# Capacitors for A.C. motor applications

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# GENERAL INFORMATION

## TECHNICAL TERMS EXPLANATION

**Rated capacitance of the capacitor C** ($\mu$F)**:** the capacitance value for which the capacitor has been designed, measured at 20°C at frequency of 1KHz.

**Rated voltage Un** (V)**:** the effective value of voltage for which the capacitor has been designed

**Rated frequency Fn** (Hz): the highest value of frequency for which the capacitor has been designed

**Rated current In** (A): the effective value of alternating current to the rated voltage and frequency.

**Minimum operating temperature** (°C)**:** the minimum permissible temperature on the external surface of the capacitor can during its working.

**Maximum operating temperature** (°C)**:** the maximum permissible temperature over the external surface of the capacitor can during its working.

**Capacitor for continuous and intermittent working:** a capacitor designed to work at a certain voltage during continuous working and at a different voltage (normally higher) during intermittent working.

**Working classes:** the total length of minimum life for which the capacitor has been designed under conditions of voltage, temperature, frequency, rated cycle:

|         |              |
|---------|--------------|
| Class A | 30.000 hours |
| Class B | 10.000 hours |
| Class C |  3.000 hours |
| Class D |  1.000 hours |

These working classes expect a failure rate not higher than 3% during the life of the capacitor.

**Climatic category:** is specified by three digits (IEC 60068-1). The first number represents the lower limit, the second one represents the higher limit, the third one represents the number of days necessary to the humidity test (example –25/100/21).

**Dissipation of a capacitor** (W)**:** the dissipated active power of the capacitor .

**Dissipation factor** (tg$\delta$)**:** the relation between the resistance equivalent series and the capacitive reactance to an alternating sinusoidal voltage and to a specific frequency.

**Insulation Resistance:** the relation, measured by M$\Omega$, between a continuous voltage applicated to the capacitor and the creepage current after one charge minute.

**Capacitive current of creepage** (A)**:** the current passing a conductor which connects the metallic can to the ground when the capacitor is powered by an alternating current system with the grounded neutral.

**Resistance to transistor:** pulse rise time (dv/dt). It characterizes the capacitance of a capacitor to withstand current peaks due to fast changes of voltage. The peak current is quantifiable by the following formula:

$$I_{PEAK} (A) = C (\mu F) * dv/dt (V/\mu S)$$

**Working and Safety conditions**

**Application:** the capacitors described in the current catalogue are specifically designed for the start and the run of single-phase electric motors. Usually the capacitor is connected in series to an inductive winding into an auxiliary circuit for a single-phase motor or in parallel phase/phase into three-phase motors when powered by a single-phase circuit.

**Safety class:** the degreee of safety is marked on the capacitor according to the following symbols:

**(P2)** the capacitor has been designed to fail only in case of circuit cut-off and it is protected against fire and electrocution risk.

**(P1)** the capacitor can fail either by a circuit cut-off or by a short-circuit and it is protected against fire and electrocution risk.

**(P0)** in case of failure, the capacitor does not have any particular protection.

**Safety device:** KEMET produces capacitors according to high level of process and quality control.
During the usual working, due to external stresses or at the end of the life, the capacitor can stop working. In order to guarantee a better internal safety, KEMET has developed C.87 series (metallic can) including an internal double safety device. The internal pressure due to gas in case of overheating, causes the expansion of the groove disconnecting the capacitor from the electric network (see picture pg. 7).

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**Rated Voltage:** is the highest continuous voltage applicable to the capacitor at rated temperature. Higher continuous voltage may cause the perforation of the dielectric or a short-circuit. The material used as dielectric owns a typical property, well-known as "self-healing": in case of discharge, the temperature creates a localized demetallization which insulates the discharge process. The rated voltage belongs to the alternating sinusoidal type.

