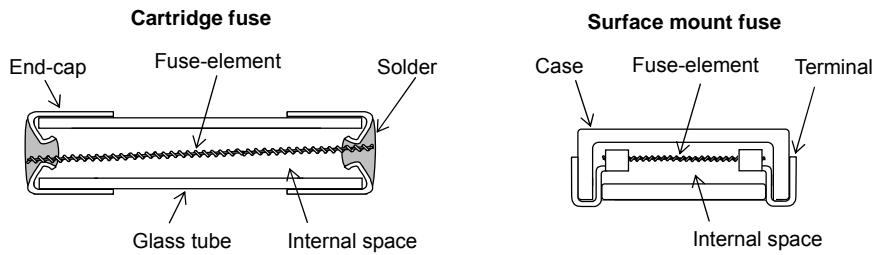


# Fuse selection process

## Keywords

### Before selecting fuses

By the use of simple principles and construction as shown in Figure 1, SOC fuses can accurately prevent such accidents as smoking and ignition in electronic circuits.



【Figure 1】 Examples of the basic construction of SOC fuses

Mistakes in fuse selection for protection requirements can cause nuisance operations or bursting of the fuse, which may result in serious injury or property damage.

### Safety precautions when selecting fuses

#### ■ What is the voltage of the circuit where the fuse is to be inserted?

The rated voltage of a fuse implies the maximum voltage of a circuit for which the fuse can safely interrupt the circuit's abnormal current up to its breaking capacity without bursting.

Please exercise caution when the voltage of the circuit is higher than the rated voltage of the fuse, as continued arcing may damage the fuse as in Figure 2.

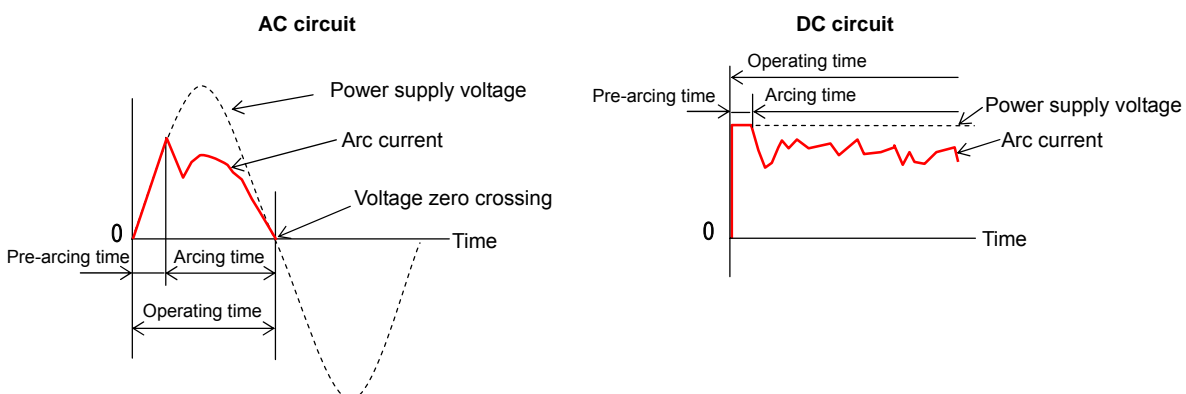


【Figure 2】 Example of a breaking test where the circuit voltage is higher than the rated voltage of the fuse

**! Make sure to select a fuse with a rated voltage equal to or higher than the voltage of the circuit.**

#### ■ Will the fuse be employed in an AC circuit or a DC circuit?

Even when the rated voltage of the fuse is higher than the voltage of the circuit, the amount of current the fuse can safely interrupt may differ due to the differences between AC and DC circuits. In AC circuits, arcing will be extinguished near a voltage zero crossing point as in Figure 3. In the case of DC circuits, however, care should be exercised as arcing may persist and a large current, which can cause the fuse to burst, may continue to flow because there is no zero crossing of the power supply voltage. The breaking ability of a fuse will differ depending on whether the circuit is an AC or a DC circuit. Fuses intended for use in AC circuits should therefore not be employed in DC circuits, and vice versa, as this may result in accidents.



【Figure 3】 Differences of current breaking waveforms between AC and DC circuits

Basic construction of SOC fuses

Rated voltage

Arcing

AC circuit

DC circuit

## Keywords

Power factor  
Time constant

Counter-electromotive force

Electrical Appliance and Material Safety Law

UL/CSA

IEC

### ■ What is the power factor/time constant of the circuit in which the fuse is to be inserted?

Even when the rated voltage of the fuse is higher than the voltage of the circuit, the amount of current the fuse can safely interrupt may vary due to differences in the power factor or the time constant of the circuit. The size of the inductance of the circuit relates to the magnitude of the power factor or the time constant. When the fuse operates in a circuit with a large inductance, a large counter-electromotive force is generated and prevents the fuse from breaking abnormal currents.

