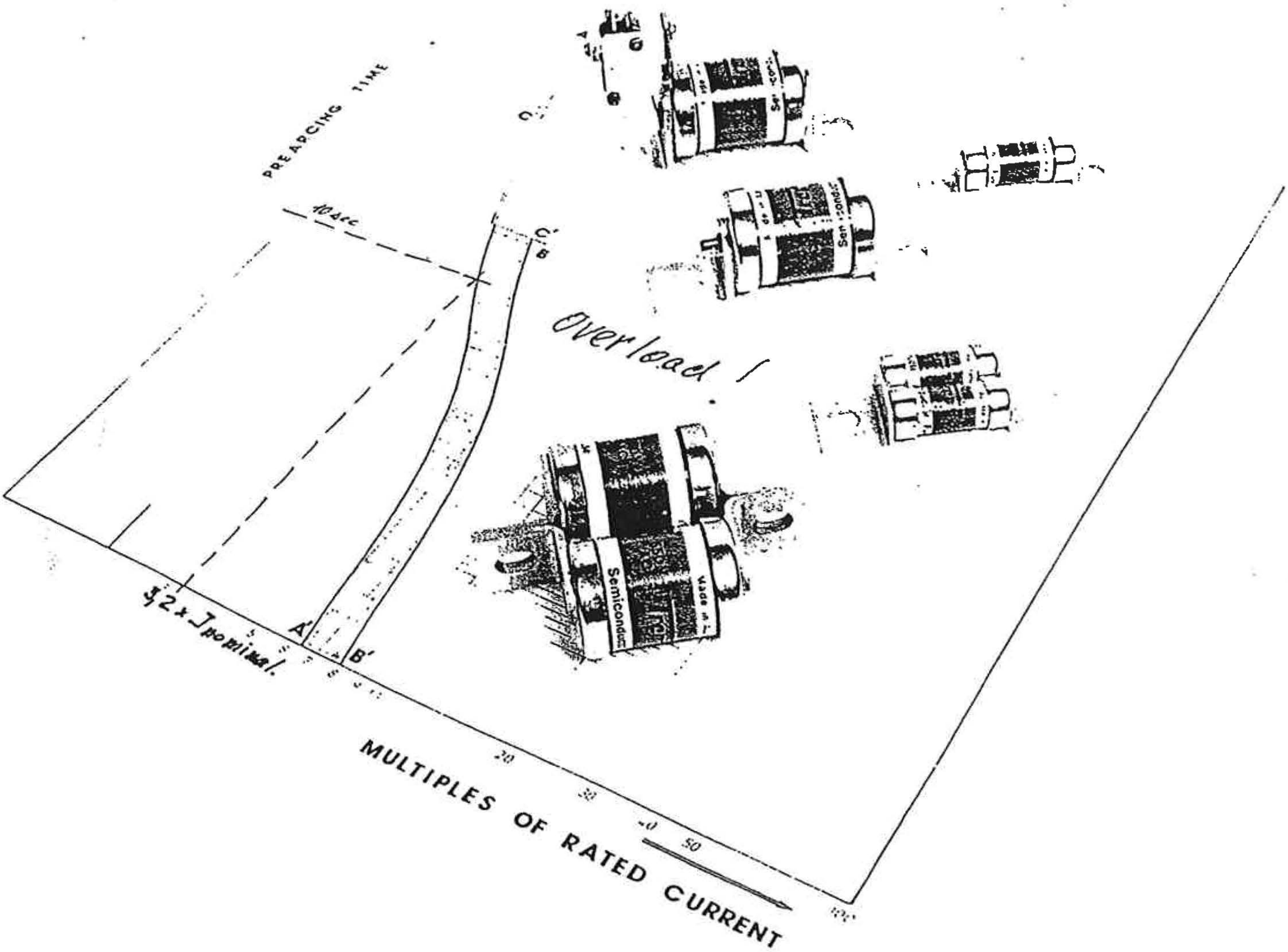
Trent

SEMI-CONDUCTOR PROTECTION FUSES



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Trent SEMICONDUCTOR FUSES

INTRODUCTION

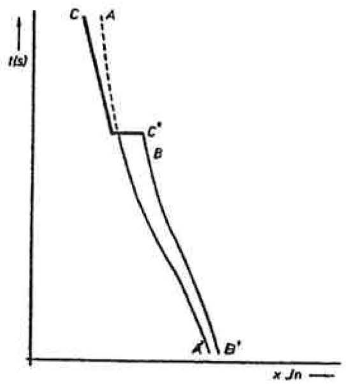
Application

Semiconductor fuses have to limit the energy which could destroy silicon rectifiers. These elements can withstand high energy pulses only for a very short period of time. The fuse has to interrupt the circuit before any damage of the silicon rectifier occurs, but on the other side must allow the use of the maximum of the semiconductor's overload capacity.

I^2t:

The energy pulse is defined as I^2t (RMS current in square multiplied by the time for which the current flows).

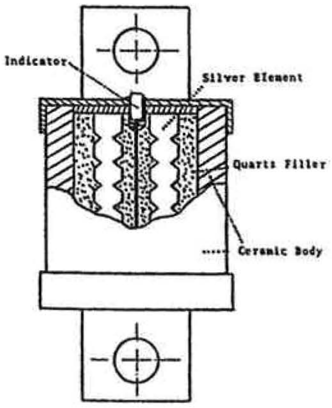
Fuse Characteristics:



The time current of power semiconductor fuses must be as close as possible to the rectifier curves. The curve gives a typical characteristic of TRENT-fuses.

AA' is the minimum real prearcing duration.
BB' is the maximum real prearcing duration.
CC' is the most important part of the curve because for all durations above this line, the fuse cannot clear safely the low overloads. An excessive temperature rise is the reason. If low overloads are produced they must be eliminated by a circuitbraker, contactor or relay.

Fuse Construction:



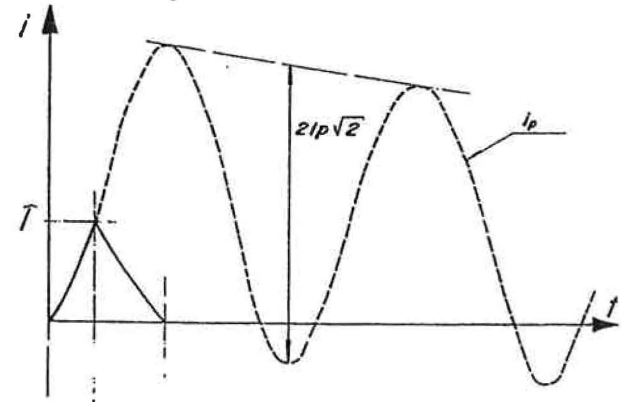
The fuses are available in a wide range of mechanically different houses and connections.
The important part of the fuse is the pure silver element which must have a minimum resistance for a given cross section of restrictions but must also have enough restrictions to cope with the system's voltage, i.e. the number of elements and restrictions varies from fuse to fuse according to the application. The elements are soldered to copper caps and tags, and potted into a pure quartz filler.

FUSE OPERATION

Fuse Heating: The fuse is designed in such a way that under normal working conditions the production and dissipation of heat is in a certain balance. Overloads in the circuits cause a temperature increase at the restrictions until the melting point of silver is reached. The time for the element to break will naturally decrease with increasing current.

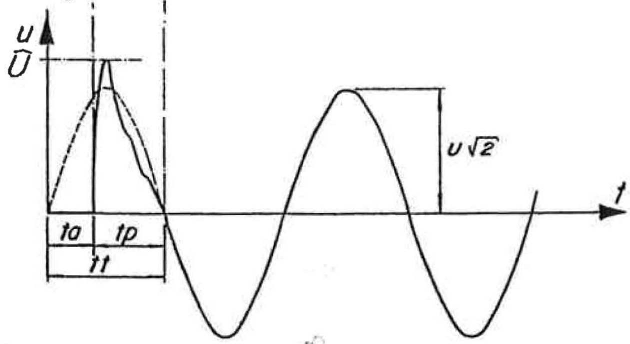
Prospective Fault Current: Under heavy short time overloads there is little time for heat dissipation and the temperature at the restrictions will reach the melting point very fast, in many cases before the prospective fault current has reached its peak.

