General technical information

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IMPORTANT:

information and data contained in the chapter "General technical information", are a completing part of the single series specifications. The series specifications are completed with the data given in the "General Technical Information" chapter.

Data and characteristics shown in this catalogue are subjected to modifications without notice.

Always refer to ICEL S.r.l. web site, www.icel.it for products updated characteristics, last revision specifications, general data and information, products certifications and news.

General technical information

A-Capacitor design and construction

Plastic film capacitors can be subdivided into two main groups on the base of their construction: film-foil capacitors and metallized film capacitors. The combination of these two technologies brings to a third group of capacitors, which gets the advantages of both the above groups.

A1- Film-foil capacitors

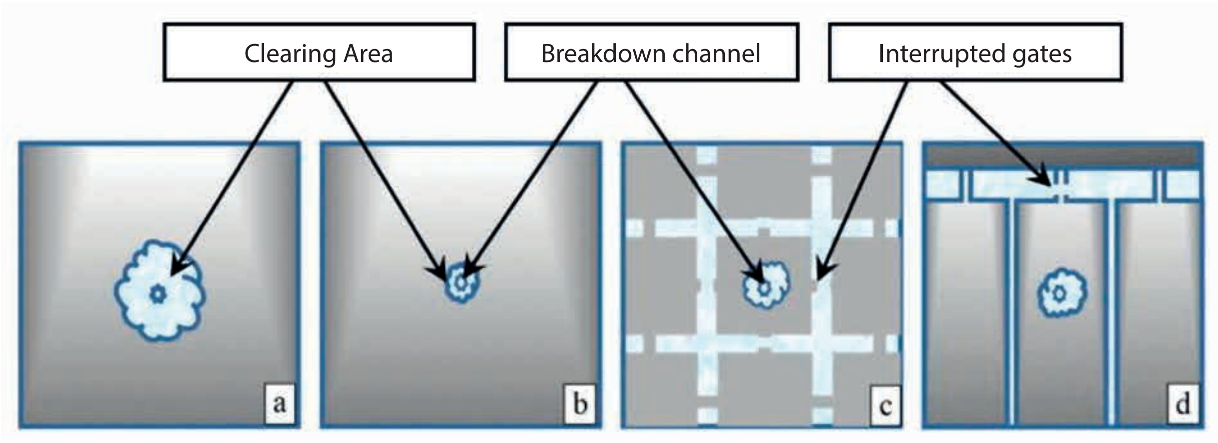
Typical film-foil capacitor consists of two metal foil electrodes with a plastic film between them, used as dielectric.
Metal foils thickness is typically 5 to 9µm and the plastic film must be thick enough to guarantee the necessary capacitor reliability in terms of voltage withstanding and long-term performances and reliability.
Film-foil capacitors, being not able to self-heal (refer to related paragraph A-3) usually need a dielectric thickness higher than the one of metallized film capacitors, having the same voltage ratings.
It means that, considering the same dielectric type, capacitance and voltage rating, the typical dimensions of the film-foil capacitors are larger than metallized film capacitors ones.
The presence of metal foil electrodes ensures high insulation resistance, very good capacitance stability, low losses even at high frequency, excellent pulse handling capability and high current withstanding.
Film-foil capacitors don't have self-healing properties.

A2- Metallized film capacitors / Segmented metallization design

In metallized film capacitors, the metal electrodes are vacuum deposited directly onto the dielectric film surface.
The different metal alloys, their shape and the thickness of the metal layer influence in a relevant way the characteristics, behavior, performances, energy density and typical usage destination of the capacitors.
The outstanding advantage of metallized film capacitor technology is the self-healing property.
The extremely thin metal layer obtainable (typical thickness from 0.02 to 0.05µm for "flat" metallization) and the availability of low thickness dielectric films allow the production of capacitors with smaller dimensions than film-foil ones, having the same voltage rating.
The contacting of metallized film capacitors is made by spraying metal alloys onto the windings face ends and then welding the terminals on those metal sprayed areas.
This ensures a low inductance and low loss characteristics.
Metallized film capacitors do not typically guarantee high pulse withstanding capability.
Nevertheless, a medium-high pulse handling capability can be reached with metallized film technology, using special films having metallization with reinforced contact edges and particular metal alloys, or adopting inner series connection design.
Special metallization design, like slope profile (variable R, metallization thickness and metal alloy combination along the film width) can be used to obtain high energy density, high performances and special characteristics, focused on particular application needs.
The segmented metallization design of the metal layer over the dielectric, is shaped in a way to allow small part of it to be isolated in case of local short circuit or breakdown. The aim is to obtain the restoring of the full functionality of the unit with a negligible loss of capacitance, restraining the propagation of the energy involved in the clearing to other sections of the winding. This prevents the possibility of dangerous failures which may cause the destruction of the components and of the equipment where they are used, with smoke, fire and explosion danger. However this theoretically higher safety level implies a lower volumetric efficiency, a possible increase of the Equivalent Series Resistance (ESR) and of the related Dissipation Factor (DF), with respect to a comparable not segmented metallization (see the related picture). Also the Irms max. ratings are correspondingly slightly decreased. The latter considerations depend also on the design of the segmented pattern, which is typically related to the foreseen application.

A3- Self-healing

Self-healing (or clearing) process consists in the removal of imperfections, pin holes and dielectric film flaws which can cause permanent voltage breakdowns when voltage is applied to t he capacitor.
The electric arc which takes place with breakdown, evaporates and changes the characteristics of the surface metallized area around the fault, insulating the defect: the capacitor almost instantaneously regains its full operation ability.
The time necessary for self-healing process is usually less than a few µs and the electric arc occurs only if the necessary energy is available either as charge energy or as external energy.
Self-healing occurs only occasionally, thanks to the capacitor design (film metallization characteristics, dielectric film thickness and films disposal and combination in the winding) even when the maximum voltage allowed is continuously applied to the capacitor up to the higher temperature limit.
Moreover, only fractions of the total energy stored in the capacitor are dissipated during the self-healing process, therefore the related voltage drop remains low.
When prescribed by approval normative, capacitors having self-healing characteristic are printed with "SH" or "#" symbol.
For segmented metallization design, please refer to paragraph A2.



a and b: not segmented metallization;
c and d: examples of segmented metallization.
Effects of clearing on the two different film metallization designs.

A4- Mixed film-foil and metallized film capacitor technology

The combination of film-foil and metallized film technology typically offers the advantages of the two above described types, obtaining self-healing property, high current and pulse capability and low losses with extended frequency ranges.
On the base of the foreseen application and needed capacitors characteristics, metal foils electrodes can be replaced by double side metallized films and some types also cover high voltage ranges thanks to a particular inner structure design.
Since these kinds of capacitors maintain the self-healing capability, they are conventionally classified among metallized film capacitors.

A5- Dielectrics

Many different materials and plastic films may be used as a dielectric. The main dielectrics used in ICEL S.r.l. products are:
Polyester
Polypropylene
(Polycarbonate is no more available / in use: EXPIRED SERIES - NOT FOR NEW DESIGN)

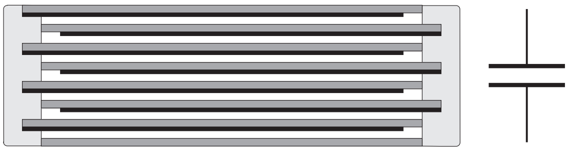
The use of different dielectrics gives different characteristics, performances and behavior to the capacitors: different dielectric types are adopted as a function of the design needs and foreseen application characteristics.
Different types of the same general film type are available, having different characteristics and allowing different performance levels (for example different temperature grade polypropylene films).
A comparison of the main, average characteristics of the above plastic film dielectrics is shown in the following table:

Comparative table of plastic film dielectric main characteristics (typical values)				
Characteristic	**Polyester**	**Polycarbonate**	**Polypropylene**	**Polystyrene**
Relative dielectric constant (25°C, 1kHz)	3.3	2.8	2.2	2.5
Max. working temperature (°C)	125	125	105 (+115)*	70
Loss factor (x10-4, at 1kHz; at 100kHz), typical	50; 180	10; 100	2; 3	2; 3
Insulation resistance (MΩ x µF, +20°C)	≥ 30	≥ 50	≥ 300	≥ 300
Temperature coefficient (ppm/°C)	-	+150	-200	-150
Dielectric strength (V/µm), typical	250	180	350÷400	150
Water absorption (% in weight), typical	0.2	0.3	<0.01	0.1
Density (g/cm^3), typical	1.39	1.21	0.91	1.05

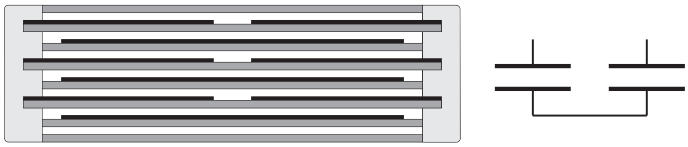
*Special base film and execution for high temperature applications

A6- Capacitors winding

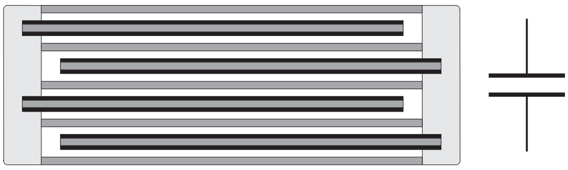
Capacitive elements are obtained rolling together a stated number of different types of films (plain and metallized) and metal foils, having characteristics, arrangement and sequence function of design targets, obtaining cylindrical rolls called windings (in the following examples, it is shown 2 sections inner series connection scheme only but, depending on design, sections can be many more).



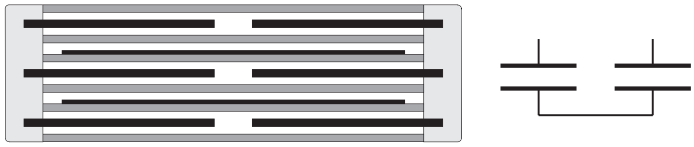
Extended metallized film design



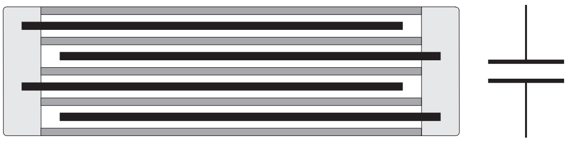
Extended metallized film design
with internal series connection
(series connection of 2 elements)



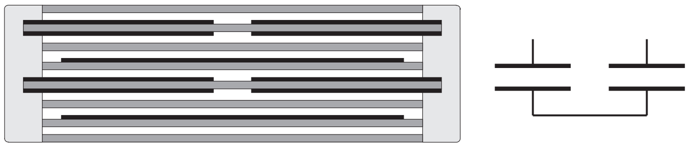
Extended double side metallized
carrier film design



Extended foil design with internal series
connection and metallized film
(series connection of 2 elements)



Extended foil design



Extended double side metallized carrier
film design with internal series
connection and metallized film
(series connection of 2 elements)

Plain film (dielectric/ protection)

Metal foil (electrodes)

Single side metallized film
(dielectric+electrodes)

Double side metallized film
(electrodes)

Sprayed metal head contact

A7- Capacitors assembly and testing

The capacitive windings are submitted to thermal treatments, heads contact spraying and then are submitted to 100% clearing and electrical parameters pre-testing.
The windings can be flattened (getting oval transverse section), in order to obtain axial or dipped units having specified dimensions or to be inserted in box. After the terminals welding, the units are finished in accordance with specifications (wrap and fill, dipped, sealed in box style and so on).
Additional 100% or statistical checks are executed at different points of the production cycle to guarantee the materials and capacitors conformity with specifications.
At the end of the production cycle, capacitors are submitted to final tests (100% of the production, net of exceptions) and printing, in accordance with reference standards and applicable approval normative.
Then they are packed for shipment or storage.

