TECHNICAL PAPER

How to Choose the Correct Accu-Guard Fuse for Circuit Protection

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Abstract
The ACCU-GUARD is designed to meet the need of electronic circuits for a small, accurate surface mount fuse. This article presents design guidelines for achieving optimal protection of circuits with ACCU-GUARD. All major parameters are described including operating temperature, circuit voltage, fault current, steady state current and current pulses (Joule integral).

HOW TO CHOOSE THE CORRECT ACCU-GUARD FUSE FOR CIRCUIT PROTECTION

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Introduction

This article presents the important ACCU-GUARD fuse design parameters. Correct choice of an ACCU-GUARD fuse for a given application is fairly straightforward. The factor of pre-arc I^2t, however, requires clarification. The proper design for pre-arc I^2t is presented by way of example.

ACCU-GUARD Design Parameters

1. Operating Temperature

The ACCU-GUARD is specified for operation in the temperature range of -55°C to +125°C. Note, however, that fusing current is sensitive to temperature. This means that the fuse must be derated or uprated at circuit temperatures other than 25°C:

Environmental Temperature	ACCU-GUARD Current Carrying Capacity*
-55°C to -11°C	1.07 x I_R
-10°C to 60°C	I_R
61°C to 100°C	0.93 x I_R
101°C to 125°C	0.90 x I_R

*As a function of nominal rated current, I_R. Refer to the ACCU-GUARD catalog.

2. Circuit Voltage

Maximum Voltage: ACCU-GUARD is specified for circuits of up to 32V peak voltage. ACCU-GUARD will successfully break currents at higher voltages as well, but over voltage may crack the fuse body.

Minimum Voltage: ACCU-GUARD cannot be used in circuits with voltage of about 0.5V and less. The internal resistance of the fuse will limit the fault current to a value which will prevent reliable actuation of the fuse (< 2 x rated current).

3. Maximum Fault Current

ACCU-GUARD is fully tested and specified for fault currents up to 50A. ACCU-GUARD will successfully break currents above 50A but such over current may crack the fuse body or damage the fuse terminations.

4. Steady State Current

The ACCU-GUARD current rating is based on IEC Specification 127-3. In accordance with this international standard, ACCU-GUARD is specified to operate at least 4 hours at rated current without fusing (25°C). Engineering tests have shown that ACCU-GUARD will in fact operate at least 1000 hours at rated current without fusing (25°).

5. Switch-on and Other Pulse Current

Many circuits generate a large current pulse when initially connected to power. There are also circuits which are subject to momentary current pulses due to external sources; telephone line cards which are subject to lightning induced pulses are one example. These current pulses must be passed by the fuse **without** causing actuation. These pulses may be so large that they are the determining factor for choosing the ACCU-GUARD current rating; not necessarily steady state current.

In order to design for current pulses, the concept of fuse pre-arc Joule integral, I^2t, must be understood. Fuse current rating is defined by the requirement that $2xI_R$ will cause actuation in <5 seconds. This rating does not indicate how the fuse will react to very high currents of very short duration. Rather, the fusing characteristic at very high currents is specified by I^2t-t curves (or I^2t-I).

I^2t expresses the amount of energy required to actuate the fuse. Total I^2t expresses the total energy which will be passed by the fuse until total cessation of current flow. Pre-arc I^2t expresses that energy required to cause large irreversible damage to the fuse element (Total I^2t = pre-arc I^2t + arc I^2t). If the Joule integral of the switch-on pulse is larger than the fuse pre-arc I^2t, nuisance actuation will occur.

In order to choose the proper ACCU-GUARD current rating for a given application, it is necessary to calculate the I^2t Joule integral of the circuit switch-on and other current pulses and compare them to the ACCU-GUARD I^2t-t curves. An ACCU-GUARD fuse must be chosen such that the pulse I^2t is no more than 50% of the pre-arc I^2t of the prospective fuse.

