

# Application Guidelines

## Application Guidelines for GE Aluminum Electrolytic Capacitors

### Sensitivity to Frequency and Temperature:

Ripple current ratings are specified at an ambient temperature of 85° C in circulating air, using the 25° C values of E.S.R.

The maximum allowable ripple current may be adjusted for frequencies other than 120 Hz and temperatures other than 85° C using the tables below.

### RIPPLE CURRENT FREQUENCY MULTIPLIERS

SERIES	100 Hz	120 Hz	400 Hz	4 KHz	10 KHz	20 KHz
23A	0.95	1.0	1.15	1.20	1.35	1.40
23B	0.97	1.0	1.10	1.15	1.25	1.25
23C	0.95	1.0	1.15	1.20	1.35	1.40
23D	0.92	1.0	1.04	1.08	1.25	1.25
23F	0.95	1.0	1.04	1.06	1.10	1.15
23H	0.95	1.0	1.10	1.15	1.25	1.25
23J	0.95	1.0	1.10	1.12	1.15	1.18
23M	0.97	1.0	1.10	1.15	1.25	1.25

Table-AP1

### RIPPLE CURRENT TEMPERATURE MULTIPLIERS

SERIES	105° C	95° C	85° C	75° C	65° C	55° C	45° C	35° C
23A	--	--	1.0	1.4	1.7	2.0	2.3	2.5
23B	--	--	1.0	1.4	1.7	2.0	2.3	2.5
23C	--	1.0	1.4	1.7	2.0	2.3	2.5	2.7
23D	--	--	1.0	1.4	1.7	2.0	2.3	2.5
23F	0.0	0.7	1.0	1.2	1.4	1.6	1.7	1.9
23H	--	--	1.0	1.4	2.0	2.3	2.5	2.7
23J	--	--	1.0	1.4	2.0	2.3	2.5	2.7
23M	0.0	0.7	1.0	1.2	1.4	1.6	1.7	1.9

Table-AP2

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## RIPPLE CURRENT AIR-FLOW MULTIPLIERS

		AIR FLOW (Linear Feet/Minute)						
LFM		0	50	100	150	200	250	300
All Series		1.0	1.15	1.25	1.40	1.50	1.60	1.70

NOTE: Air-Flow Multiplier is in addition to other applied multipliers.

Table-AP3

## AIR-FLOW MULTIPLIERS

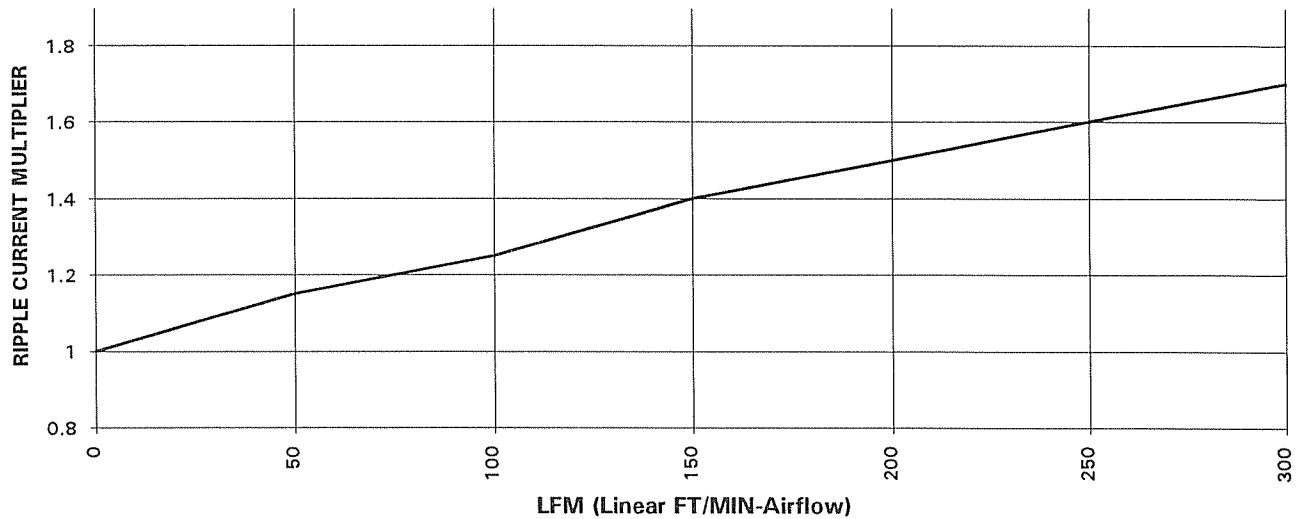


Chart-APC1

## APPLIED VOLTAGE

The combined Peak AC Voltage and DC Voltage shall not exceed the DC Voltage Rating of the capacitor, or the reverse DC Voltage Rating of the capacitor.

