FUSEGEAR ELECTRIC

HIGH SPEED HRC FUSE LINK
FOR
POWER SEMICONDUCTOR PROTECTION

250 V ~ 5 to 700 AMPS
600 V ~ 5 to 500 AMPS
1000 V ~ up to 1000 AMPS

Page No.

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INTRODUCTION

Power Semiconductors are associated with HRC fuse links (fast acting type) for their protection, due to their smaller thermal withstand capacity. These fast acting fuses allow a smaller I^2t let-through during fault conditions, and thereby protect the Semiconductor. The operation of these fuse links, is affected by the higher ambient temperature (because of the smaller space available in the semiconductor circuit panel for the dissipation of heat to the surrounding) and severe load duty cycle. The various types of fuses available for semiconductor protection and the fuse performance figures and the characteristic curves are described in detail in this brochure. A few examples are also given, on the method of selection of the fuse links.

PARAMETERS OF POWER SEMICONDUCTOR FROM THE PERFORMANCE POINT OF VIEW

Power Semiconductors such as rectifiers and thyristors are widely used in electrical traction, large power supply unit and in the motor drive circuits in Textile Industries, Cement Mills and Paper Mills. The prospective fault current in such installation is very high and the costly semi-conductors are liable to get damaged on the occurrence of a fault. Due to the smaller thermal withstand capacity of these devices (because of their smaller size) the energy let through by the protecting equipment in series with it, must be much lower than the device itself. The failure of the Semiconductor could be due to one of the following reasons :

a. Very high I^2t value let through by the fuse.
b. Very high current peak produced by the fuse.
c. Very high amount of reverse voltage developed by the fuse.
d. Low values of overload current for a long time.

To prevent this failure, fast acting type HRC fuse links are developed which have low I^2t, cut-off current and arc voltage compared to the device value.

All the manufacturers of Power Semiconductors specify the limiting values of the above parameters for their device. As the temperature produced by these devices during operations is very high (of the order of 150°C) the connected equipments, especially the rating of the protecting fuse must be properly selected as it is temperature-sensitive. From the four main parameters mentioned, it can be seen how they are useful in deciding the fuse rating for protection, in the next chapter.

FUSE LINK FOR SEMICONDUCTOR PROTECTION

General purpose HRC fuse links are not normally used for Power Semiconductor protection as they do not give adequate protection, because of their higher energy let through. An improved and specially designed version of the former type is fast acting HRC fuse links, which are being used with power semiconductors.

For power semiconductor protection, two types of fuses are available. One is fast acting HRC fuse link, the other is ultra fast acting fuse link. The former type is used for "internal protection" in high power equipments. Here, the fuse usually eliminates an overcurrent fault, following the failure of a semiconductor. The purpose of the fuse is to disconnect the faulty Semiconductor and protect the other devices.

The latter type, i.e. ultra fast acting fuses act very fast with minimum energy let through. These are used for "total protection", basically, to protect the Semiconductors when subjected to overload fault.

The fuses have been designed and tested to international specifications. The actual service conditions differ far from the designed conditions. As an example, the load that will be connected to the fuse may be cyclic overload or variable load as in the case of motor drive circuits. The fuses have also been tested for pulse withstand capabilities and overloads. The normal tests were carried out at a room temperature, of 25°C to 30°C. For higher ambient temperature application, (the temperature inside the panel of high power rectifier drive circuits may be of the order of 50 to 55°C), proper correction factors are taken into account to fix the rating.

The following characteristic curves define the fuse behaviour. Basically there are two ranges of fuses in English type i.e. 250 volt and 600 volt range. For higher current requirement double body fuses are suitable, which give low cut-off and I^2t values.