ICEL S.r.l. Quality Assurance system is in conformity with ISO9001 normative (please refer to ICEL S.r.l. web site www.icel.it for details and current approval **state and additional certifications availability**).

B-Technical terms (reference standards: EN, IEC, CECC and DIN normative; for other applicable references please refer to the single type specification) and general technical data

B1- Nominal Capacitance (C_N or Cn)

It is the capacitance value for which the capacitor has been designed.
If not differently specified, it is typically measured at 1kHz ±20% at a max. testing voltage 3% of the rated voltage or 5V (whichever is the lowest), at 20°±5°C.
Capacitance rated values are typically graded in accordance with E series (refer to E series table; paragraph B38).

B2- Capacitance Tolerance

It is the maximum admitted deviation from the nominal capacitance value C_N, measured at 20±5°C. It is expressed in % or with related tolerance letter codes.
Preferred tolerance values and correspondent letter codes are:

±1%= F; ±1.25%= A; ±2%= G; ±2.5%= H; ±3%= I; ±5%= J; ±10%= K; ±20%= M

M letter code may not appear in units printing. In this case the capacitance tolerance is assumed as ±20% by default.

B3- Temperature Coefficient of Capacitance (α)

Applies mainly to capacitors of which the reversible variation of capacitance as function of temperature is linear or approximately linear and can be expressed with a certain precision.
It is the rate of change with temperature measured over a specified temperature range within the category temperature range. It is normally expressed in parts per million per degree Celsius (10^{-6}/°C) referred to 20°C and shall be calculated as follows:

$$\alpha_i = \frac{C_i - C_0}{C_0(\theta_i - \theta_0)}$$

C_0 = capacitance measured at 20±2°C
q_0 = 20±2°C
C_i = capacitance measured at q_i
q_i = temperature measured on test

B4- Long Term Stability

It is the maximum irreversible capacitance change after a period of 2 years at standard environmental conditions (refer to "Storage conditions and Standard environmental conditions"; paragraph D).

B5- Rated Voltage (U_R or Ur; Urms; U_N; U_{NDC})

The rated voltage is the voltage for which the capacitor has been designed.
It is the maximum direct voltage (U_R) or the maximum r.m.s. (Urms) alternating voltage or peak value of pulse voltage which may be continuously applied to a capacitor at the rated temperature T_R and at any temperature between the lower category temperature T_A and the rated temperature T_R (unless other declared limitations or otherwise stated in reference specifications).
For capacitors for power applications it might be used also,
U_N: maximum operating peak voltage of either polarity of a reversing type waveform for which the capacitor has been designed
U_{NDC}: maximum operating peak voltage of either polarity but of a non-reversing type waveform, for which the capacitor has been designed, for continuous operation.

Important: always refer to what indicated at type specifications about the applicable voltages values and waveforms applicable and allowed.

B6- Category Voltage (U_C)

It is the maximum voltage that can be applied continuously to a capacitor at its upper category temperature T_B.

B7- Temperature De-rated Voltage

It is the maximum voltage that may be applied continuously to a capacitor, when it is at any temperature between the rated temperature T_R and the upper category temperature T_B

B8- Superimposed AC Voltage
When alternating voltage is present, the working voltage of the capacitor is the sum of the direct voltage and the peak alternating voltage. This sum shall not exceed the rated voltage value, unless differently specified.

B9- Permissible AC Voltage up to 60Hz
It is the pure sine wave voltage that may be applied to the capacitor at a frequency up to 60Hz. The dissipated power and currents must be considered in case of operation at higher frequency. The AC rated voltages stated for each series refer to an operating frequency of 50÷60Hz and sinusoidal waveforms (no transient voltages). The permissible AC voltage at frequency over 60Hz, under sinusoidal waveforms, can be obtained from the AC voltage versus frequency graphs of each capacitor series. If not differently specified, the graphs are referred to an estimated typical capacitor temperature rise from the ambient temperature of +10°C.

Warning: even if the permissible AC voltage covers the lines voltage range, standard film capacitors are basically not suitable for operation in direct connection to public power networks. Unless not specified and if not approved in accordance with related applicable normative, capacitors cannot be used as class X or class Y units.

B10- Test Voltage between terminals (Ut)
It is the specified voltage value that may be applied for a specified time to the capacitor to test its dielectric strength. The occurrence of self-healing during the application of test voltage is typically permitted for metallized film capacitors.

Warning: unless differently specified, many capacitors connected in parallel or self-healing capacitor connected in parallel with other capacitors types should not be tested without using adequate limiting discharging devices and care. Discharging or protecting devices are necessary to prevent the rapid dissipation of the complete energy of the capacitors bank at the breakdown and clearing point, in case of self-healing, which can cause the damage (even hidden, not visible or immediately detectable) or destruction of the self-healing capacitor. This must be taken in consideration when making voltage proofs and high voltage tests prescribed by relevant normative on equipment where several connected together capacitors are used.

B11- Test Voltage between terminals and case (Utc)
It is the specified voltage value (insulation voltage) that may be applied for a specified time to the capacitor between its terminals and case to test insulation characteristics of its external protection. The occurrence of breakdown or discharge during the application of test voltage is not admitted.

B12- Non Recurrent Surge Voltage (Upk) and Recurrent Peak Voltage (Upkr)
Upk is the maximum non recurrent peak DC voltage that may be applied to the capacitor for a limited number of times and for a short period. The application of voltage higher than Upk may result in premature dielectric failure, capacitors damage and reliability reduction. Upkr is the maximum recurrent peak DC voltage that may be applied, under specified conditions, during the life of the capacitor.

B13- Rated Ripple Current (Ir)
It is the r.m.s. current value of the maximum allowable alternating current of a specified frequency at which the capacitor can be operated continuously at a specified temperature.

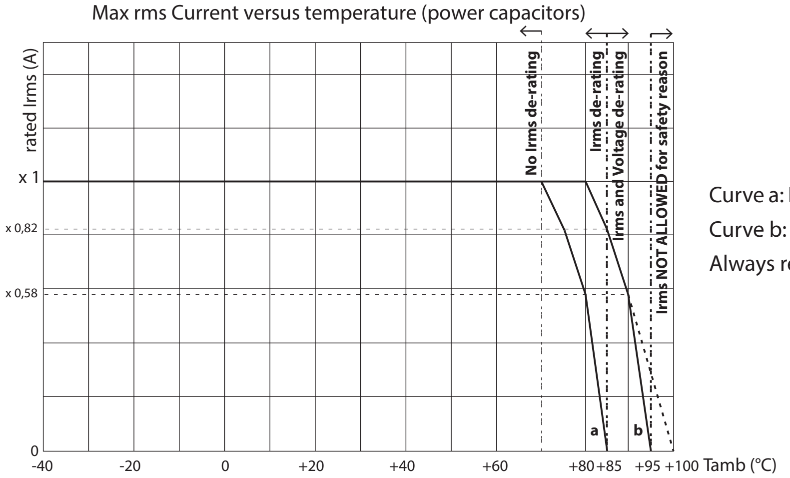
B14- Rated r.m.s. Current (Irms)
It is the highest permissible r.m.s. value of the continuous current flowing through the capacitor at the specified max. case temperature, corresponding to a specified T rise with respect to the ambient temperature, and within an allowed frequency range. Upon sinusoidal conditions

$Irms = \omega \times C \times Urms$

$(\omega = 2 \times \pi \times f)$

Unless differently specified, the typical reference ambient temperature (θamb or Tamb) is +70°C for power capacitors. If not differently indicated in the reference specifications, the Irms of the power series must be typically de-rated in relation to the ambient temperature according to the following graph (for the derating due to skin effect in case of short duration of peak current refer to correspondent graph; paragraph C2):

Max rms Current versus temperature (power capacitors)



Curve a: DCB, DCH, DCS, PHC, RHB, RMC, PPS, PPA, RSB, RMB, MAR.
Curve b: other series for power applications.
Always refer to the max. operating temperature at specifications.

B15- Max. Repetitive Peak Current (Ipeak)
It is the maximum value of the repetitive peak current that can be applied to the capacitor. Refer to Pulse Rise Time (du/dt) and Waveform Energy Content (K_0); paragraph B21.

B16- Max. Non Repetitive Peak Current (Ipk)
It is the maximum non recurrent peak current that may be applied to the capacitor for a limited number of times and for a short period. The application of higher peak currents than Ipk may damage the capacitor permanently, even in a not immediately visible and detectable way.

B17- Category Temperature Range
It is the range of temperature for which the capacitor has been designed to operate continuously.
It is defined by the temperature limits of the appropriate category (between T_A and T_R at rated voltage; up to T_B at de-rated voltage).

B18- Lower Category Temperature (T_A) and Upper Category Temperature (T_B)
It is the minimum and the maximum ambient temperature for which the capacitor has been designed to operate continuously (between T_A and T_R at rated voltage; up to T_B at de-rated voltage).

B19- Rated Temperature
It is the maximum ambient temperature at which the rated voltage may be continuously applied.

B20- Ambient Temperature (θamb or Tamb)
It is the temperature in the immediate surrounding of the capacitor and it is identical with the body surface (case) temperature of the unloaded capacitor.

B21- Rated Pulse Load, Pulse Rise Time (du/dt) and Waveform Energy Content (K_0)
The Rated Pulse Load is the maximum pulse load that can be applied at a certain pulse repetition frequency to the terminations of a capacitor at any temperature between T_A and T_R.
The pulse rise time is the slope of voltage wave shape during charging or discharging of the capacitor and it is expressed in V/µs. The maximum pulse rise time value is typically referred to the rated voltage of the capacitor.

The current loading correspondent to the pulse rise time value is:

$$Ipeak = C_N \times du/dt$$

Ipeak in A, C_N in µF, *du/dt* in V/µs.

The peak current flowing through the capacitor, causes a localized heating of the contact area in the capacitor, due to contact resistance between terminals - metal sprayed on the winding heads - electrodes of the winding (winding film contact edges or metal foils).
Note: the contacts localized heating extend to the entire capacitor body, when the pulse stress is repetitive and constantly applied.

The energy W involved in the heating can be obtained by the formula

$$W = \int Ipeak^2 \cdot R_i \cdot dt$$

R_i = inner resistance

The energy content of the waveform applied to the capacitor is defined as follows

$$K_0 = 2 \cdot \int_0^t (du/dt)^2 \cdot dt$$

t = pulse width
K_0 is expressed in $V^2/\mu s$

At low voltage or medium-low pulse levels, when working at lower voltage Ua than the rated voltage U_R, capacitors may be operated at a pulse rise time= du/dt at specification x U_R / Ua.
In any case, correspondent Ipeak must be ≤ Ipk (max. non repetitive peak current admitted) and maximum K_0 values stated in specifications must not be exceeded in order to avoid a dangerous overheating of the capacitors.
Note: in any case, for safety reasons, in the above conditions do not overcome 1,5 x rated du/dt value

B22- Equivalent Series Resistance (ESR)
It is the resistive part of the equivalent series circuit.
It is due to the resistivity of electrodes, internal connections and dielectric losses and depends on frequency and temperature. The ESR is related to the capacitive reactance and dissipation factor of the capacitor by the formula:

$$ESR = \frac{tg\delta}{\omega \cdot C}$$

C = capacitance in Farad
ω = 2πf (f = frequency in Hz)

B23- Dissipation Factor (tgδ or DF)

It is the power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of a specified frequency. The reciprocal value of the dissipation factor is known as the quality factor Q.

$$DF = tg\delta = \frac{I^2 ESR}{I^2 |X_C|} = \omega C \; ESR = \frac{1}{Q}$$

B24- Impedance (Z)

It is the magnitude of the vectorial sum of the ESR and the capacitive reactance in an equivalent series circuit, not considering the negligible self inductance

$$|Z| = \sqrt{ESR^2 + \frac{1}{(\omega \cdot C)^2}}$$

B25- Power Dissipation and Thermal Resistance (Rth)

A real capacitor will dissipate as heat a fraction of its energy.
The amount of this dissipation is strictly dependent on the technical and design choices and materials used characteristics.
It is also related to the kind of usage and application conditions, performances target, reliability, expected life and sizing.
Is then a complex compromise of several different interacting factors.

