GUIDELINES FOR ALUMINIUM ELECTROLYTIC CAPACITORS

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• POLARITY
In DC applications polarity is required; if polarity is reversed, the circuit life will be shortened or the capacitor may be damaged. Generally, an intermittent reverse voltage of 1V DC is allowed.
If during operation, it is possible that polarity could be reversed or unknown, extensive use of a bipolar capacitor is required.

• *CHARGE - DISCHARGE APPLICATIONS*
Kendeil aluminium electrolytic capacitors are suitable for circuits in which a charge and discharge cycle is requested. The frequent cycles due to a charge or discharge operation could take some drop of capacitance value. In general one million of switching with rated voltage one cycle for second a time costant of 0.1 carries an overall capacitance decrease less then 10%.

• INSULATION
In general all aluminium electrolytic capacitors are covered with a PVC sleeve, that is also used for marking. The aluminium can is not insulated from the cathode, so when the internal element needs to be electrically insulated from the can, capacitors specially designed for insulation requirements should be used.

• *OPERATING TEMPERATURE*
A capacitor should be chosen with a maximum specified temperature greater than the operating temperature of the application; this will increase the capacitor useful lifetime.

• CLIMATIC CONDITIONS
All **Kendeil** capacitors maintain good behaviour under any climatic conditions when operating conditions are within the design specifications limits of each product type.
Since each capacitor is hermetically sealed, the wet element inside impregnated with electrolyte will not be exposed to external conditions such as high pressure or vacuum.
Furthermore, all electrical parameters such as impedance, leakage current, ESR and capacitance, will not be significantly changed by these external conditions.

Temperature range of **Kendeil** electrolytic capacitors (IEC 68-1):

Capacitor type	IEC 68-1 code	Temperature Range
K01 screw	GP	-40°C + 85°C
K02 screw	GM	-40°C +105°C
K05 snap in	GM	-40°C +105°C
K06 snap in	GP	-40°C + 85°C
K13 fast on (lug)	HS	-25°C + 75°C

AIR PRESSURE
When operating at low values of external air pressure, there could also be an increase in the pressure inside the case. When an external vacuum exists, the pressure inside the capacitor could rise up to 1 bar. In these circumstances the internal vapour loss becomes greater resulting in an overall reduction in expected life.

ALTITUDE
When in extreme altitude situations, consideration must be given to the shortening of capacitor life due to the reduced air density, preventing heat from being adequately dissipated from the external surfaces of the capacitor leading to an increase in internal temperatures.

• *MECHANICAL STRESS*

If excessive force is applied to terminations, they may break or their connections with the inside element may be badly affected. The distance between terminations holes on the circuit board should be the same as the spacing between terminations on the capacitor.

SCREW TERMINAL - **Kendeil** K01/K02 type

Excessive torque force applied in tightening the screws into terminals will result in stripping the threads and possibly increasing the contact resistance. On the other hand, if screws are not enough tightened enough, the high contact resistance will cause localized heating at terminals plus an early failure of the capacitor.

SNAP IN - **Kendei**l K05/K06 type

Improper insertion into the circuit boards may break the terminals or impair their electrical connections with the internal elements. When provided, blank terminals of a multi-terminal capacitor should be considered to be at the same potential as the electrolyte, or cathode, and should therefore be isolated from the circuit.

APPLICATION OF TORQUE TO ALUMINIUM THREADS

Please note the max applicable torque strength to K01 and K02 capacitors:
With M5 insert screw torque = 2Nm
With M6 insert screw torque = 4Nm
Screw torque strength for stud M8 = 4Nm
Screw torque strength for stud M12 = 8Nm

• SOLDERING

Incorrect soldering may shrink or break the capacitor sleeve. Please read the following information carefully.

