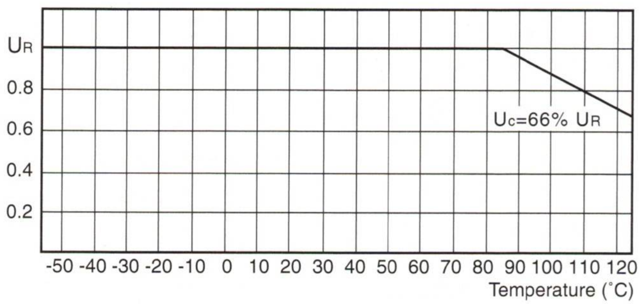
1 - Direct DC voltage

The rated voltage (U_R), indicated on the capacitor, is the maximum DC voltage which can be applied continuously between -55°C and +85°C.

For the types which can be used up to 125°C, the voltage must be derated between 85°C and +125°C according to the following curve.



2 - Reverse voltage

This characteristic is not guaranteed for all types.

Maximum reverse voltage is generally:
- 0.15 times U_R at +20°C
- 0.05 times U_R at +85°C
- 0.01 times U_R at +125°c

Tests are performed with the following conditions:
- 125 hours under reverse voltage followed by 125 hours under direct voltage.

3 - Leakage current

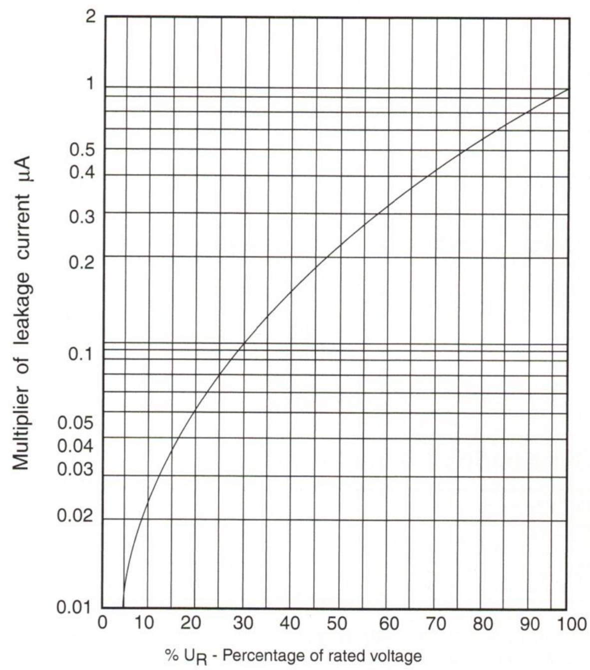
Leakage current is the residual current which flows through the capacitor after the charging time, under rated voltage. It is measured after a time not exceeding 5 minutes and is given in µA.

It is equivalent to the insulation resistance to the capacitor and it must be as low as possible.

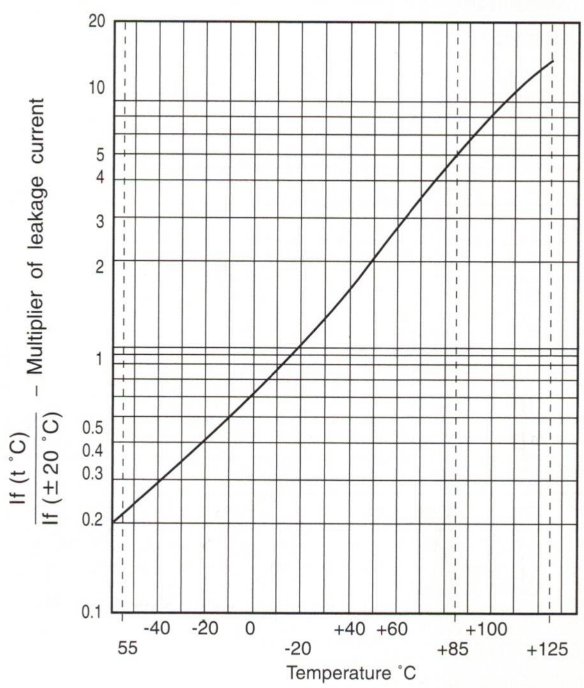
Maximum leakage current is a function of capacitance and rated voltage values and is given, for each type, in the data sheets.

At 20°AC, the limit is generally:
If max (µA)=0,01 x C_R x U_R
with C_R in µF and U_R inV.