**! When selecting fuses, please confirm that the fuse you have selected can safely clear abnormal currents in the equipment in which it is to be used.**

### ■ How will the fuse be installed?

The basic shape and size of fuses are determined by various standards, as per Table 1 on PP. 175-176. The Electrical Appliance and Material Safety Law of Japan and the UL/CSA standards limit the maximum dimensions, while the IEC standards restrict both the shape and size of fuses.

#### Surface mount type



#### Sub-miniature type with leads



#### Bolted connection type



#### Pin terminal type



#### Cartridge type



#### Cartridge type with leads

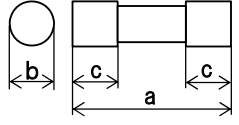
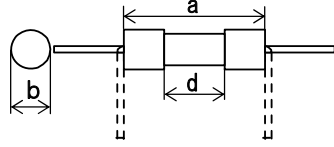
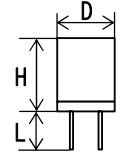
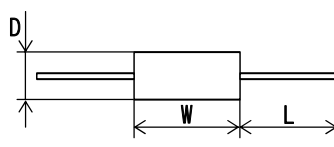
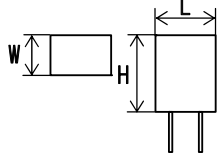
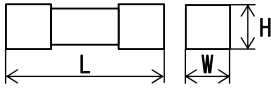


【Figure 4】 Example of fuse shapes

**! Please contact SOC for the development of custom-designed fuses based on your requirements for shape and size.**

【Table 1】 Fuse shapes and principal dimensions by standards

Standard		Type	Size (Unit: mm)	Shape
Electrical Appliance and Material Safety Law of Japan	Paragraph 1, Appended Table 3 of the Ministerial Ordinance establishing technical requirements for electrical appliances and materials	Miniature cartridge fuse-links	$a \leq 40$ $b \leq 11$ $c \leq b \times 0.6$ $d \geq 6$	
	J60127-2 S.S.1/S.S.2/S.S.3 S.S.5/S.S.6	Miniature cartridge fuse-links	$a=20 \pm 0.5$ $b=5.2^{+0.1}_{-0.2}$ $d=10 \pm 2$	
	J60127-2 S.S.4		$a=31.8 \pm 0.8$ $b=6.35 \pm 0.1$ $d=20^{+3}_{-4}$	
	J60127-3 S.S.1/S.S.3	Sub-miniature fuse-links	$H \leq 10$ $D \leq \phi 10$ $(L=4.3 \pm 0.3)$	
	J60127-3 S.S.2		$D \leq 10$ $W \leq 10$ $(L \leq 40)$	
	J60127-4 S.S.1	Through-hole fuse-links	$W \leq 7.5$ $H \leq 10$ $L \leq 8, 10.5, 12.5, 15, 18$ *Dimensions vary depending on the rated voltage	
	J60127-4 S.S.2	Surface mount fuse-links	$W \leq 6$ $H \leq 5$ $L \leq 6, 8, 10$ *Dimensions vary depending on the rated voltage	
UL248-1 UL248-14 CSA C22.2No.248.1 CSA C22.2No.248.14	Other than microfuses	Not specified		
	Microfuses	Principal dimensions excluding the leads or terminals: $\leq 10$	Not specified	
UL198G	Miniature fuses	$a \leq 36.1$ $b \leq 7.1$ However, for $a \leq 20$ : $b \leq 5$ ; or for $a \leq 15.9$ : $b \leq 6.3$		
	Miscellaneous fuses	$a \leq 38.1$ or $b \leq 10.3$		
	Micro fuses	Tubular	$L \leq 10$ $D \leq 5$	
		Cylindrical	$H \leq 10$ $D \leq 8$	
Rectangle		$W \leq 6$ $H \leq 10$ $L \leq 15$		