## REVERSE VOLTAGE

Unless otherwise specified, the maximum permissible reverse voltage rating for all GE Aluminum Electrolytic capacitors is 1.5 volts.

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## RMS CURRENT LIMITS FOR TERMINAL TYPES \*

Terminal Type	Case Diameter				
	1.375	1.750	2.000	2.500	3.000
P	25	25	25	N/A	N/A
L	30	30	30	30	30
H	30	30	30	40	40
D	N/A	N/A	N/A	50	50
N	N/A	N/A	N/A	50	50
M	30	30	30	40	40
K	N/A	N/A	N/A	50	50

Table-AP4

\* **NOTE:** The maximum values shown in the above table are expressed in Amps RMS, and based on the minimum specified torque in Table AP4A, and assuming a minimum of 4 threads are fully engaged.

## SHELF LIFE

Aluminum Electrolytic capacitors which have been stored for extended periods or in elevated temperatures undergo dielectric deterioration causing DC Leakage currents to increase beyond allowable levels. Sustained elevated Leakage currents cause decreased service life due to higher device operating temperatures. Use of capacitors exhibiting excessive leakage currents may cause premature activation of the pressure sensitive safety vent, or total dielectric failure.

The normal shelf life expectancy for these capacitors is described by **Charts APC2 & APC3** on page 72. Units suspected of exceeding the "Maximum Shelf Life" line in this chart, should be discarded and replaced. It is recommended that units be reformed only once, using the procedure described in **GE Bulletin CP-B-117** to reduce the DC Leakage current to specification levels.

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## SHELF LIFE (CONT'D)