1. **Time - current characteristics**
   It helps in finding out the time required for clearing a particular overload fault.
2. **Operating I^2t characteristics**
   This gives the variation of energy let through by the fuse with different prospective fault current. This graph is useful when comparing the I^2t value with that of the semiconductor device value.
3. **Cut-off current characteristics**
   The peak value of the current let through by the fuse is obtained from this graph for any particular prospective current. This value must be smaller than the IFSM value of the semiconductor device.
4. **Arc Voltage Characteristics**
   The relationship between the peak arc voltage generated by the fuse at various applied voltage is given here. This is compared with the devices, peak inverse voltage.
5. **Variation of I^2t with Applied Voltage**
   As the I^2t is a function of the voltage, a relationship between the applied voltage and I^2t value at these points is given here. The fuse value will be compared with the device I^2t withstand.
6. **Pre-Arcing I^2t**

This value is given in Annexure II for all the rating of fuses. This data is useful when comparing the operation of the fuses of different rating in a circuit.

SELECTION AND CO-ORDINATION OF FUSE LINK WITH THE SEMICONDUCTOR DEVICE

The steps for selecting the fuse link are listed below:

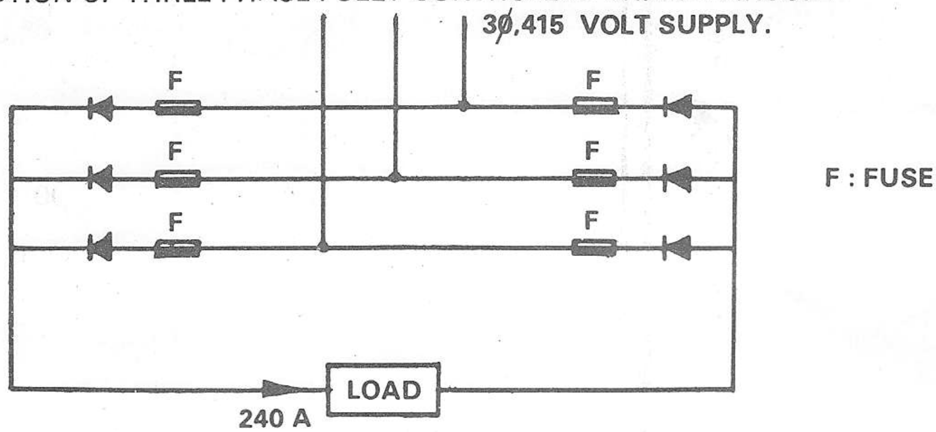
1. Note down the semiconductor device information such as IFSM, I^2t, VRSM etc.
2. Type of the circuit in which the device is used. From the Annexure I, corresponding to the circuit, note down the various values.
3. Choose a fuse link whose voltage and current rating are slightly higher than the semi-conductor value.
4. Calculate the prospective short-circuit current expected to flow in the circuit, knowing the percentage impedance of the source.
5. With the above prospective current, obtain the I^2t let-through by the fuse, from the I^2t characteristics of the fuse. This must be smaller than the device withstand value.
6. Obtain the peak value of the let through current by the fuse from the fuse cut off current characteristics. This value must be lesser than the Transient current withstand value (IFSM) of the device.
7. Note down the arc-voltage developed by the fuse from the Arc-voltage characteristics, knowing the voltage at which the device operates. This value must be less than the Non-repetitive peak reverse voltage (VRSM) of the device.
8. The fuse rating selected thus, to conditions 5, 6 and 7 will protect the device. If there is any deviation from the conditions, select the next nearest rating. As the ambient temperature and load duty cycle play a vital role in the selection of the fuse, consult Works for the correct selection.

TECHNICAL DATA (ENGLISH RANGE FUSE)