Peak Fuse Link Current J:
Prospective Current J_p:



Prearcing Time: The sudden current interruption will result in an arc at each restriction. The time from the initiation of the fault to the creation of the arc is called the prearcing time.

Prearcing Time t_a:
Arcing Time t_p:
Total Operating Time t_t:
Peak Arc Voltage Û:
Supply Voltage U:



The prearcing I^2t is a constant, influenced mainly by the design and construction of element and fuse. The arcing I^2t, however, depends on the circuit conditions. The arcing time is the time from appearance of the arc to its final extinction.
The sum of prearcing and arcing time is the total operating time.

Arc voltage:

The forming of the arc creates a voltage across the fuse links. The voltage can be substantially high, depending on the circuit's inductivities and on the construction of the element itself. It has to make sure that the total of supply voltage and arc voltage does not superceed the maximum peak reverse voltage of the rectifier.

CALCULATION

Average- and RMS-currents:

Unfortunately the terminology of fuses and rectifiers is different. While the operation of fuse links primarily depends on the thermal effect of current, fuse data are given in r.m.s. values. The rectifiers are usually presented in terms of average values.

Table 1:
RMS-
Average-
Peak-
current for
Rectifier Circuits
(resistive load)

Circuit	Waveform	I(RMS) / I(MEAN)	I(RMS) / I(PEAK)	I(MEAN) / I(PEAK)
1∅ half-wave	180°	1.57	0.500	0.318
1∅ full-wave	180°	1.11	0.707	0.637
3∅ full-wave	120°	1.76	0.486	0.276
6∅ full-wave	60°	2.45	0.390	0.159

In order to work out the right fuse, Table 2 shows the typical circuit currents. These figures are changing for various conduction angles in thyristor circuits. In this case, special care has to be taken because of the high peak current.

Table 2:
Circuit Currents
for Rectifier
Circuits
(resistive load)

Circuit	In series with element (I_R)		RMS - Fuse Current in Line (I_L)	
1∅ half-wave	$I_{DC} \times 1.57$	$I_L \times 1.0$	$I_{DC} \times 1.57$	$I_R \times 1.0$
1∅ centre tap	$I_{DC} \times 0.79$	$I_L \times 1.0$	$I_{DC} \times 0.79$	$I_R \times 1.0$
1∅ full-wave bridge	$I_{DC} \times 0.79$	$I_L \times 0.71$	$I_{DC} \times 1.11$	$I_R \times 1.41$
3∅ half-wave	$I_{DC} \times 0.58$	$I_L \times 1.0$	$I_{DC} \times 0.82$	$I_R \times 1.0$
3∅ full-wave	$I_{DC} \times 0.58$	$I_L \times 0.73$	$I_{DC} \times 0.82$	$I_R \times 1.37$
6∅ half-wave	$I_{DC} \times 0.29$	$I_L \times 1.0$	$I_{DC} \times 0.29$	$I_R \times 1.0$
6∅ full-wave	$I_{DC} \times 0.29$	$I_L \times 1.41$	$I_{DC} \times 0.41$	$I_R \times 0.71$

DC-OPERATION

To use fuses in dc-circuits is more complicated because of the lack of zero voltage crossing. The rise of short circuit currents on dc-systems depends on the time constant of the circuit which in many cases is unknown to the user, but is normally much lower than for ac-circuits.
At the same prospective fault current, the peak fuse current on a dc-fault is lower than on an ac-fault.

Voltage Rating:	Following dc-ratings can be used for 550 V (RMS) rated fuses: 300 V DC time constant up to 20 ms for 250 V (RMS) rated fuses: 110 V DC time constant up to 15 ms.
Cut-off Current:	Fuses operating on dc will normally have a smaller peak current let-though than working on ac. Because of a nearly constant current at the end of the prearcing period, this current can be used as the peak let-through current.

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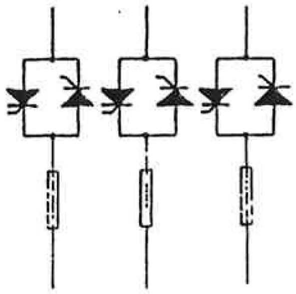
APPLICATION EXAMPLES

A. AC-Motorstarter



Basic Information:

A 1. 200 kW-drive

A 2. Nominal supply voltage 415 V RMS

A 3. Maximum starting current:
1200 A RMS at 20 sec.

A 4. Supply transformer: 750 kVA, 5% impedance

A 5. Thyristor particulars:

I^2t rating (3ms)	200.000 A^2s
Peak current (fusing)	9.000 A
Peak reverse voltage	1600 V

Basic Design:

1. Maximum prospective fault current:

$$\frac{750 \times 10^3 \times 100}{\sqrt{3} \times 415 \times 5} = 20.900 \text{ A (RMS)}$$

2. Selection of fuse:

current through fuse $\frac{200 \times 10^3}{\sqrt{3} \times 415} = 280$ A (RMS)

Starting current (see Fig. 2) at 20 sec. is 2.9 times nominal current. Our example requires 1200 A. To find the right size fuse, 1200 A have to be devided by 2.9 = 413 A.
Fuse 400 BBF is selected.

3. I^2t:

According to Fig. 3 with maximum prospective fault current of 20.900 A, the total I^2t - Let-through is 120.000 A^2s. With correcting factor Fig. 8, 550 V/415 V = 0.85, we will find a final 120.000 x 0.80 = 96.000 A^2s.

4. Cut-off current:

Fig. 4 shows for 400 BBF and a prospective fault current of 20.900 A (RMS) a cut-off current 10.000 A x 0.85 = 8500 A.

5. Peak voltage:

With Fig. 9 peak voltage will be 900 V at 415 V (RMS).

APPLICATION
EXAMPLES

B. Three-phase Fully Controlled Rectifier Bridge

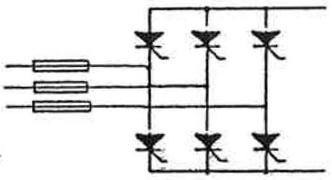
Basic Information:

B 1. 600 A DC output

B 2. Nominal supply voltage 415 V RMS

B 3. Prospective fault current 25.000 A RMS

B 4. Thyristor particulars:



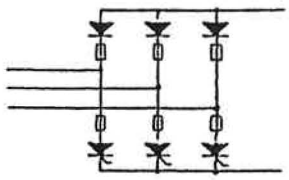
I^2t rating (3ms)	290.000 A^2s
Peak current:	10.000 A
Peak reverse voltage	1600 V

Basic Design:

1. Important for the fuse rating is the RMS current through the lines. According to Table 2 I_1 (RMS) = 0.82 x I_d = 0.82 x 600 - 492 A (RMS).
2. Fuse selected 500 BBF.
3. I^2t: According to Fig. 3 and prospective current = 25.000 A, I^2t = 180.000 A^2s with correcting factor Fig. 8 180.000 x 0.80 = 144.000 A^2s at 415 V RMS.
4. Cut-off current: Fig. 4 shows for 500 BBF and a prospective current of 25.000 A a cut-off current of 12.000 A (corr. 12.000 A x 0.80 = 9600 A).
5. Peak voltage: With Fig. 9 peak voltage will be 900 V at 415 V (RMS).

APPLICATION
EXAMPLES

C. Three-phase Half Controlled Bridge Rectifier with Individual Fuses



Basic Information:

C 1. 200 A DC output

C 2. Nominal supply voltage 240 V RMS

C 3. Prospective fault current 14.000 A RMS

C 4. 100% overload for 20 sec.