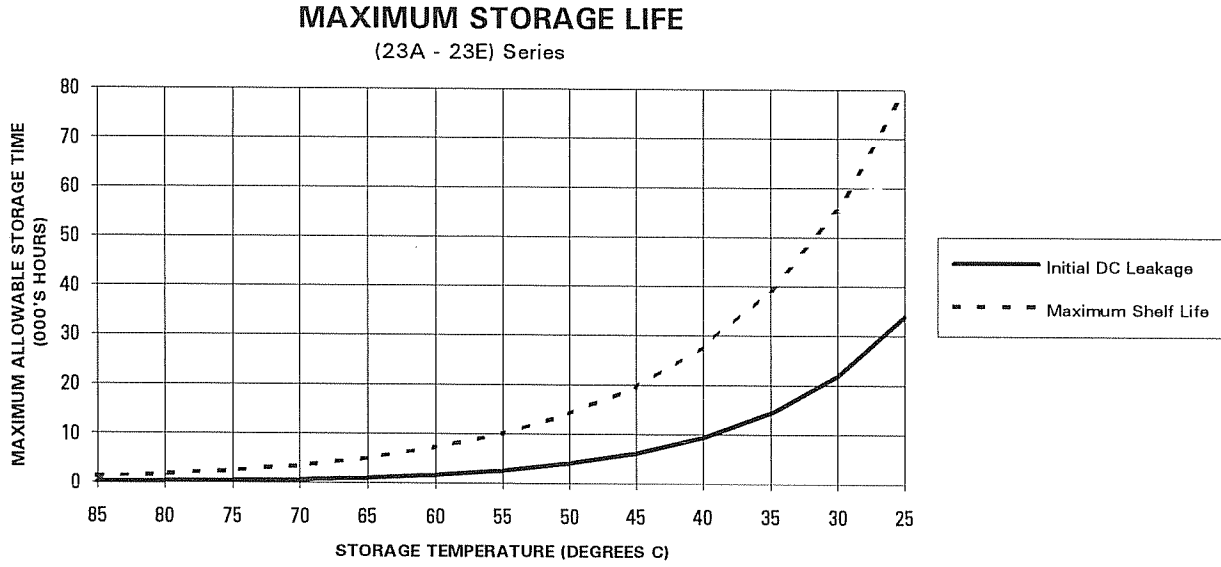


Chart-APC2

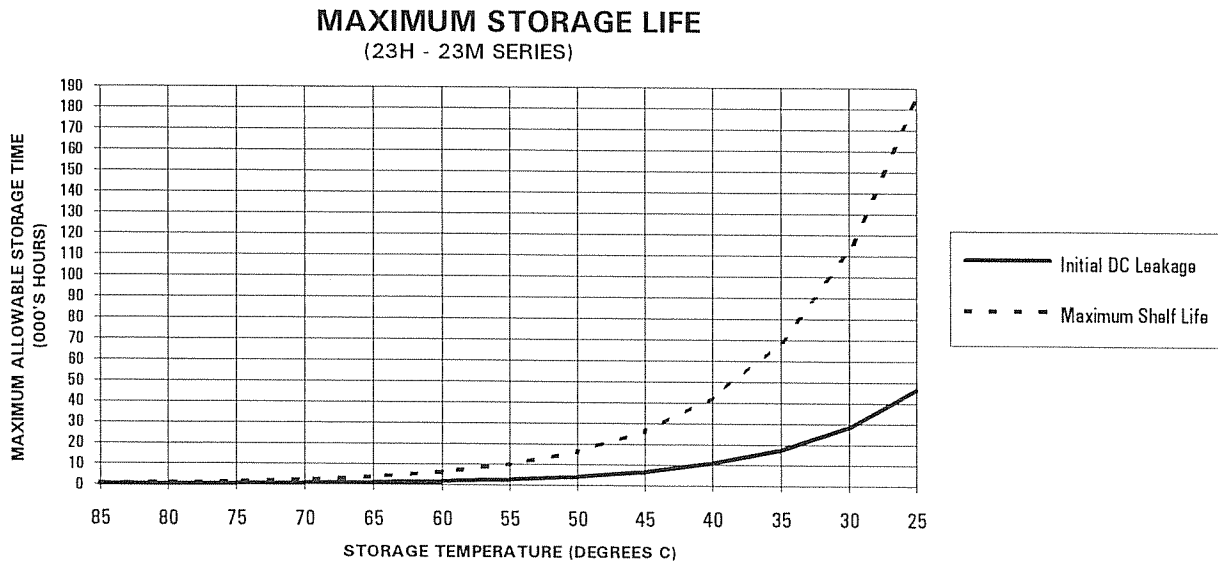


Chart-APC3

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## OPERATING LIFE

Operating life of capacitors is determined by operating temperature and applied voltage. Operating life can be extended by derating applied voltage, operating temperature, or applied RMS ripple current. Refer to the equations below for estimating capacitor life:

## EXPECTED CAPACITOR OPERATING LIFE

$$L_e = L_b \times L_v \times L_t$$

To calculate the predicted life expectancy at 100% DUTY CYCLE for a given GE Electrolytic capacitor, the following specification information and operating parameters must first be determined.

**Le: Expected Capacitor Life**

**Lb:** This is the base life for the capacitor being used, as shown in **Table-AP5 (BASE LIFE BY SERIES)** on page 76 of this catalog.

**Lv:** Represents the extension of life of the capacitor due to voltage derating; determined by the following calculation:

$$L_v = 2^{\left[ \frac{V_r - V_a \times 6.66}{V_r} \right]}$$

**Va:** Represents the applied DC working voltage (worst case) the capacitor will see during operation.

**Vr:** Represents the maximum rated DC working voltage (WVDC) of the capacitor selected; this value is shown on the capacitor specification sheet or listed by part number in catalog **CPD-517**.

**Lt:** Represents the extension of life of the capacitor due to the derating of the core temperature; determined by the following calculation:

$$L_t = 2^{\left[ \frac{(T_m - T_c)}{10} \right]}$$

**Tm:** Represents the maximum allowable core temperature, for the series, as shown in **Table-AP5**.

**Tc:** Is the operating core temperature determined by the following calculation:

$$T_c = T_a + \frac{(I)^2 (ESR) + (V_a) (Idc)}{(AREA) (Kt)}$$

**Ta:** Represents the highest ambient temperature in the immediate vicinity of the capacitor. (in Degrees C)

**I:** Represents the **applied** RMS ripple current.

**ESR:** Represents the equivalent series resistance of the capacitor as shown on the specification sheet, or listed for the capacitor in catalog **CPD-517**.