Standard	Type	Size (Unit: mm)	Shape
IEC60127-2 S.S.1/S.S.2/S.S.3 S.S.5/S.S.6	Cartridge fuse-links	$a=20\pm0.5$ $b=5.2^{+0.1}_{-0.2}$ $c=5.1\pm0.6$	
IEC60127-2 S.S.4		$a=31.8\pm0.8$ $b=6.35\pm0.1$ $c=6.2\pm0.6$	
IEC60127-2	Miniature fuse-links with wire terminations	$a\leq 24$ $b\leq 6$ $d=10\pm 2$	
IEC60127-3 S.S.1/S.S.3	Sub-miniature fuse-links	$H\leq 10$ $D\leq \phi 10$ ( $L=4.3\pm 0.3$ )	
IEC60127-3 S.S.2		$D\leq 10$ $W\leq 10$ ( $L\leq 40$ )	
IEC60127-4 S.S.1	Through-hole fuse-links	$W\leq 7.5$ $H\leq 10$ $L\leq 8, 10.5, 12.5, 15, 18$ *Dimensions vary depending on the rated voltage	
IEC60127-4 S.S.2	Surface-mount fuse-links	$W\leq 6$ $H\leq 5$ $L\leq 6, 8, 10$ *Dimensions vary depending on the rated voltage	

Please contact SOC for the development of custom-designed fuses based on your requirements for shape and size.

■ How many amperes will flow through the circuit the fuse is to be used in?

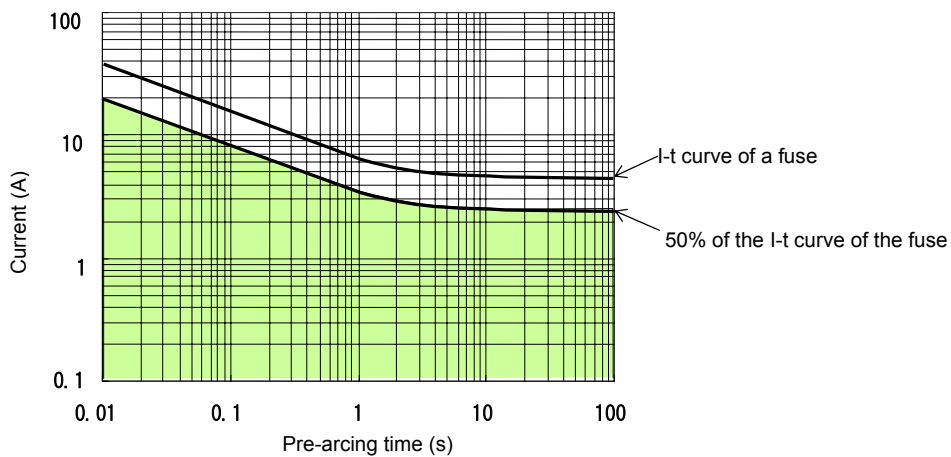
The rated current determined for the fuse is shown on it. When selecting fuses by rated current, it is important to fully examine the following current conditions of the circuit (including current waveform) in which the fuse is to be inserted, in order to prevent nuisance operation of the fuse and ensure that all necessary protection goals are met.

- Steady-state current
- Inrush current
- Abnormal current

Steady-state current  
Inrush current  
Abnormal current  
  
Steady-state current  
I-t curve

(1) Evaluation of a steady-state current

In order to minimize nuisance operation and ensure a long service life, select fuses so that the load factor of the measured steady-state current (r.m.s. value) of the circuit the fuse is to be employed in is not more than 50% of the time/current characteristic (I-t curve\*) of the fuse (the    area in Figure 5). This guideline of “not more than 50%” should only be applied to SOC fuses as it is based on SOC’s longstanding track record.

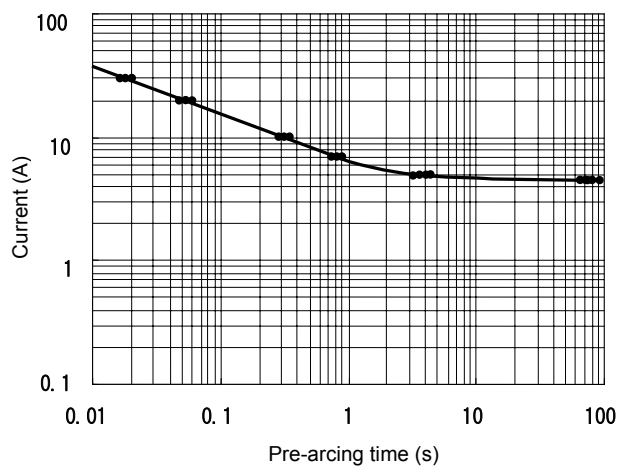


【Figure 5】 50% area of a fuse’s I-t curve

\*I-t curve

An I-t curve is a plot of the average pre-arcing times measured with various constant currents being applied to the fuse as shown in Figure 6. Therefore, the values it is based on are not guaranteed.

Current applied	Average pre-arcing times
30A	0.018s
20A	0.058s
10A	0.33s
7A	0.91s
5A	3.9s
4.5A	82s



【Figure 6】 Example of how to plot an I-t curve

(2) Evaluation of an inrush current

Variations in inrush current are generally so complicated that it is difficult to evaluate the inrush current by means of an I-t curve. When the fuse is less affected by heat dissipation (when a current has flowed for only a short period of time), it is possible to evaluate the occurrence of nuisance operation by comparing the Joule integral of the current waveform of the circuit ( $I_m^2t$ ) with the pre-arcing  $I_f^2t-t$  characteristic of the fuse.