**Dissipation:** the power dissipated by the capacitor is quantifiable by the following formula:

$$P \text{ max(W)} = 2 * \prod * f * C * tg\delta * V^2_{RMS}$$

The current passing the capacitor causes a heating of the component. If the heat is excessive, the performances of the component can get worse to the short-circuit, the out-of-working and the fire risk.
If the current applied is generated by a periodical sine wave, the whole cartridge could heat. It will be necessary to check the temperature does not exceed the maximum permissible limit.
If the current is generated by non-periodical waves (pulse and harmonic currents) a heating localized over the terminals could occur, in addition to an heating of the component. In this case, it will be necessary to check the sealing of the capacitor at current peak (dv/dt).

**Ionization processes:** the dielectric strength is the key characteristic to choose a dielectric material. Increasing the voltage, there is a value where the dielectric loses his insulating properties and the passage of a strong conduction current occurs: this is the discharge process. Even if the discharge is generally a thermal process, it is important to know the voltage applied: normally, the dielectric strength has minimum values with alternating voltages (thermal discharge) and maximum values with pulse voltages (electronic or intrinsic discharge).
Together with these two processes, there is to consider the process of partial discharges due to the ageing of the material and to external stresses, some vacuoles are born, points of partial discharges. These discharges cause a progressive expansion of empty spaces with and a consequent erosion process taking to the definitive discharge.

**Storage:** particular conditions of temperature and relative humidity may cause a deterioration of the electric characteristics of the capacitor.
KEMET suggests the following parameters in order to carry out a correct storage:

| | |
|---|---|
| Temperature | : from 5 to 50° C |
| Humidity | |
| ❑ Average yearly value | : ≤ 60% |
| ❑ All other days | : ≤ 70% |
| ❑ For 30 days spread over the year (statistical data) | : ≤ 80% |

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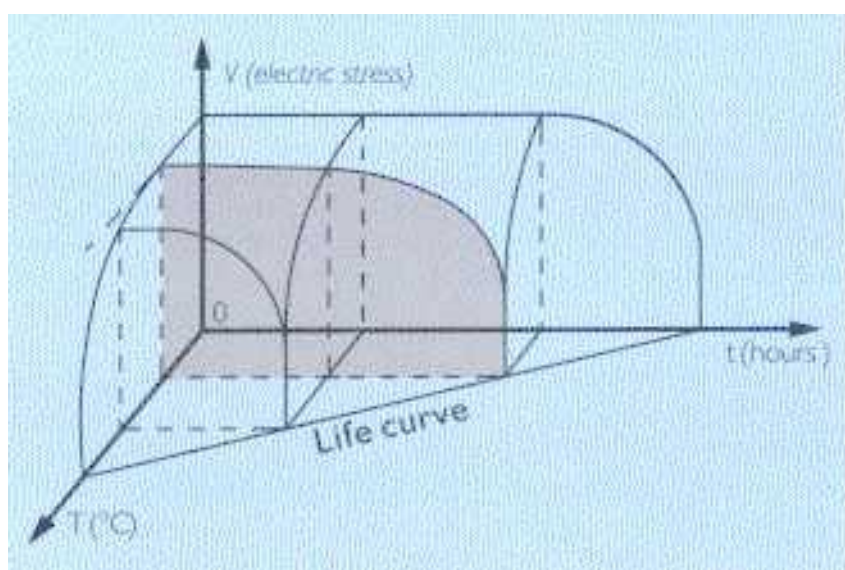CHARGED:

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# GENERAL INFORMATION

**Expected Life**

Any material or element has a longer or shorter life according to the working conditions to which it is submitted and to its intrinsic property. The capacitor is submitted to several types of stresses: over voltages, overheating, pollution, humidity, radiations, vibrations ….. The ageing is an irreversible change of the properties as a result of the application of an external stress. The expected life is time necessary to the capacitor to reach the expected limit value.

The main stresses have electric and thermal origin. It is possible to assume a model of life for each series of product and type of stress so as to expect the life of the component in function of temperature and voltage applied.

$$L \text{ (hours)} = F (V, T).$$

In the catalogue, here below, the curves of expected life in function of the voltage applied to the component, referred to rated temperature. These curves refer to life tests fixed by EN60252 standard where it is allowed a maximum variation of capacitance of 3% .