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## OPERATING LIFE (Cont'd)

**Idcl:** Represents the rated DC leakage current. This value is found on the individual specification sheet for the capacitor intended for this application, or determined from the following calculation:

$$Idcl = (\chi) \sqrt{C \times V} \quad \text{Where } C = \text{capacitance in } \mu\text{F}; V = \text{Rated working voltage (WVDC) of the capacitor, and } (\chi) = \text{the value found in Table-AP8 on page 76.}$$

**AREA:** Represents the area of the aluminum case of the capacitor as shown in **Table-AP6 (SURFACE AREA OF ALUMINUM CASE)** on page 77.

**Kt:** Represents the thermal conductivity of the selected capacitor. This is found by using the case code of the capacitor part number, and selecting the appropriate **Kt value** shown in **Table-AP7 (THERMAL CONDUCTANCE)** on page 77.

**EXAMPLE:** GE part number- 23J252F400FH1H1

THE FOLLOWING ARE SAMPLE APPLICATION PARAMETERS TO BE USED IN THE EXAMPLE FOR LIFE EXPECTANCY CALCULATION.

- 1) **C** = 2500  $\mu\text{F}$  (Microfarads of example part)
- 2) **Vr** = 400 WVDC (Rated Voltage)
- 3) **Va** = 325 VDC (The applied voltage for application)
- 4) **ESR** = .026 Ohms (Rated E.S.R. of the capacitor as shown in the catalog or specification sheet)
- 5) **Ta** = 65° C (Ambient temperature in application)
- 6) **I** = 9.2 Amps RMS @ 120 Hz. (Applied RMS ripple current)

$$Le = Lb \times Lv \times Lt$$

7) **Lb** = 2000 (Base life from **Table-AP5** on page 76.)

$$8) \quad Lv = 2^{\left[ \frac{400-325 \times 6.66}{400} \right]} = 2.38$$

$$9) \quad Idcl = (\chi) \sqrt{C \times V} = (.75) \sqrt{2500 \times 400} = (.75) 1000 = 750 \mu\text{A}$$

For purposes of calculating **Tc**, **Idcl** should be expressed in **AMPS**.

$$10) \quad Tc = Ta + \frac{(I)^2 (ESR) + (Va) (Idcl)}{(AREA) (Kt)} = 65 + \frac{(9.2)^2 (.026) + (325) (.00075)}{(55.37) (.0044)} = 75.05$$

$$11) \quad Lt = 2^{\left[ \frac{105-75.05}{10} \right]} = 8$$

$$12) \quad Le = Lb \times Lv \times Lt$$

$$13) \quad Le = 2000 \times 2.38 \times 8 = 38,080 \text{ Hrs. (At 100 \% Duty Cycle)}$$

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## OPERATING LIFE (Cont'd)

In the foregoing example for estimating capacitor life, all calculations were made based on 120 Hz. operation and convective air-flow condition. For additional considerations at other than 120 Hz. and where airflow is available, see the additional calculations below.

**EXAMPLE:** Use the following to determine Life Expectancy, when the capacitor is exposed to 150 LFM (linear feet per minute) air flow and operating at 400 Hz.

1) Where **T<sub>c</sub>** = **Core temperature** and is used to determine derating or extension of life; the following should be used to determine life extension where above adjustments are to be considered.

$$T_c = T_a + \frac{(I)^2 \left( ESR \times \sqrt{\frac{1}{\text{Ripple current mult.}}} \right) + (V_a) (I_{dcl})}{(AREA) (K_t \times \sqrt{\text{Airflow mult.}})}$$

The Ripple current multiplier = 1.10 (found in Table-AP1 on page 69)

The Airflow multiplier = 1.40 (found in Table-AP3 on page 70)

$$\text{Therefore: } T_c = 65 + \frac{(9.2)^2 (.026 \times \sqrt{\frac{1}{1.10}}) + (325) (.00075)}{(55.37) (.0044 \times \sqrt{1.40})} = 73.12$$

Recalculating expected life under the additional operating conditions results in the following:

$$L_e = 2000 \times 2.38 \times L_t$$

$$L_t = 2^{\left[ \frac{105-73.12}{10} \right]} = 9$$

$$L_e = 2000 \times 2.38 \times 9 = 42,840 \text{ Hrs. (Operated at 400 Hz. and forced air at 150 LFM)} \\ \text{(At 100\% Duty Cycle)}$$

