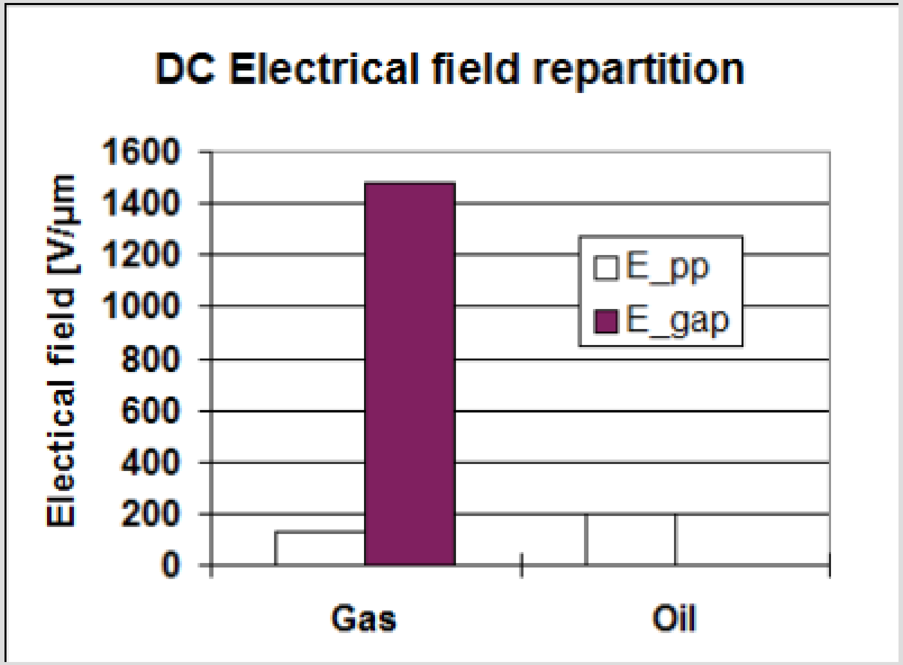
Impregnated

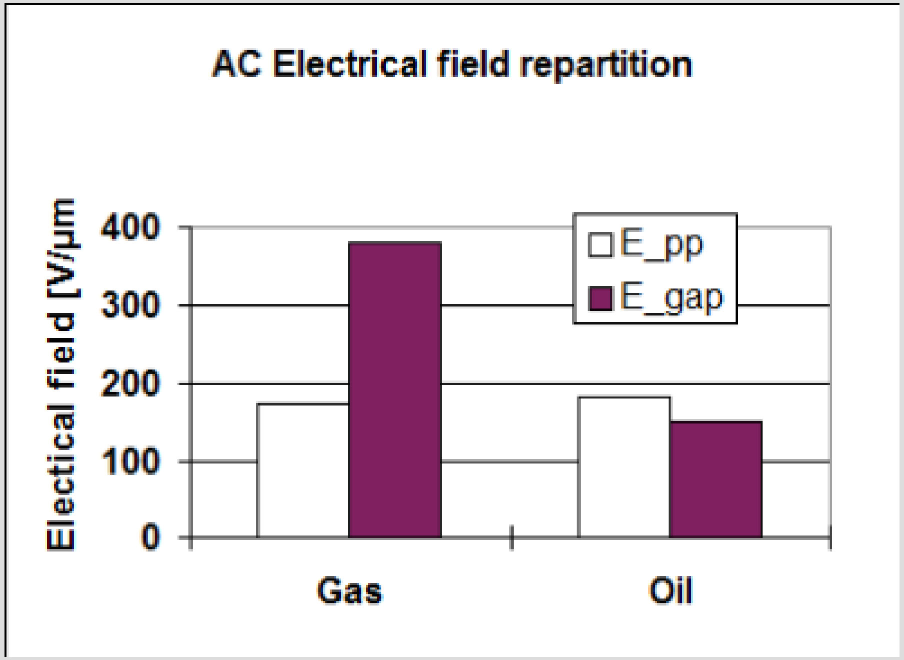
E = U / d = 180 V/µm
d = dielectric film thickness
h = gap thickness
Spf = (d + h)/d