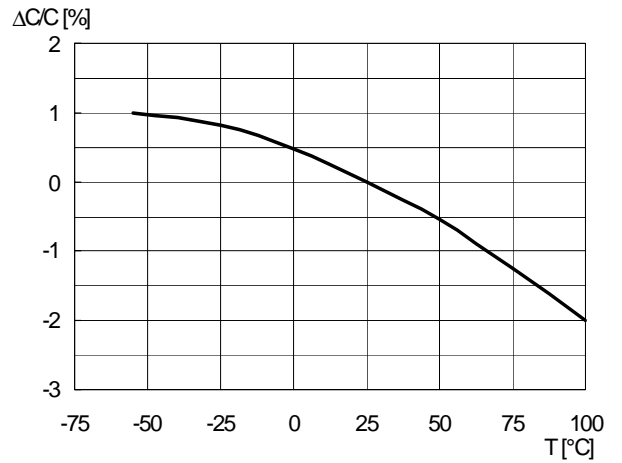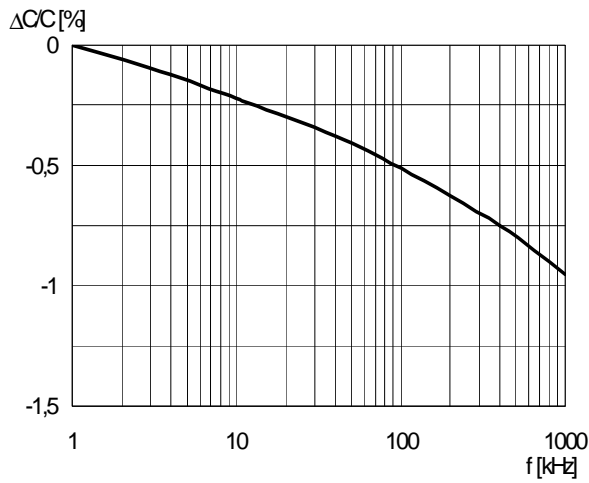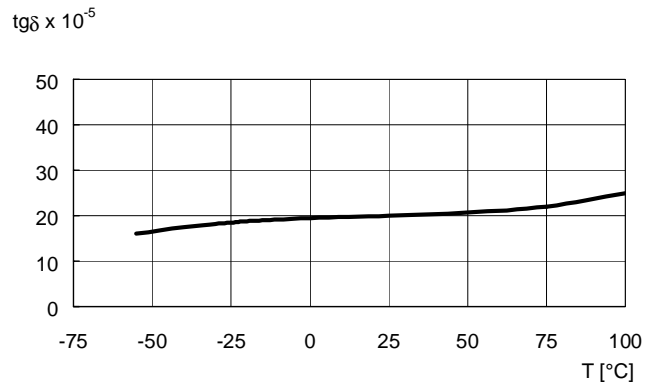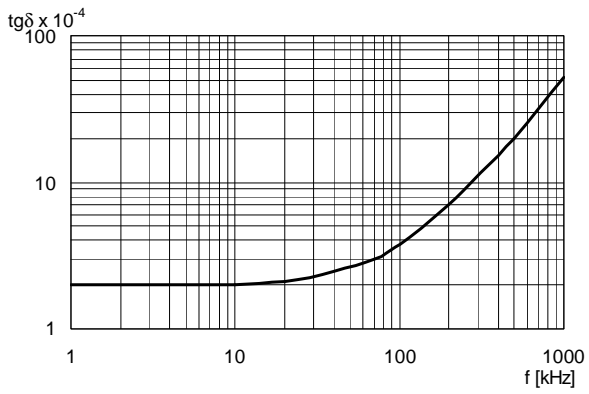Please get in touch with KEMET for further details.