C 5. Thyristor and diode particulars:

I^2t rating	SCR	20.000 A^2s
	Diode	22.000 A^2s
Peak current:	SCR	3.000 A
	Diode	2.600 A
Peak reverse voltage:		800 V

Basic Design:

1. RMS current per fuse is, according to Table 2, for a three-phase bridge I_{DC} x 0.58 = 200 x 0.58 = 116 A RMS.
2. Fuse selected:
   Without overload conditions, fuse 150 BF may be suitable. A check with Fig. 1 shows that 150 BF could carry 2.4 x I_n during 20 sec = 360 A (RMS). 150 BF is therefore good even for overload conditions. It is not necessary to use a bigger fuse.
3. I^2t:
   According to Fig. 3 and prospective current 14.000 A, I^2t = 10.000 A^2s, corr. 10.000 x 0.5 = 5.000 A^2s at 240 V RMS.
4. Cut-off current:
   Fig. 4 shows for 150 BF and a prospective current of 14.000 A a cut-off current of 5.000 A or corr. 2.500 A at 240 V.
5. Peak voltage:
   With Fig. 9 peak voltage will be 720 V at 240 V RMS.

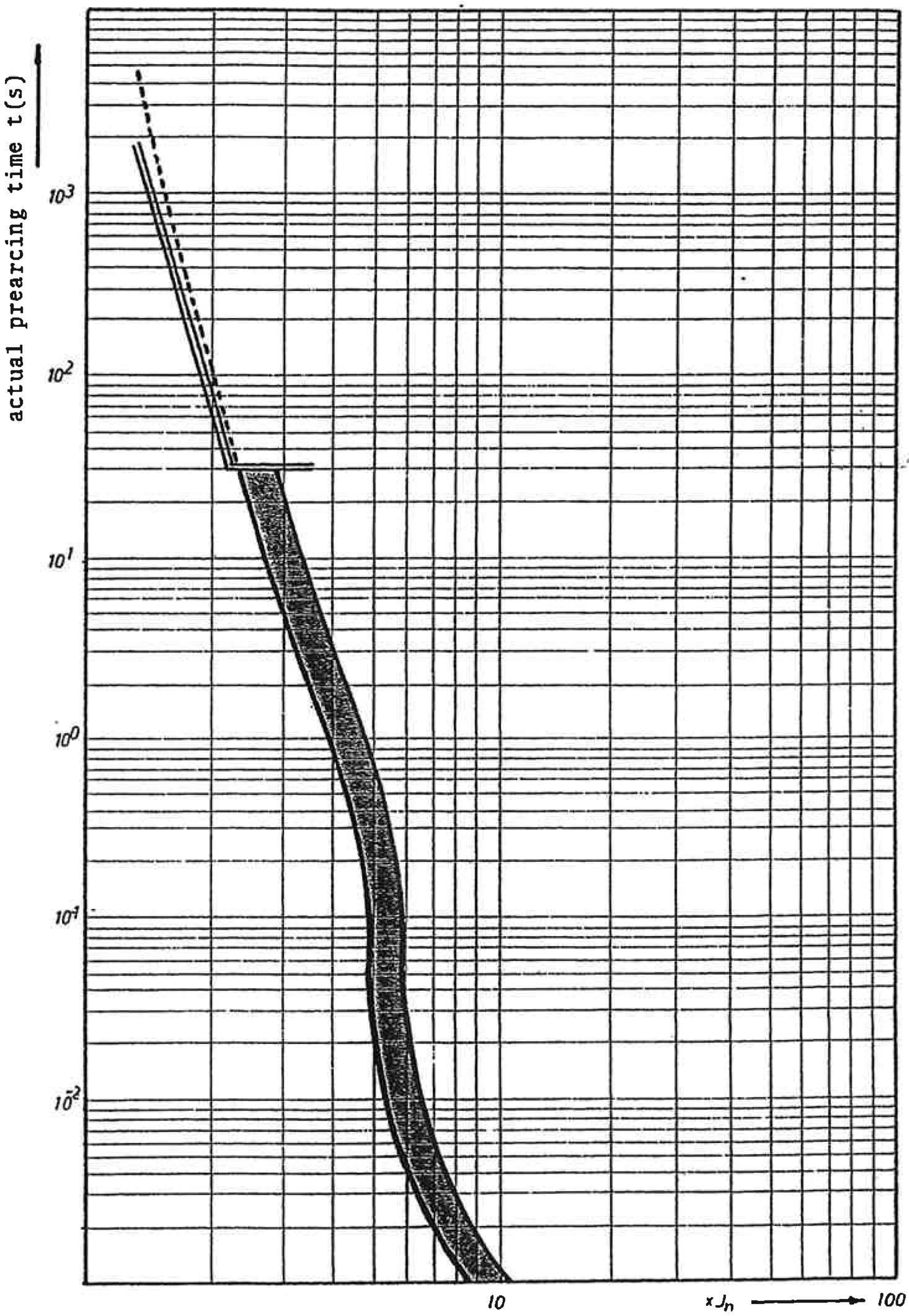
AC VOLTAGE RATINGS 550 V RMS

Fuse type	Max. current rating A	Losses at max. rating W	Max. cap. temp. at cont. ratings °C	Case style
45 AF	45	12	75	AF
55 AF	55	16	125	AF
65 AF	65	16	125	AF
75 AF	75	17	125	AF
90 AAF	90	28	125	AAF
110 AAF	110	28	125	AAF
150 AAF	150	28	125	AAF
150 BF	150	33	125	BF
200 BF	200	37	125	BF
250 BF	250	37	125	BF
200 BBF	200	42	125	BBF
275 BBF	275	60	125	BBF
300 BBF	300	66	125	BBF
350 BBF	350	66	125	BBF
400 BBF	400	75	125	BBF
500 BBF	500	75	125	BBF

AC VOLTAGE RATINGS 250 V RMS

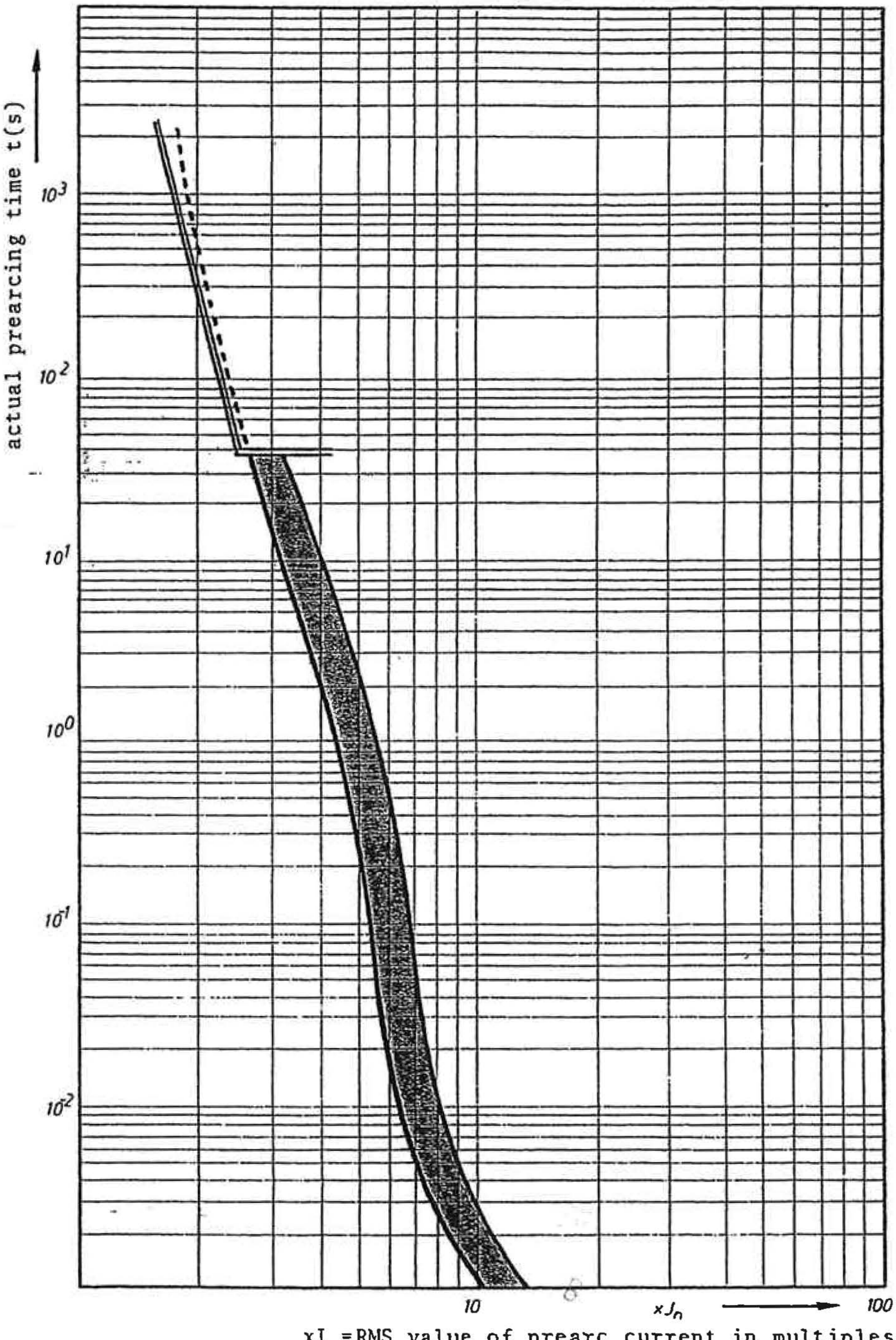
Fuse type	Max. current rating A	Losses at max. rating W	Max. cap. temp. at cont. ratings °C	Case style
25 NAF	25	3	100	NAF
35 NAF	35	4	100	NAF
60 NAF	60	8	100	NAF
75 NAF	75	9	100	NAF
100 NAF	100	10	100	NAF
125 NAF	125	14	100	NAF
150 NAF	150	15	100	NAF
200 NBF	200	25	100	NBF
250 NBF	250	26	100	NBF
300 NBF	300	28	100	NBF
350 NBF	350	30	100	NBF
400 NBBF	400	60	100	NBBF
500 NBBF	500	62	100	NBBF
600 NBBF	600	68	100	NBBF
700 NBBF	700	72	100	NBBF

