[Attached Data]

1. Technical Data No. 002　Service Life of Capacitors
2. Technical Data No. 039　Self-healing (Clearing)

[References]

Isamu Onoda: “Manual for Best use of Capacitors” issued in 1975 by Publishing Department, Tokyo Electrical Engineering College

Masuda, et., al.: “How to Choose and Use Devices/Parts” issued in 1993 by Nikkagiren Publishing Company

“ Electronic Device Data Book 85: Circuit Parts” issued in 1985 by NEC

“ EIAJ RCR-2350B: Guidelines for Precautions on Use of Plastic Film Capacitors to Be Fixed to Electronic Devices and Equipment” published in 2002 by Electronic Industries Association of Japan

[Other Books for Reference]

The books issued by CQ Publishing Company, etc. as enumerated below:

- “Characteristics and Actual Performance of Electronic Parts to Be Learnt from Waveforms”
- “Handbook for Best Use of Electronic Circuit Parts”
- “Proper Use of Resistors & Capacitors Suited for Purposes” Attached Data (1)
- “Good Grounding in Best Use of Electronic Parts for Beginners”
- ”Perfect Pictorial Book of the Electronic Circuit Parts for Beginners”
- “Know-hows to Choose and Make Best Use of Passive Parts”

Appendix 1

Service life of capacitors

1. Applied voltage and service life

For the relation between the applied voltage and service life of film capacitors, the Formula 1-1 is taken up as a standard for the time being because it is generally easy and simple to handle and no other suitable relation formulas are available, though there is a slight shadow of doubt whether it may be totally accepted, judging from the fact that it is based on flimsy theoretical grounds.

$$L = Lo \times (Vo/V)^n \quad \cdots\cdots\cdots \quad 1\text{-}1$$

L	:	Service life when operating voltage V, VDC is applied	(Hr)
Lo	:	Service life when operating voltage Vo, VDC is applied	(Hr)
Vo	:	Rated voltage of capacitor	(VDC)
V	:	Actual operating voltage of capacitor	(VDC)
n	:	Constant	(4~7)

2. Operating ambient temperature and service life

The temperature-dependence of film capacitor's service life follows the Arrhenius Law, so-called the 10℃ Law. Namely, if the temperature rises by 10℃, the service life will be reduced down to 1/2. Therefore, the relation between the ambient temperature and service life is given by the Formula 2-1.

$$L = Lo \times 2^{\frac{Tmax - Ta}{10}} \quad \cdots\cdots\cdots\cdots \quad 2\text{-}1$$

L	:	Service life at actual use	(Hr)
Lo	:	Service life at maximum operating temperature	(Hr)
Tmax	:	Maximum operating temperature	(℃)
Ta	:	Ambient temperature	(℃)

3. Derating of the rated voltage depending on the operating temperature

If a capacitor is used at high temperatures, its service life will be shortened due to thermal deterioration. In case when a capacitor is to be used at high temperatures, derate the operating voltage in accordance with the graphs as given below.

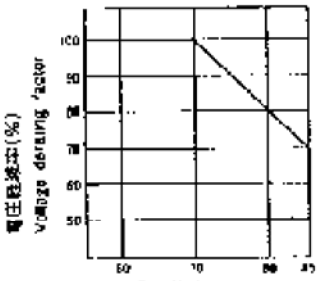


Fig 1
適用品種/Application
P2S

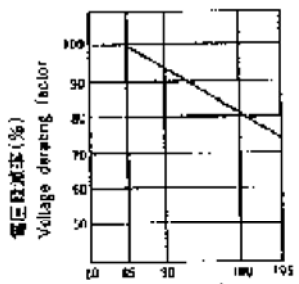


Fig 2
適用品種/Application
F2S(50V)
MMW,MMW-EF,MMC,MMT

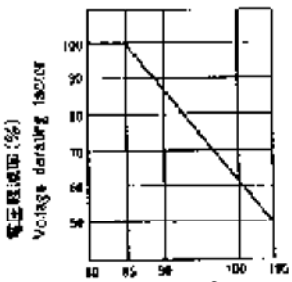


Fig 3
適用品種/Application
F2D, F2S(100V,200V)

4. Ripple current and service life

In case when ripple current is applied on a capacitor, Joule heat will be generated. The capacitor temperature rise on this occasion is given by the Formula 4-1.

$$\triangle T = \frac{1}{\beta \cdot S} \times \frac{I^2 \text{ rms} \cdot \tan \delta}{\omega C} \quad 4\text{-}1$$

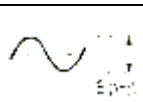
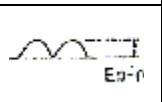
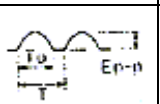
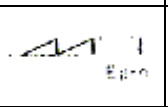
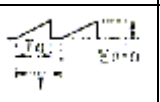
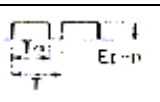
△T	:	Surface temperature rise of capacitor	(℃)
B	:	Radiation coefficient	(W/℃・c ㎡)
S	:	Surface area of capacitor	(c ㎡)
C	:	Electrostatic capacity of capacitor	(μF)