Type Reference	Rated Voltage (in Volts)	Current rating (in Amps)	Power loss (in Watts)	Maximum Breaking capacity (kA rms)
SFA (SINGLE BODY)	240	5	1.4	100
	240	10	2.0	
	240	15	3.2	
	240	20	4.0	
SFC (SINGLE BODY)	300	25	4.2	100
	300	50	5.0	
	300	75	9.0	
	300	100	9.0	
	300	125	10.5	
	300	150	14.0	
	300	175	17.5	
SFE 3 (SINGLE BODY)	300	125	14.0	100
	300	150	16.0	
	300	200	20.0	
	300	250	25.0	
	300	300	29.0	
	300	350	33.0	
SFG3 (DOUBLE BODY)	300	400	36.0	100
	300	500	42.0	
	300	600	50.0	
	300	700	58.0	
SFB (SINGLE BODY)	600	5	2.0	100
	600	10	3.0	
	600	15	4.0	
	600	20	5.0	
SFD (SINGLE BODY)	600	25	5.5	100
	600	45	8.5	
	600	50	10.0	
	600	75	11.5	
SFF (SINGLE BODY)	600	100	9.0	100
	600	150	15.0	
	600	200	20.0	
	600	250	25.0	
SFJ (SINGLE BODY)	600	16	4.3	100
	600	25	5.5	
	600	30	6.2	
	600	35	7.5	
	600	40	8.0	
	600	50	10	
	600	55	11	
SFJ (TWIN BODY)	600	75	13.0	100
	600	85	13.5	
	600	110	16.0	
	600	150	20.0	
SFH (DOUBLE BODY)	600	175	20.0	100
	600	200	21.5	
	600	235	23.0	
	600	275	25.0	
	600	300	30.0	
	600	325	33.0	
	600	350	37.0	
	600	400	40.0	
	600	450	46.0	
	600	500	50.0	

EXAMPLES

1 PROTECTION OF THREE PHASE FULLY CONTROLLED BRIDGE CIRCUIT.



1.1. **Circuit Information :**

Input voltage	:	415 Volts AC, 3 phase
Percentage Impedance of transformer	:	6%
DC output current	:	240 Amps

1.2. **Device Information**

One thyristor is connected per arm.

I^2t withstand value : 30 x 10^3 Amp. sq.sec.

(IFSM) Max. non repetitive forward surge current : } 2400 Amps

(VRSM). Max. non repetitive peak reverse voltage : } 1200 Volt

1.3. **Procedure for selection of fuselink**

From the load diagram, we have the following relationships.

$\frac{I_{ac1}}{Idc} = 0.816$ ie $I_{ac1} = 195$ Amps

$\frac{I_{ac2}}{Idc} = 0.577$ ie $I_{ac2} = 138$ Amps

1.3.1 The Maximum short circuit current that is likely to flow during fault conditions

$$= 195 \times \frac{100}{6}$$

$$= 3250 \text{ Amps}$$

1.3.2. Choose a fuse link of rating, nearly equivalent to the line current (or the device nominal rating) which it is going to carry. So we get SFH/200 as the nearest/rating.

1.3.3. From the characteristics of SFH/200, we get I^2t let-through, cut-off and peak arc voltage at 415 volts and prospective fault current of 3250 Amps.

I^2t let-through = 16.8 x 10^3. This is much smaller than the device I^2t withstand capacity.

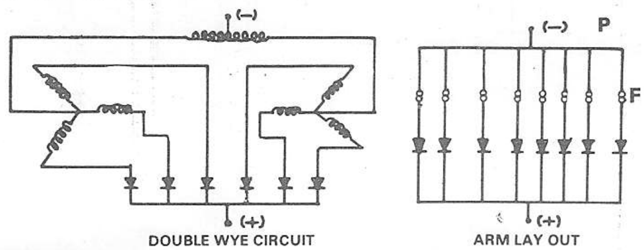
1.3.4. Cut-off current = 2.7 KA. This is also much smaller than the device peak withstand current (ie 4800 Amps assuming a factor of 2)

1.3.5. Peak arc voltage = 615 volt. This value is also very much lower compared to the device Non repetitive peak reverse voltage.

1.4. From the above steps it is found that SFH/200 is the right choice for the above circuit.

2. PROTECTION OF POWER RECTIFIER CIRCUIT.

The diagram of the circuit is shown below :



2.1 Circuit Information :

Three phase double wye rectifier connection.
AC voltage (line to line) : 185 Volt.
Transformer percentage inpedance : 8%
DC output current : 8000 Amps
8 diodes per arm. One fuse in series with each diode.