Type BF, BBF, NBF, NBBF available with microswitch



xI_n=RMS value of prearc current in multiples of rated current

FIG. 1:
TIME/CURRENT CHARACTERISTICS FOR FUSES 45A TO 250A - 550V(RMS)



xI_n = RMS value of prearc current in multiples of rated current

FIG. 2:
TIME/CURRENT CHARACTERISTICS FOR FUSES 300A TO 1250A - 550V(RMS)

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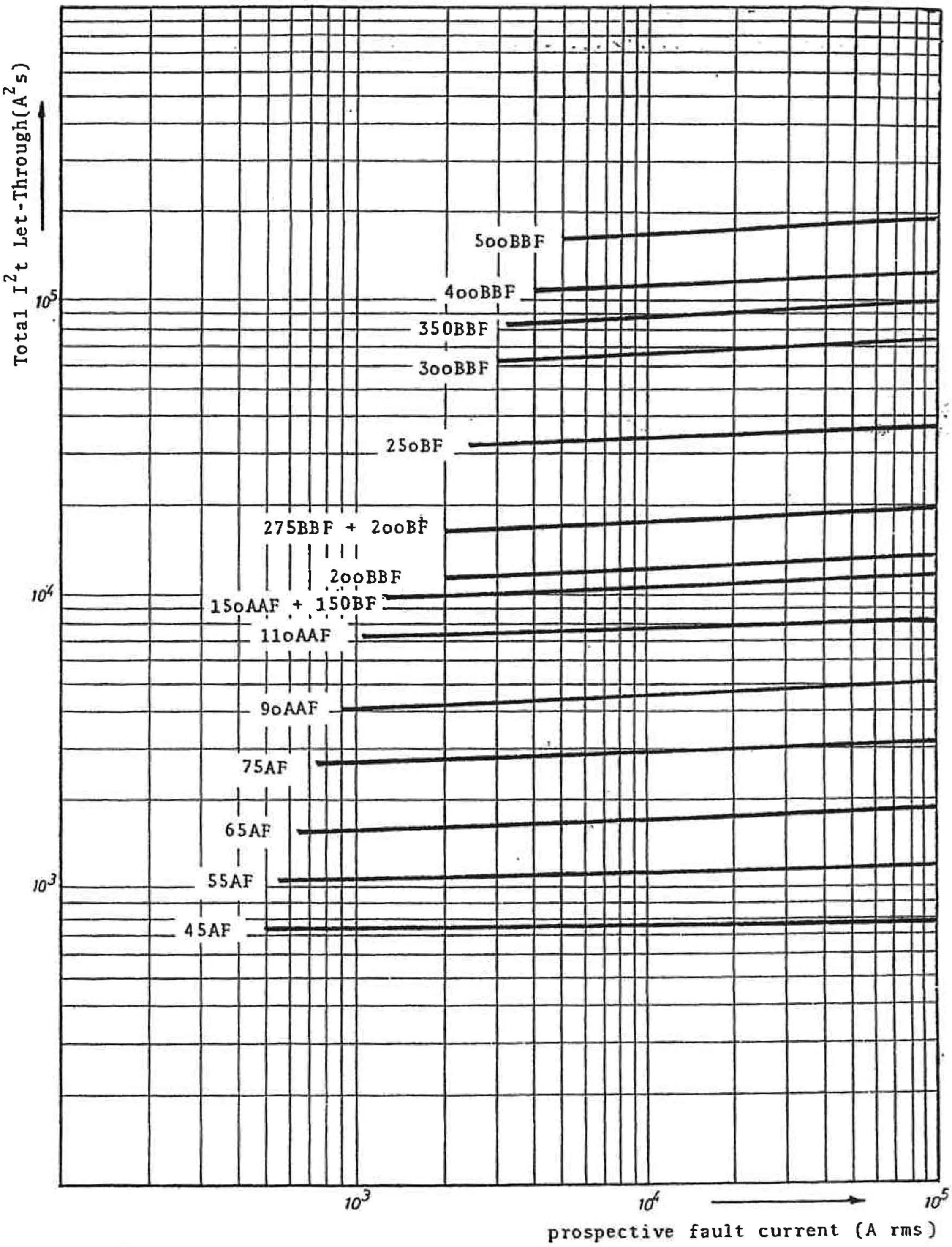

FIG. 3:
TOTAL I^2T LET-THROUGH AT 550V(RMS)