Pre-arc I^2t of the ACCU-GUARD fuses is well characterized; I^2t-t and I^2t-I graphs are attached to this article. The problem is calculating the I^2t of the circuit current pulses. This concept is not familiar to most engineers. Correct calculation of pulse Joule integral and subsequent choice of ACCU-GUARD current rating is illustrated by way of the attached examples.

Designing for Current Pulse Situations

1. Sine wave current pulse.

The Joule integral for sine wave pulse is

$$[(I_{max})^2 \cdot t]/2,$$

see Fig. 1a.

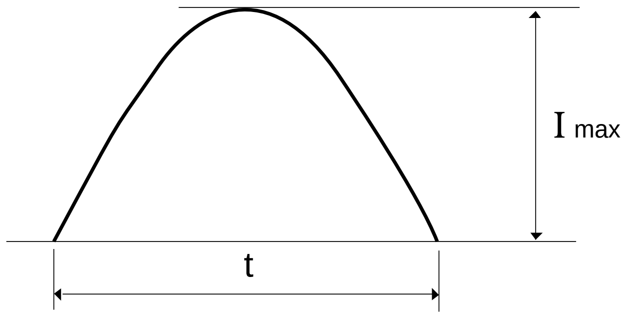

Fig. 1a. Sine wave pulse parameters for Joule integral calculation, example #1.

Thus, for the current pulse in Fig. 1b, the Joule integral is

$$[(4.8A)^2 \cdot 7.7 \cdot 10^{-6}\ sec]/2 = 8.9 \cdot 10^{-5}\ A^2\ sec.$$

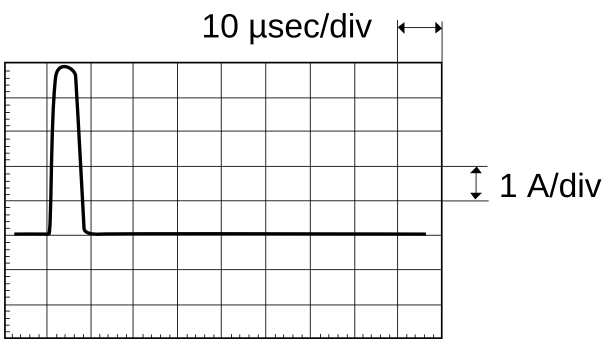

Fig. 1b. Sine wave pulse, example #1.

The pulse duration is 7.7 μsec. We must find a fuse that can absorb at least $8.9 \times 10^{-5} \cdot 2 = 1.8 \times 10^{-4}\ A^2sec$ Joule integral within 7.7 μsec without actuation. According to Fig. 7, pre-arcing Joule integral is $2.3 \times 10^{-4}\ A^2sec$ for the 0.5A fuse, which is slightly more than needed. The next lower rating (0.375A), has only $6 \times 10^{-5}\ A^2sec$, which is not enough. Therefore, 0.5A fuse should be chosen for this application, see Fig. 1c.

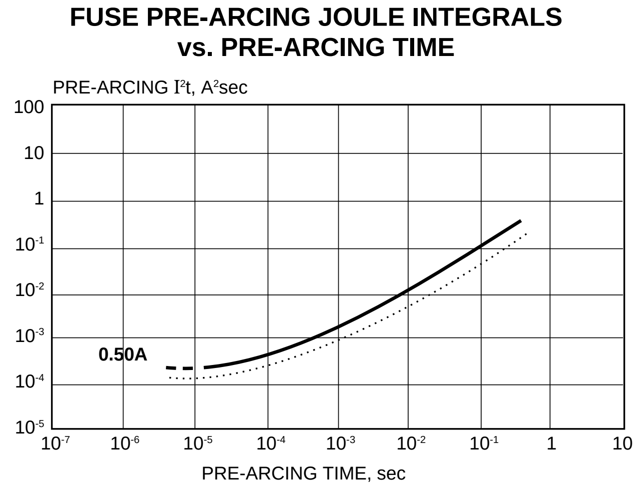

Fig. 1c. Choice of 0.5A fuse, example #1.