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## TERMINAL TORQUE

(Expressed in Inch Pounds)

(Minimum of 4 threads engaged)

TERMINAL STYLE	CLASS 2B		CLASS 2C	
	Min.	Max.	Min.	Max.
L	14	20	8	10
H	20	30	10	15
D	32	50	16	25
N	32	50	20	30
M5	20	30	10	15
M6	32	50	16	25

Table-AP4A

## BASE LIFE by SERIES

SERIES TYPE	RATED AMBIENT TEMP(C)	MAX CORE TEMP	BASE LIFE (HOURS)
23A	85	95	1000
23B	85	105	3000
23C	85	100	2000
23D	85	95	1000
23F	85	105	3000
23H	85	95	2000
23H (500 V)	65	75	1000
23J	105	105	2000
23M	85	95	2000

Table-AP5

## Idcl value of $\chi$

SERIES TYPE	Value of $\chi$
23A	3.00
23B	1.50
23C	3.00
23D	1.50
23F	1.50
23H	1.00
23J	0.75
23M	2.00

Table-AP8



# Application Guidelines for GE Aluminum Electrolytic Capacitors

**SURFACE AREA of ALUMINUM CASE**  
(Square Inches)

CASE CODE	DIA.	LNG.	AREA
BB	1.375	2.125	10.66
BC	1.375	2.625	12.82
BD	1.375	3.125	14.98
BE	1.375	3.625	17.14
BF	1.375	4.125	19.30
BG	1.375	4.625	21.45
BH	1.375	5.125	23.62
BI	1.375	5.625	25.78
CB	1.750	2.125	14.09
CC	1.750	2.625	16.84
CD	1.750	3.125	19.59
CE	1.750	3.625	22.33
CF	1.750	4.125	25.08
CG	1.750	4.625	27.83
CH	1.750	5.125	30.58
CI	1.750	5.625	33.33
DB	2.000	2.125	16.49
DC	2.000	2.625	19.63
DD	2.000	3.125	22.78
DE	2.000	3.625	25.92
DF	2.000	4.125	29.06
DG	2.000	4.625	32.20
DH	2.000	5.125	35.34
DI	2.000	5.625	38.48
DJ	2.000	5.875	40.05
DL	2.000	8.625	57.33
EC	2.500	2.625	25.52
ED	2.500	3.125	29.45
EE	2.500	3.625	33.38
EF	2.500	4.125	37.31
EG	2.500	4.625	41.23
EH	2.500	5.125	45.16
EI	2.500	5.625	49.09
FD	3.000	3.125	36.52
FE	3.000	3.625	41.23
FF	3.000	4.125	45.95
FG	3.000	4.625	50.66
FH	3.000	5.125	55.37
FI	3.000	5.625	60.08
FJ	3.000	5.875	62.44
FK	3.000	7.625	78.93
FL	3.000	8.625	88.36
FM	3.000	6.625	69.51

Table-AP6

**THERMAL CONDUCTANCE**  
(Watts per square Inch Degrees C)

CASE CODE	DIA.	LNG.	Kt
BB	1.375	2.125	0.0130
BC	1.375	2.625	0.0101
BD	1.375	3.125	0.0083
BE	1.375	3.625	0.0071
BF	1.375	4.125	0.0062
BG	1.375	4.625	0.0054
BH	1.375	5.125	0.0049
BI	1.375	5.625	0.0044
CB	1.750	2.125	0.0139
CC	1.750	2.625	0.0102
CD	1.750	3.125	0.0081
CE	1.750	3.625	0.0068
CF	1.750	4.125	0.0058
CG	1.750	4.625	0.0051
CH	1.750	5.125	0.0045
CI	1.750	5.625	0.0041
DB	2.000	2.125	0.0140
DC	2.000	2.625	0.0107
DD	2.000	3.125	0.0083
DE	2.000	3.625	0.0068
DF	2.000	4.125	0.0057
DG	2.000	4.625	0.0050
DH	2.000	5.125	0.0044
DI	2.000	5.625	0.0040
DJ	2.000	5.875	0.0038
DL	2.000	8.625	0.0033
EC	2.500	2.625	0.0102
ED	2.500	3.125	0.0082
EE	2.500	3.625	0.0071
EF	2.500	4.125	0.0058
EG	2.500	4.625	0.0049
EH	2.500	5.125	0.0043
EI	2.500	5.625	0.0038
FD	3.000	3.125	0.0081
FE	3.000	3.625	0.0070
FF	3.000	4.125	0.0064
FG	3.000	4.625	0.0052
FH	3.000	5.125	0.0044
FI	3.000	5.625	0.0038
FJ	3.000	5.875	0.0035
FK	3.000	7.625	0.0026
FL	3.000	8.625	0.0022
FM	3.000	6.625	0.0030