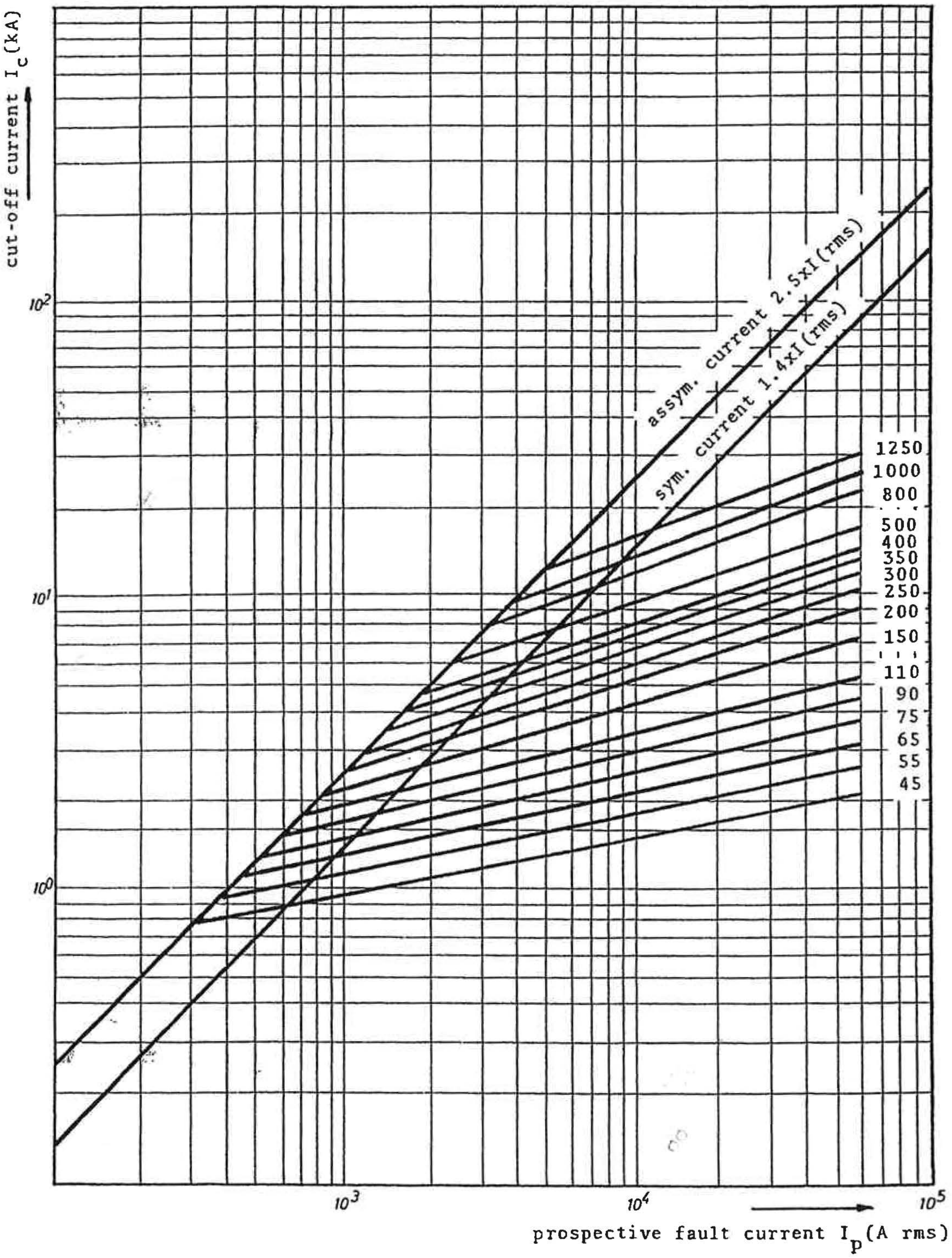

FIG. 4:
CUT-OFF CHARACTERISTICS AND CURRENT LIMITING 550V(RMS)

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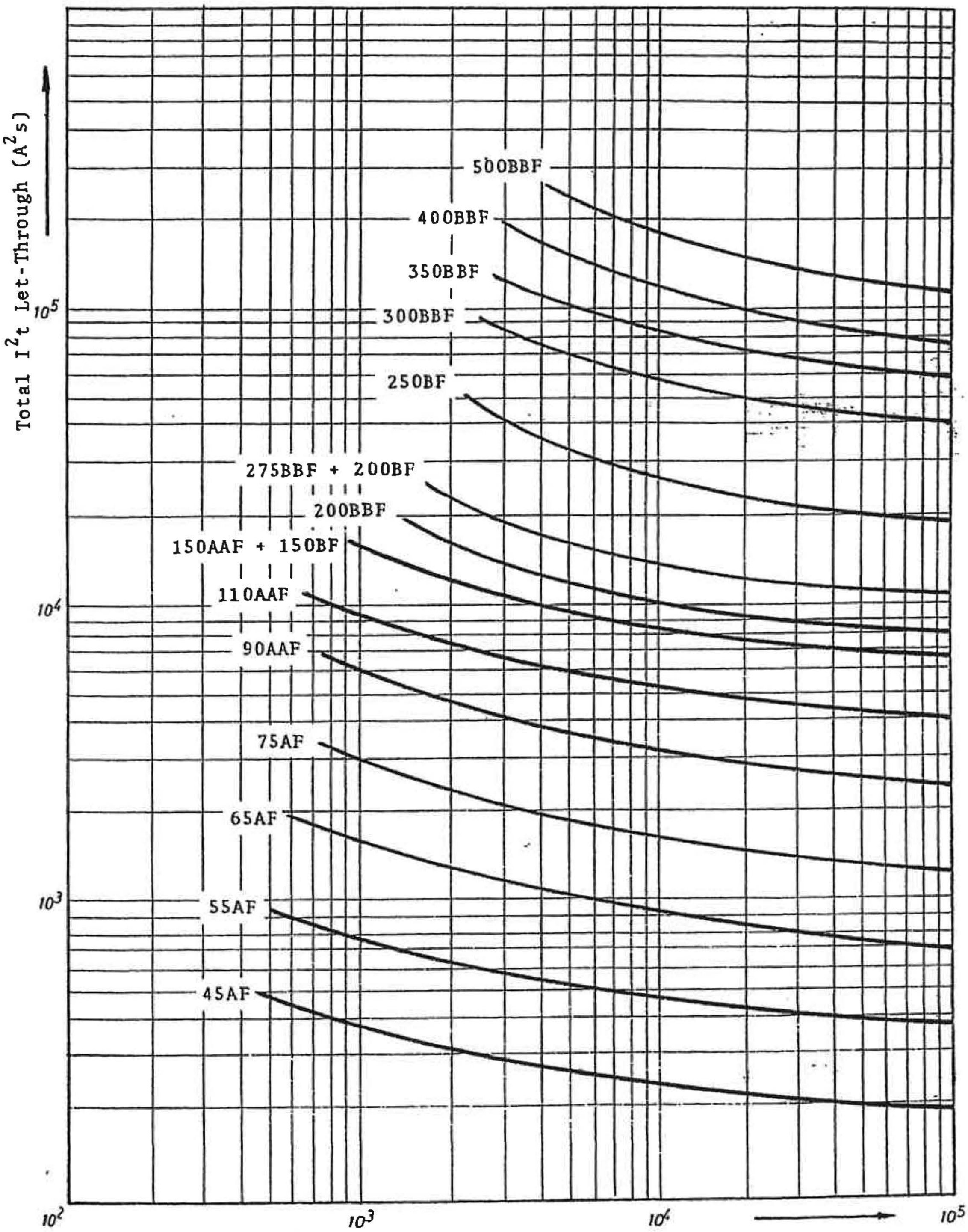

