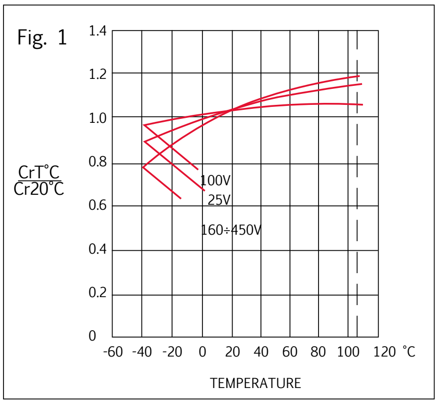
ELECTRICAL CHARACTERISTICS

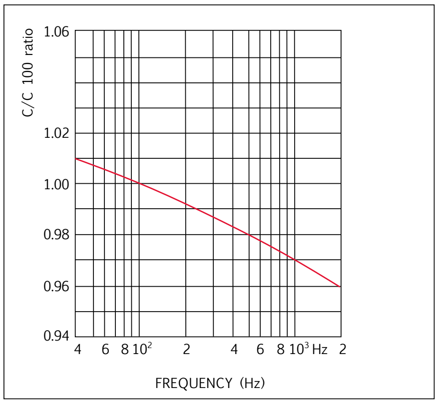
RATED CAPACITANCE

The rated capacitance, defined at 100 Hz and 20°C, is the capacitance of an equivalent circuit having capacitance and resistance series connected. The value is indicated on the external sleeve, specified in micro Farads [μF]. Typical capacitance drift versus temperature and frequency, see below.

CAPACITANCE DRIFT VERSUS TEMPERATURE



CAPACITANCE VERSUS FREQUENCY



RATED VOLTAGE (V_r)

The rated voltage is the value of voltage that could be applied continuously within the operating temperature range of capacitors. When using a capacitor with AC voltage superimposed on a DC voltage, care should be taken such that the peak value of AC voltage plus the DC voltage does not exceed the rated voltage.
Reverse polarization shall not exceed two times VDC value.
When capacitors are series connected, the voltage distribution across the series may not be the same. This is due to normal DC leakage distribution and should be considered in the design process either using a higher rated voltage capacitor or using balancing resistors in parallel with each series capacitor.

SURGE VOLTAGE (V_p)

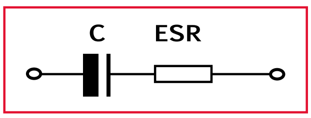
The surge voltage is the maximum overvoltage including DC, peak AC and transients to which the capacitor could be subjected for short periods of time (not more then 30 seconds in any 5 minute period).
Depending on applicable specifications, this test is usually performed at maximum operative temperature.
A current limiting resistor of 1000 ohm should be used.
Charge is held for 30 seconds for 1000 cycles, then the capacitor is allowed to discharge without load for 5 minutes.
Rated and surge voltage values for Kendeil capacitors are listed in following table, where a different relation is applied depending on rated value (Vr).

	V_p = 1.15 V_r											V_p = 1.10 V_r				V_p = 1.05 V_r		
RATED VOLTAGE [V]	16	25	40	50	63	75	80	100	160	200	250	350	400	420	450	500	550	600
SURGE VOLTAGE [V]	18	29	46	57	72	86	92	115	184	230	287	385	440	462	495	525	578	630

EQUIVALENT SERIES RESISTANCE (ESR)

The equivalent series resistance is the resistance that a capacitor has to the alternating current flow. Various resistive components such as: electrolyte, paper foil, aluminium foil, tabs, and others determine the total ESR value. It is measured at 100 Hz and 20°C. It is related and dependant on temperature and frequency and generally when either these factors increase, a reduction in ESR results.
The construction technology of Kendeil capacitors reduces significantly the ESR value.

Equivalent Standard Circuit



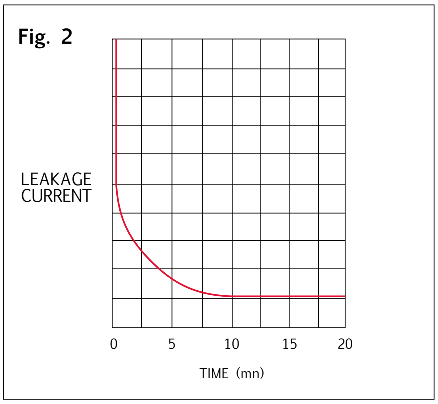
$ESR = R_1 + R_2 + R_3$
R_1 = Resistance of aluminium oxide thickness
R_2 = Resistance of electrolyte, spacer
R_3 = Resistance due to materials: foil lenght, tabs, terminations contact resistance

LEAKAGE CURRENT (IL)

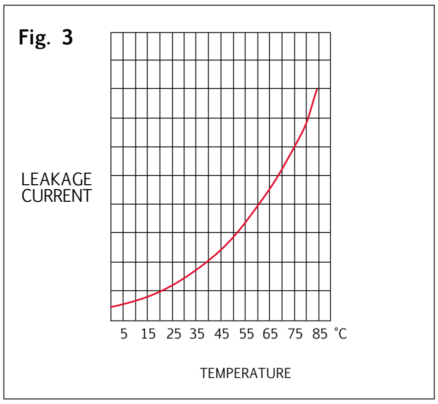
Measured at 20°C after 5 minutes under rated voltage.
It is the current flowing through the insulation resistance when a direct current is applied to the capacitor. After charging a capacitor to a set voltage we obtain, initially, a high current flow which decreases rapidly until a constant very small value is reached, the final leakage current. The leakage current value increases both with voltage and temperature. After a long storage period, the leakage current value can be exceeding the rated value and before the output measurement reanodization is necessary.