Not considering inductances and electromagnetic losses caused by currents potentially induced by strong electromagnetic fields in not non-magnetic metal parts or cases, the main factors related to losses are:
-**Rd**: equivalent parallel resistance related to **dielectric losses**, mainly related to polarization phenomena in the dielectric mass (prevalent at low frequencies).

Related power dissipation= 2Eω x tgd$_0$= ω **x C x V² x tg**d$_0$

tgd$_0$: dissipation factor of the dielectric
-**R_{INS}**: equivalent parallel resistance related to the **Insulation Resistance (leakage),** corresponding to extremely low current flowing through the dielectric when a voltage is applied (sensible to high temperature, **negligible except for extremely low frequency**).
-**Rs**: equivalent **series resistance related to connections to the capacitive element dielectric**, including terminals, heads spraying, winding heads surface contacts and film metallization (electrodes).
Rs depends on frequency, because it is affected by the skin effect (prevalent at medium-high freq.).

Important note: Rs is not equal to the ESR.

Related power dissipation= Rs x I²

Nevertheless, a real capacitor can be at first order, profitably modeled as a perfect capacitor in series with a resistance including ALL the relevant "contributes" causing losses.
This resistance is the **ESR= equivalent series resistance**, related to frequency and Cap. value by the already seen formula

tgδ= ω x ESR x C

Important: capacitors ESR (and DF) can be directly measured and read with RLC bridges, this gives an immediate and easy possibility to estimate losses and power dissipation on the base of ESR.

(Global) Power dissipation in the component= Pd= I² x ESR

Important: DF and ESR are not constant with frequency, always consider limitations given in the type specifications.

The power dissipation Pd, can be calculated as follows

$$P = \sum_{i=1}^{n} Vrms_i^2 \cdot 2\pi f_i \cdot C \cdot tg\delta(f_i)$$

P = dissipation in Watt
$Vrms_i$ = r.m.s. voltage of the ith harmonic in Volt
f_i = frequency of the ith harmonic in Hz
C = capacitance in Farad
$tg\delta(f_i)$ = dissipation factor at the frequency of the i_{th} harmonic
n = number of significant harmonics

In case of sinusoidal waveforms (n=1), the formula is

$$P = Vrms^2 \cdot 2\pi f \cdot C \cdot tg\delta(f)$$

This formula may be also used to approximate the capacitor dissipation when submitted to non sinusoidal or pulse conditions, where

Pd = dissipation in Watt
Vrms = r.m.s. value of the AC voltage
f = repetition frequency of the pulse waveform
C = capacitance in Farad
tgδ = dissipation factor at the frequency of the steepest pulse part (pulse frequency=1/ pulse width)

General technical information

The maximum power dissipation admitted for a capacitor under normal conditions, depends on many different factors like the execution, design, shape, dimensions, materials and so on.
An estimated value of the power dissipation capability may be calculated with the following formula

$$Pd = K \times S \times \Delta T$$

K [mW/ (°C x cm^2)]: it can assume different values in function of different types, design and executions of the capacitors; typical values are in the range 0,7÷1,8.
Lower K values are typical for general purpose metallized film capacitors and capacitors having construction and shape not suitable for high heat dissipation (units having long length or wide pitch compared to the other sizes, small surface heads).
Higher K values are typical for film-foil capacitors and capacitors having specific design, construction and shape suitable for high heat dissipation (wide surface heads, short length and narrow pitch compared to the other sizes or thin shape) like power capacitors.
The heat transmission from the inside to the surface of the capacitor is typically much more efficient and fast along the metallized or metal layers of the winding than through the dielectric: high K values are typically related to capacitors having wide heads surfaces compared with the total dissipating body surface or capacitors with low transversal section.
Separated double side metallized current carriers (the metal ones even more effectively) or special design metallization films do typically allow a better heat dissipation, helping the heat extraction from the inside of the capacitors body, as also supported by wide section and oversized terminals like lugs or multiple pins.
The choice of types having lower K values will ensure higher safety margin in Pd estimation.

S: case surface (cm^2)
Parts of the capacitors surface not able to adequately dissipate the heat because of capacitor position or other limitations, like the radial–box capacitors face laying on PCB surface, should not be taken in consideration.

ΔT (°C): difference between the hot spot case temperature of the capacitor in stationary working conditions and the ambient temperature (example: assuming an ambient temperature = +55°C, if the hot spot case temperature of the working capacitor has to be maintained ≤+70°C, the maximum ΔT must be 15°C).

The heat transmission mode in the capacitors body and dissipation capability depends on a high number of factors, such as materials constituting the capacitor intrinsic physical characteristics, connections shape and mass, capacitors shape, sizes, dimensional ratios, useful surface dissipation and environmental conditions.
For capacitors having a relatively simple and almost homogeneous structure, the above can be simplified taking under control the case surface temperature reached at steady state under a known power applied, on the base of a known ambient temperature.
Measurable hot spots are typically at the heads contacts, bottom box heads, where terminals contact the winding heads or at the lateral walls perimeter near box heads or at the center of the lateral box walls corresponding to the middle of the winding.
At steady state condition, the relation between power dissipation and capacitor temperature rise is expressed by the **Thermal Resistance (Rth):**

$$Rth = \frac{\Delta T}{Pd}$$

So, the total operating temperature of the capacitor can be estimated with:

$$T_{tot} = Tamb + Rth \times Pd$$

Too high ΔT due to power dissipation shall be avoided because it may lead to capacitor over-stress resulting in reliability and expected life reduction or damage. As a general indication, capacitors having metal foil electrodes, double side metallized electrodes or specifically designed power types better withstand heating stresses.

***Important*:** in the specifications about capacitors series for power applications, Irms ratings are typically referred to a max. ΔT of +15°C from ambient temperature (operation at rated power, current, voltage, at natural cooling, +70°C or +85°C observing voltage and current derating; unless differently specified).

Nevertheless, for safety reasons and unless differently specified, following suggested max. ΔT due to power dissipation shall be considered when capacitors operate at high temperatures, near the rated maximum operating ones:
≤ 10°C at +85°C ambient temperature whichever is the type of capacitor considered
≤ 5°C at +85°C ambient temperature for general purpose metallized polypropylene film capacitors (capacitors not having metal foil or double side metallized electrodes and not designed for power applications).
Moreover, in case of special operating and cooling condition, the ΔT must be anyway limited to reasonable values: ΔT +20°C max. for general purpose capacitors and +40°C max. only for special capacitors designed for power applications, provided that evaluation and adequate tests have been performed. And after that the above data and results and related reliability levels and performances respect is judged acceptable upon discussion and analysis with ICEL S.r.l. technical office.
As a general indication, with all the other conditions unchanged,

- a ΔT limited to about +10°C can be obtained applying a Irms reduced to about 0.82 x Irms max rated.
- a ΔT limited to about +5°C can be obtained applying a Irms reduced to about 0.58 x Irms max rated.

If not differently indicated and permitted in accordance with reference specifications, avoid operation conditions which cause relevant power dissipation at ambient temperatures over +95°C, even in case of capacitors having higher rated upper category temperature.
During stationary operation, the capacitor temperature must be always lower than the max. operating temperature stated for the capacitor.

Important note: maintaining a safe temperature margin, avoiding the reaching of the max. temperature limit, increases the capacitors reliability and expected life.

Therefore, power dissipated under operation must be always lower than the max. power dissipation rated Pd.

If the above condition is not respected, possible actions are:
- reduction of the ambient temperature
- forced air cooling (in any case taking in consideration the heating level inside the capacitor)
- parallel connection of many capacitors
- use of different type of capacitors or capacitors having better dissipation characteristics

Important: regardless of the estimated Pd, always consider the max. voltage and the max. current (and their de-rating, if applicable) tolerable by the capacitor and in particular the current capability allowed by the terminals type.
In fact, a theoretical obtained Pd value may correspond to higher voltage values than permissible Urms voltage (over ionization level at medium-low frequencies) or may correspond to current values not tolerable by the capacitor and its terminals (at medium-high frequencies).
In other words, it must be considered the rated a.c. load, expressed as:

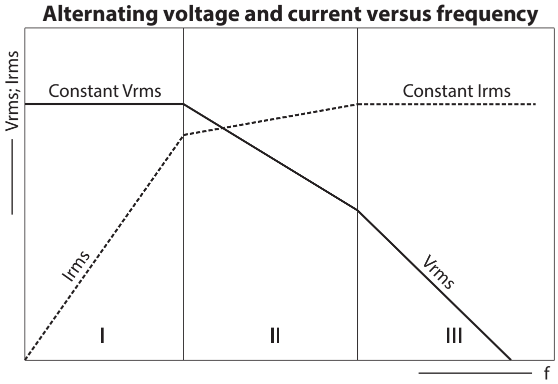
a) rated a.c. voltage at low frequencies

b) rated a.c. current at high frequencies

c) rated reactive power (var) at intermediate frequencies

The typical capacitor Urms and Irms (sinusoidal waveform) limits versus frequency are as follows:

Alternating voltage and current versus frequency



I: area where voltage is limited by ionization
II: area where voltage and current are limited by reactive power dissipation and tgδ
III: area where current is limited by terminals characteristics

The following indicative max. current values, as a function of the terminals type, shape and section (referred to a single terminal) shall be taken in consideration (referred to +70°C):

Tinned copper wire leads or cables, 0.6mm diameter / approx. 0.385mm^2 section= up to about 5A

Tinned copper wire leads or cables, 0.7mm diameter / approx. 0.385mm^2 section= up to about 7A

Tinned copper wire leads or cables, 0.8mm diameter / approx. 0.50mm^2 section= up to about 8A

Tinned copper wire leads or cables, 1.0mm diameter / approx. 0.785mm^2 section= up to about 10,5A

Tinned copper wire leads or cables, 1.2mm diameter / approx. 1.13mm^2 section= up to about 14A

Lugs used for axial units (MPHL type)= up to about 25A

Other lugs types= up to about 35÷40A (depending on type and shape)

Important factors when estimating the capacitors terminals-contacts current capability, are the terminals welding mode, the contacts welded surface, the winding heads spraying type and thickness and the capacitor working temperature.
For this reason, the above listed currents must be considered as indicative values.
Always refer to the capacitors specifications to obtain max. rated current limits.

If needed data are not present in the capacitors specification, not corresponding or referred to the operating conditions (particularly in case of severe application with complex voltage and current waveforms which may cause relevant power dissipation and capacitor heating), ICEL Technical Office must be contacted to ensure the use of the correct kind of capacitor for the application.
ICEL S.r.l. is not responsible for problems caused by critical usage and application, not preventively discussed and acknowledged by ICEL Technical Office

Moreover, since above data are based on very generalized assumptions, they do not allow absolute correct deductions in case of critical cases: a practical test at the real working conditions shall be made to verify the correctness of the theoretical assumptions.

B26- Self Inductance (L) and Resonant Frequency (fr)
Self inductance mainly depends on the inductance of the connecting terminals and of the winding.
Thanks to heads metal spraying that connects all the winding turns, the self inductance is typically extremely low.
Since the inductance can be reduced but never completely eliminated, at a certain frequency (f_r) the capacitive and inductive reactance are equal.

$$\frac{1}{(\omega_r \cdot C)} = \omega_r \cdot L \qquad \text{where} \quad \omega_r = 2\pi f_r$$

f_r is called resonant frequency and at frequencies greater than f_r the inductive component of the capacitor prevails.
The inductance values indicated in the specifications are typical and referred to the resonant frequency, at 20±5°C.