FIG. 5:
TOTAL I^2T LET-THROUGH AT 300V DC

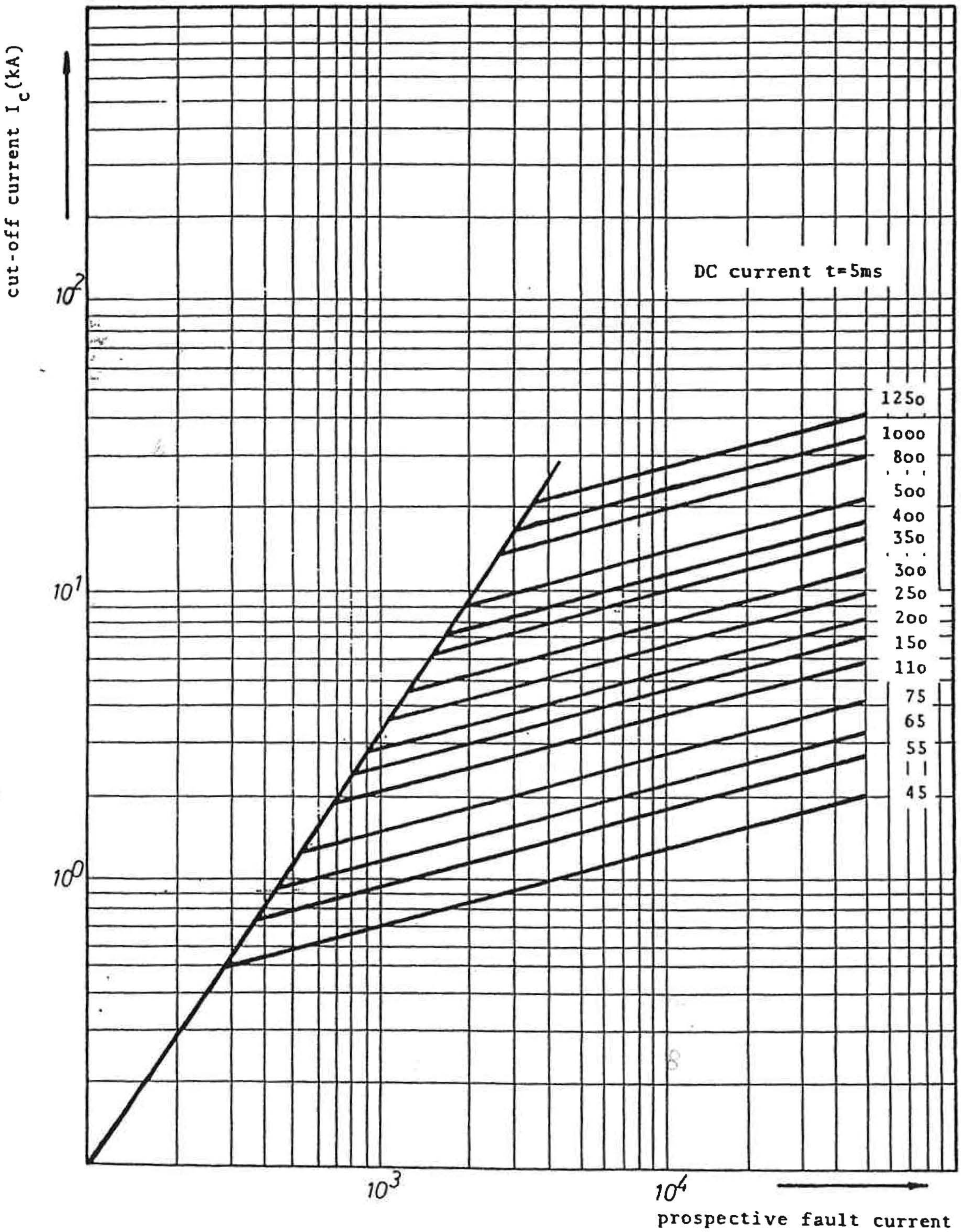

FIG. 6:
CUT-OFF CHARACTERISTICS AND CURRENT LIMITING PERFORMANCE 300 V DC

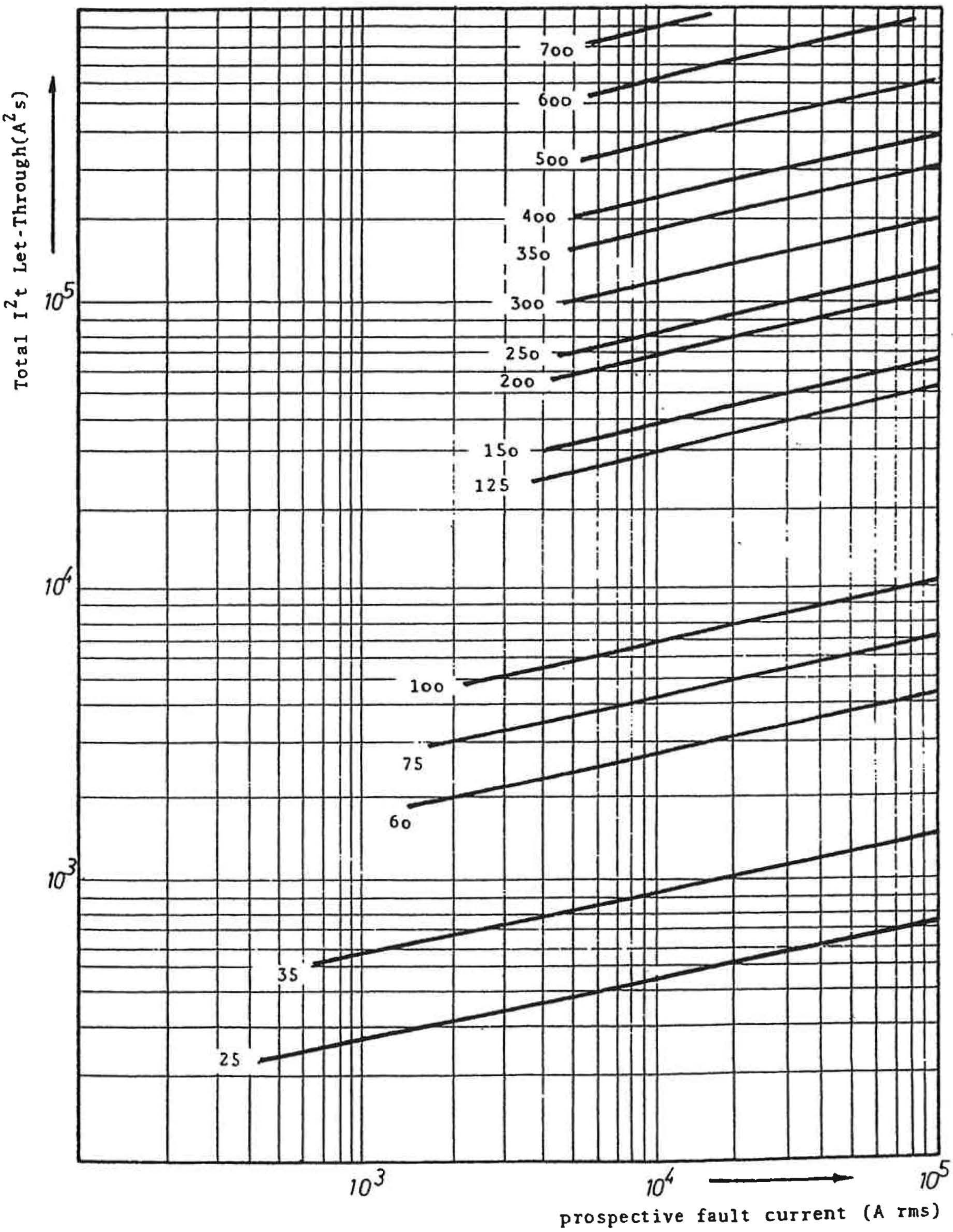

FIG. 10:
TOTAL I^2T LET-THROUGH AT 250 V (RMS)