Table-AP7

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## REPETITIVE DISCHARGE APPLICATIONS

Applications wherein the capacitor may experience repetitive discharges into inductive loads, should be protected using a free wheeling diode, or a blocking diode to prevent the capacitor from being exposed to excessive reverse voltage.

## HIGH ALTITUDE APPLICATIONS

GE Electrolytic capacitors may be stored or operated at altitudes up to 100,000 feet with no adverse effects.

## CAPACITOR MOUNTING APPLICATIONS

GE utilizes a pitchless construction for all case sizes. This allows capacitors to be mounted in any orientation; however, GE recommends that all electrolytic capacitors be mounted with the terminals in a vertical position. This provides best possible protection against loss of electrolyte in the event of vent activation. (SEE ELECTROLYTE FLUIDS)

As with all Electrolytic capacitor "Electrolyte Fluids", precaution should be taken and appropriate action should be taken in the event of spill or exposure, as described in GE Material Safety Data Sheets.

## ELECTROLYTE FLUIDS

GE will upon request, provide Material Safety Data Sheets for the various fluids used in manufacture of any GE Electrolytic capacitor. The GE part number must be advised so we may supply the correct Data Sheet.

## USE OF CLEANING SOLVENTS or ELECTRICAL JOINT COMPOUNDS

GE recommends using only those cleaning solvents and electrical compounds which are free of halogens, or halogen groups. Further, GE recommends not using any petroleum or petroleum distillate products.

## VIBRATION SPECIFICATIONS

GE Electrolytic capacitors are capable of withstanding 10 G's of sinusoidal vibration with a frequency range of 10 to 500 Hz., provided mounting is accomplished using an approved clamp around the capacitor case.

(Reference MIL Std 202(F); Method 204D; Test condition A) Products are designed and produced commercially with the capability of meeting the vibration conditions referenced.

# Application Guidelines for GE Aluminum Electrolytic Capacitors

## USE OF CAPACITORS IN SERIES

### DC Voltage Sharing

Capacitors can safely be used in series pairs to allow application at higher DC bus voltages, provided proper voltage sharing within the series group is maintained using balancing resistors. This will provide proper voltage sharing over the course of the useful life of the capacitor, if the resistors are sized such that the current through the resistor is roughly a factor of 10 greater than the initial specified DC Leakage current of the capacitor.

### Transient Voltage Sharing

Voltage sharing of series-connected capacitors under transient voltage conditions can be accomplished by matching the capacitance values of the series connected units. The degree of matching required is determined by the degree of derating on the unit. The greater the derating allowed, the less critical exact voltage sharing becomes. Generally, a 10 percent symmetrical tolerance is sufficient for most applications.

### Fusing of Series Capacitors

Fusing of individual series groups is recommended to minimize the risk of catastrophic failure in the event of a device fault. It is recommended that a common midpoint connection NOT be used due to the risk of cascaded failures.

## SAFETY

ELECTROLYTIC CAPACITORS HAVE A HIGH WATT-SECOND CAPABILITY. IT IS IMPORTANT THAT SUITABLE PRECAUTIONS BE OBSERVED IN THE TESTING AND APPLICATION OF THESE CAPACITORS. BLEEDER RESISTORS AND OTHER DISCHARGE CIRCUITRY SHOULD BE USED FOR PROTECTION AGAINST ELECTRICAL SHOCK. MECHANICAL STRUCTURES MUST BE DESIGNED TO WITHSTAND CATASTROPHIC FAILURE DUE TO THE LARGE FAULT CURRENTS WHICH MAY OCCUR IN THE EVENT OF A CAPACITOR SHORT CIRCUIT. THE MECHANICAL STRUCTURE SHOULD BE CONSTRUCTED SUCH THAT IT WILL BE CAPABLE OF CONTAINING THE CAPACITOR(S) IF A CAPACITOR EXPLOSION SHOULD OCCUR. EXTREME CAUTION SHOULD BE TAKEN AT ALL TIMES WHEN WORKING WITH ENERGIZED SYTEMS. **UNDER NO CIRCUMSTANCES SHOULD ANY ENERGIZED EQUIPMENT BE RENDERED UNSECURE AS TO CAUSE PERSONAL INJURY OR PROPERTY DAMAGE IN THE EVENT OF A CAPACITOR EXPLOSION.**

# Capacitor Application Data Sheet

To ensure correct selection of a capacitor for your application, please provide the information indicated below. This sheet may be duplicated or additional copies may be obtained from GE. Of particular importance are the voltage and current waveforms complete with values of voltage and current over a complete cycle.