B27- Insulation Resistance (R_{INS}) and Time Constant (τ)
The insulation resistance R_{INS} of a capacitor is a measure of its resistivity in DC. Under a stationary DC voltage, a leakage current flows through the dielectric (R_{INS} between terminals, determined by the dielectric characteristics) and over the capacitor surfaces (R_{INS} between terminals and case, determined by the quality and characteristics of the insulating materials, such as insulating tapes, plastic boxes, sealing resins and so on).
So, R_{INS} is the ratio of an applied DC voltage to the current flowing after a specified time. It is dependent on temperature, voltage and time.

The time constant (τ) of a capacitor is the product of R_{INS} and the Capacitance value.

B28- Test Categories (reference: IEC 60068-1)
Capacitors can be graded in accordance with the following 3 groups of test categories; they result from the test conditions according to which capacitors have been tested:

Test	Preferred values			
A (cold, °C) IEC60068-2-1	-65	-55	-40	-25
B (dry heat, °C) IEC60068-2-2	+70	+85	+100	+125
C (damp heat test Ca, steady state, days) IEC60068-2-3*	04	10	21	56

*unbiased unless differently specified

Example:
Test category= 40/085/56
test A= -40°C; test B= +85°C, test C= 56 days

B29- Permitted Temperature and Humidity (reference: DIN40040)
They are dependent on capacitor type and are identified in accordance with DIN40040:

Permitted temperature and humidity in accordance with DIN 40400				
1st code letter	**E**	**F**	**G**	**H**
Minimum temperature (°C)	-65	-55	-40	-25
2nd code letter	**S**	**P**	**M**	**K**
Maximum temperature (°C)	+70	+85	+100	+125
3rd code letter humidity category	**G**	**F(E[3]))**	**D**	**C**
Average relative humidity	≤65%	≤75%	≤80%	≤95%
30 days per year, continuously[1)]	-	95%	100%	100%
60 days per year, continuously	85%	-	-	-
For the remaining days, occasionally[2)]	75%	85%	90%	100%

1) These days should be suitably spread evenly out over the year.
2) Keeping the annual average.
3) For humidity category E, rare and slight dew precipitations additionally permitted

***Important*:** film capacitors prolonged exposure to combined high humidity and high temperature will produce dangerous irreversible effects, therefore it must be avoided.
Related critical environmental conditions must be carefully evaluated since potentially leading to a rapid deterioration of the performances and reliability (also refer to paragraph C10).
Direct contact with liquid water or excess exposure to high ambient humidity or dew will eventually remove the film metallization and thus destroy the capacitor.

Simulations of the effect of humidity can be done through the humidity test defined in the climatic category.
Accelerated testing can be performed under more severe conditions, if the relative severities are taken into account.

The stress entity is related to the relative humidity and temperature.
Moreover, possible voltage load highly increases the stress level and the acceleration of the detrimental effects, resulting in a very fast failure probability unless performed on specifically designed and rated types.
For this reason, reference damp heat tests are not typically performed with voltage applied, unless differently indicated in the type specifications.

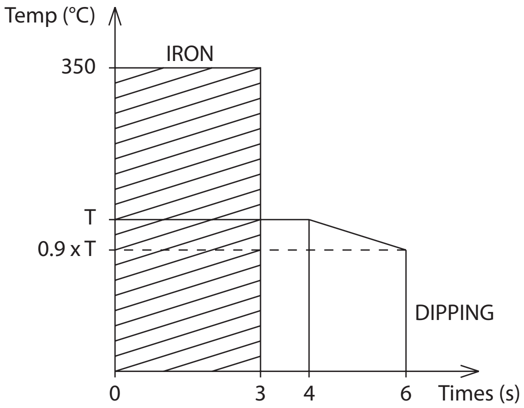
Only special designed and specifically THB (Temperature Humidity Biased) rated capacitors shall be considered for harsh environment conditions usage (and may be submitted to biased humidity tests).

B30- Solder conditions for capacitors on printed circuit boards; terminals RoHS compliance

Solder bath (soldering iron to be carefully executed) temperature and time must be set to obtain good solderability avoiding the components damage. The soldering temperature must be set keeping the temperature inside the capacitors below the following general limits:

+110°C for KP and MKP units (+100°C for radial units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm)
+155°C for MKT (KC and MKC) units (+145°C for radial units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm)

Temperature profile:



T= 260±5°C for 4s (general*)
* for KP/MKP P=5; 7.5mm and L=10.5mm: Tmax. = 250°C for 3s

Pre-heating: it must be made at +110°C max. for 1 min. max. (+100°C max. for KP/ MKP units with leads pitch P≤ 7.5mm or axial units with body length L≤ 10.5mm).
Avoid excessive thermal stress which may result in the capacitors damage, in particular for small size units.
General soldering conditions:

- if repeated PCB soldering cycles are needed, it is necessary a recovery time until the capacitors surface temperature is below +50°C
- eflow soldering by combining the leaded types with SMD ones must be avoided
- when fixing SMD parts in combination with leaded ones, any passing through adhesive curing oven must be avoided
- capacitors with radial terminals must rest stably on the PCBs.
- for axial terminals capacitors has to be kept a soldering distance of min. 6mm between the capacitor body and the solder connection
- it has to be kept a min. 1.5mm distance for vertical mounting (only upon agreed execution and when the vertical mounting is exceptionally allowed)

***Warning*: the permissible heat exposure on film capacitors is limited by upper category temperature. Long exposure to temperature levels above this limit cause irreversible changes of the capacitor characteristics or its damage.**
In addition to solder bath temperature and the soldering process time, thermal load applied to the capacitor is also affected by pre-heating and post soldering temperature.
Since the soldering heat is mainly transmitted in the units through the leads, the process is more critical for small size capacitors.
For critical types capacitors soldering, in addition to checks of the process effect on the capacitors, a particular care is required; the keeping of maximum possible distance from solder bath, the use of solder resistant coatings or shields and the forced ventilation cooling is necessary. When the pre-heating cannot be avoided, the soldering process conditions should be possibly readjusted.
Particular assembly need, like welding on metal bars or other relevant mass conductors, requiring long time, high heating levels exposal, potentially causing inner contacts damages or hidden deterioration must be avoided or made by taking the utmost care and attention.
Terminals RoHS compliance: terminals are Lead-free and in conformity with RoHS and REACH requirements (please refer to the web site www.icel.it for detailed information).
Typical terminals structure is 100% massive copper with matte (double) Tin coating.

B31- Dimensions, tolerances, terminals position and centering, lugs screws fixing torque and connection modes

Dimensions and materials may be subjected to reasonable variations due to available raw materials and normal fluctuations in the manufacturing process; moreover, high stress working conditions, like operation at maximum ratings and at the max. rated temperature and humidity, may cause dimensional variations which should be taken into account when designing capacitors placement in equipment and on PCBs. Tolerances on dimensions are usually specified for every type in the series specifications.

Box with radial terminals capacitors:

Unless otherwise specified, the following tolerances on nominal box dimensions "Bd" declared must be taken in consideration:

Size tolerances	
Bd (mm)	Tolerance (mm)
≤ 10	±0.30
10 < Bd ≤ 18	±0.45
18 < Bd ≤ 32	±0.60
32 < Bd ≤ 42.5	±0.80
> 42.5	±1.0

Radial terminals position (wire terminals): the terminals off-set To from the capacitors body longitudinal center-line is

To≤ d (d= terminals diameter)

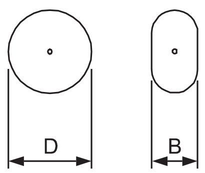
but need not to be lower than 0,8mm; for 4 or 6 x terminals versions, the maximum terminals off-set To from the symmetrical position from the capacitors body center-lines is To= 1,5 x d (d= terminals diameter)

Axial terminals capacitors:

Axial terminals position and centering (99,7% of the pieces): the centering error from the capacitors body axis is

Ce ≤ (Y/X)+d

where d is the terminals diameter and Y is the nominal diameter or thickness.



Y = D or B (mm)	X
≤ 16	9
> 16 and ≤ 34	11
> 34	10

In any case, Ce need not to be lower than 2 x d (d= terminals diameter).
0,3% of the pieces may show terminals centering error up to 1,2 x the above limits.

Important: the vertical mounting of axials on PCBs is generally not allowed. Only exceptionally this can be considered after evaluation and discussion with ICEL Technical Office, needing special capacitors execution and mounting care.

Box capacitors with lug terminals:

Lugs position: within drawings quotes and tolerances specified for each type and lug style, the lateral shifting of lugs position referred to the box center-line must be ≤ 2.5mm, unless differently specified. A little lugs inclination, lacking of parallelism or lugs fixing surfaces laying on slight offset planes is admitted, if not affecting the fixing pitch and the correct mounting and fixing.

Lugs screws fixing torque: 5Nm max. The fixing force must be enough to ensure the electrical connection and a stable positioning and contact against vibrations and mechanical stresses (it is necessary and enough that the connection is not loose, not allowing the capacitor body free moving; excess torque is almost useless).

Lugs material: lugs are normally made with (lead free tinned) massive copper (brass as a possible alternative, upon specification)

WARNING: lugs bent, torsion, inclination or any change of the original design, shape, geometry and position for mounting and fixing of the capacitors onto equipment contacts is not admitted, since potentially causing contacts irreversible damage, mechanical weakening or even sealing cracking.

Box capacitors with cable terminals:

Cables position: within drawings quotes and tolerances specified for each type, the cables exit point position from the sealing is not ruled and standardized, even if typically located near the box head walls, almost at the centerline of the sealing, unless differently indicated in specifications upon agreement with customers.

Cables sealing: at the exit point from sealing, cables are not required to be exactly perpendicular to the sealing surface, unless differently indicated in specifications upon agreement with customers.
In any case the cable sheath must be completely and permanently fixed and surrounded by the sealing, without showing unprotected or unsealed cables conductors.

B32- Standard Environmental Conditions for Test

Unless otherwise specified, all the electrical data stated in the specifications are referred to a temperature of +15÷35°C, an atmospheric pressure of 86÷106 kPa and a relative humidity of 25÷75% (reference: IEC 384-1).

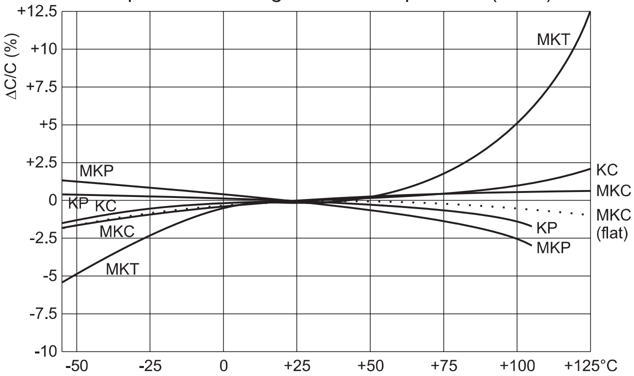
Preferred references: 23±1°C; 48÷52% RH; 86÷106 kPa

B33- Typical curves

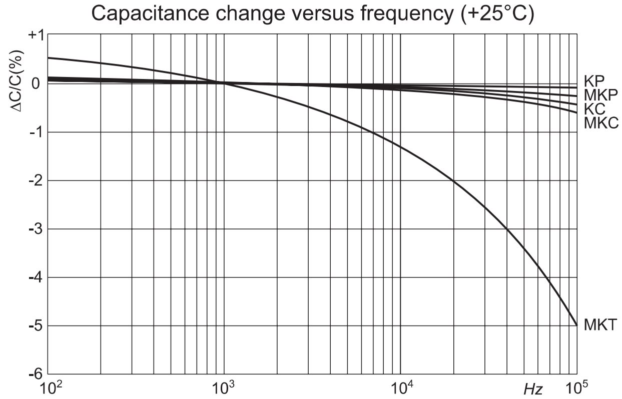
Main electrical parameters variation in function of temperature and frequency. General data for comparison aims only, based on typical estimations. The real behavior of each single capacitor and its parameters variations versus temperature and frequency may be quite different from the following typical curves, depending on capacitance value, execution, shape, design-construction and several other interacting factors.