2.2 Device Information

Continuous current rating of the semiconductor : 350 Amps
I^2t withstand capacity of the semiconductor : 240 x 10^3 Amp. sq. sec.
Maximum Non repetitive forward surge current (IFSM) : 6230 Amps
Maximum Non repetitive peak reverse voltage (VRSM) : 1200 Volts

2.3 Analysis of the circuit.

2.3.1 Knowing the circuit arrangement we have the following relationships from Annexure I
The rms value of line current = 8000 x 0.289 = 2312 Amps

The magnitude of the arm current = 2312 Amps

2.3.2 From the transformer percentage impedance the maximum fault current is given by :

$$= 2312 \times \frac{100}{8}$$

$$= 28{,}900 \text{ Amps}$$

2.3.3 The avaerage value of rectified current per arm = 8000 x 0.167
= 1336 Amps

2.3.4 In order to get the required arm current of 2312 Amps a number of diodes are connected in parallel. (ie 8 diodes are in parallel)
In the event of failure of one path, the actual current through the other paths

$$= \frac{2312}{7} = 330 \text{ Amps}$$

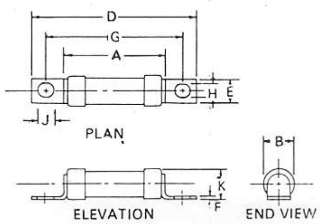
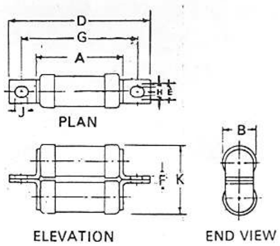
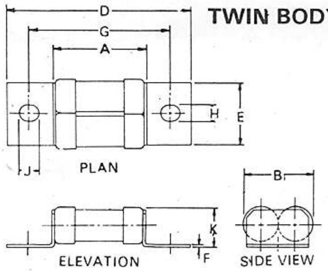
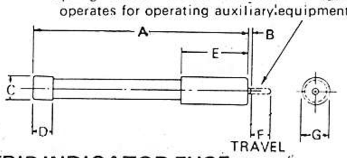
Expected short circuit fault current $= \frac{28{,}900}{7} \backsim 4130$ Amps

2.3.5 Choosing now SFE3/350A in series with each diode, the I^2t let through at 4130 Amp and 185 Volts = 77 x 10^3 Amp. sq. secs.
This is lesser than the I^2t withstand value of the device

2.3.6 The cut-off current value is 5 kA. This is also lesser than the peak withstand current of the device.

2.3.7 Peak arc voltage at 185 volts is 460 volts which is also lesser than the Non repetitive peak reverse voltage.
The rating SFE 3/350 will protect the device positively.