E = U / (d+h) = 180 V/µm

E_C = U / d = 200 V/µm

Gas – Oil capacitor electrical field





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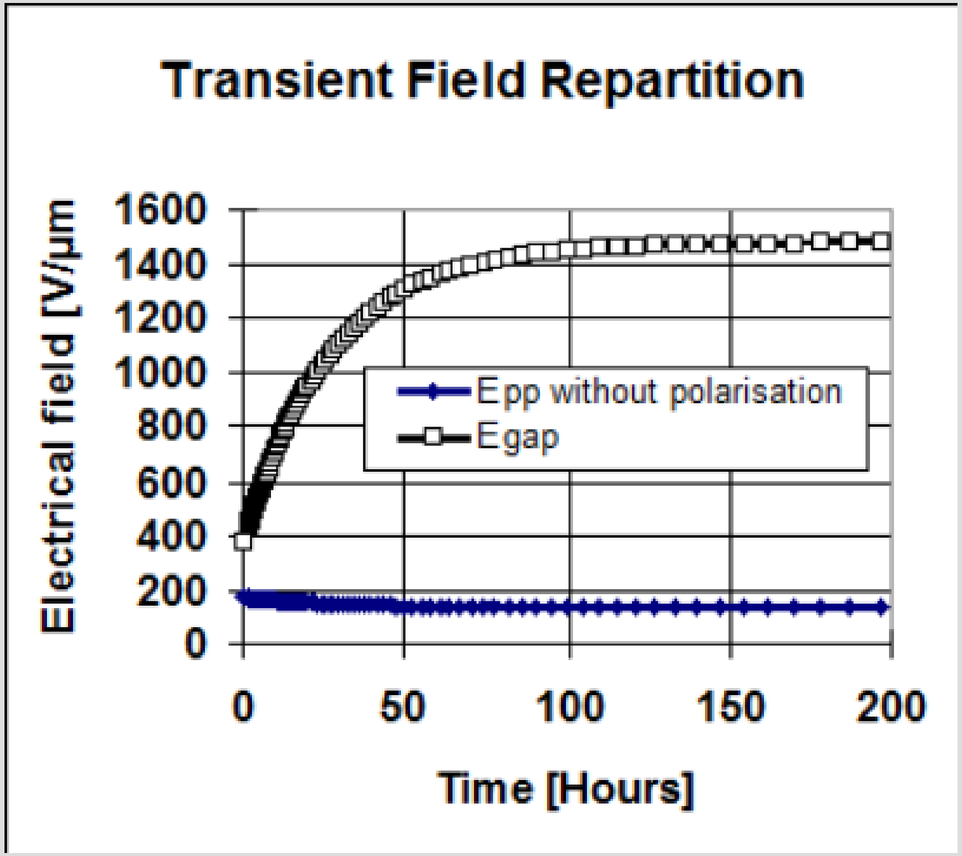
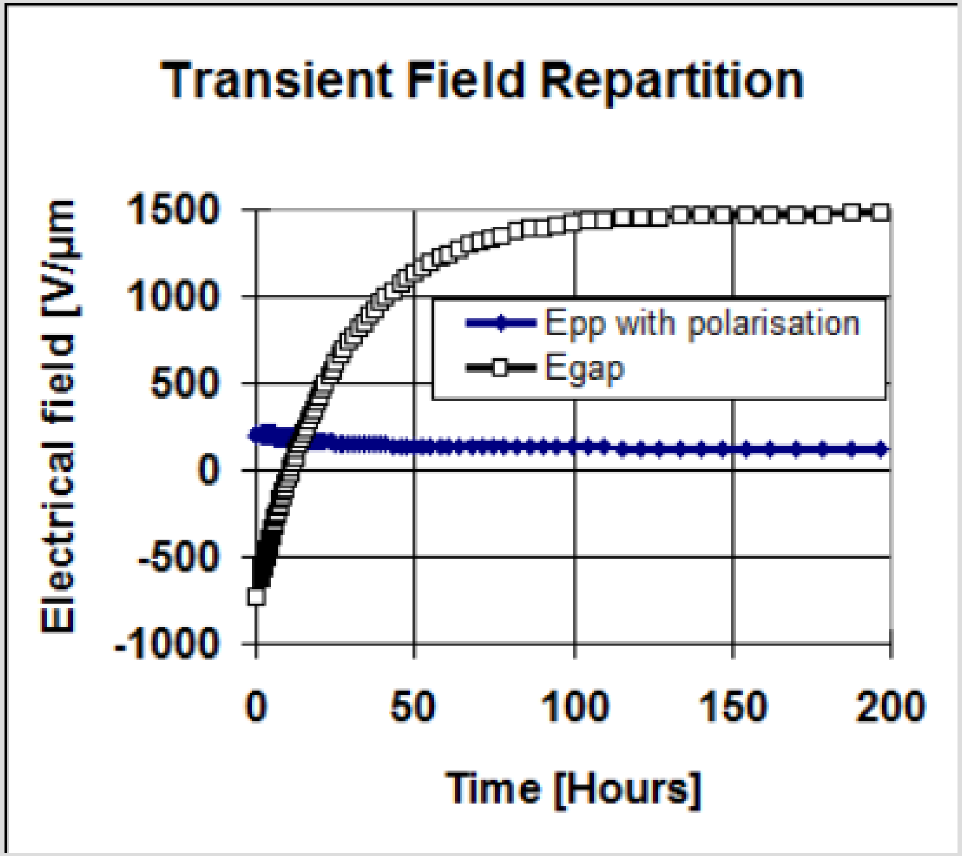
Electrical field in gas impregnated capacitors