——— Pre-arcing I^2t

.... Maximum I^2t design rule

X I^2t for sample current pulse

2. Triangular current pulse.

The Joule integral for triangular pulse is

$$[(I_{max})^2 \cdot t]/3,$$

see Fig. 2a.

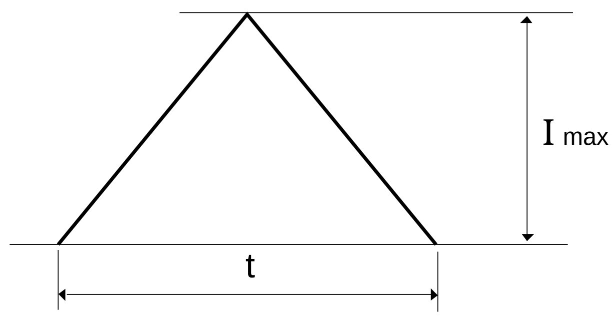

Fig. 2a. Triangular pulse parameters for Joule integral calculation, example #2.

Thus, for the current pulse in Fig. 2b, the Joule integral is

$$[(1.5A)^2 \cdot 3 \cdot 10^{-3}\ sec]/3 = 2.25 \cdot 10^{-3}\ A^2sec$$

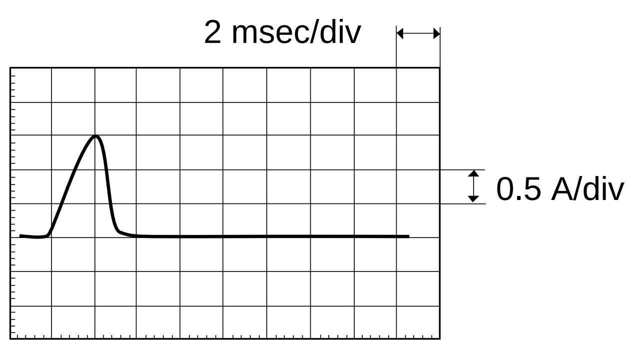

Fig. 2b. Triangular pulse, example #2.

The pulse duration is 3 msec. In Fig. 7, pre-arcing Joule integral for 3 msec pulse is $4 \cdot 10^{-3}$ A^2sec for the 0.5A fuse (not enough) and $2 \cdot 10^{-2}$ for the 0.75A fuse (more than enough). Therefore, 0.75A fuse should be chosen for this application, see Fig. 2c.

FUSE PRE-ARCING JOULE INTEGRALS vs. PRE-ARCING TIME

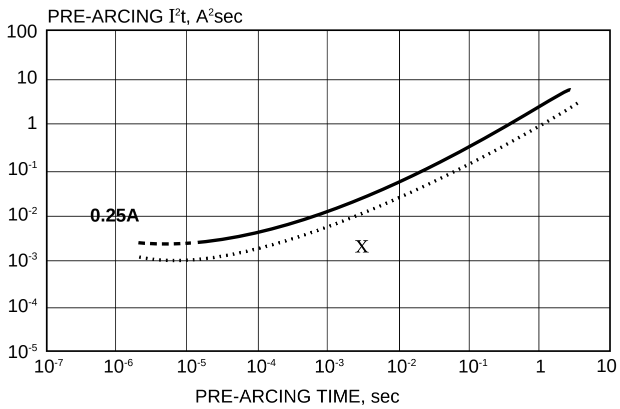

Fig. 2c. Choice of 0.75A fuse, example #2.

—— Pre-arcing I^2t

.... Maximum I^2t design rule

X I^2t for sample switch-on pulse

3. Trapezoidal current pulse.

The Joule integral for a trapezoidal pulse is

$$\{(I_{min})^2 + I_{min} \cdot (I_{max} - I_{min}) + [(I_{max} - I_{min})^2/3]\} \cdot t,$$

see Fig. 3a.