Evaluation process:

- 1) Repeatedly measure the current waveform data of the equipment from the inrush current at power-on to the steady-state current.
- 2) When there is a capacitor in the circuit, measure the current waveform data after completion of the discharge. Also, when there is a device like a thermistor whose resistance varies depending on temperatures, measure the current waveform data under the conditions where impedance of the circuit becomes the minimum.
- 3) Based on the measured data, calculate the  $I_m^2t$  as follows: ( $\Delta t$ : Sampling time)

$$I_m^2t = \sum i_m^2 \times \Delta t$$

$$= \int_0^t i_m(t)^2 dt$$

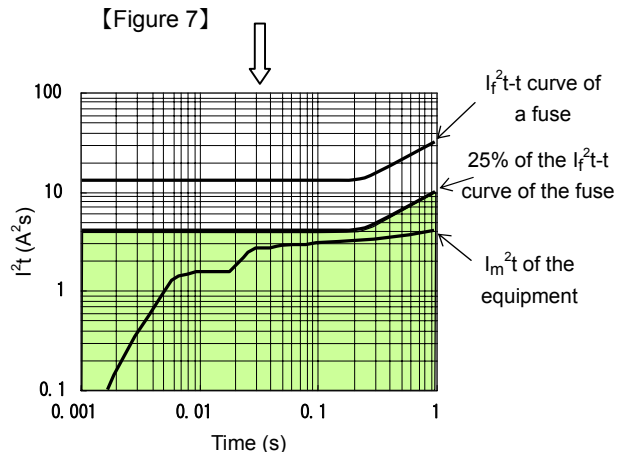
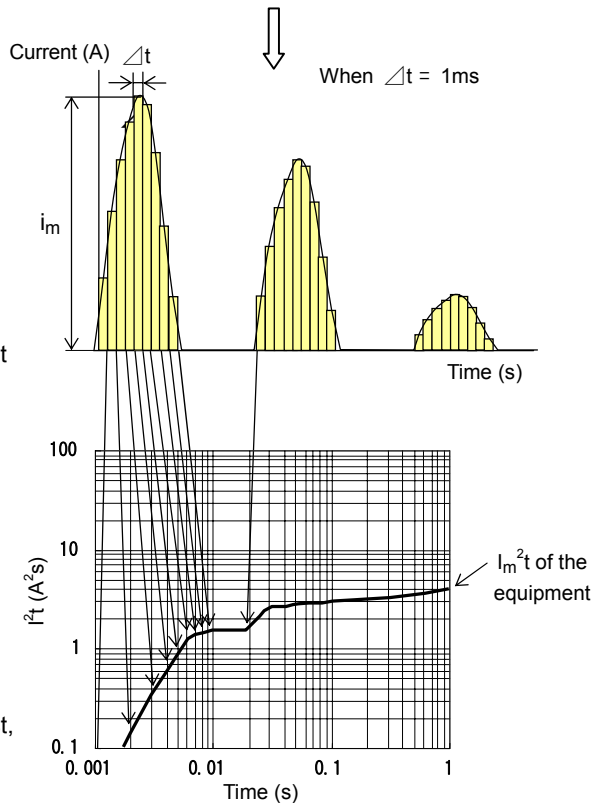
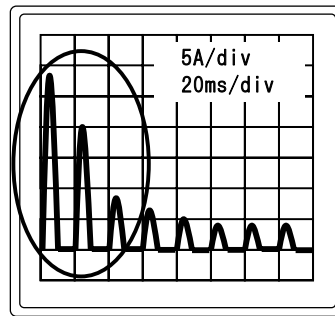
- 4) Plot the obtained  $I_m^2t$  as in Figure 7.
- 5) In order to prevent nuisance operation caused by electromigration of the fuse-element over the years, select a fuse which possesses an  $I_f^2t-t$  curve satisfying the following formula, even where  $I_m^2t$  of the equipment is the largest, as per Figure 8:  
 $I_m^2t \leq I_f^2t \times 0.25$  (25%)  
 This guideline of "not more than 25%" is based on SOC's longstanding track record, and should only be applied to SOC fuses.

(3) Evaluation of an abnormal current

Measure the minimum possible abnormal current, and select a fuse which meets the conditions of the following formula:  
 $I_f^2t \leq I_m^2t$

For the maximum possible abnormal current, make sure that it does not exceed the rated breaking current of the fuse.