For typical leakage current versus time and temperature, see Fig. 2-3.

I_L DRIFT VERSUS TIME



I_L DRIFT VERSUS TEMPERATURE



DISSIPATION FACTOR (tan δ)

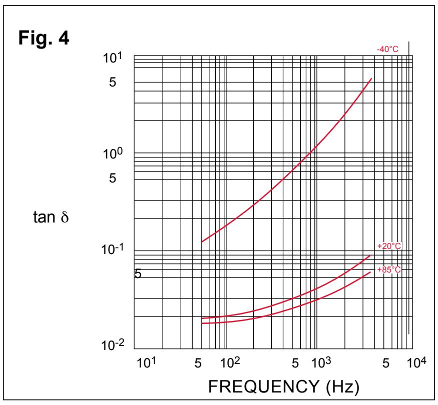
Dissipation factor or loss angle tangent (tan δ) is a main electrical characteristic of an electrolyte capacitor, a measure of the deviation from an ideal capacitance value.
Relationship is included in the following formula:

$$\tan\delta = 2\pi f\ C\ ESR$$

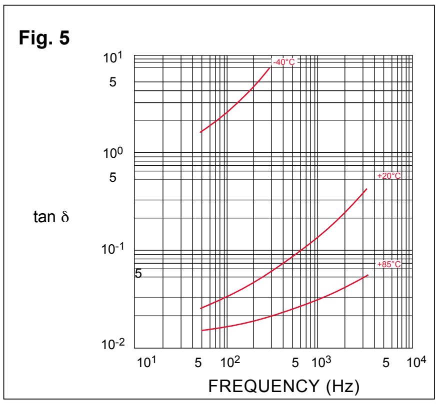
where f = frequency   C= rated capacitance

Maximum values in the datasheets have been indicated at 100Hz and 20°C.
Drift versus frequency as Fig. 4-5.

tg δ DRIFT VERSUS FREQUENCY
LOW VOLTAGE (≤100 V_r d.c.)



tg δ DRIFT VERSUS FREQUENCY
HIGH VOLTAGE (> 100 V_r d.c.)



INDUCTANCE

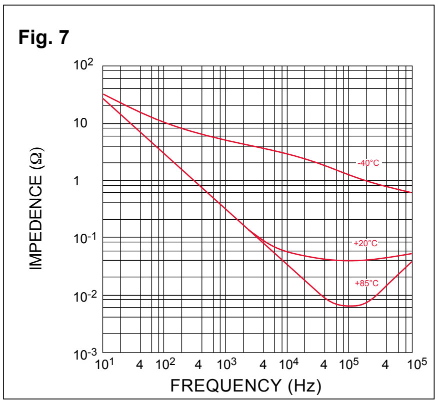
Some inductance is present in aluminium electrolytic capacitors, but values are usually less then few tens of nH.

IMPEDANCE (Z)

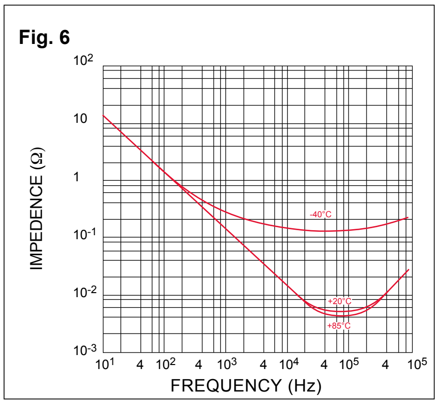
$Z = \sqrt{ESR^2 + (X_L - X_C)^2}$

Impedance is dominated by the capacitive reactance (X_C) at low frequencies and by the inductive reactance (X_L) at high frequencies. At the point of series resonance Z=ESR.
Typical impedance drift versus frequency, see Fig. 6-7.

Z DRIFT VERSUS FREQUENCY
HIGH VOLTAGE (> 100 Vr d.c.)



Z DRIFT VERSUS FREQUENCY
LOW VOLTAGE (≤100 Vr d.c.)



RIPPLE CURRENT (Ir)

It is defined as the superimposed alternated ripple current (sinusoidal alternating current at 100 Hz). It depends mostly on an allowable temperature rise within a capacitor section due to the power relation formula: $I^2 \times R$. Heating occurs, due to an alternating current flowing through the equivalent series resistance of capacitor. Actual power must be considered when defining ripple current capability. The thermal gradient of an aluminium foil capacitor in an aluminium can is 10^{-3} Watt/cm²/°C. Since the ripple current raises the temperature of the capacitor it has a significant effect on the operational life of the component. A diagram of useful life specifies life under given operating conditions of different temperatures values and ripple current values.

SHELF LIFE (Voltage free storage)

Capacitors generally can be stored at temperatures up to 50°C without any reduction of their reliability. Overall characteristics such as capacitance, ESR and impedance should show good performance with no sensitive changes while the leakage current will exhibit a slow drift upwords.
In practical use, we experienced the following scheme meaningful for voltage rated classes of capacitors:

Shelf life	Nominal Voltage	Diameter
Three years	≤ 100V DC	Ø < 76mm
Two years	≤ 100V DC	Ø ≥ 76mm
Two years	> 100V DC	All Ø

After an extended storage period, the leakage current value may exceed the rated value and, before the output measurement, a reanodization process is required.
It could be realized by applying the rated voltage at room temperature for one hour.
In any case it is advisable to use a maximum charging current of 5mA or twice typical value specified for each series.