- When soldering a printed circuit board (PCB), the soldering temperature should not be excessive while time taken should be short. Otherwise it could have adverse effects on the electrical characteristics and insulating sleeves.
- During the soldering process, the sleeve may melt or break if it gets in contact with circuit board traces. Try to avoid this problem and do not locate circuit board traces under capacitor body.
- The sleeves may be melted by solder which migrates up through terminations holes in the circuit board.
- When soldering adjacent components to the capacitor, preheated lead wires or terminals may tear the capacitor sleeve if they come in contact with it. Therefore, capacitors are to be mounted carefully so that adjacent components terminations do not come into contact, particularly when mounting on through-hole circuit boards.

• *CLEANING*

Aluminium can be aggressively attacked by halide ions, particularly by chloride ions. Even small amounts of chloride ions inside the capacitor will cause corrosion which contributes to rapid capacitance drop and venting. Therefore, the prevention of chloride contamination is the most important check point for quality control in production. Solvent proof capacitors are required when chlorinated hydrocarbons are used for cleaning. If aluminium electrolytic capacitors without the solvent-proof construction are present on the circuit board, alcohol based solvents are recommended for cleaning. In this case, solvents such as methanol, ethanol, propanol and isopropanol should be used. Normal tests show that any detrimental effect is eliminated. An alkaline detergent may damage the aluminium metal and marking. Aqueous cleaning methods in conjunction with saponification are commonly used. However it is advisable to dry immediately with hot air, which is best achieved at 85°C for few minutes.

• STORAGE

After having a capacitor exposed to high temperatures such as direct sunlight or heating elements, the capacitor life may be adversely affected. Also when capacitors have been stored under humid conditions for a long period of time, humidity will cause terminals to oxidize. Therefore it is highly recommended they should be stored at room temperature, in a dry place, out of direct sunlight.
A voltage treatment process should be applied after some years storage period.
When capacitors have been stored above room temperature, the anode foil may react with the electrolyte causing increased leakage current values. Application of normal voltages to these capacitors may result in higher leakage current values, but in most cases, they will return to normal levels in short time.
However on occasion it is possible that a certain amount of gas will be generated which might cause the safety vent to open. Capacitors that have been stored for long time should be subjected to a voltage reforming process which will regenerate internal dielectric layers.

• *SAFETY*

When an escape of electrolyte has occurred, wash the affected area with hot water. Use rubber gloves to avoid skin contact. Any contact with eyes should be immediately irrigated with water and medical advise is sought.
Kendeil electrolyte blends do not contain materials currently listed as carcinogetic or mutagenic such as polychlrolinated biphenyls (PCB) or dimethylformamide (DMF). No Butyrolactone used as solvent.
Under exposure to electrolyte skin could become dry. Other irritations or effects may be caused to the mucous membranes particularly eyes, where conjunctivitis may result.

• BALANCING RESISTORS in series and parallel connections

The following explanation is given for a typical connection scheme, when two capacitors have been connected in series, this is a brief approach answering to the question *"How much could be the maximum voltage applied to a capacitor?"*

If we have two capacitors of 400V rated with ±20% tolerance range each.
Total voltage applied is 800V ($V_{circuit}$), in the best situation each capacitor is well balanced.
Anyway the maximum and minimum values due to the tolerance range is then put in the formula. It is easy to calculate the maximum exposing voltage to whom the minimum capacitor could be applied.

$$V_{MINCAP} = V_{circuit} \times (1+20\%) / (MIN_{tolerance} + MAX_{tolerance})$$

Using the values from example, we have: $V_{MINCAP} = 800 \times 1.2 / (0.8 + 1.2) = 480V$
This is the real maximum voltage value applied to the capacitor in a serial connection. It is strongly recommended to use a resistor that would share the over-voltage.
In the practical field of designing these kind of circuits, we have found that a good balancing system could be obtained using the following formula in which only the capacitor value is required.
We assume that a current from 15 to 20 times the leakage current value would be flowing in the resistor, therefore a simple relationship could be applied:

Balancing Resistor [kΩ] = 60,000 / Capacitance [µF]