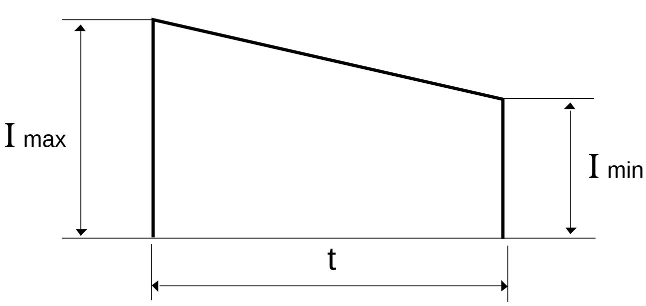

Fig. 3a. Trapezoidal pulse parameters for Joule integral calculation, example #3.

Thus, for current pulse in Fig. 3b, the Joule integral is

$$\{(0.56A)^2 + 0.56A \cdot (1A\text{-}0.56A) + [(1A\text{-}0.56A)^2/3]\} \cdot 3 \cdot 10^{-3}\ s = 1.9 \cdot 10^{-3}\ A^2\ sec.$$

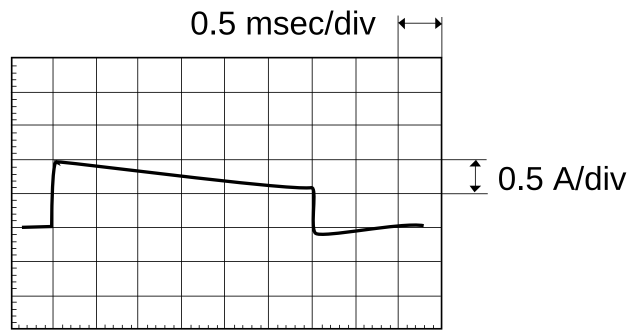

Fig. 3b. Trapezoidal pulse, example #3.

According to Fig. 7, the 0.5A fuse should be chosen for this application, see Fig. 3c.

FUSE PRE-ARCING JOULE INTEGRALS vs. PRE-ARCING TIME

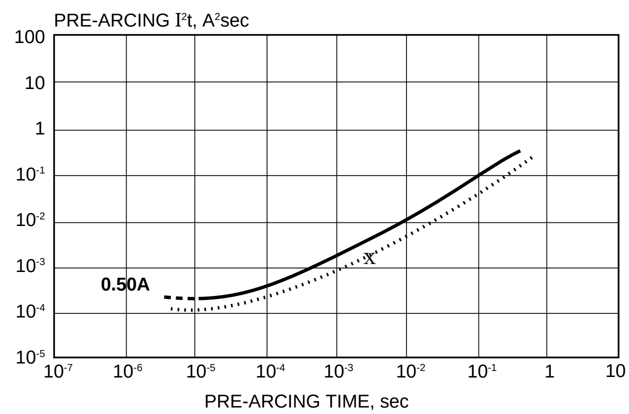

Fig. 3c. Choice of 0.5A fuse, example #3.

—— Pre-arcing I^2t

.... Maximum I^2t design rule

X I^2t for sample switch-on pulse

4. Lightning strike.

A lightning strike pulse is shown in Fig. 4a. After an initial linear rise, the current declines exponentially.

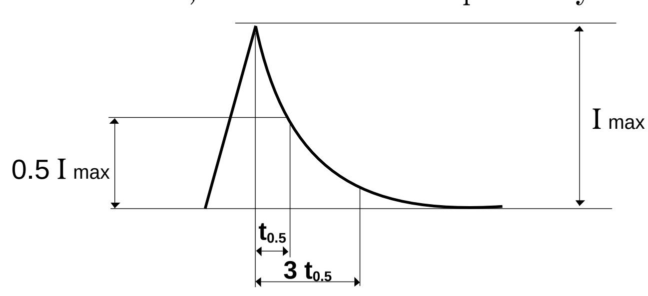

Fig. 4a. Lightning pulse parameters for Joule integral calculation, example #4.