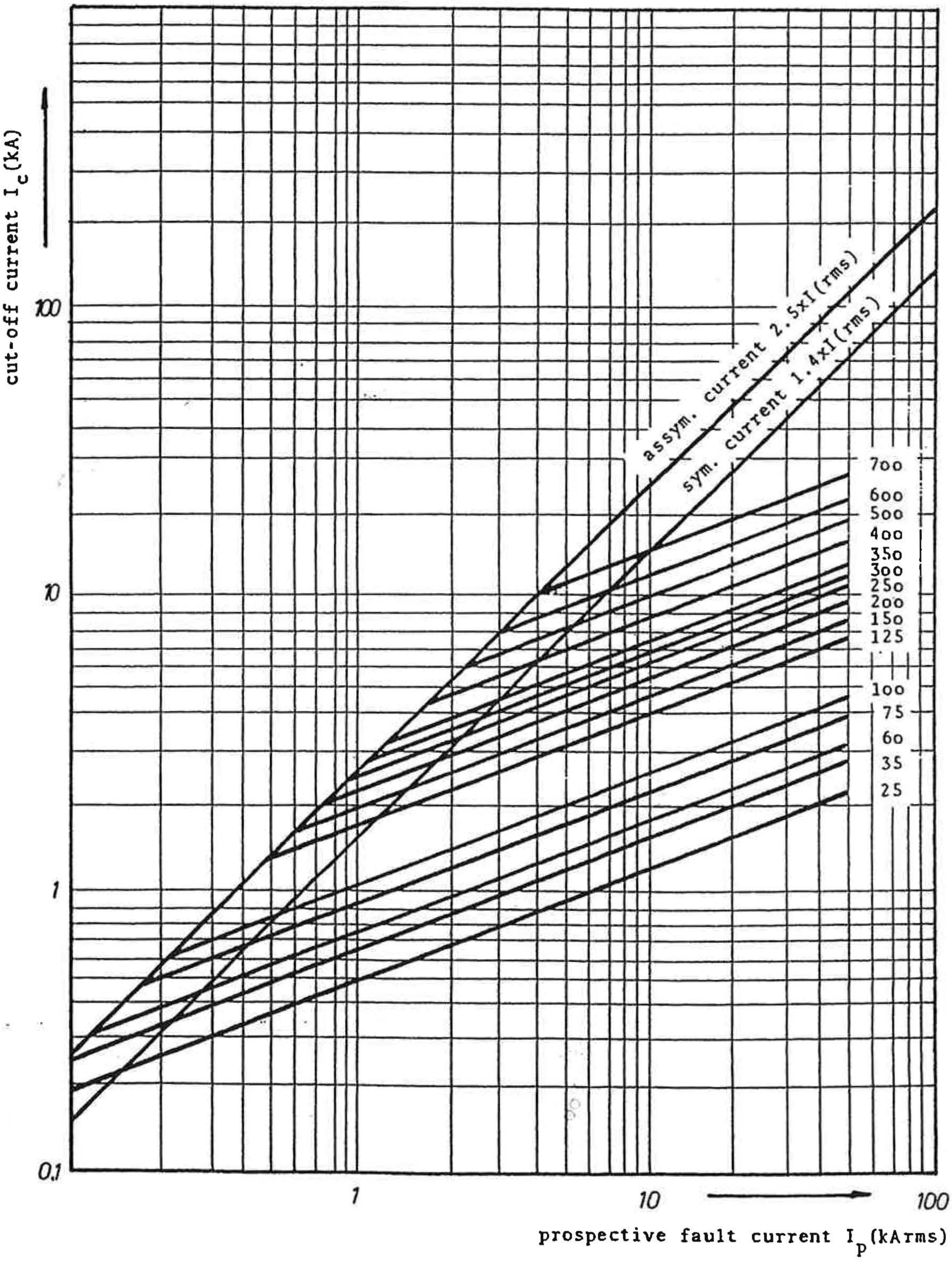

FIG. 11:
CUT-OFF CHARACTERISTICS AND CURRENT LIMITING PERFORMANCE 250 V (RMS)