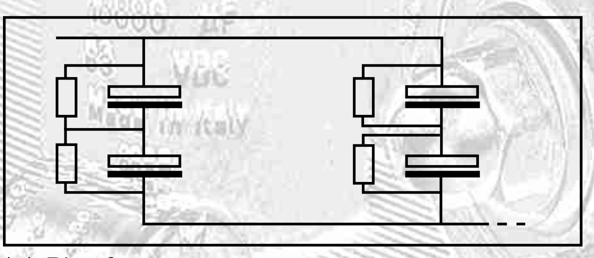
The resistor should have very good characteristic, usually with tolerance range of ±5% but better tolerance range is preferred when dealing with high transients and a top level performance is required.
When designing high current applications, a parallel configuration should be preferred.

PRACTICAL TABLE

Capacitor	Balancing Resistor
470 µF	127 k Ω
680 µF	88 k Ω
1000 µF	60 k Ω
2200 µF	27 k Ω
4700 µF	13 k Ω
6800 µF	9 k Ω
10000 µF	6 k Ω

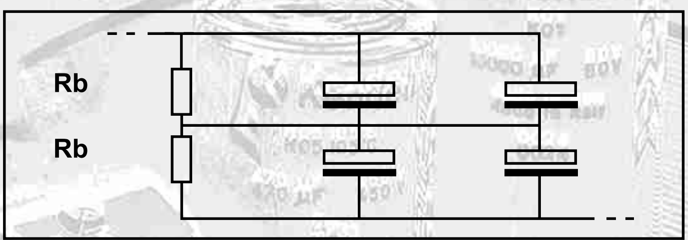
CONFIGURATION SCHEMES
Two ways of connecting balancing resistors are implemented in the industry, depending on design and experience. Both of them have important features that must be borne in mind for the appropriate performances required.

Single balancing resistor



(+) Plus features
When one capacitor fails, the adjacent capacitor will probably fail too, but the other capacitor will remain undamaged.
(-) Minus features
There are many resistors to be placed in the circuit.

Two parallel resistors



(+) Plus features
A better balancing system is achieved with "the most parallel capacitors used".
The total leakage current as the sum of the single branches components gives a very good balancing system.This configuration needs only two resistors and since the delta LC would be a very small value, it could be realized also without any resistor.
(-) Minus features
When one capacitor fails, the parallel branch in which it is operating will also fail as the total voltage will be applied under operating voltage conditions.

• *FLAMMABILITY*

Some component parts of a capacitor are suitable to burn depending on ambient temperature and adjacent elements, being made of plastic, PVC or other, even when classified as non flammable material.
In the table you find the main materials with self extinguish capability under normal circumstances:

PART	USE	MATERIAL	
DECK	for screw type terminal K01 K02 for snap in type terminal K05 K06	Phenolic Rubber bakelite coupled	No ignition non flammable No ignition non flammable
CAN	for Motor Start type K13 ONLY	Polycarbonate (plastic)	Ignition not self extinguishing
SLEEVE	all K01 K02 K05 K06	PVC	No ignition
VENT PLUG	for screw type terminal K01 K02 only	Silicone	Ignition non flammable
ELECTROLYTE	all internal wound elements in each capacitor	Glycol based (*)	not self extinguishing non flammable (*1) flash point 110°C higher then rated 85° or 105° class

(*) NOTE FOR ELECTROLYTE
Kendeil uses glycol based electrolyte through all ranges of products.
The impregnation process is computer controlled with supervisor agent software to assure the correct time and level of electrolyte needed by each single capacitor.
Different kinds of electrolyte blends are being used, especially designed for low voltage, medium voltage and high voltage range.
Each production batch is controlled in the internal laboratory to test the specifications of recipes.

<120V	120V - 400V	>400V
LOW VOLTAGE	MEDIUM VOLTAGE	HIGH VOLTAGE

(*1) Flash point is defined as the lowest temperature at which a flame is ignited.
In our case, no flammable behaviour is possible as the rated class of capacitors are under that value.