Leakage current change vs applied voitage : see curve below



Leakage current change vs temperature : see curve below



4 - Dissipation factor

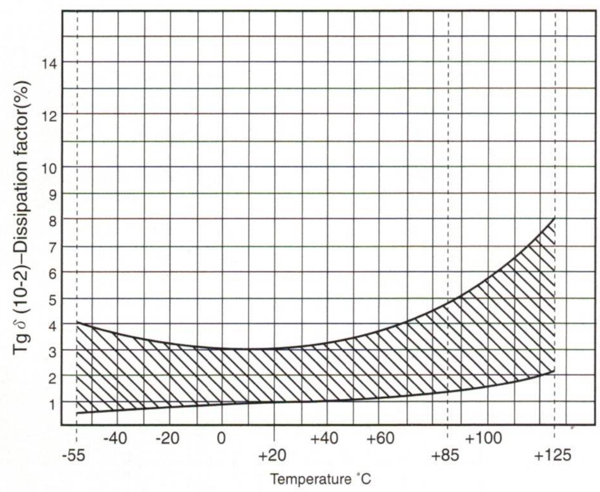
Dissipation factor is generally measured at the same time as the capacitance, with the same conditions. It is a function of the series resistance of the capacitor and the capacitance at low frequency.

DF = ESR x C x 2π f

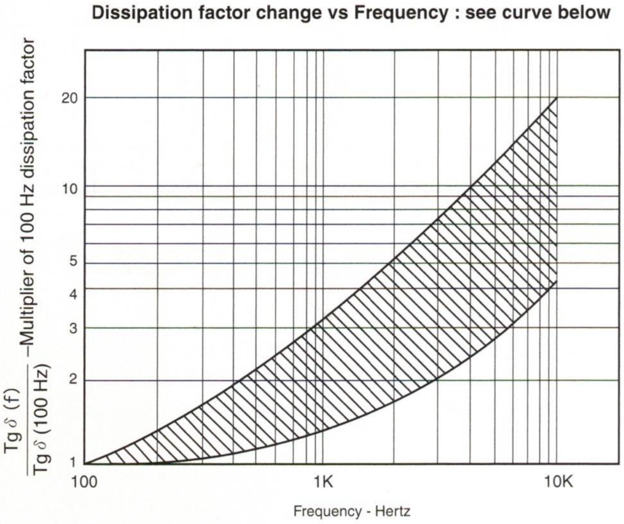
At low frequency, the series resistance is the sum of an ohmic part (leads, contacts, MnO_2,.....) and the dielectric losses.

Dissipation factor is given in % and maximum limits are given for each type in the data sheets.

Dissipation factor change vs temperature : see curve below

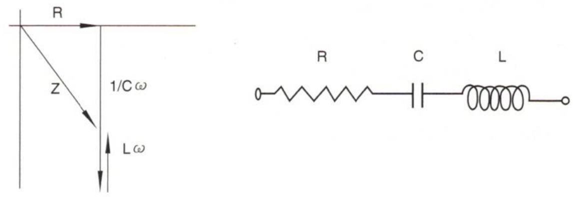


Dissipation factor change vs Frequency : see curve below



5 - Equivalent series resistance or impedance

Equivalent circuit of a capacitor



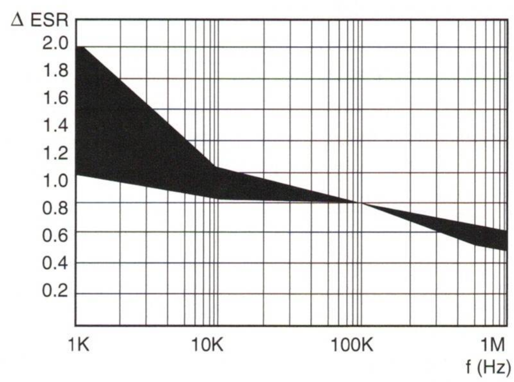
R: equivalent series resistance of the capacitor (leads, contacts, MnO_2, dielectric losses)
L: inductance mainly due to the leads
C: capacitance

Equivalent Series Resistance for CTS types

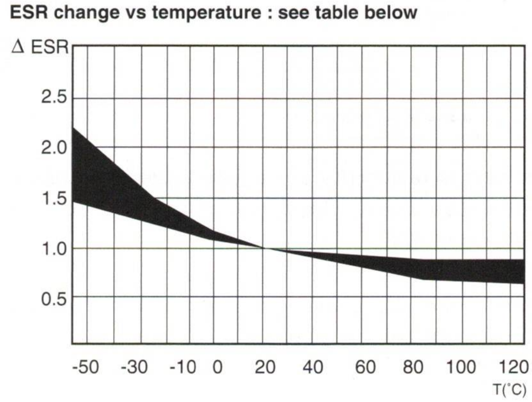
For these types which are specially designed to be used in power supplies and converters, a maximum ESR is given at a frequency of 100kHz or 500kHz. Parameters such output ripple voltage and ripple current capability are directly a function of the ESR value.

ESR change vs frequency : see table below.