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Reliability

Weibull distribution

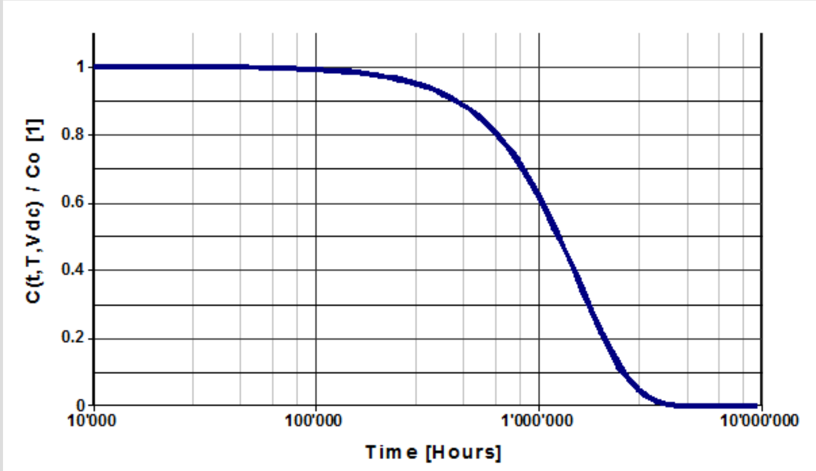
Survivor function

The Survivor function F(t) is the number of elements of the statistical sample which have not failed or lost their function at time t and are still working.

$$F(t) = \exp^{-(\lambda_o t)^p}$$

λ_o = 1'500'000 hours

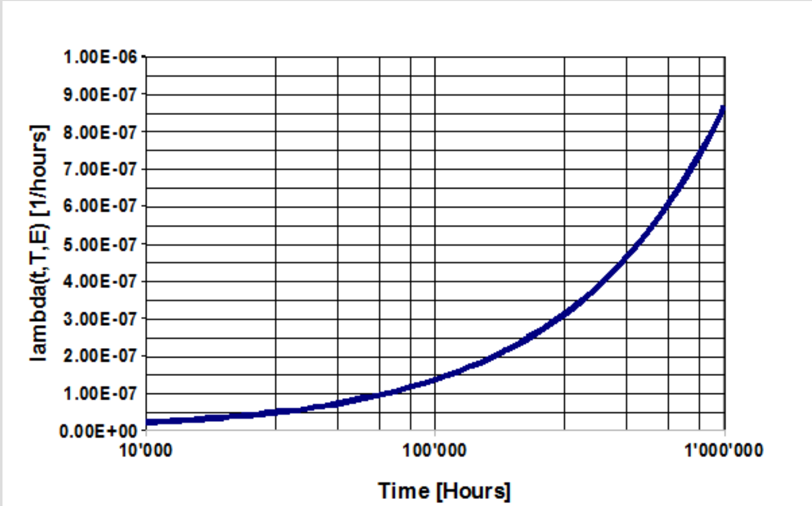
p = 1.8



Failure rate

The failure rate is given in FIT (Failure In Time) which is the number of failures occurring during 10^9 hours of working of 1 object. λ_o is a constant (independent of time, but dependent on the temperature and voltage) which corresponds to the inverse of the time necessary for 63 % of the sample to fail.