**Materials**

The materials used for KEMET capacitors are the result of long experience and constant attention to field improvements. KEMET, certified according to ISO9001 standard, selects its suppliers and carries out systematical checks to the step of materials acceptance. All materials to our present knowledge are non-toxic and free from: Cadmium, Mercury, Chrome and compound, PCB (PolyChlorineTriphenyl), Bromide and Chlorine Dioxins, CFC e HCFC, Asbestos.
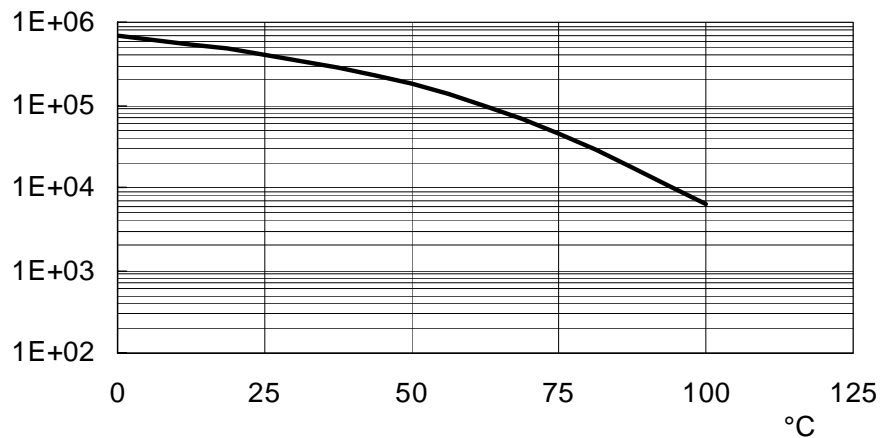
**Disposal**

The capacitors can be disposed of in compliance with the laws in force (DL22/97) according to the following classification:

C.27 Series    CER 150106    Special waste not dangerous
C.24 Series    CER 150106    Special waste not dangerous
C.87 Series    CER 150106    Special waste not dangerous

tgδ x 10⁻⁴

tgδ x 10⁻⁵

ΔC/C [%]

ΔC/C [%]

MΩ x µF [s]

# GENERAL INFORMATION

## PRODUCT CODIFICATION

C 2 7 4 A A 3 4 2 5 0 A A 0 J

Internal variant

The digits 9,10,11 specify the capacitance, while the digit 8 specifies the number of 0's to be added to obtain the rated capacitance in pF.

**Tolerance percentage on capacitance**

| | | | |
|---|---|---|---|
| **J** | $\pm$ 5% | **K** | $\pm$ 10% |
| **X** | Special tolerance | | |

**Termination**
| | | | |
|---|---|---|---|
| **1** | Fast-on 2.8 x 0.8 (hole) | **2** | Single Fast-on 6.3 x 0.8 |
| **3** | Double Fast-on 6.3 x 0.8 | **4** | Fast-on 2.8 x 0.8 (slot) |
| **5** | Fast-on 2.8 x 0.5 (hole) | | |

**A - .. D** Flexible unipolar cable, section 0.75 mm$^2$
**F** Bipolar cable: 40mm unsheating – 8mm stripped – tinned
**J** Bipolar cable: End terminal
**H** Bipolar cable: Straight 6.3 fast-on
**G** Bipolar cable: Straight 4.8 female fast on
**L** Bipolar cable: Flag female 4.8 fast-on
**K** Bipolar cable: Flag female 6.3 fast-on
**I** Bipolar cable: Ring M4 terminal
**R** Stiff unipolar cable, section 0.75 mm$^2$
**Z** Special termination

**Can and fixing device**

**A** Plastic can without fixing bolt
**B** Plastic can with M8 x 10 plastic fixing bolt
**C** Plastic can with M8 x 10 metal fixing bolt
**D** Plastic can with quick fit connection
**E** Aluminium can without fixing bolt
**F** Aluminium can with M8 x 10 fixing bolt
**G** Aluminium can with M12 x 12.5 metal fixing bolt

**Marking**
| | |
|---|---|
| **A** | C27.4 - C87.8 |
| **C** | C27.6 – C87.0 |
| **L** | C27.7 |
| **B** | C87.8 (UL) |
| **D** | C87.0 (UL) |
| **N** | C27 (UL) |
| **Z** | Special marking |