Joule integral for the linear current rise is calculated as for a triangular pulse, see example #2.

The Joule integral for the exponential decline is

$$I_{max}^2 \cdot t_{0.5} \cdot (-1/2\ln 0.5) = 0.72 I_{max}^2 \cdot t_{0.5}$$

Thus, for the sample lightning strike pulse in Fig. 4b, the total Joule integral is

$$(25A)^2 \cdot 2 \cdot 10^{-6}\text{sec}/3 + 0.72 \cdot (25A)^2 \cdot 10 \cdot 10^{-6}\text{sec} = 4.92 \cdot 10^{-3}\ A^2\text{sec}$$

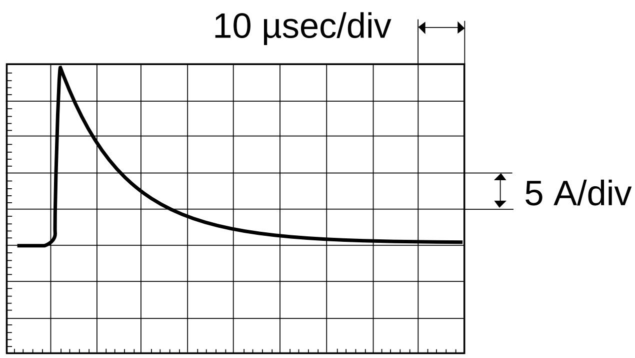

Fig. 4b. Lightning strike pulse, example #4.

For practical calculations, the duration of exponential decline may be assumed to be $3t_{0.5}$, because within this time 98.5% of the pulse energy is released. Thus, the total pulse duration in this example is 30 µsec, and the 1.25A fuse should be chosen for this application, see Fig. 4c.

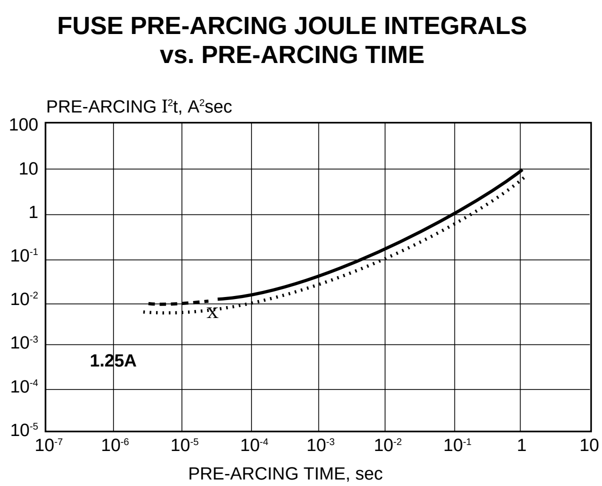

Fig. 4c. Choice of 1.25A fuse, example #4.

Pre-arcing I^2t
Maximum I^2t design rule
X I^2t for sample current pulse

5. Complex current pulse.

If the pulse consists of several waveforms, all of them should be evaluated separately, and then the total Joule integral should be calculated as well.

Fig. 5a. Complex pulse, example #5.

In Fig. 5a, the Joule integral for the first triangle is

$$[(4.67A)^2 \cdot 294 \cdot 10^{-6}\text{ sec}]/3 = 2.14 \cdot 10^{-3}\ A^2\text{sec},$$

and 0.75A fuse should meet this condition, see Fig. 5b.