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SEMICONDUCTOR FUSES

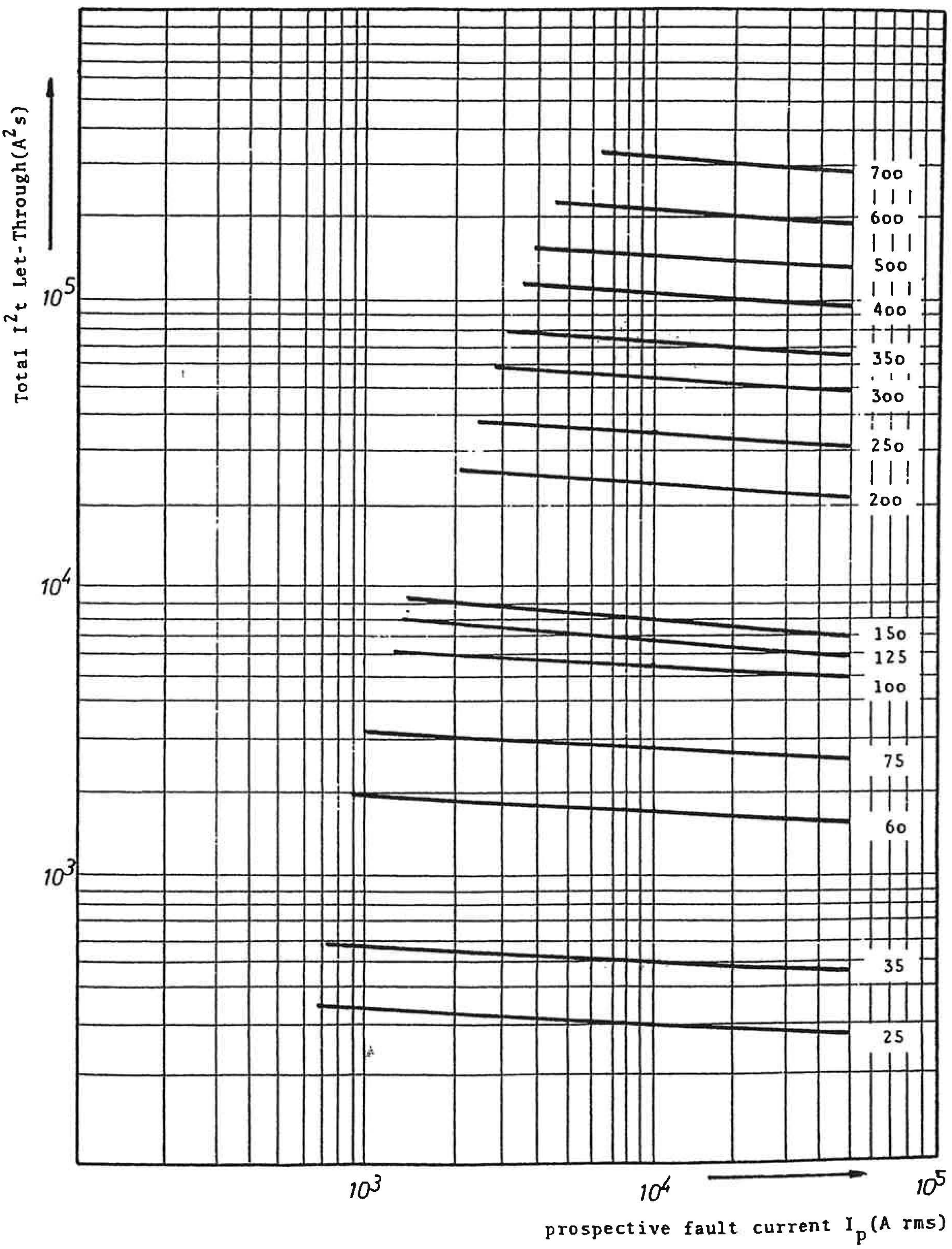


FIG. 12:
TOTAL I^2T LET-THROUGH AT 200 V DC

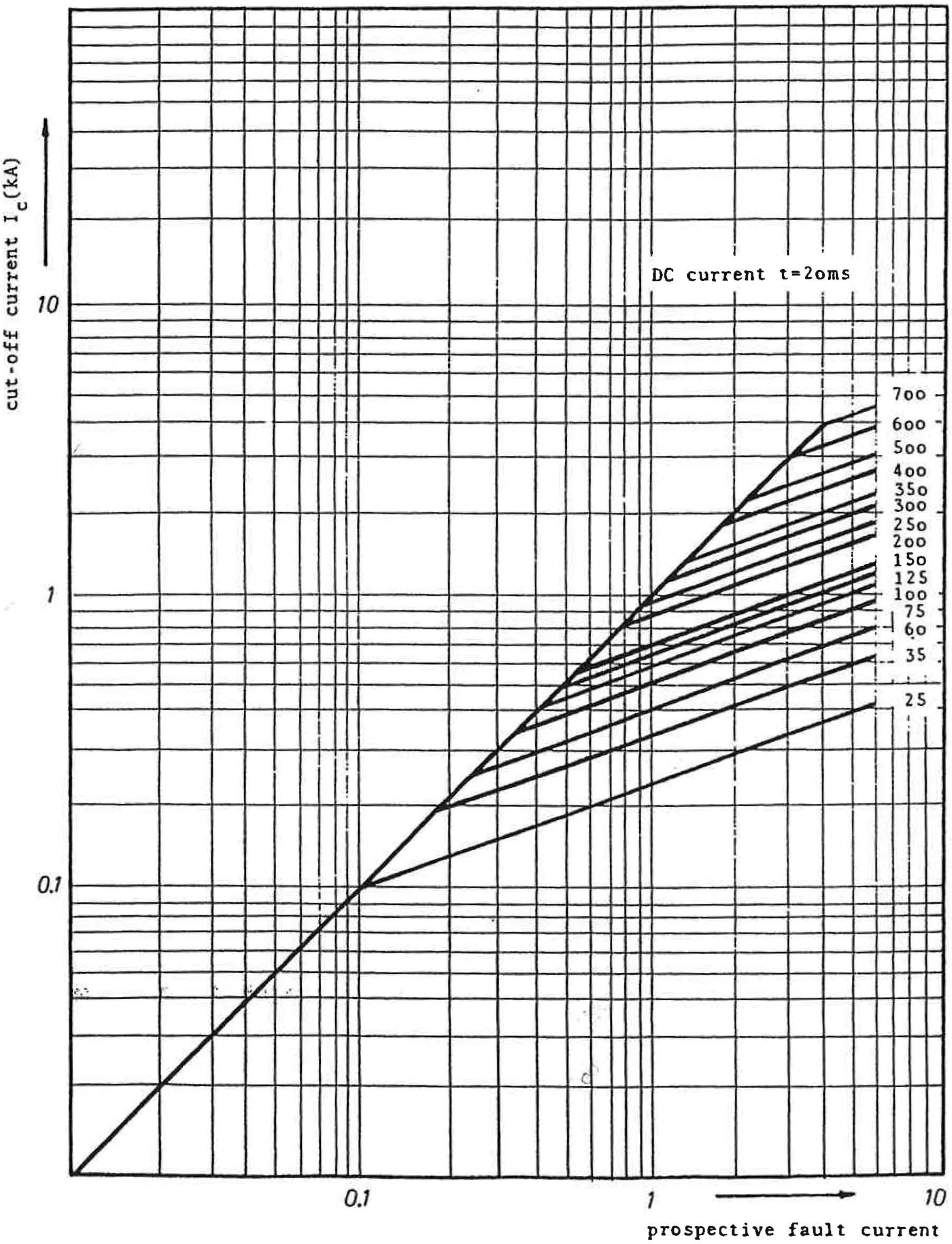


FIG. 13:
CUT-OFF CHARACTERISTICS AND CURRENT LIMITING PERFORMANCE 200 V DC

SEMICONDUCTOR FUSES

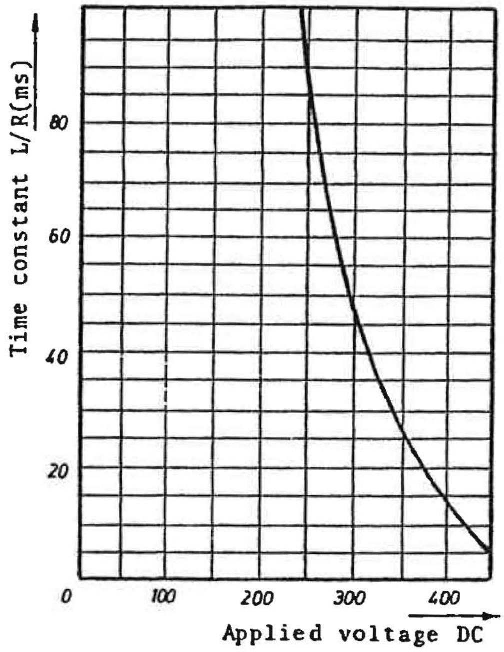


FIG. 7:
VARIATION OF APPLIED DC-VOLTAGE WITH TIME CONSTANT

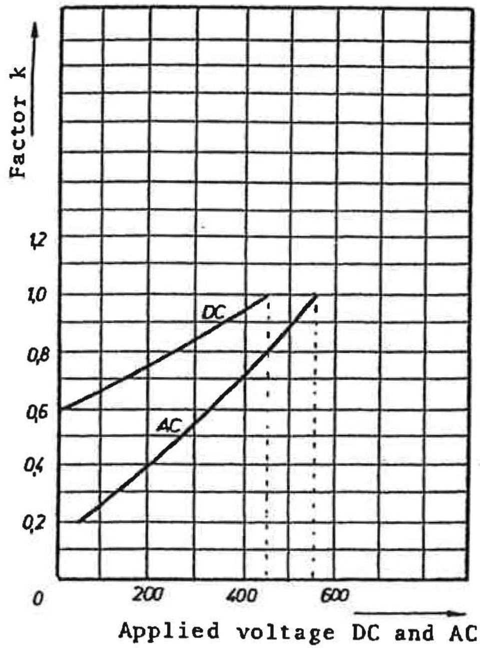


FIG. 8:
I^2T - CORRECTION FACTOR

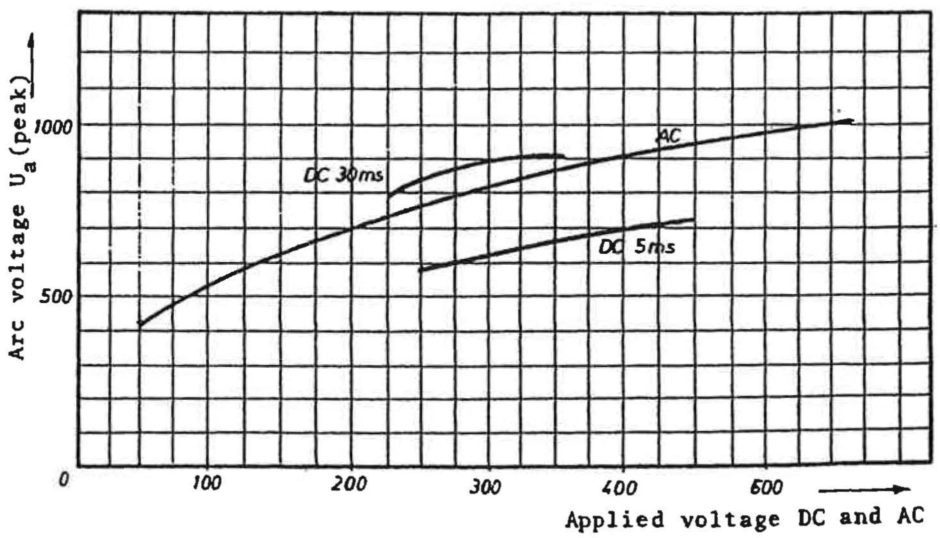
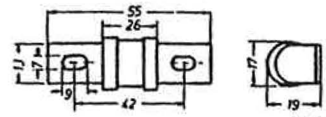
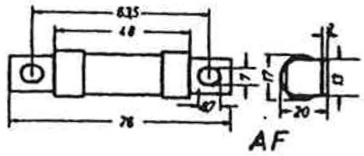


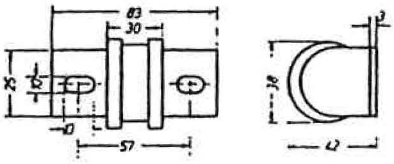
FIG. 9:
VARIATION OF ARC-VOLTAGE WITH APPLIED VOLTAGE



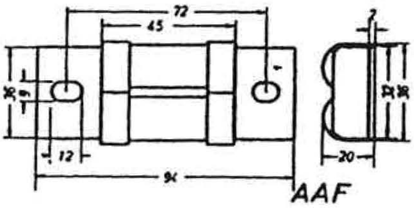
NAF



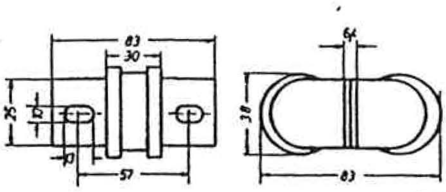
AF



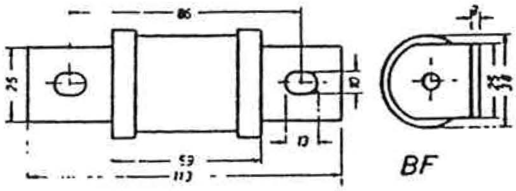
NBF



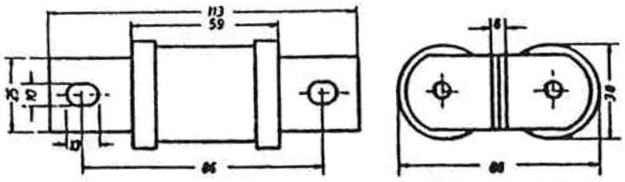
AAF



NBBF



BF



BBF

All dimensions in millimetres