**Product series**

Plastic can.     **C27** Series
Aluminium can:  **C87** Series

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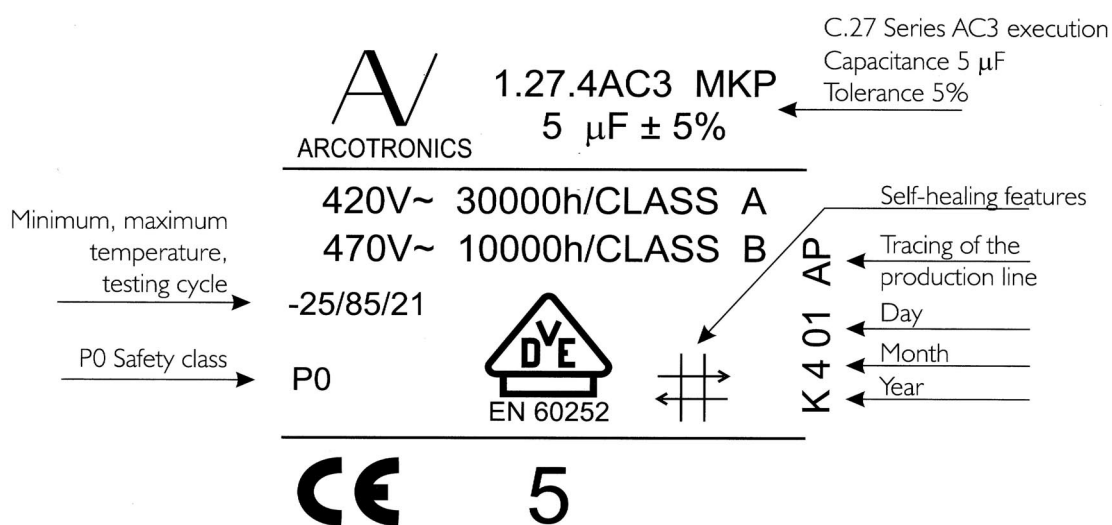CHARGED:

# GENERAL INFORMATION

## TRACEABILITY OF THE PRODUCT

KEMET assures the whole traceability of the product by marking each component with day, month, year and production line coded according to an international standard (IEC62).

| Year | Letter |
|------|--------|
| 1995 | F |
| 1996 | H |
| 1997 | J |
| 1998 | K |
| 1999 | L |
| 2000 | M |
| 2001 | N |
| 2002 | P |
| 2003 | R |
| 2004 | S |
| 2005 | T |
| 2006 | U |

| Month | Letter |
|-------|--------|
| January | 1 |
| February | 2 |
| March | 3 |
| April | 4 |
| May | 5 |
| June | 6 |
| July | 7 |
| August | 8 |
| September | 9 |
| October | O |
| November | N |
| December | D |