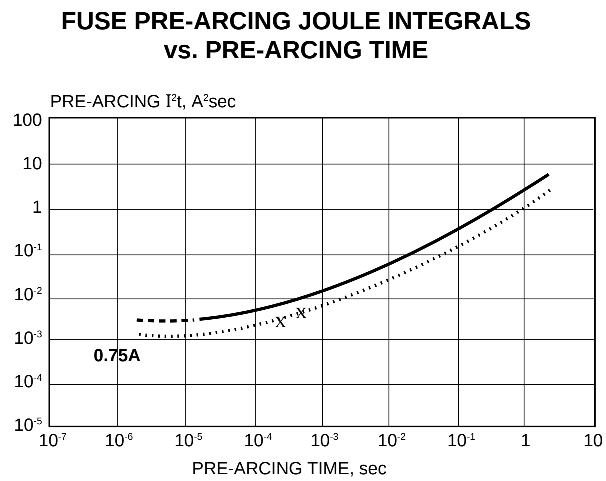

Fig. 5b. Choice of fuse, example #5.

Pre-arcing I^2t
Maximum I^2t design rule
X I^2t for sample switch-on pulse

The Joule integral for the second triangle is

$$[(5.33A)^2 \cdot 269 \cdot 10^{-6}\text{ sec}]/3 = 2.55 \cdot 10^{-3}\ A^2\text{sec},$$

and 0.75A fuse is suitable for this case also, see Fig. 5b.

However, for the whole pulse, the Joule integral is $4 \cdot 7 \cdot 10^{-3}\ A^2$sec, and the total duration is 563 µsec. For the 0.75A fuse, the Joule integral is only $8.6 \times 10^{-3}\ A^2$sec for this pulse duration, so the 1A fuse should be chosen for this application, see Fig. 5b.

6. Switch-on pulse and steady-state current.

In Fig. 6a, the switch-on pulse is a triangle pulse with a $5.1 \cdot 10^{-3}\ A^2$sec Joule integral of 5 msec duration; the 0.75A fuse will meet this requirement, see Fig. 6b.

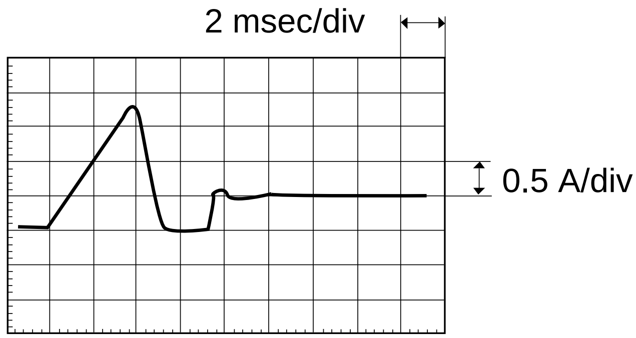

Fig. 6a. Switch-on pulse and steady-state current, example #6.

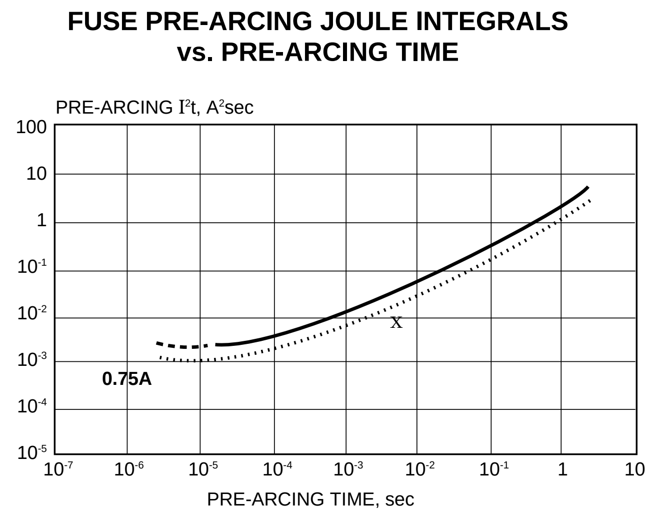

Fig. 6b. Choice of 0.75A fuse, example #6.

Pre-arcing I^2t
Maximum I^2t design rule
X I^2t for sample switch-on pulse

The steady-state current is 0.5A, and 1A fuse is typically recommended to meet the steady-state condition. Based on steady-state current, the 1A fuse should be chosen for this application.