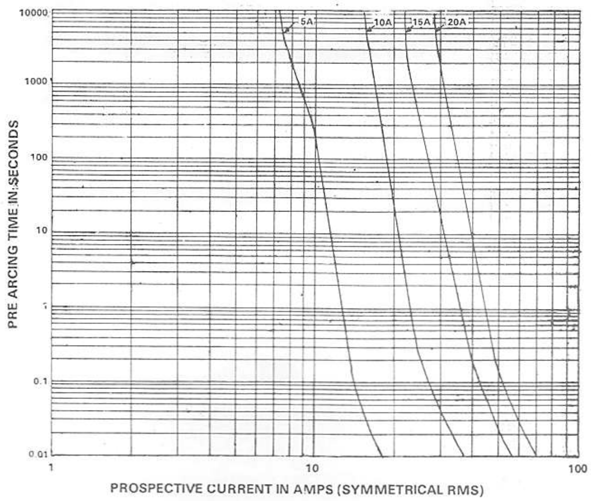
OVERALL DIMENSIONS OF FUSE

	TYPE	RATING AMPS	A	B	C	D	E	F	G	H	J	K
SINGLE BODY 	SFA	5 to 20	28 ± 1.0	8.2	—	46 ± 1.0	6.4	0.8	38 ± 0.5	4	4.8	8.8
	SFB	5 to 20	54 ± 1.0	8.2	—	74 ± 1.0	6.4	0.8	64.3 ± 0.5	4	4.8	8.8
	SFC & SIFC	25 to 175	29 ± 1.0	17.5	—	58 ± 1.0	12.6	2	41.8 ± 0.5	6.4	8	19
	SFD & SIFD	25 to 75	50 ± 1.0	17.5	—	78.5 ± 1.0	12.6	2	63.5 ± 0.5	6.4	8	19
	SFE3 & SIFE3	150, 200 250, 300 350	31.5 ± 1.0	38.5	—	84 ± 1.0	25.4	3.2	59 ± 1.0	10.3	13	41.5
	SFF & SIFF	100, 150 200, 250	59 ± 1.0	38.5	—	113 ± 1.0	25.4	3.2	83 ± 1.0	10.3	13	41.5
	SFJ & SIFJ	15 to 55	50 ± 1.0	17.5	—	78 ± 1.0	12.6	2	63 ± 1.0	6.4	8	19
DOUBLE BODY 	SFG3 & SIFG3	400 500 600 700	32.5 ± 1.0	38.5	—	84 ± 1.0	25.4	6.4	59 ± 1.0	10.3	13	88 ± 1.0
	SFH & SIFH	175 200 225 235 275 300 325 350 400 450 500	59 ± 1.0	38.5	—	113 ± 1.0	25.4	6.4	83 ± 1.0	10.3	13	88 ± 1.0
TWIN BODY 	3FJ & SIFJ	75 To 150	47 ± 1.0	36	—	94 ± 1.0	32	1.6	70 ± 0.5	8.7	10.3	19
TRIP INDICATOR FUSE 	SF 400	300 V	47 ± 1.0	0.8	6.4	5.6	19	5.6	7.9	—	—	—
	SF 500	1000 V	61 ± 1.0	0.8	6.4	5.6	19	5.6	7.9			

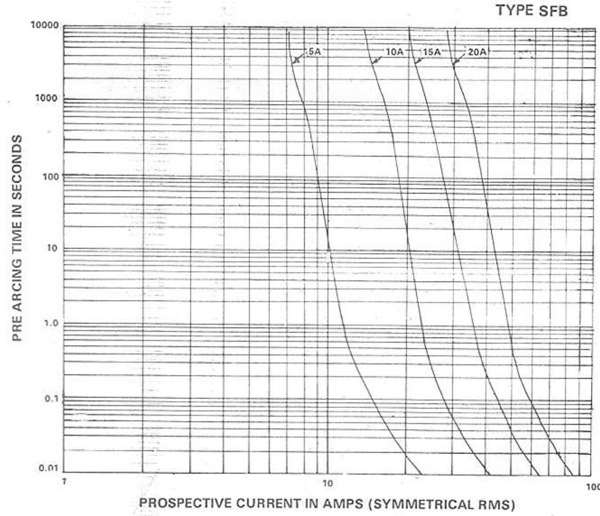
SIFC, SIFD, SIFE3, SIFF, SIFG3 SIFH and SIFJ are with indicator.