$$\lambda(t) = \lambda_o \, p \, (\lambda_o t)^{p-1}$$



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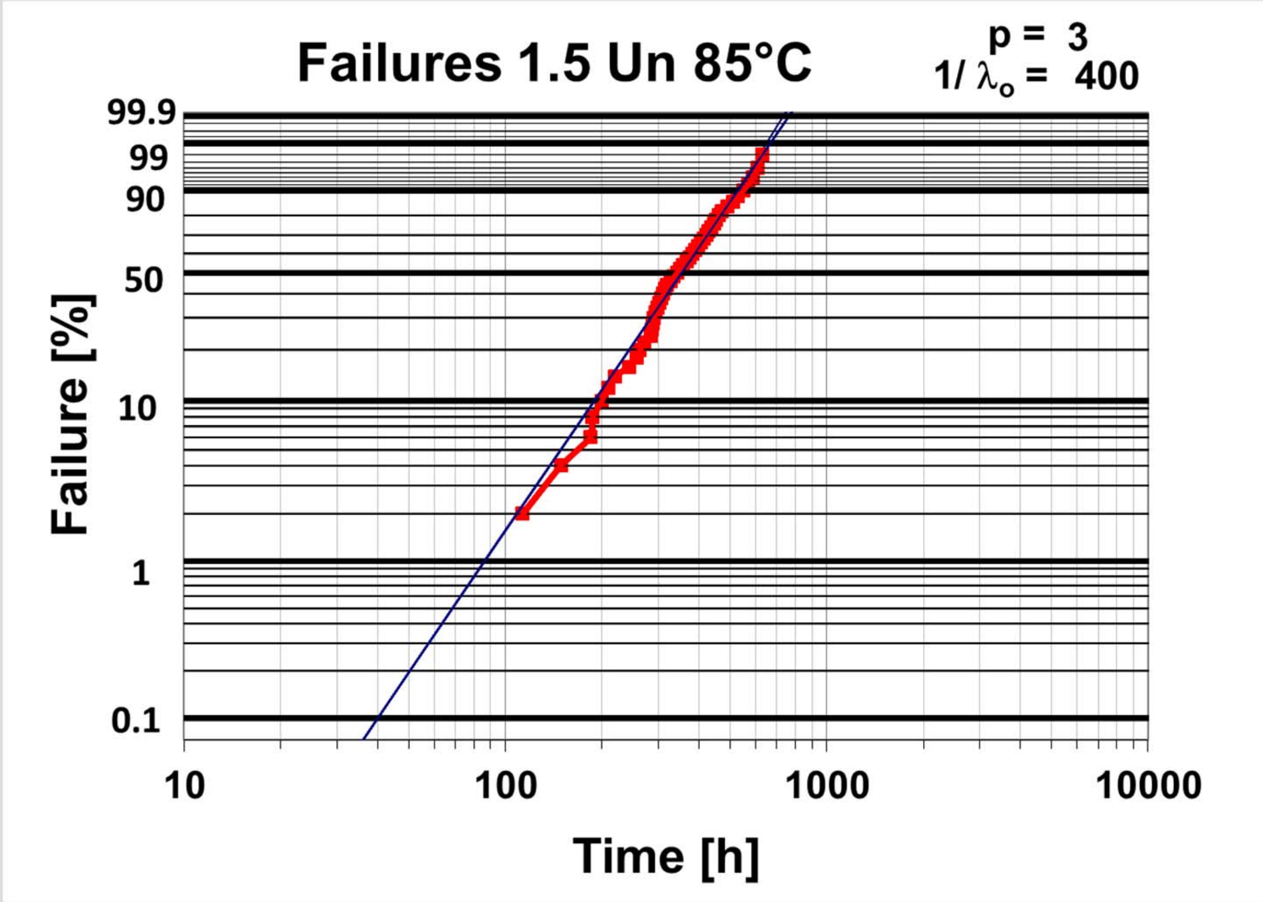
Example

Initial batch of 50 capacitor samples
The Failure in % is represented in a Weibull graphic which is a Log(Log(1/F(t))) function as a function of Log(t).

t [s]	N * F(t)	Log(Log(1/F(t)))
1	50	-9.0037887
113	49	-2.0568061
149	48	-1.7513214
184	47	-1.5706976
187	46	-1.4411454
200	45	-1.3395378
209	44	-1.2555714
219	43	-1.1837484
242	42	-1.1207853
256	41	-1.0645625



Acceleration factors: theory

- Voltage

$$t = t_{un}\left(\frac{U_n}{U}\right)^n$$

Power law

- Temperature

$$t(T) = t_{Tn}\exp\left(\frac{E_a}{k_B}\left(\frac{1}{T}-\frac{1}{T_n}\right)\right)$$

Exponential law
(Arrhenius law)

- Humidity

$$t(RH) = t_{Hn}\left(\frac{RH_n}{RH}\right)^m$$

Power law
(Hallberg-Peck law)