MKT= metallized polyester
KP= film-foil polypropylene
MKP= metallized polypropylene
KC= film-foil polycarbonate
MKC= metallized polycarbonate

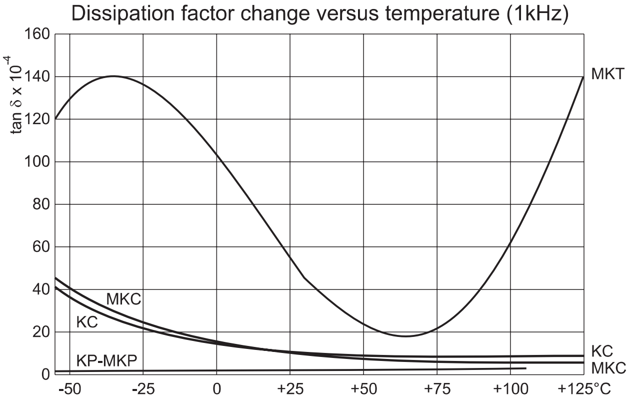
Capacitance change versus temperature (1kHz)



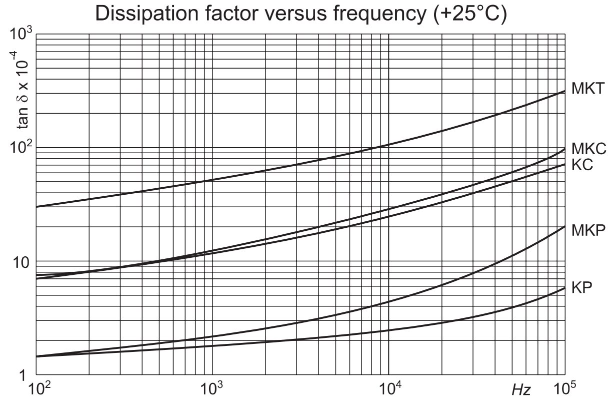
Capacitance change versus frequency (+25°C)



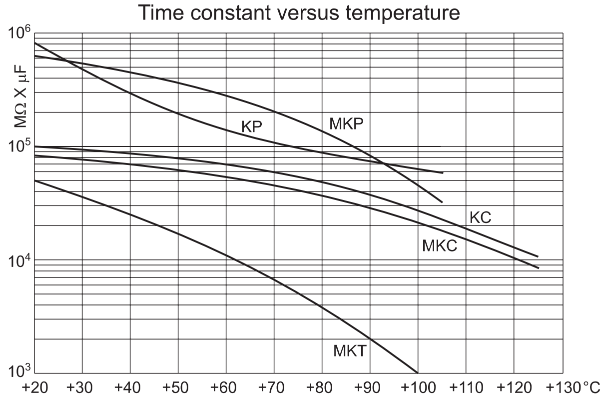
Dissipation factor change versus temperature (1kHz)



Dissipation factor versus frequency (+25°C)



Time constant versus temperature



B34- Reference Reliability and Failure Rate (λ)

The reference reliability states a component type fraction failure under a defined load or operating condition. This fraction failure will not be exceeded within a specified operating time.
The reference operating condition to which the reliability and failure rate are referred is typically +40°C with 0.5 x Ur (DC) continuously applied to the capacitor (no humidity considered); for capacitors for power applications the maximum ratings are taken as a reference (without de-ratings applied and no humidity considered). Unless differently specified at types specifications.

Failure rate λ is the fraction failure divided by a specified operating time and it is expressed in fit (failure in time), as follows:

1 FIT= 1 x 10^9 / h (1 failure per 10^9 component hours)

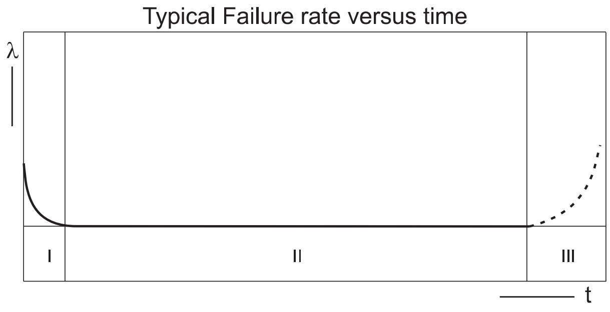
Failure rate, when available, is referred to failure rate criteria like short or open circuit, main electrical parameters variation limits and so on, declared in each series specification.
Typical failure criteria:
- short or open circuit
- capacitance variation >±10%
- Dissipation Factor variation > 2 x initial limits
- possible additional criteria to be indicated in the type specification
- excessive body distorsion (refer to size tolerances)

In order to estimate the typical expected failure rate as a function of load or operation characteristics different from the one taken as a reference for nominal failure rate, following conversion factors (CF) may be used:

Working Voltage (Uw/Ur)	CF
1	x 20
0,75	x 4
0,5	x 1
0,25	x 0,4
0,1	x 0,2

Working Temperature(°C)	CF
≤ +40	x 1
+55	x 2,5
+70	x 6
+85	x 15
(+ 100)	(x 45)

The estimations shall be made within the allowed operating limits.
Typical components failure rate curve in function of time, shows three characteristic periods in the components life:
- a first period (I), when early failures occur
- a second period (II) during which the failure rate can be considered approximatively constant
- a third period (III) when failures increase due to aging wear:



Failure rates data at specifications are typically referred to the second period (II) only.

WARNING: figures stated about expected life and failure rates are mainly based on application experience and accelerated ageing tests; they are referred to average production conditions and must be considered as mean values, based on statistical expectations for a large number of lots of identical capacitors.
The above information and data must be considered as general indications. Always refer to the data listed in the specifications for each type of capacitor.

B35- Life expectancy (Le)

The Life Expectancy of the power capacitors series is typically referred to a reference nominal voltage Un and to the hot spot temperature of the capacitor case (the typical reference temperature is stated at type specifications).
The Life Expectancy may be improved derating the operating voltage and/ or the operating temperature.

Important: capacitors used in power applications are typically exposed to relevant stresses level and possible failure may result in very serious consequences. For this reason, **the keeping of a wide safety margin** (about 25÷30%) compared to ratings is a wise and long term profitable approach.
Life Expectancy as a function of operating voltage can be approximately estimated with the following formula:

$$Lw = Le\ (Un / Uw)^{E}$$

Lw (h)= life expectancy at the operating voltage Uw
Le (h)= life expectancy at the voltage Un (given in specifications) Un (V)= reference voltage to which Le is referred
Uw (V) = operating voltage (Uw ≤ Un)
E = 7÷8 (typical value; depending on capacitor design and construction)

WARNING: a good approximation of the capacitor behavior can be obtained at Uw values reasonably close to Un reference.
If Uw> Un the life expectancy drops very fast with a big uncertainty of the estimation, that becomes the more unpredictable and unreliable the higher is Uw/ Un.
Do not operate capacitors over the allowed voltage.

Life Expectancy as a function of the hot spot temperature of the capacitor case can be approximately obtained with the following formula:

$$Lw = Le \times 2^{(T-Ths) / Ac)}$$

Lw (h)= life expectancy at the operating temperature
Le (h)= life expectancy at the reference temperature T (given at specification) T (°C)= reference temperature
Ths (°C)= hot spot case temperature at stationary working conditions (≤ max. rated Operating temperature)
Ac (Arrhenius coefficient expressed in °C)= 7÷8 (typical; depending on capacitor design and construction)

WARNING: the above formula is derived from Arrhenius equation which describes the ageing of organic dielectrics as a function of the temperature. It gives an acceptable approximation of the capacitor behavior only if the temperature range taken in consideration is not too large and too far from the reference one.
If Ths> T the life expectancy drops very fast with a big uncertainty of the estimation, that becomes the more unpredictable and unreliable the higher is Ths/ T.
Do not operate capacitors over the allowed temperature.

***Important:* obtained estimations are based just on voltage and temperature parameters, NOT considering any other possible stress source, in particular the humidity level.** Whichever is the obtained estimation, orders of magnitude higher than the reference value do not represent realistic data: keep a rational approach interpreting the result.
The failure rate estimation anyway prevails as a primary criteria to evaluate the reliability of the component The above formulas shall not be used for estimations outside the specification rating limits..

ICEL Technical Office shall be contacted in order to estimate life expectancy data, to ensure the use of the correct type of capacitor for the application and to evaluate the adequate reliability level for the life time target reference.
To obtain long life and low failures incidence **always consider large enough safety margins on ratings compared to application operating conditions,** when choosing capacitors.

B36- EN60252-1 normative Life Expectancy Classes

The following Life Expectancy Classes are used to rate the capacitors types approved in conformity with EN60252-1 normative:

Class A: 30000 hours
Class B: 10000 hours
Class C: 3000 hours
Class D: 1000 hours

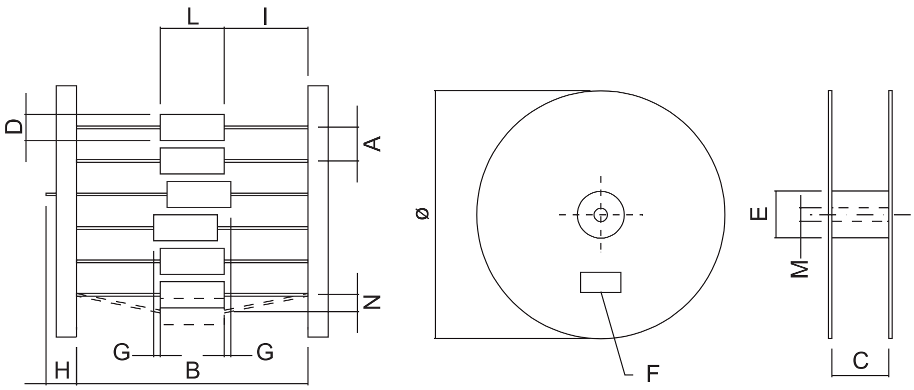
The Life Expectancy Class is referred to an operating

- voltage
- frequency
- temperature
- possible duty cycle

Related to the EN60252-1 approval class obtained.
The Life Expectancy Class code is printed in EN60252-1 approved capacitors markings.

General technical information

B37- Taping specification for axial capacitors



Description	Symbol	Dimensions (mm)
Capacitor diameter	D	4,5 ÷ 19,5
Capacitor length	L	10,5 ÷ 32,0
Component pitch	A*	See table I
Reel core diameter	E	60
Arbor core diameter	M	16
Reel diameter	ø	340+5
Marking	F	See table II
Tape width	H	6±0,5
Body location (lateral deviation)	G	≤ 0,8
Body locatio n (longitudinal location)	N	≤ 1,2
Tape spacing	B	See table III
Lead length from the capacitor body to the adhesive tape	I	≥ 20
Distance between reel flanges	C	See table III

* Cumulative pitch tolerance does not exceed 1.5mm over six consecutive components.

Table I	
D (mm)	A (mm)
< 5	5
5 ÷ 9,5	10
9,6 ÷ 14,7	15
14,8 ÷ 19,5	20

Table II (reel marking)

- Manufacturer's name
- Capacitor type and code
- Electrical values
- Component quantity
- Date

Table III		
L (mm)	B±2	C (mm)
≤ 13	53	75
19	63	86
> 19	73	95

Typical capacitor quantity per reel	
D (mm)	Qty.
< 5	2000
5 ÷10	500 ÷ 1000
10,1 ÷ 19,5	125÷ 350

B38- E series according to IEC 60063 (preferred capacitance values;
note: different, special values may be adopted in specific cases or upon customer request; **DIN41426**)

E series according to DIN 41426 and IEC 63 (preferred capacitance values).