Since significant self-heating of capacitor may lead to the deterioration and/or damage to the capacitor, self temperature rise of capacitor should be limited to lower than 10℃ for polyester film capacitors and to lower than 5℃ for polypropylene film capacitors.
In case of use at high temperature/high frequency, the voltage derating factor is different from that of DC voltage. This is partly because heating by ripple current is severer in conditions than the Arrhenius 10℃ Law and partly because in the polyester film capacitors, etc., tan δ may change with the temperature, thus leading to the change in self temperature rise accordingly.

5. Allowable voltage in various voltage waveforms

The allowable voltage of various voltage waveforms varies with the kinds of waveforms and the frequency. The allowable voltage in various voltage waveforms shall be the value obtained by multiplying the sine wave allowable voltage at each frequency by any of the coefficients as given below. Moreover, in case of the voltage containing the DC bias component, the AC voltage obtained by subtracting the bias voltage from the DC rated voltage shall be the allowable value. Then, this voltage should be derated for use depending on the respective frequencies and waveforms.

(In case when the voltage values on the voltage derating curves for various kinds of products in Technical Data No. 002 are given by effective values, the value obtained by increasing the allowable voltage value by $2\sqrt{2}$ shall be the Ep-p value. Then, the value obtained by multiplying it by any of the coefficients as given below shall be the allowable voltage value Ep-p at the frequency of the relevant waveform.)

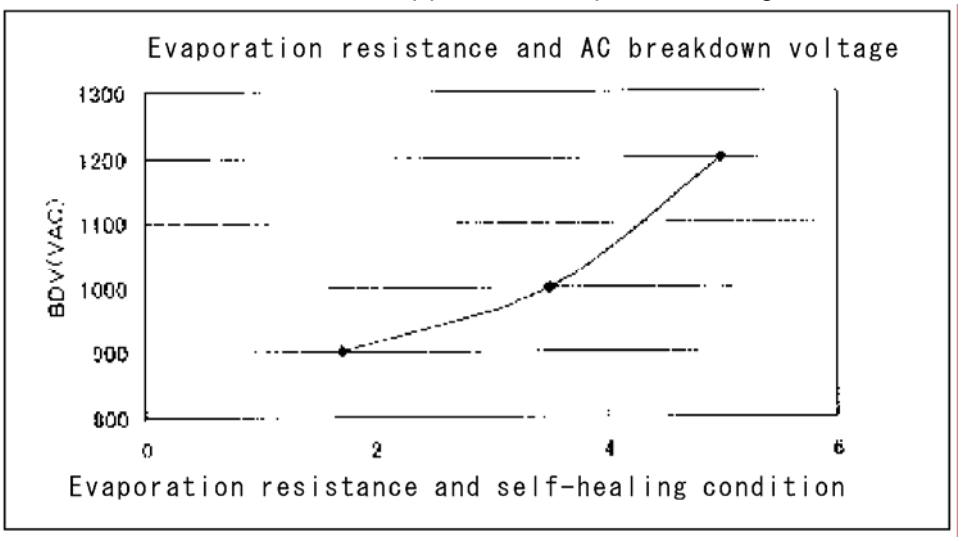
Kind	1	2	3	4	5	6	7
Waveform							その他 Others
Coefficient	1.0	0.5	$0.5\sqrt{T/To}$	0.61	$0.5\sqrt{3T/2To}$	$0.5\sqrt{T/2To}$	0.5

Appendix 2

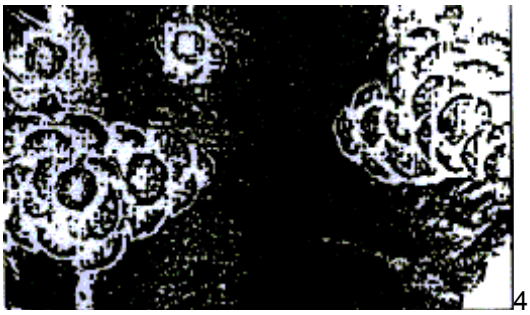
Self-healing (Clearing)

Since an electrode is evaporated as a very thin metal film (about 150 to 400Å) on the dielectric, even if dielectric breakdown is caused on the weakest portion in the dielectric, only the weakest portion and its peripheral portion will be dispersed instantaneously by energy of 1/2CE2 or I2R and the functions as a capacitor will not be still lost. This phenomenon is called the self-healing.

The higher the evaporation resistance is and the thinner the evaporated film is, the better the self-healing property is. However, this may lead to the poor connection with metallicon and increase in ESR in the high frequency zone. Therefore, full investigations should be made on the applications upon its design.



Vacuum evaporation resistance and Self-healing state (AL)

2Ω 

4Ω 

6Ω