ESR change vs frequency : see table below.



ESR change vs temperature : see table below



Impedance *(for standard products)*

For the others types, a maxuimum limit is given for the impedance. The formula for impedance is:

$Z = \sqrt{(R^2 + (L\omega - 1/C\omega)^2)}$

Examples of impedance curves vs frequency are given in the following:

It can be seen that:
- *at low frequencies, impedance is a function of capacitance*
- *at high frequencies, impedance is a function of inductance*
- *at medium frequencies, it is a function of the ESR*

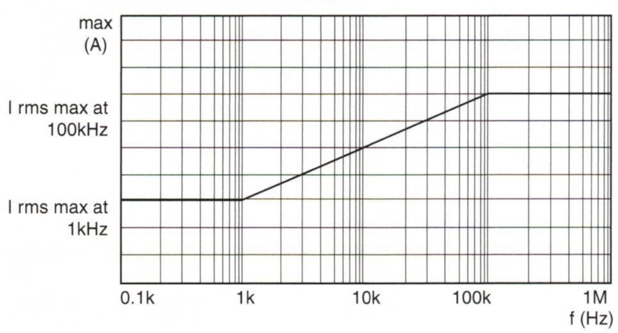
Maximum impedance : see data sheets.

6 - Maximum ripple current
Maximum ripple voltage

The maximum value of the ripple current, or ripple voltage which can be applied to the capacitor is only limited by the thermal effect. Indeed, as the electrolyte is in this case a solid semi-conductor, there is no damage and physical change in the structure when a ripple current is flowing through it.

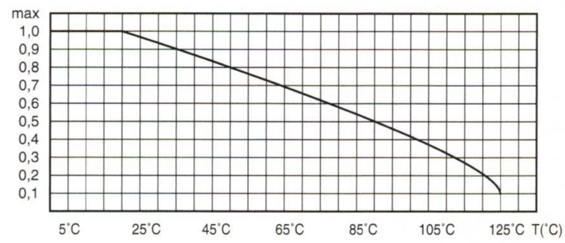
On the other hand, as the series resistance is not zero, there will be a heating which is proportional to the ESR and to the square of ripple current ($P = ESR \times Irms^2$)

As the ESR changes in frequency, maximum ripple currents are given for two frequencies (1kHz and 100kHz). For other frequencies, apply the rule given by the curve below.



As there is heating due to the ripple current, it is also necessary to derate the maixmum ripple current when the room temperature is higher than 20°C:

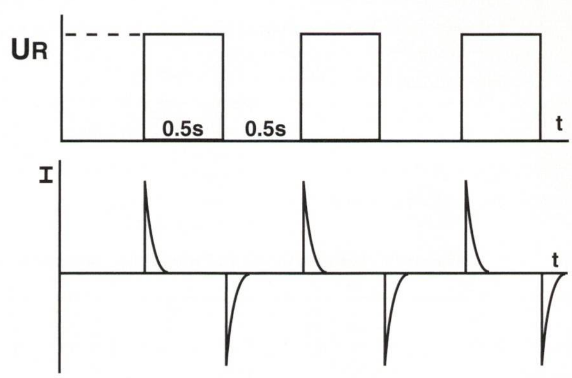
Coefficient to apply to the maximum ripple current vs temperature: see curve below



7 - Charge discharge
Surge current

For classical types of solid tanatlum capacitors, it is necessary to limit the surge current by placing a resistance in series with the capacitor. The value of this resistance will be calculated by using the rule of 3Ω per volt (Imax = 0,33A).

The high surge current test is performed to check that these capacitors can be used in low impedance circuits, and to make sure of their capability to withstand high surge currents. The test circuit is the following one:



The test being performed under rated voltage with a maximum 0,5Ω circuit resistance, the peak surge current will be a minimum equal to $Ip = U_R / 0,5$ (if the ESR of the capacitor is considered as negligeable).

e.g.: high surge current test performed on a CTS 100µF-20V (ESR-75mΩ, negligeable compared to 0,5mΩ)
Surge current = 20 / 0,5 = 40A during a few tens of µs.

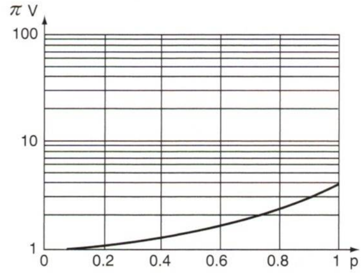
Depending upon the types, this test can be 100% performed or on a sampling basis, during 3 to 5 cycles. During periodic tests, 1 million cycles are performed.

RELABILITY - LIFE TIME

1 - Reliability

Reliability of a component can be defined as its probability to work without any failure, in defined conditions and during a fixed time.