Values	E96 (±1%)	E48 (±2%)	E24 (±5%)	E12 (±10%)	E6 (±20%)	Values	E96 (±1%)	E48 (±2%)	E24 (±5%)	E12 (±10%)	E6 (±20%)
1,00	X	X	X	X	X	3,30			X	X	X
1,02	X					3,32	X	X			
1,05	X	X				3,40	X				
1,07	X					3,48	X	X			
1,10	X	X	X			3,57	X				
1,13	X					3,60			X		
1,15	X	X				3,65	X	X			
1,18	X					3,74	X				
1,20			X	X		3,83	X	X			
1,21	X	X				3,90			X	X	
1,24	X					3,92	X				
1,27	X	X				4,02	X	X			
1,30	X		X			4,12	X				
1,33	X	X				4,22	X	X			
1,37	X					4,30			X		
1,40	X	X				4,32	X				
1,43	X					4,42	X	X			
1,47	X	X				4,53	X				
1,50	X		X	X	X	4,64	X	X			
1,54	X	X				4,70			X	X	X
1,58	X					4,75	X				
1,60			X			4,87	X	X			
1,62	X	X				4,99	X				
1,65	X					5,10			X		
1,69	X	X				5,11	X	X			
1,74	X					5,23	X				
1,78	X	X				5,36	X	X			
1,80			X	X		5,49	X				
1,82	X					5,60			X	X	
1,87	X	X				5,62	X	X			
1,91	X					5,76	X				
1,96	X	X				5,90	X	X			
2,00	X		X			6,04	X				
2,05	X	X				6,19	X	X			
2,10	X					6,20			X		
2,15	X	X				6,34					
2,20			X	X	X	6,49	X	X			
2,21	X					6,65	X				
2,26	X	X				6,80			X	X	X
2,32	X					6,81	X	X			
2,37	X	X				6,98	X				
2,40			X			7,15	X	X			
2,43	X					7,32	X				
2,49	X	X				7,50	X	X	X		
2,55	X					7,68	X				
2,61	X	X				7,87	X	X			
2,67	X					8,06	X				
2,70			X	X		8,20			X	X	
2,74	X	X				8,25	X	X			
2,80	X					8,45	X				
2,87	X	X				8,66	X	X			
2,94	X					8,87	X				
3,00			X			9,09	X	X			
3,01	X	X				9,10			X		
3,09	X					9,31	X				
3,16	X	X				9,53	X	X			
3,24	X					9,76	X				

C- Application notes, operation and safety conditions

Because of the many different types of capacitors and the many factors involved, it is not possible to cover, by simple rules, installation and operation in all possible cases. The following information, in addition to single series specifications and to the data up to now listed in "General Technical Information" chapter, are given with reference to the most important points to be considered. Nevertheless, they are not exhaustive: they need to be completed with careful evaluations about the specific customers applications and operative condition.

C1- Voltage applied and ionization effects

Higher voltage values than the rated voltage applied to the capacitor may cause permanent damage like the dielectric perforation, short circuit or, in case of metallized film capacitors, Insulation Resistance progressive decrease and capacitance drop, with reduction of reliability and expected life.
Capacitors shall be adequately protected in order to prevent potential damages caused by voltages higher than the rated one, due to particular conditions such as equipment malfunction, equipment test conditions, etc.
Rated voltage (rated current) can be applied at temperatures up to rated temperature.
At higher temperatures than the rated one, an adequate voltage (or current) de-rating must be applied in conformity with each series specifications. In order to guarantee a high reliability and long life expectancy, capacitors for power applications should not be operated at maximum permissible voltage and maximum operating temperature contemporaneously: this should be considered an emergency operating condition, for short periods of time.
Suggested safety margins should be about 25÷30% lower than ratings.
Capacitors rated voltage is usually specified DC. For AC applications it is suggested to refer to series specifically designed for this kind of usage (do check the foreseen main applications at specifications and the "Capacitors selection guide").
If a DC rated capacitor is used in AC applications, do not use higher AC voltages than the one stated at specification.
With the exception of series designed for power applications, the AC voltages stated at specifications are referred to sinusoidal waveform.
If DC rated capacitors are used in an application with not sinusoidal or different waveforms from what specified at catalogue, ICEL Technical Office must be contacted before using the capacitor to evaluate the application. At high working voltage, ionization may cause a destructive process in the capacitor, often having consequences at medium-long term. The ionization phenomenon (also called corona effect) is due to air contained in the dielectric, between the winding layers of the capacitor and present at the face ends of the capacitive element. If the electric field in the capacitor exceeds the air dielectric rigidity, micro-discharges might take place in the winding, damaging the film metallization and the film itself. This usually causes capacitance drop and may also cause overheating due to Insulation Resistance drop, up to short circuit in case of persistent ionization. The voltage at which ionization phenomenon overcomes a reference limit is called corona on-set or off-set voltage as a function of its taking place at the rising or at the decreasing of the voltage applied to the capacitor.
The grade of the phenomenon and the damage that ionization causes depends on many different factors like the amount of air trapped in the capacitor, the type of dielectric and electrodes, the design and construction, the accuracy of manufacturing process and the working conditions.
To minimize potentially dangerous ionization effects, do always respect the voltage ratings and if possible, choose capacitors having higher voltage ratings than the foreseen application ones, guaranteeing a safety margin high enough for a good reliability.
In particular, ensure the respect of the following condition:

Vpp (peak to peak voltage) $\leq 2 \times \sqrt{2} \times$ Ur (AC)

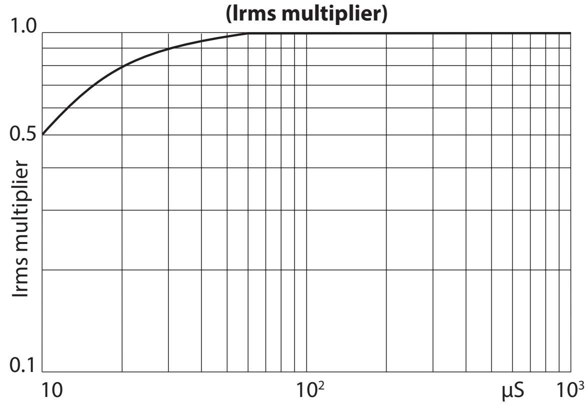
C2- Pulse applications

In case of pulse applications, it is necessary to consider the following main capacitor characteristics and application data (which are the minimum conditions to be satisfied in order to prevent capacitors damages):

Vmax. (max. voltage) $\leq$ Ur (DC)
Vpp (peak to peak voltage) $\leq 2 \times \sqrt{2} \times$ Ur (AC)
du/dt or Ipeak $\leq$ specifications value
$K_0 \leq$ specifications value
Urms., Irms and waveform or pulse frequency (1/T): refer to permissible AC voltage versus frequency graphs Upk and Ipk $\leq$ specifications value

Moreover, in case of short current pulse duration, also the skin effect in the contacts and terminations should be taken in account, in accordance with the following graph:

Rated rms current value versus pulse current duration (Irms multiplier)



C3- Noises produced by capacitors

During pulse stresses or when submitted to AC signals or complex waveforms having high frequency distortion rate, capacitors might produce buzzing noises due to coulomb forces generated between opposite poles electrodes.
This noise is usually proportional to the size of the stress and its characteristics and may be different with different capacitor construction and design. It is not typically dangerous for the capacitor and does not typically relate to any damage or performances reduction of the capacitor.

C4- Permissible current

The main effect produced by the current flowing through the capacitor is its heating. This heating, in addition to the ambient temperature, (Ttot. = Tamb.+ΔT due to Irms flowing) must be maintained lower than the maximum operating temperature for which the capacitors have been designed. An excessive heating reduces capacitors reliability, expected life and performances.
It might cause capacitors deterioration up to a short or open circuit, body deformation and melting with smoke emission or fire danger, even if components are protected by flame retardant materials and/or segmented matallization design.
The fact that dissipation factor may increase at temperature exceeding the max. rated temperature, causes a further dangerous heating effect which brings to a fast increase of the risk of severe damage of the capacitor.
In addition to current linked with pulse operation (please refer to the related paragraphs), the effective currents (Irms) due to periodic waveforms cause the entire capacitor body heating.
The combined effect of pulse and rms currents must be taken in consideration when evaluating the capacitor heating in order to avoid a global over-heating condition. The specifications of capacitors for power applications and designed for high current operation list the max. Irms values.
The max. Irms ratings are typically referred to a temperature rise from ambient of 15°C.

Important: the maximum Ipeak and Irms stated at specification must not be overcome. Please contact ICEL Technical Office for support in case of any doubt about application of capacitors subjected to high pulse and rms currents or particular waveforms.

C5- Operating temperature

A capacitor used in AC applications is submitted to heating due to currents flowing through it. The working conditions and the correct choice of the capacitor must ensure that capacitor working temperature and all the other parameters, remain within the limits stated in the specification.
Operating temperature in excess to the max. admitted or very rapid changes from hot to cold and vice-versa may accelerate electrochemical dielectric degradation and may cause physical damage to protecting materials (accelerated ageing, sealing breaking and de-touching from box walls, important drop of the protection against humidity and so on).
The direct test of the capacitor heating over the ambient temperature (ΔT) and the Total operating temperature (Ttot. = Tamb.+ΔT due to power dissipation) shall be made at load conditions equivalent to the real operating ones, but also simulating the worst working conditions foreseen in the application.
The capacitor temperature must be measured at the hottest part of its body surface (typically in correspondence with terminals, near heads areas or areas having poor dissipation capability because of external reasons like particular disposal on PCBs, presence of other hot components in the surroundings and so on).
The dissipation factor (and the related ESR) of the capacitor should be measured and compared with specification data, taking in consideration the typical range of values that different units of the same lot and different lots of the same type may reasonably have.

Important: the ESR value does not only change with the frequency but also with the Capacitance value. Tolerance on Capacitance must then be taken in account: max. Irms ratings are typically referred to Capacitance tolerances ≤ ±10%. Moreover, the typical ESR rise in function of the frequency might be steeper in case of segmented metallization design.

In addition to working conditions in terms of electrical parameters, particular attention must be paid to the correct installation of the capacitor and its position on PCB and in the equipment.
Capacitors shall be placed where there is adequate dissipation by convection and radiation of the heat produced by the capacitor losses. The ventilation and cooling of the environment and the placement of the capacitor units shall provide good air circulation around each unit (considering the global environmental conditions, including humidity).
This is particularly important for units mounted in rows, one above the other: **always respect the suggested minimum distances between units.**
Extra heating, even if localized on parts of the capacitor body, could be caused by other components or parts in the immediate surroundings either as a consequence of their heating or as a consequence of strong magnetic fields inducing alternating magnetization and currents in metal parts.
Capacitors should be situated at a safe distance from heavy current conductors.
The influence of other components near to the capacitor under operating conditions must be always carefully evaluated.

C6- Components fitting on PCBs and arrangement in equipment layout

Dimensional tolerances must be taken in consideration when designing capacitors fitting on PCBs and in the equipment (please also refer to B31 paragraph).
The fitting of capacitors on PCBs and their arrangements in equipment lay-outs with touching bodies or body faces in contact one with the other must be absolutely avoided, in particular if capacitors are positioned in rows, one above the other.
A not adequate distance between units would not allow the correct capacitors heat dissipation and cooling, especially in case of power applications and in equipment where components are submitted to sensible heating.
The contact between capacitors body may also cause physical damage in case of mechanical stresses (vibrations, shocks) and small settlements of the units body which may occur at high temperature or in particular ambient conditions (this must be carefully evaluated upon special testing needs).