Send this data to your local GE Sales Representative or directly to:  
**General Electric Company**  
**Capacitor & Power Protection**  
**381 Broadway**  
**Fort Edward, NY 12828-1000, U.S.A.**  
**Attn: Component Capacitor Sales**  
**FAX (518) 746-5447**

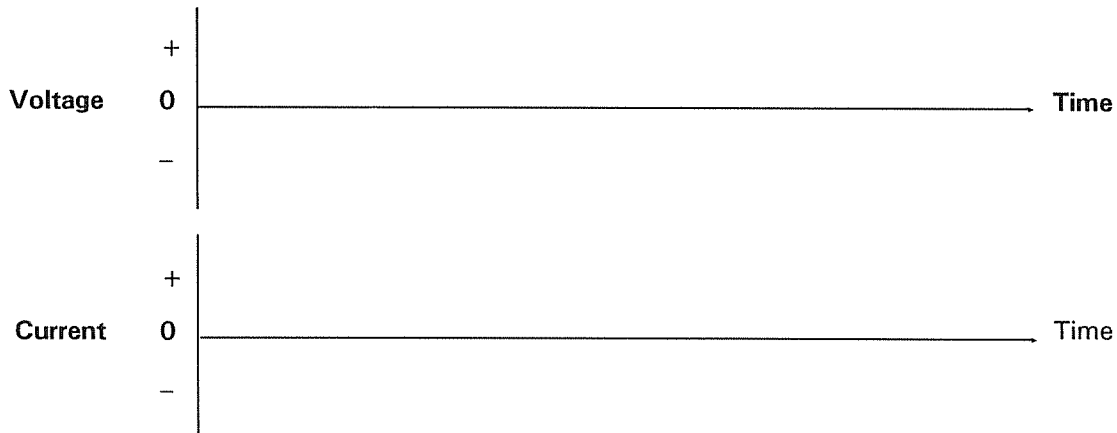
**CUSTOMER NAME:** \_\_\_\_\_ **Engineering Contact:** \_\_\_\_\_

**PRIMARY INFORMATION: (Essential)**

**Phone:** \_\_\_\_\_

1. **Application :** \_\_\_\_\_
2. **Capacitance:** \_\_\_\_\_ **Tolerance:** \_\_\_\_\_
3. **Peak Voltage:** \_\_\_\_\_ **RMS Voltage:** \_\_\_\_\_
4. **Peak Current:** \_\_\_\_\_ **RMS Current:** \_\_\_\_\_
5. **Transient Voltage:** \_\_\_\_\_ **Duration:** \_\_\_\_\_ **Freq. of Occurrence:** \_\_\_\_\_
6. **Frequency or Repetition Rate (Hz):** \_\_\_\_\_ **Duty Cycle:** \_\_\_\_\_
7. **Ambient Temperature:** \_\_\_\_\_ **Max.:** \_\_\_\_\_ **Min.:** \_\_\_\_\_
8. **Capacitor Charge Time:** \_\_\_\_\_ **Discharge Time:** \_\_\_\_\_
9. **Required Operating Life (Hours):** \_\_\_\_\_

10. **Waveforms:**



**SECONDARY INFORMATION (Provide as Appropriate)**

11. **Physical Size Limitations:** \_\_\_\_\_
12. **Mounting Requirements:** \_\_\_\_\_
13. **Applicable Specifications:** \_\_\_\_\_
14. **Air Flow Velocity:** \_\_\_\_\_
15. **Unusual Atmospheric Conditions:** \_\_\_\_\_
16. **Other Special Requirements:** \_\_\_\_\_
17. **Number of Samples Required:** \_\_\_\_\_
18. **Type of Thermal Couple (J < K < T) :** \_\_\_\_\_
19. **Annual Potential Usage:** \_\_\_\_\_