Reliability is not therefore only a function of the component quality, but also of the application and environmental conditions. The parameter which is the most commonly used for the reliability is the failure rate in time, generally expressed in % per 1000 hours.



π_t = temperature influence
Formula:
$\pi_t = \exp(1{,}8 \cdot (t / tm)^2)$
with:
t = using temperature
tm = maximum temperature
Curve for tm = 125°C
see curve

π_V = influence of applied voltage vs rated voltage
Formula:
$\pi_V = \exp((p / 0{,}85)^2)$
$p = \frac{\text{peak voltage}}{\text{rated voltage}}$
Curve $\pi_V = f(p)$: see curve

1-1 Established failure rate capacitors

Equivalent to MIL types, can be supplid with a fixed faiure rate. This failure rate is coded with the following letters:
M = 1.0% / 1000 h
P = B = 0.1% 1000 h
R = C = 0.01% 1000 h
S = D = 0.001% / 1000 h
The rate is calculated by recording the failures during the burn-in and according to the Weibull method.

1-2 Calculation of a component failure rate used in an equipment

The failure rate is calculated with parameters which are function of the capacitor (capacitance, case type, approvals, high surge current test) and others ones which are representative of application conditions (voltage, temperature, resistance in serie, environmental conditions).

Example:
CTS 150µF-25V used under 12 volts, at 40°C, without serie resistance, in satellite in orbit:

$\pi_t = 1{,}2$ $\pi_v = 1{,}38$ $\pi_R = 1$ $\pi_B = 1$
$\pi_C = 1{,}8$ $\pi_E = 0{,}5$ $\pi_q = 1$

$\lambda = 4 \times 1{,}2 \times 1{,}38 \times 1 \times 1 \times 1{,}8 \times 1.10^{-9} / h$
$= 6.10^{-9} / h = 0{,}0006\%$ defect / 1000 hours

RELIABILITY CALCULATION

$$\lambda = 4 \cdot \pi_t \cdot \pi_V \cdot \pi_R \cdot \pi_B \cdot \pi_C \cdot \pi_E \cdot \pi_q \cdot 10^{-9} / h$$

π_R = influence of circuit resistor in serie
V = using voltage
R = circuit resistance between capacitor and power supply
1 / Types with high surge current test
$\pi_R = 1$
2/ Others types: π_R = function of R/V in Ω/V

R/V ≥ 3	$\pi_R = 1$
R/V = 2	$\pi_R = 1{,}5$
R/V = 1	$\pi_R = 3$
R/V = 0,8	$\pi_R = 4{,}5$
R/V = 0,6	$\pi_R = 6$
R/V = 0,4	$\pi_R = 9$
R/V = 0,2	$\pi_R = 12$
R/V = 0.1	$\pi_R = 15$

π_B = influence of capacitance

Metal case	$\pi_B = 1$
Molding case	$\pi_B = 3$
Dipped	$\pi_B = 5$

π_C = influence of case type

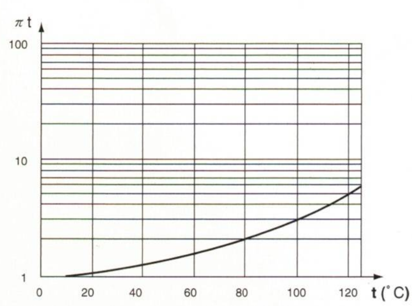
0.1 µF	$\pi_C = 0{,}75$
150 µF	$\pi_C = 1{,}8$
330 µF	$\pi_C = 2{,}0$
1000 µF	$\pi_C = 3{,}0$

π_E = influence of surroundings conditions

Satellite in orbit	$\pi_E = 0{,}5$
Ground; stationary; protected	$\pi_E = 1{,}0$
Ground; stationary; non protected	$\pi_E = 2{,}5$
Ground; mobile; soft conditons	$\pi_E = 4{,}0$
Aurcraft; soft conditions	$\pi_E = 4{,}0$
Ship; soft conditions	$\pi_E = 4{,}0$
Ground; mobile; hard conditions	$\pi_E = 5{,}5$
Ship; hard conditions	$\pi_E = 7{,}0$
Aircraft; hard conditons	$\pi_E = 10{,}0$
satellite; launching	$\pi_E = 12{,}0$

π_q = influence of qualification

Products approved to CECC	$\pi_q = 1{,}0$
Others products	$\pi_q = 1{,}0$



2 - Life time

There is no known damaging mechanism in time for solid tantalum capacitors; that is why is difficult to give a precise life time.
However, life tests at 85°C under rated voltage and 125°C under derated voltage are periodically performed.
In addition, during qualification programs for new types, life test at 85°C and 125°C have been performed during 1000 hours and no significant parameter change have been observed.