TIME CURRENT CHARACTERISTICS

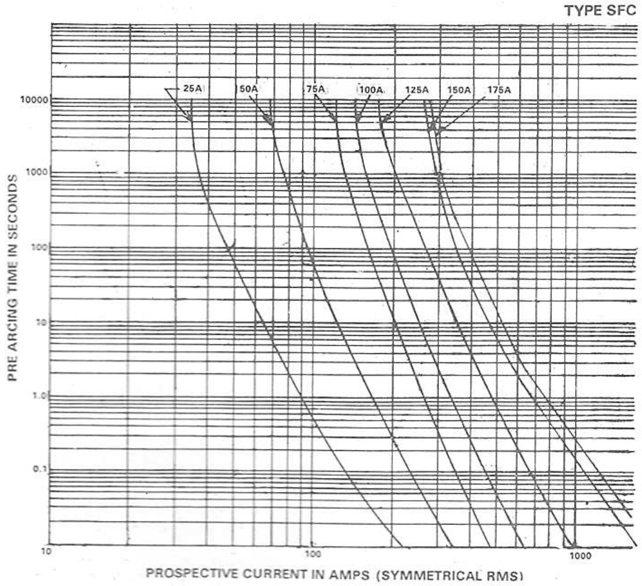
D-1
TYPE SFA



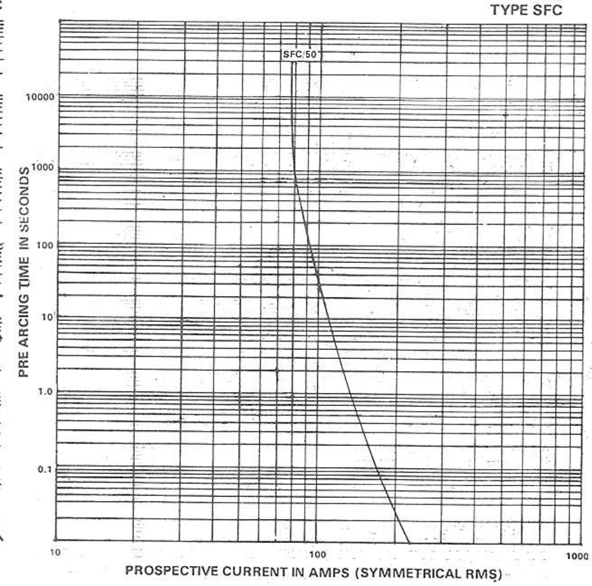
D-1
TYPE SFB



D-1
TYPE SFC

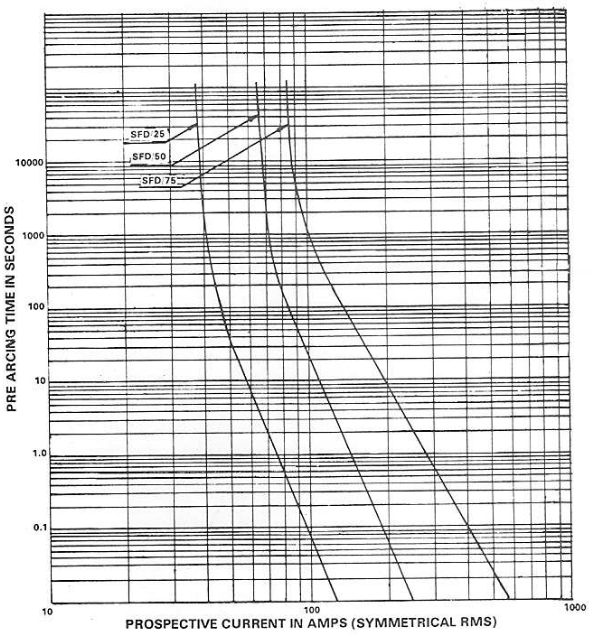


D-2
TYPE SFC