Acceleration factor: voltage

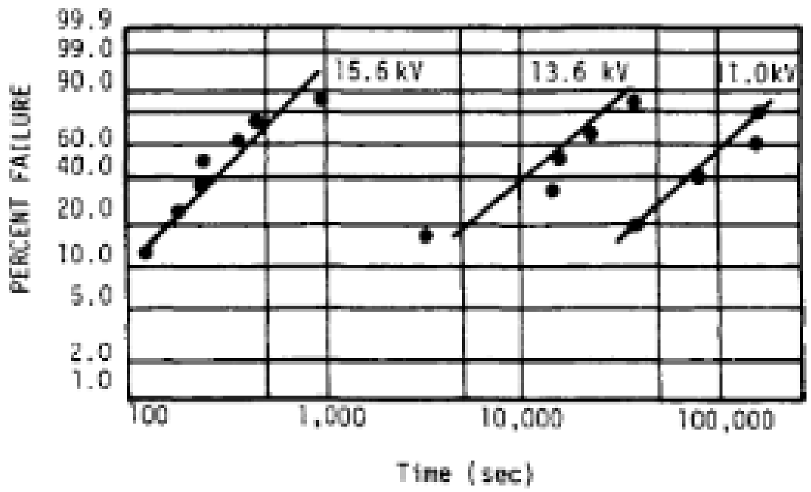


Figure 3.

Weibull plots for times to breakdown under dc stress at 23°C.

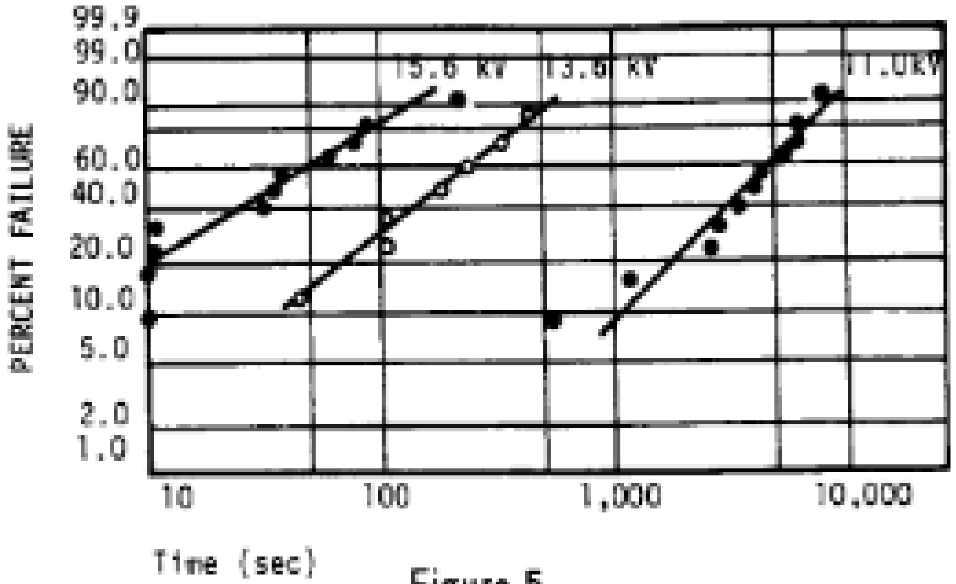


Figure 5.

Weibull plots for times to breakdown under dc stress at 90°C.

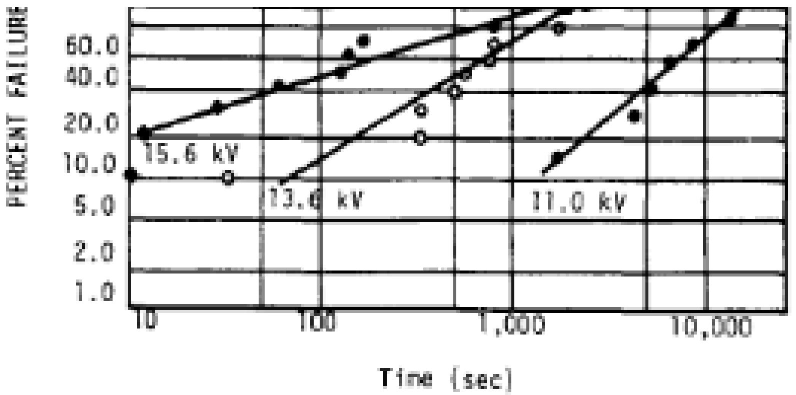


Figure 4.

Weibull plots for times to breakdown under dc stress at 70°C.

Cygan et al.: Lifetime of Films under Combined Stresses , IEEE Transactions on Electrical Insulation , vol. 24 No. 4, August 1989, p. 619

Acceleration factor: temperature

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