## PRODUCT MARKING



ARCOTRONICS

1.27.4AC3 MKP
5 μF ± 5%

C.27 Series AC3 execution
Capacitance 5 μF
Tolerance 5%

420V~  30000h/CLASS  A
470V~  10000h/CLASS  B

-25/85/21

P0

EN 60252

Minimum, maximum temperature, testing cycle

P0 Safety class

Self-healing features

Tracing of the production line
Day
Month
Year

K 4 0 1 AP

CE    5

## DOUBLE SAFETY DEVICE

KEMET has developed an intrinsic safety system. In case of fail, the increase of internal pressure causes a prolongation of the can. The disconnection of the cartridge occurs just next to two nuggets produced on the conductors for this purpose.
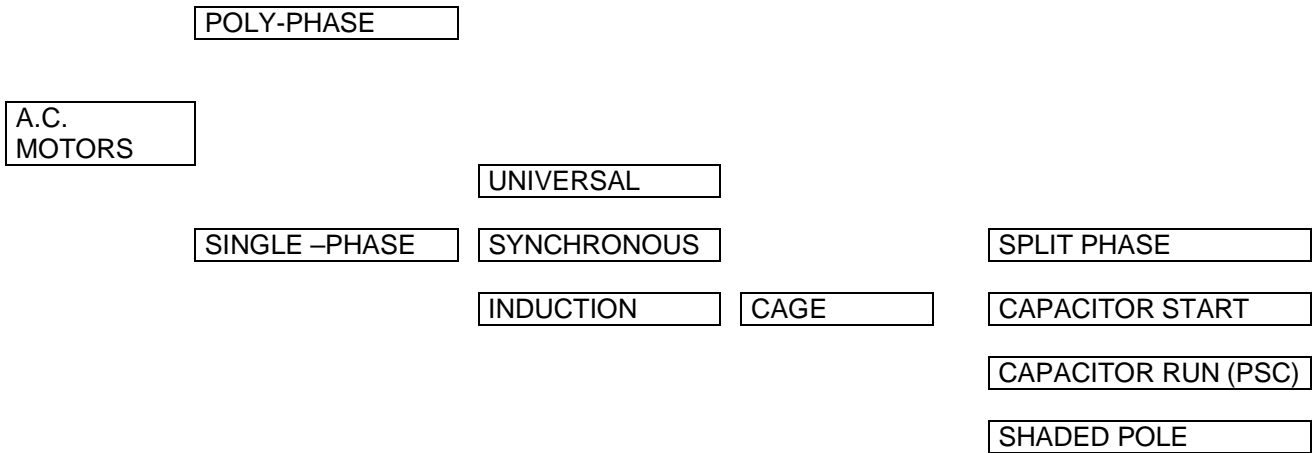


Internal safety device
(only for C.87 series)

In order to allow a correct working of the safety device and to assure a sufficient electric insulation, a room of almost 10 mm will have to be assured.

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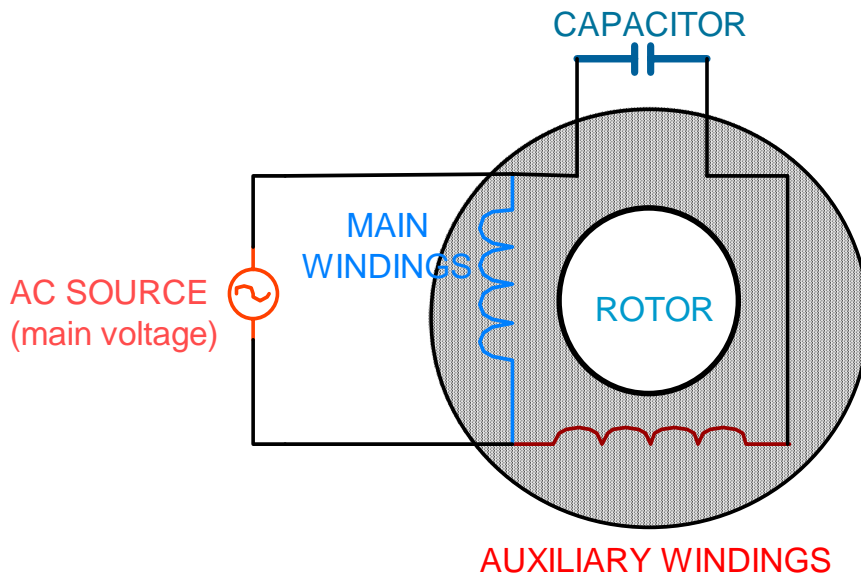CHARGED.

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# GENERAL INFORMATION

## HOW TO CHOOSE THE RIGHT CAPACITOR

A.C. single-phase motors can be broadly divided into three categories: synchronous, universal, & induction. The typical power is defined in Horse Power ( HP or CV ) or its multiples and submultiples.

```
POLY-PHASE

A.C.
MOTORS
                        UNIVERSAL

SINGLE –PHASE          SYNCHRONOUS                  SPLIT PHASE

                        INDUCTION      CAGE          CAPACITOR START

                                                     CAPACITOR RUN (PSC)

                                                     SHADED POLE
```

### TYPES OF SINGLE-PHASE MOTORS

**PERMANENT SPLIT CAPACITOR MOTOR (PSC).**

CAPACITOR
MAIN WINDINGS
ROTOR
AC SOURCE (main voltage)
AUXILIARY WINDINGS

### TYPICAL CHOICE PARAMETERS:

**TURNS RATIO n**: Although it is possible to choose this ratio on the basis of a large number of combinations, usually the main / auxiliary winding turns ratio is chosen in order to generate a voltage on the capacitor closest to its rated values.