Example of current waveform of equipment



[Figure 8] 25% of the fuse's pre-arcing  $I_f^2t-t$  curve

**!** Before final fuse selection, always test the proposed fuse in your actual equipment to ensure that the fuse satisfies all your operational and safety requirements.

Inrush current

Joule-integral

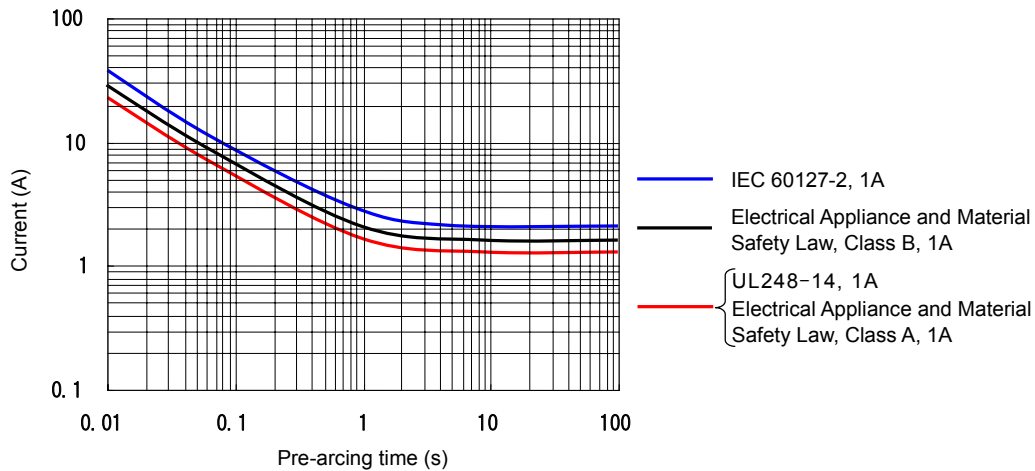
$I_f^2t-t$  curve

Abnormal current

Rated breaking current

■ Explanation of rated current

The testing conditions stipulated for each standard differ even among fuses with the same rated current. Each standard specifies the pre-arcing (clearing) times for the multiple of the rated current ( $I_N$ )\* as per Table 2. Accordingly, as in Figure 9, I-t curves differ depending on the standard even when the rated current is the same.

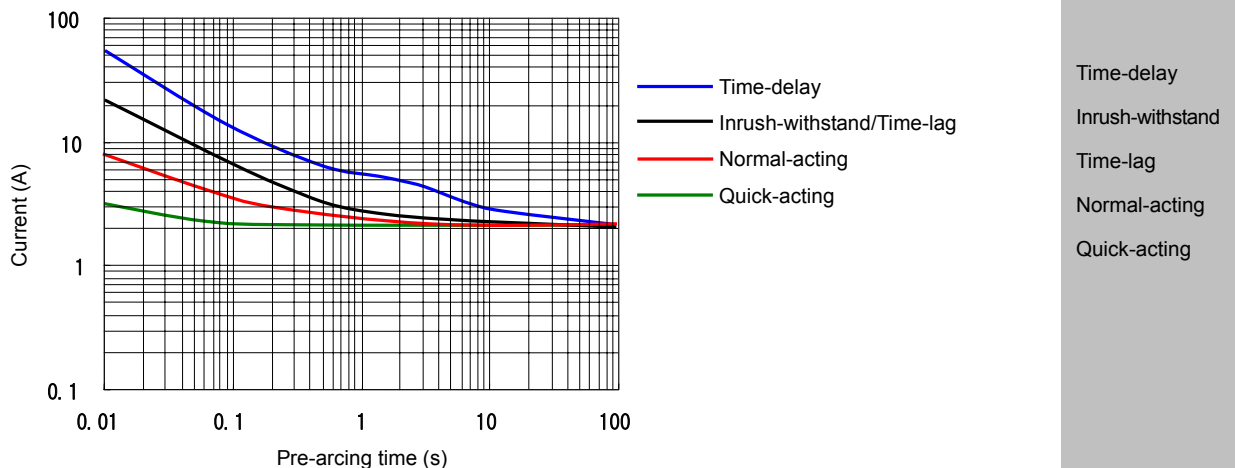


【Figure 9】 Variety of I-t curves for the same rated current based on different standards

\* $I_N$  indicates the rated current. For example,  $2.0 I_N$  indicates a value of twice the rated current.

■ Fuse characteristics

As per Figure 10, it is possible to design fuses having the same rated current, but with differing I-t curves and characteristics. Please consult SOC sales representatives when it is necessary to prevent fuse operations due to an inrush current, or when an abnormal current should be interrupted more quickly.