FUSE PRE-ARCING JOULE INTEGRALS vs. PRE-ARCING TIME

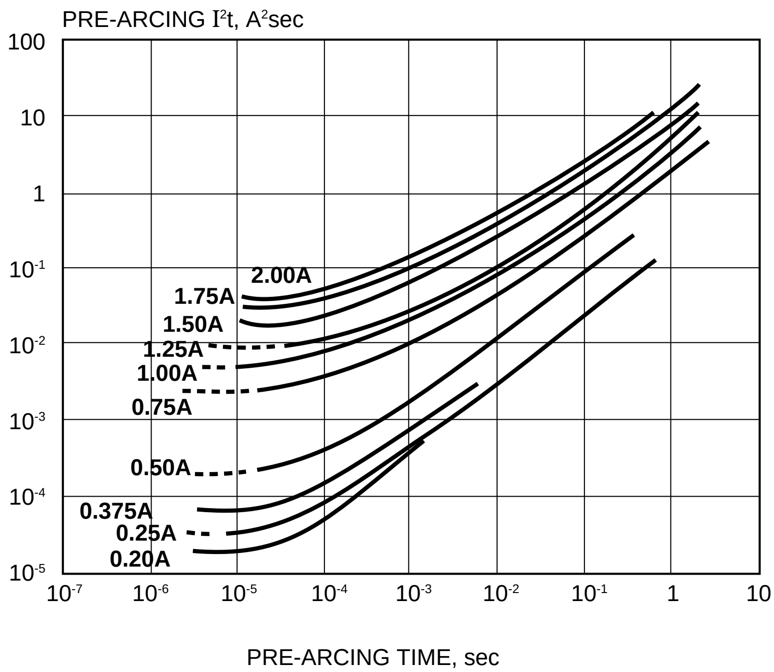

Fig. 7. I^2t vs. t curves for ACCU-GUARD fuses.

FUSE PRE-ARCING JOULE INTEGRALS vs. CURRENT

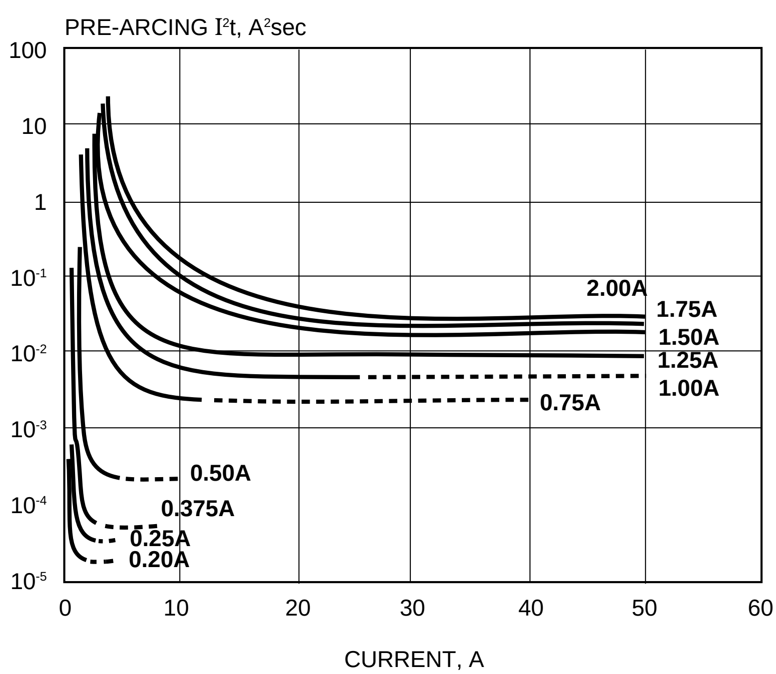

Fig. 8. I^2t vs. I curves for ACCU-GUARD fuses.

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