As a general indication, the suggested minimum distance between side by side elements should be at least about 1/12 of the diameter or thickness in case of axial terminals components and at least about 1/8 of the thickness in case of radial terminals capacitors and capacitors in box with lug terminals (on all the components faces). Particular attention shall be paid to possible body deformations when capacitors are use in high humidity environments.

C7- Vibrations and mechanical shocks

Capacitor fixing method is very important to minimize detrimental effects due to vibrations or mechanical shocks.
In particular, when foreseen application will submit capacitors to mechanical stresses, axial leaded capacitors shall be adequately fixed to PCBs and capacitors having lug terminals should be positioned in order to guarantee additional body support against vibrations, shocks and mechanical stresses, (elastic silicon gluing, fixing bands etc.).
The above is particularly important for units having big size and weight.
The mere lugs connection may not be enough to withstand relevant mechanical stresses or vibrations.
Axial capacitors should have the body resting onto the PCB surface.
The vertical mounting of axial capacitors (resting on one head) should be avoided, adopted just in case of no alternative possibilities and taking in consideration the effects on mechanical stresses and vibration withstanding. Axial units vertical mounting need must be communicated to ICEL S.r.l. in order to adopt execution features preventing potentially problematic mounting and soldering to PCB.
Radial in box capacitors must rest onto PCBs surface (capacitor mounted on PCB with the box supporting area in contact with PCB surface). If not differently declared or stated by normative taken as a reference in series specifications, the vibrations withstanding for radial in box capacitors is in accordance with IEC 60068-2-6 (test Fc, sinusoidal vibration):

f = 10÷500Hz for leads pitch P ≤ 22.5mm
f = 10÷55Hz for leads pitch P > 22.5mm

3 x 2 hours with 0.75mm amplitude (below 57.6Hz) or 98m/s2 (above 57.6Hz), applied in three orthogonal axis No visible damage, no open or short circuit admitted.

Do not exceed the tested ability to withstand mechanical stresses and vibrations. Anyway, in case of possible particularly stressing vibration or mechanical shocks operating conditions, an adequate test and behavior evaluation under real working conditions must be made.

C8- Connections

The current carrier contacts into the capacitors (especially when they are high section lugs, blades and so on) can dissipate heat from the unit but they may also transfer heat generated in outer connections into the capacitor.
For this reason, it is necessary to keep the connections leading to the capacitors cooler than the capacitor itself. Important: special care is necessary when designing circuits with capacitors connected in parallel or in series.

In parallel connections, the current splitting depends on slight differences of resistances and inductances in the current paths, then one of the capacitors may be easily overloaded. Moreover, when one capacitor fails by short-circuit or simply self-heal, the complete energy of the bank will be rapidly dissipated at the breakdown - clearing point with possible destruction of the unit; the global voltage withstanding capability of a bank of several capacitors connected in parallel is typically (slightly) lower than the performance of a single unit.

In series connections, because of variations in the circulation resistances of units, the correct voltage division between capacitors should be ensured by resistive voltage dividers. The insulation voltage of the single units shall be appropriate for the series arrangement. The above must be taken in consideration when submitting equipment to over-voltage or over-load tests and evaluating potential equipment malfunctions or failure modes and conditions.

The modification of the original lug (and "rigid" in general) terminals shape and geometry to fix capacitors on the circuit is not admitted.

C9- Across the line and interference suppression applications (class X and Y caps.)

This type of capacitors is permanently submitted to mains voltage and additional surge or high pulse stress typical of this kind of application. The capacitor must have a high safety margin and must be approved in conformity with related reference standards (EN134200, IEC60384-14 etc.).
Do not use capacitors not approved in interference suppressors applications.
For safety reasons, the use of approved components in conformity with the above mentioned standards is mandatory. In case of across the line application with pulses or anomalous spikes the use of additional surge suppressors in parallel to the capacitor is strongly suggested.

C10- Special working conditions

Following special working conditions must be carefully evaluated before using a capacitor in the application:

- ***humid ambient:*** a capacitor operating in moist ambient might absorb humidity. The humidity may enter from the leads-sealing and/or box-sealing contact surfaces and gradually reaches the winding. This can cause gradual electrodes oxidation leading in medium - long term to the capacitor damage or failure. Humidity can cause also electrochemical corrosion, depending on capacitors design and materials, destroying the metallization leading to capacitance drop, overheating, swelling of the capacitors body and potentially ending up to short circuit and relevant damage up to explosion and burning.
  The potential related ageing effect due to electrochemical corrosion strongly depends on the amplitude of the applied voltage.

  Capacitors eventually modify their characteristics according to environmental conditions. The magnitude and speed of these modifications depend on dielectric, design and protecting material.

  With special design and insulation materials the speed of this process can be slowed, but not completely eliminated.
  Moreover, a certain capacitance variation takes place as a consequence of air humidity.
  The combination of high operation temperature and high humidity levels, even more with AC voltage operation and with high energy density design, is a particularly dangerous and critical condition, potentially causing a fast ageing of the capacitor (re.: DIN40040 temperature-humidity graphs), with related relevant main parameters variations, body distortion, decrease of the expected life and rapid increase of the failure probability. This should be taken in account, in particular if units are supposed to be used in tropical countries or at critical environmental and climatic conditions.

General technical information

Important: special attention shall be paid when choosing capacitors to harsh environmental and climatic conditions. For this kind of application, special execution capacitors having THB ratings shall be designed and adopted (THB: Temperature Humidity Biased).

Most common tests adopted to evaluate high humidity - temperature performances for harsh environment are:

- 40°C/ 93% RH: standard damp heat steady state test (IEC60068-2; IEC 384-1; AEC Q-200 ref., cockpit, biased=voltage applied, test duration 1000h; IEC 60384-17:2019, grade II, robustness under high humidity, AC Power and Pulse capacitors, test duration: 1344h = 56 days)
- 60°C/ 93% RH: Grade III, high robustness under high humidity test (IEC 60384-17:2019, AC Power and Pulse capacitors, test duration: 1344h = 56 days)
- 85°C/ 85% RH: it corresponds to the extreme environmental condition of the THB test. These conditions are very rarely reachable in real-life applications adopting film capacitors (IEC 384-1; AEC Q-200 ref., Level 1, biased= voltage applied). This test is extremely tough, or even destructive, for the vast majority of fixed metallized capacitors, if not specifically designed and rated for.

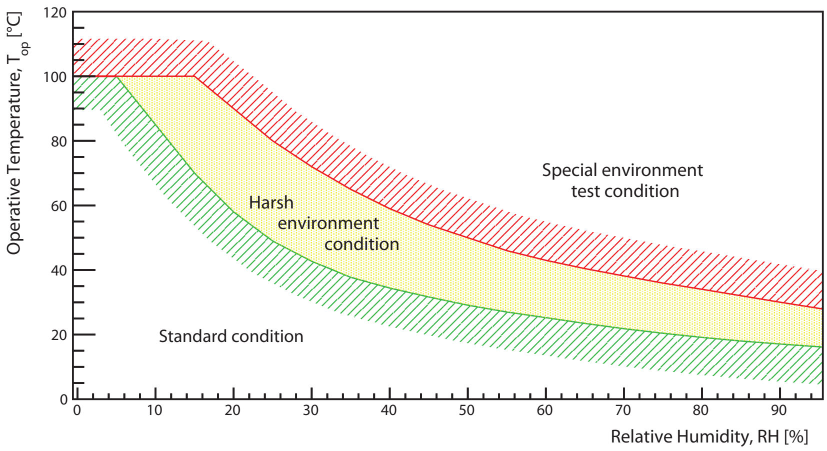
  And possible intermediate levels (usually corresponding to high stress levels but more realistic operating conditions and real usage) as

- 70°C / 70% RH; 60°C / 60% RH

Note: testing capacitors upon the most severe test classes (85/85/1000), a typical effect could be the box bulging, even if with electrical parameter still within admitted variations and not corresponding to real electrical damages (please refer to type specifications).

Always refer to type specifications for suitable usage allowed and possible application under harsh environment conditions.

Temperature and Humidity Operating Reference



- ***sealing resins:*** chemical and thermal effects due to capacitors embedding in resins and curing process must be taken in account. Solvents contained in the resin might cause capacitor characteristics deterioration and physical damage to protection materials. The heat generated in the resin mass during polymerization process may bring to high temperatures and the resin shrinking during hardening may also cause leads breaks or other physical damage of the capacitor.
- ***immersion in oils-liquids:*** oils or other insulating-protecting liquids may cause the damage of the capacitors protecting materials and or units destruction. In particular, they may attack the tape adhesive, causing the rapid flagging and de-touch of the insulating tape from the axial capacitors body. Depending on the substances, a possible relevant and fast penetration inside the capacitors may take place, typically at terminals-sealing contact and at sealing-case or tape contact surfaces. In general, immersion in any kind of liquids is not admitted: any need of immersion of the units in oils or other kind of insulating-protecting liquids must be communicated to ICEL S.r.l. for preventive evaluation. In any case, enough long time and exhaustive evaluation tests shall be performed.
- ***adhesive curing:*** the resin used to glue SMD components might cause damage to capacitors dielectric (in particular to polypropylene film) if they are cured in the same oven, especially when long curing time is combined with the heat necessary for the curing process. When polypropylene capacitors are used with SMD components, they must be fit after the SMD gluing process.
- ***rapid mould growth,*** *corrosive atmosphere and ambient with a high degree of pollution (also a very long permanence at stock before usage if not at controlled conditions):* carefully evaluate operating conditions which may cause capacitors damage or accelerated aging. Very long term permanence at stock before usage may cause oxidation or other chemical phenomena taking place on the terminals surface, in particular in ambient having high humidity levels, relevant temperature oscillations or presence of contaminating or reacting chemical substances. Unusual storage or transport temperatures or conditions may cause damages too.
- ***dust in the cooling air:*** particularly if conductive.
- ***operating altitude:*** capacitors used at big altitudes are subjected to special operating conditions, in particular they are submitted to reduced heat dissipation efficiency related to the air density and characteristics variation.

  The maximum allowable altitude above sea level is typically 2200 meters, 1000 meters for capacitors for power applications.

- ***following further unusual service conditions and misapplications may cause failures:*** superimposed radiofrequency voltages (units not suitable for radio interference suppression), unusual vibrations, bumps of mechanical shocks, abrasive particles, corrosive substances, explosive or conducting dust in cooling air and oil or water vapors, explosive gas or substances, radioactivity, rapid or excessive humidity or temperature changes of working ambient, unusual transportation or storage temperature and environmental conditions.

General technical information

C11- Materials flame retardancy, RoHS, REACH, Conflicts Free Minerals normative and regulations compliance

Unless differently specified, ICEL S.r.l. products are protected with flame retardant materials.
Please refer to the series specifications for detailed information.
ICEL S.r.l. products are manufactured in compliance with RoHS and REACH normative requirements, Conflicts Free Materials regulation.
Related statements, data and additional information are available at the web site www.icel.it.

C12-Safety warnings for capacitors usage in power equipment

A deep and detailed study of the suitability of the capacitors for the application and their correct usage in the equipment is extremely important.
Adequate qualification and reliability tests made on an enough high number of samples for an enough long time are necessary as well.
A discussion of the operating conditions and the evaluation of tests results shall be made in cooperation with ICEL Technical Office.
Since potential consequences of malfunctions, problems or failures upon power applications may be extremely serious, the equipment must be designed with adequate safety systems for detection, monitoring and problems prevention, devices for main electric parameters monitoring, temperature sensors, smoke – fire sensors etc.
As soon as an anomalous behavior of the system appears, the circuit supply prompt stop shall take place to prevent the progression to irreversible capacitors damage levels.
The equipment design and circuit layout shall be made in order to contain and minimize the possible effect of a failure, avoiding damage propagation to surrounding areas.