【Figure 10】 Differences in I-t curves for the same rated current due to differing fuse characteristics

■ Rated breaking current (capacity)

Rated breaking current is the maximum r.m.s. current value that a fuse is capable of safely interrupting at a circuit voltage equal to the rated voltage of the fuse, under the testing conditions specified by each standard. The specifications for the rated breaking current vary depending on which standard the fuse conforms to, as per Table 3 on P. 181.

[Table 2] Fuse shapes and principal dimensions by standard

■ Electrical Appliance and Material Safety Law (EAMSL) of Japan \*1

Regulations and standards		Rated current	Pre-arcing time by applied current		
			1.35I <sub>N</sub>	1.6I <sub>N</sub>	2.0I <sub>N</sub>
EAMSL	Class A	1A-31.5A	≤ 60min	-	≤ 2min
	Class B	1A-31.5A	-	≤ 60min	≤ 2min

Regulations and standards		Rated current	Pre-arcing time by applied current						Characteristic	
			1.0I <sub>N</sub>	1.25I <sub>N</sub>	2.0I <sub>N</sub>	2.1I <sub>N</sub>	2.75I <sub>N</sub>	4.0I <sub>N</sub>		10I <sub>N</sub>
J60127-2	S.S.1	50mA - 3.15A	-	-	-	≤ 30min	10ms - 2s	3ms - 300ms	≤ 20ms	Quick-acting
		4A - 6.3A	-	-	-	≤ 30min	10ms - 3s			
	S.S.2	32mA - 100mA	-	-	-	≤ 30min	10ms - 500ms	3ms - 100ms	≤ 20ms	
		Over 100mA - 6.3A	-	-	-	≤ 30min	50ms - 2s	10ms - 300ms		
	S.S.3	32mA - 100mA	-	-	-	≤ 2min	200ms - 10s	40ms - 3s	10ms - 300ms	Time-lag
		Over 100mA - 6.3A	-	-	-	≤ 2min	600ms - 10s	150ms - 3s	20ms - 300ms	
	S.S.4	50mA - 100mA	-	-	≤ 20s	-	2ms - 200ms	1ms - 30ms	≤ 5ms	Quick-acting
		Over 100mA - 10A	-	-	≤ 20s	-	20ms - 1.5s	8ms - 400ms	≤ 80ms	
	S.S.5	100mA - 3.15A	-	-	-	≤ 30min	1s - 80s	95ms - 5s	10ms - 100ms	Time-lag
		Over 3.15A - 6.3A	-	-	-	≤ 30min		150ms - 5s	20ms - 100ms	
	S.S.6	32mA - 100mA	-	-	-	≤ 2min	200ms - 10s	40ms - 3s	10ms - 300ms	
		Over 100mA - 6.3A	-	-	-	≤ 2min	600ms - 10s	150ms - 3s	20ms - 300ms	
J60127-3	S.S.1	2mA - 5A	4h ≤	-	≤ 5s	-	≤ 300ms	≤ 30ms	≤ 4ms	Quick-acting
	S.S.2	50mA - 5A	-	-	-	-	-	-	-	
	S.S.3	50mA - 5A	-	-	-	≤ 30min	10ms - 3s	3ms - 300ms	≤ 20ms	Time-lag
	S.S.4	40mA - 4A	-	-	-	≤ 2min	400ms - 10s	150ms - 3s	20ms - 150ms	
J60127-4	S.S.1 S.S.2	32mA - 6.3A	-	60min *2	≤ 2min	-	-	-	< 1ms	Super-quick-acting
									1ms - 10ms	Quick-acting
									10ms - 100ms	Time-lag
									100ms - 1s	Super-time-lag

\*1: Technical requirements stipulated by the Ministerial Ordinance of the Japanese Ministry of Economy, Trade and Industry (the Ministerial Ordinance establishing technical requirements for electrical appliances and materials)

\*2: Endurance test: After repeating 100 cycles of 1.05 I<sub>N</sub> for 60 min and switching-off for 15 min, 1.25 I<sub>N</sub> can be passed through the fuse for 60 min or more.