**VOLTAGE ON CAPACITOR VC :** The following is a formula able to approximately calculate the voltage on the capacitor. If the voltage measured at both ends of the auxiliary winding is equal to n*Vp (where **Vp** is the voltage measured at both ends of the main winding and **n** is the turns ratio), the voltage at both ends of the capacitors can be estimated as follows

$$V_C = V_P \cdot \sqrt{1 + n^2}$$

**CRITERION FOR THE SELECTION OF THE RIGHT CAPACITOR**: A capacitor motor does not appear to be highly affected by the capacitance reactive power, therefore, it is not necessary to use an accurate capacitance value. It will be possible to choose a capacitance reactive power equalising the inductive-reactive power

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absorbed by a full loaded motor, generated by the main winding. Considering that the no-load power (Volt-ampere) is almost the same as the full load capacitance reactive-power, it will be possible to use the following simple expression: (where **Vc**: is the voltage at both ends of the capacitor; **V** is the line voltage and **Io**: the no-load main winding current):
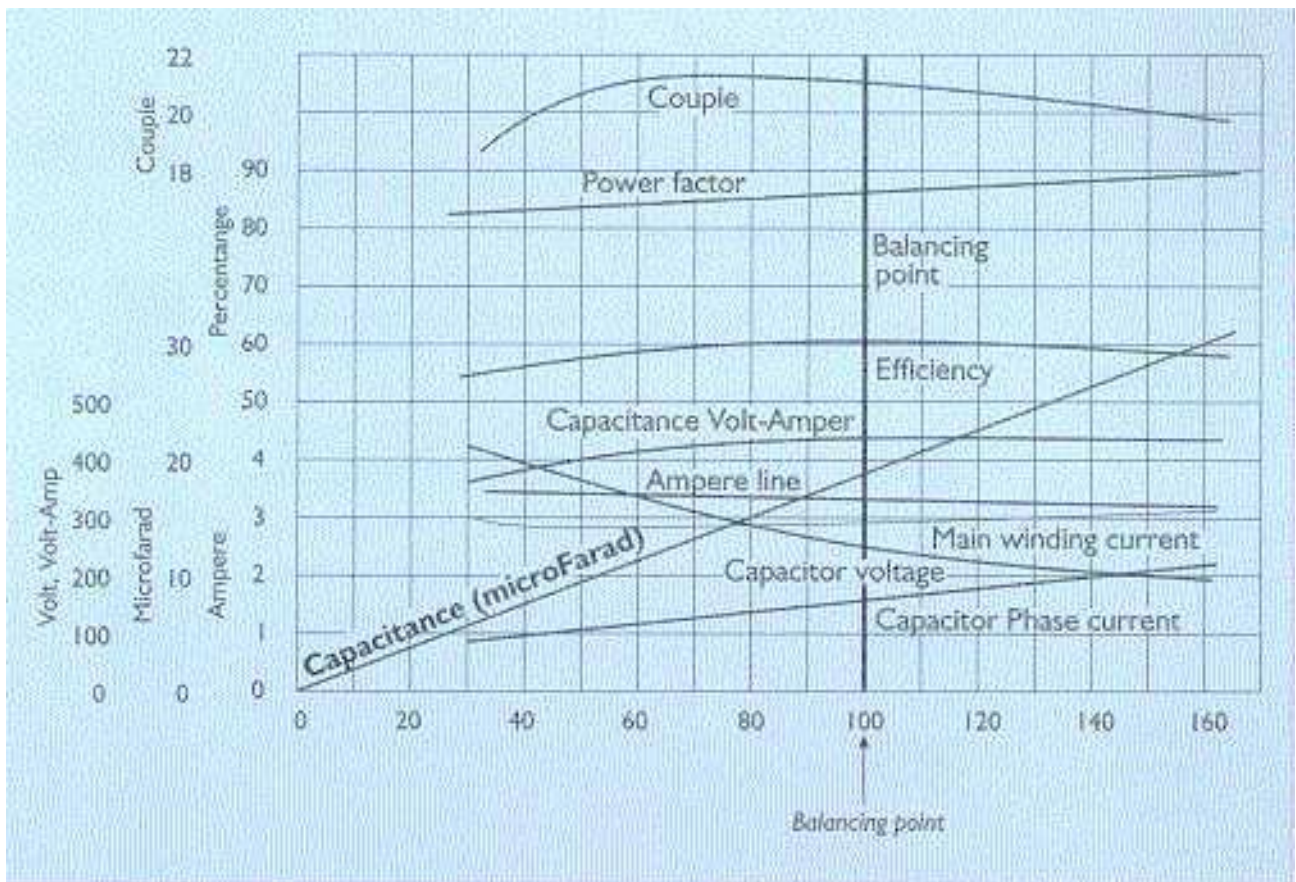
$$x_C = \frac{Vc^2}{V \cdot I_0}$$