Important: a wide safety margin of capacitors ratings compared to the operating conditions must be kept (25-30% suggested).
Periodic checking plans of the equipment state and components conditions shall be adopted, including replacement plans for ageing prevention.

D-Storage conditions and Standard environmental conditions

In order to minimize the units ageing and electrical parameters variation before the units real use in the application, it is suggested to avoid capacitors storage where environmental conditions are different from the following (standard environmental conditions):

- Temperature: +15°C ÷ +35°C (ideal), up to +5°C ÷ +50°C admitted.
- Humidity (+25°C): average per year ≤ 60%, 30 days random distributed throughout the year ≤ 80%, other days ≤ 70%, dew not admitted.

These humidity levels should be reduced at ambient temperatures ≥ +25°C, of about 15% for every 5°C of ambient temperature increase, up to +50°C max.

Important: very long term storage may be related to surface oxidation phenomena or other chemical reactions on the copper exposed parts of the terminals (cutted sections); very long term storage, particularly in presence of humidity, may also reduce the terminals solderability.
Moreover, **service life must be considered as the sum of operating hours, operating breaks, storage and testing time at users - customers facility and transport times.**

E-Printing and production date code; resistance to solvents

If not otherwise stated by reference normative, by approvals related to capacitors series or agreed with customers, the typical printing data shown on capacitor body are:

- ICEL trade mark or name
- Series or type
- Rated capacitance and measuring unit
- Tolerance on capacitance (shown in % or with correspondent letter code)
- Rated voltage
- Manufacturing date codes according to DIN41314 and IEC60062 + 2 characters corresponding to the week code (**total 4 characters**):

Year	Code	Year	Code
2007	V	2019	L
2008	W	2020	M
2009	X	2021	N
2010	A	2022	P
2011	B	2023	R
2012	C	2024	S
2013	D	2025	T
2014	E	2026	U
2015	F	2027	V
2016	H	2028	W
2017	J	2029	X
2018	K	2030	A

(codes sequence repeating every 20 years)

Month	Code
January	1
February	2
March	3
April	4
May	5
June	6
July	7
August	8
September	9
October	O (letter)
November	N
December	D

Example: capacitors manufactured 20 February 2015 code= F208; capacitors manufactured 8 October 2017 code= JO41.

If necessary, special production data code printing may be used or adopted upon request in order to ensure an extra-detailed products traceability; for example, if several repeated productions and shipments are made in the same week the std. code could be followed by a further character, obtaining a 5 characters code. Other special identification codes could be managed, upon agreement.
In addition to above listed data, following additional printing are typically shown on approved series:

- Operating temperature range or climatic class
- Self-healing property
- Protection class
- Expected life class
- Operating frequency
- Approval references and approval Marks

Some of the above mentioned data may be lacking when capacitors shape, dimensions or available printing surfaces do not allow a complete data marking.
Printing resistance to solvents (laser printing excluded): the printing is usually made on capacitors body with dark ink, resistant to the main common solvents (like alcohol, fluorhydro-carbons and their mixtures) used for PCBs washing and flux residues removal.
Particularly aggressive solvents and cleaning agents based on chloroydro-carbons or ketones must not be used since they may damage the capacitors and their coating materials.
In particular, any substance containing ketones will probably cause printing melting.
Moreover, also ***some kind of protecting and tropicalizing varnishes having the same chemical base may cause printing melting*** and potential capacitors damage.

Important: before applying any varnish or protecting liquid or solvent onto capacitors surface, do test its effect on markings and coating materials. It is recommended to carefully dry the components after the cleaning.

F-General Warning (general rules and indications for problems and failures management or rejections)

Not respecting specifications and parameters limits, improper installation, use or application of ICEL S.r.l. products might cause damage to the components, induce their characteristics modification and a decrease of their reliability and expected life.
This could bring to dangerous failures which may cause the destruction of the components and of the equipment where they are used, smoke, fire and explosion danger.
Note that the adoption of segmented metallized film design does not directly imply that the capacitors are not subjected to potentially dangerous failures.
Before using ICEL S.r.l. products in any application, please read carefully the related specifications and all the information included in this catalogue.
Information and data contained in the chapter "General technical information", must be considered as a completing part of the single series specifications.
Overstressing and overheating shorten the life of a capacitor, therefore the operating conditions (like temperature, voltage, installation, operation and so on) should be strictly controlled.
Be sure that the component is proper for your application, that the application parameters do not overcome the limits stated at related specification and that all the warnings and instructions for use are correctly followed.
Do check in the intended application and operating conditions of the component before using it in any product or equipment, to ensure that the component is proper for your application.
In case of doubt about service conditions and correspondent capacitors characteristics and performances, or ***in case of application not foreseen or working parameters not stated at capacitors specifications, ICEL Technical Office must be consulted*** (please refer to the "Application data questionnaire"; paragraph H).

ICEL S.r.l. is not responsible for problems caused by critical usage and application, not preventively discussed and acknowledged by ICEL Technical Office.

Products manufactured by ICEL S.r.l. are made with maximum attention to quality, in order to be free from defects in design, materials and workmanship, following related series specifications and applicable national and international normative, regulations and approvals obtained requirements. A fundamental aim of the ICEL S.r.l. Quality Assurance system is the prevention of defects occurring.

The cooperation between ICEL S.r.l. and customers is fundamental to solve possible problem, prevent and reduce the consequences of failures.
In particular, ***the prompt and exhaustive communication at least of following main information is necessary to allow a quick and effective response to the complaints you may have:***

- detailed description of the failure - problem
- when and how the failure - problem was detected
- operating conditions, environmental conditions and application description
- operating time before the failure - problem occurred
- number of damaged and their percentage on total quantity used or supplied
- original supplied lots data and references (production date code, delivery date, quantity etc.)
- first time usage in a new application or long term, consolidated application (other lots previously supplied?)
- problems detected during tests (which one? Under which conditions?) or controls or during normal working on field
- any additional information about special conditions which may have been associated with the failure - problem occurred
- possible similar problems occurred in the same application- conditions on other capacitors types (or from competitors)

ICEL S.r.l. is not responsible for possible delays in the Non-Conformities management in absence of prompt, complete and detailed information provided by the customer.

Samples of damaged, if available, should be sent to ICEL S.r.l. for analysis upon agreement and indications from ICEL S.r.l.
They must be clearly identified and possibly separated by other "good" units or units damaged for other reasons.
They must be adequately packed and protected to prevent any additional damage than the one claimed.

Important: **the customer is required to have an adequate and effective traceability system to keep finite and focused the problem management (and related costs) on involved pieces or lots only.**
ICEL S.r.l. is not responsible for any additional cost or undue management need related to a not precise and not reliable customer traceability and products identification system.

ICEL S.r.l. liability shall be limited to replacement or repair free of charge of the ascertained defectives, provided that notification of failures or defects is given to ICEL S.r.l. immediately when the same becomes apparent.

These actions are possible only after that the returning conditions have been agreed with the customer or buyer and ICEL S.r.l. has analyzed the defectives and authorized the returning of goods.

Any components rejection of samples delivery must be packed and adequately protected in order to prevent any additional damage different from the originally detected failure or problem, anyway ensuring the material integrity and protection against environmental conditions.

ICEL S.r.l. is not responsible for any possible damages to persons or things, of any kind, derived from improper installation, wrong usage or incorrect application of ICEL S.r.l. products.

ICEL S.r.l. shall not be liable for any defect which is due to accident, fair wear and tear, negligent use, tampering, improper handling, improper use, operation or storage or any other default on the parts of any person other than ICEL S.r.l.

In case of defective goods, ICEL S.r.l. shall not be liable, under no circumstances, for any consequential loss or damage arising from the goods sold. The above limitations to ICEL S.r.l. liability for defective goods apply also to product liability: ICEL S.r.l. shall have no responsibility for injury to persons or damage to goods or property of any kind.

In case of any product liability claim from third parties against ICEL S.r.l., not falling within ICEL S.r.l. liability in accordance with above statements, customer or buyer shall hold ICEL S.r.l. harmless.

G-Updating and validity of product specifications - General data and information

All drawings, descriptions, characteristics, materials and performance data given by ICEL S.r.l. are as accurate as possible but must be considered as a general information, so they are not binding on ICEL S.r.l., unless specifically agreed in writing.

Unless otherwise stated, dimensions and materials may be subjected to reasonable variations due to available raw materials or normal manufacturing process tolerances.

The characteristics of the components are subjected to improvements and upgradings related to norms evolutions and the continuous improvement approach adopted. The production lot code identifies a specific period and the related compliance with the applicable specifications reference.

The data and information given in the General Technical Information chapter must be considered a part of the single types and capacitors families specifications contained in the general catalogue.

Data and characteristics shown in this catalogue are subjected to modifications without notice.

Always refer to ICEL S.r.l. web site, www.icel.it, for products updated characteristics, last revision specifications, general data and information, products certifications and news.

General technical information

H-Application Data Questionnaire

In order to help ICEL Technical Office to correctly individuate the component suitable for your needs, please fill this questionnaire, giving us all the available information about the application and the working conditions.

Capacitance (1kHz): Tolerance (%):

Resistor value (Ω, for RC networks only): Resistor power (W, for RC networks only):

Rated DC voltage (Vdc): Operating DC voltage (Vdc):

Rated AC voltage (Vac): Operating AC voltage (Vac):

Repetitive Peak voltage (Vdc): Non Repetitive Peak voltage (Vdc):

Operating frequency (Hz):

Irms max.(A): , at frequency= Hz, at temperature= °C

Max. Pulse Rise Time (V/µs) : Max. Repetitive Peak Current (A):

Max. Non Repetitive Peak Current (A):

Pulse width (s): Pulse repetition frequency (Hz):

Max. Dissipation Factor (x10-4): tgd= at frequency= Hz; tgd= at frequency= Hz

Max. E.S.R.(mΩ): at frequency= Hz; at frequency= Hz

Insulation Resistance at+25°C (MΩ): after 1 minute at Vdc

Operation: continuous D Intermittent D with Cycle duration / Duty cycle:

Test voltage between leads: Vdc D / Vac D, for s, notes:

Test voltage between leads and case: Vdc D / Vac D, for s, notes:

Max. rated operating temperature (°C): Min. rated operating temperature (°C):

Max. ambient temperature (°C): Min. ambient temperature (°C):

Cooling: natural D; forced D, notes:

Climatic category (IEC60068-1 cold test / heat test / damp heat duration): / /

Ambient operating humidity conditions:

Other critical operating conditions:

Expected life (h): Failure rate (x10-9 component hours):

Reference conditions: voltage applied= ; temperature= ; others=

Failure modes:

Preferred execution: axial cylindrical ☐ , axial flat ☐ , radial dipped ☐ , radial in box ☐ , radial with lugs ☐ , other ☐

Notes:

Diameter (mm): , tolerance± mm Thickness (mm): , tolerance± mm

Height (mm): , tolerance± mm Length (mm): , tolerance± mm

Leads type: Leads dim. (mm): , tolerance± mm

Printing requirements:

Approvals:

Reference Normatives:

Packing requirements:

Reference / presently used components:

Additional technical information (please enclose drawings, schematic circuit diagram, voltage and current waveforms and application description if available):

Needed quantity: Foreseen order frequency:

Delivery terms: Target price:

Notes:

List of enclosed documents:

I - Capacitors selection guide (Main Applications and Products destination)

PLEASE REFER TO ICEL S.R.L. WEB SITE WWW.ICEL.IT FOR PREFERREND USAGE AND SUITABILITY UPON APPLICATIONS.