■ UL/CSA standards

Regulations and standards		Rated current	Clearing time by applied current			Characteristic
			1.35I <sub>N</sub>	1.5I <sub>N</sub>	2.0I <sub>N</sub>	
UL 248-1 UL 248-14 CSA C22.2 No.248.1 CSA C22.2 No.248.14	Supplemental fuses	≤ 30A	≤ 60min	-	≤ 2min	Other than time-delay
		Over 30A - 60A			≤ 4min	
		≤ 3A			-	5s - 2min
	Supplemental fuses (Microfuses)	≤ 60A	-	-	≤ 1min	Other than time-delay
		≤ 3A			5s - 1min	Time-delay
		3A <			12s - 1min	Time-delay
UL 198G	Micro fuses	≤ 10A	-	≤ 10min	≤ 1min	Other than time-delay
		≤ 3A			5s - 1min	Time-delay
		Over 3A - 10A			12s - 1min	Time-delay
	Miniature fuses	≤ 30A	≤ 60min	-	≤ 2min	Other than time-delay
		≤ 3A			5s - 2min	Time-delay
		Over 3A - 30A			12s - 2min	
	Miscellaneous fuses	≤ 30A	≤ 60min	-	≤ 2min	Other than time-delay
		≤ 3A			5s - 2min	Time-delay
		Over 3A - 30A			12s - 2min	

■ IEC standards

Standards		Rated current	Pre-arcing time by applied current						Characteristic		
			$1.0I_N$	$1.25I_N$	$2.0I_N$	$2.1I_N$	$2.75I_N$	$4.0I_N$		$10I_N$	
IEC 60127-2	S.S.1	50mA - 4A	-	-	-	$\leq 30\text{min}$	10ms - 2s	3ms - 300ms	$\leq 20\text{ms}$	Quick-acting	
		Over 4A - 6.3A					10ms - 3s				
		Over 6.3A - 10A					40ms - 20s	10ms - 1s	$\leq 30\text{ms}$		
	S.S.2	32mA - 100mA	-	-	-	$\leq 30\text{min}$	10ms - 500ms	3ms - 100ms	$\leq 20\text{ms}$		
		Over 100mA - 6.3A					50ms - 2s	10ms - 300ms			
		Over 6.3A - 10A					10ms - 400ms	$\leq 40\text{ms}$			
	S.S.3	32mA - 100mA	-	-	-	$\leq 2\text{min}$	200ms - 10s	40ms - 3s	10ms - 300ms		Time-lag
		Over 100mA - 10A					600ms - 10s	150ms - 3s	20ms - 300ms		
	S.S.4	50mA - 100mA	-	-	$\leq 20\text{s}$	-	2ms - 200ms	1ms - 30ms	$\leq 5\text{ms}$		Quick-acting
		Over 100mA - 10A					20ms - 1.5s	8ms - 400ms	$\leq 80\text{ms}$		
	S.S.5	100mA - 800mA	-	-	-	$\leq 30\text{min}$	250ms - 80s	50ms - 5s	5ms - 150ms		Time-lag
		Over 800mA - 3.15A					750ms - 80s	95ms - 5s	10ms - 150ms		
Over 3.15A - 10A		150ms - 5s									
S.S.6	32mA - 100mA	-	-	-	$\leq 2\text{min}$	200ms - 10s	40ms - 3s	10ms - 300ms			
	Over 100mA - 10A					600ms - 10s	150ms - 3s	20ms - 300ms			
IEC 60127-3	S.S.1	2mA - 5A	$4\text{h} \leq$	-	$\leq 5\text{s}$	-	$\leq 300\text{ms}$	$\leq 30\text{ms}$	$\leq 4\text{ms}$	Quick-acting	
	S.S.2	50mA - 5A	-	-	-	-	-	-	-		
	S.S.3	50mA - 5A	-	-	-	$\leq 30\text{min}$	10ms - 3s	3ms - 300ms	$\leq 20\text{ms}$		
	S.S.4	40mA - 4A	-	-	-	$\leq 2\text{min}$	400ms - 10s	150ms - 3s	20ms - 150ms		Time-lag
IEC 60127-4	S.S.1 S.S.2	32mA - 6.3A	-	$60\text{min} \leq$ *1	$\leq 2\text{min}$	-	-	-	$< 1\text{ms}$	Super-quick-acting	
									1ms - 10ms	Quick-acting	
									Over 10ms - 100ms	Time-lag	
									Over 100ms - 1s	Super-time-lag	

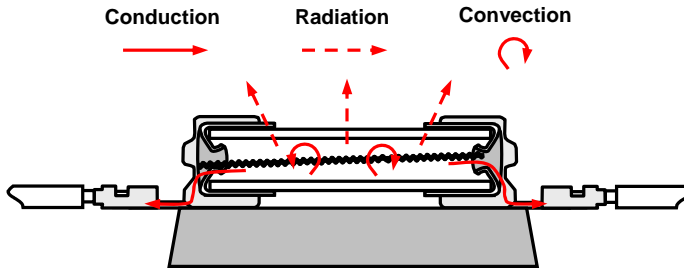
\*1: Endurance test: After repeating 100 cycles of  $1.05 I_N$  for 60 min and switching-off for 15 min,  $1.25 I_N$  can be passed through the fuse for 60 min or more.