With regard to the above, it is possible to establish the following relation:

$$x_C = \frac{V(1+n^2)}{I_0}$$

Where **V** represents the line voltage; **n** the turns ratio; **Io** the sub-circuit current. The capacitance is obtained by:

$$C = \frac{x_C}{2 \cdot \pi \cdot f}$$

When the auxiliary-winding current is equal to the amount of current absorbed by the main winding divided by the turns ratio **n,** the motor can be considered as balanced. As shown in the following graphic, capacitance variations with respect to the balance point do not cause substantial changes to the electric motor performances.

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**CAPACITANCE IN RELATION TO MOTOR POWER**: In order to achieve an approximate indication of the capacitance required by a PSC motor (Phase Single Capacitor – Single-phase asynchronous motor) please consider the following table for motors with rated voltage 220Vac, 50hz.

| 3000 cycles per minute-50hz-2 poles | | | 1500 cycles per minute-50hz-4 poles | | | 1000 cycles per minute-50hz-6 poles | | |
|------|------|------|------|------|------|------|------|------|
| CV | Cycles/Min Load | Cap | CV | Cycles/Min Load | Cap | CV | Cycles/Min Load | Cap |
| 0.10 | 2740 | 6.3 | 0.10 | 1340 | 6.3 | | | |
| 0.25 | 2780 | 10 | 0.25 | 1360 | 12.5 | 0.25 | 880 | 10 |
| 0.50 | 2780 | 16 | 0.50 | 1380 | 16 | 0.50 | 900 | 20 |
| 0.75 | 2800 | 20 | 0.75 | 1380 | 20 | 0.75 | 910 | 25 |
| 1 | 2840 | 25 | 1 | 1420 | 25 | 1 | 920 | 25 |
| 1.5 | 2840 | 32 | 1.5 | 1440 | 32 | 1.5 | 920 | 36 |
| 2 | 2840 | 40 | 2 | 1440 | 40 | 2 | 920 | 50 |
| 3 | 2820 | 60 | 3 | 1400 | 60 | | | |

**STEIMETZ CONNECTION**. By connecting a capacitor to the two phases it is possible to make a three-phase motor work as a single-phase motor. Consider the following table:

| HP | KW | FULL LOAD |
|------|------|-----------|
| | | |
| 0.25 | 0.18 | 12.5 µF |
| 0.5 | 0.37 | 25 µF |
| 0.75 | 0.55 | 37 µF |
| 1 | 0.75 | 50 µF |
| 1.5 | 1.1 | 75 µF |
| 2 | 1.5 | 100 µF |

**SELECTION OF THE MOST SUITABLE KEMET CAPACITOR:**

| EQUIPPED WITH A SAFETY DEVICE | C.87/8 | Refrigerator compressors, Air-conditioning compressors, Dishwashers | |
|---|---|---|---|
| | C.87/0 | Refrigerator compressors, Air-conditioning compressors, Dishwashers | EXPECTED LIFE |

| NO ADDED | C.27/4 | Pumps, Circulators, Compressors, Washing machines | |
|---|---|---|---|
| SAFETY | C.27/6 | Pumps, Circulators, Compressors, Washing machines | EXPECTED LIFE |
| DEVICE | C.27/7 | Battery chargers, Start-motors, Gate openers, Rolling shutters | |

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