【Table 3】 Example of rated breaking current (capacity) compared by standard

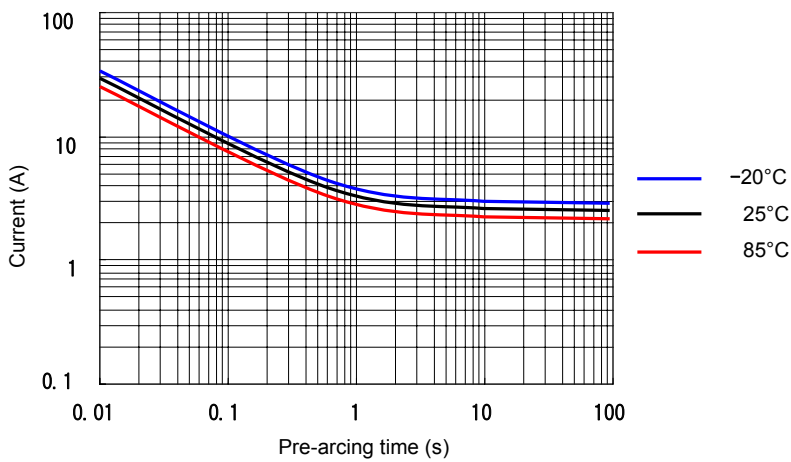
Standards	Type/Characteristic	Rated voltage	Rated current	Rated breaking current (capacity)	Power factor
Electrical Appliance and Material Safety Law (Paragraph 1 of the Ministerial Ordinance)	For electronic equipment	125V/250V	$1\text{A} \leq$	100A/300A/500A	0.7 - 0.8
UL 198G UL 248-1 UL 248-14 CSA C22.2 No.248.1 CSA C22.2 No.248.14	Listed products, other than microfuses	125V	$\leq 30\text{A}$	10000A	0.7 - 0.8
		250V	$1\text{A} < \leq 3.5\text{A}$	100A	0.7 - 0.8
			$3.5\text{A} < \leq 10\text{A}$	200A	
			$10\text{A} < \leq 15\text{A}$	750A	
			$15\text{A} < \leq 30\text{A}$	1500A	
IEC 60127-2	S.S.1	250V	100mA - 10A	1500A	0.7 - 0.8
	S.S.2		32mA - 6.3A	35A or $10I_N$ , whichever is greater	Resistive circuit
	S.S.3		50mA - 6.3A		
	S.S.4		50mA - 2A		
	S.S.5		100mA - 10A	1500A	0.7 - 0.8
	S.S.6		32mA - 10A	150A	Resistive circuit
IEC 60127-3	S.S.1	125V	2mA - 5A	50A	Resistive circuit
	S.S.2		50mA - 5A		
	S.S.3	250V	50mA - 5A	35A or $10I_N$ , whichever is greater	
	S.S.4	40mA - 4A			
IEC 60127-4	S.S.2	32V	32mA - 6.3A	1500A	0.7 - 0.8
	250V	32mA - 6.3A			

■ What is the fuse's ambient temperature?

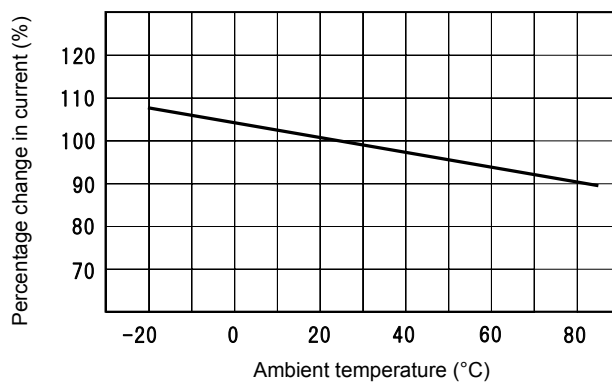
A fuse will operate when the fuse-element temperature exceeds its melting point due to Joule heating caused by overcurrents. As shown in Figure 11, the temperature of the fuse-element is strongly influenced by heat dissipation, which also differs according to the ambient temperature, and heat conduction or heat capacity of the surroundings such as the fuse clip, fuseholder, wiring and board. Therefore, it is essential that final equipment testing be conducted with the end application subjected to actual mechanical, electrical and ambient conditions to assure that satisfactory results and desired reliability will be achieved as the fuse's time/current characteristic and current carrying capability may change depending on these factors, as per Figures 12 and 13, respectively.



【Figure 11】 Example of the heat dissipation of a glass cartridge fuse



【Figure 12】 Example of changes to an I-t curve due to the ambient temperature



【Figure 13】 Example of changes to current carrying capability at different ambient temperatures