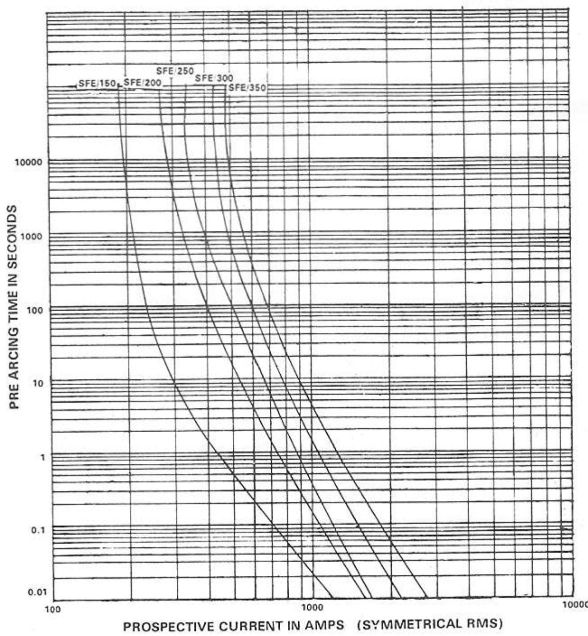


TIME CURRENT CHARACTERISTICS

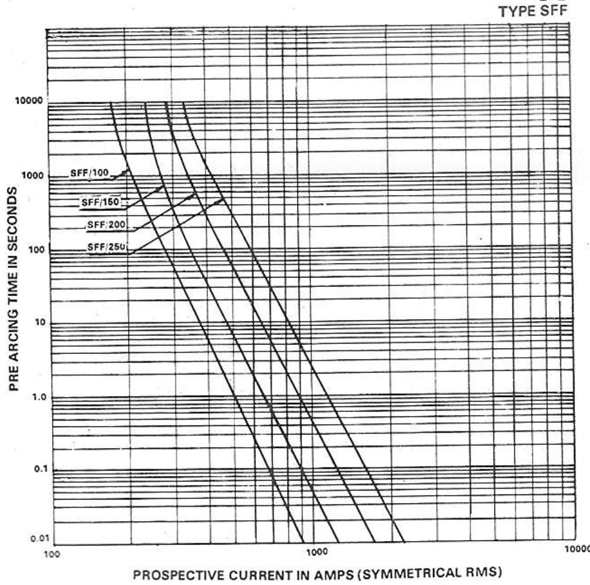
TYPE SFD



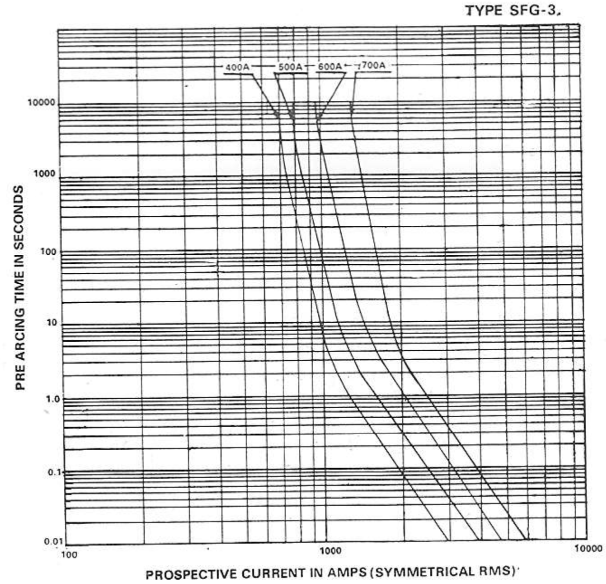
D-1
TYPE SFE-3



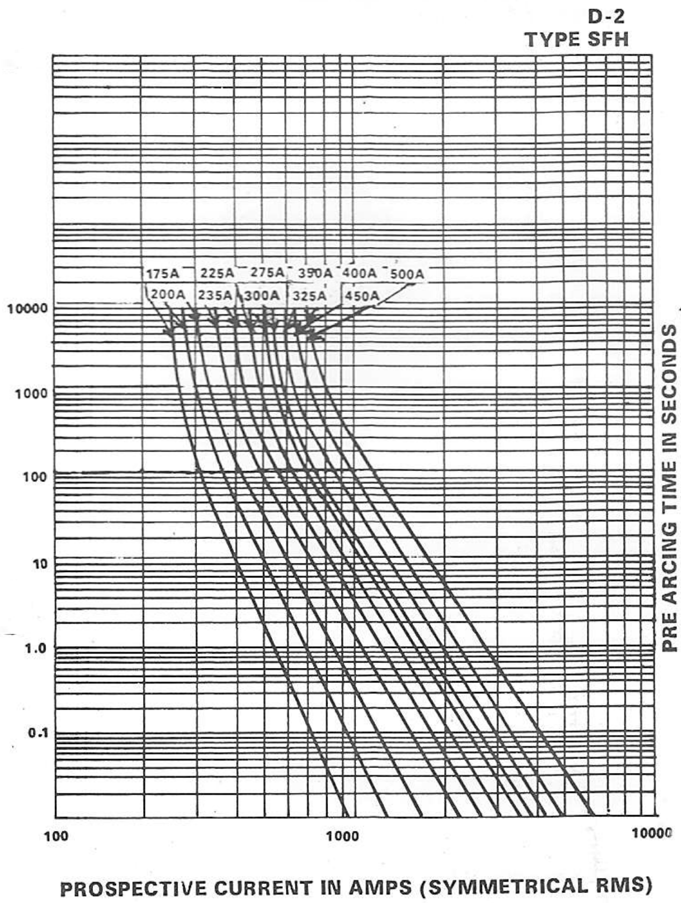
D-2
TYPE SFF

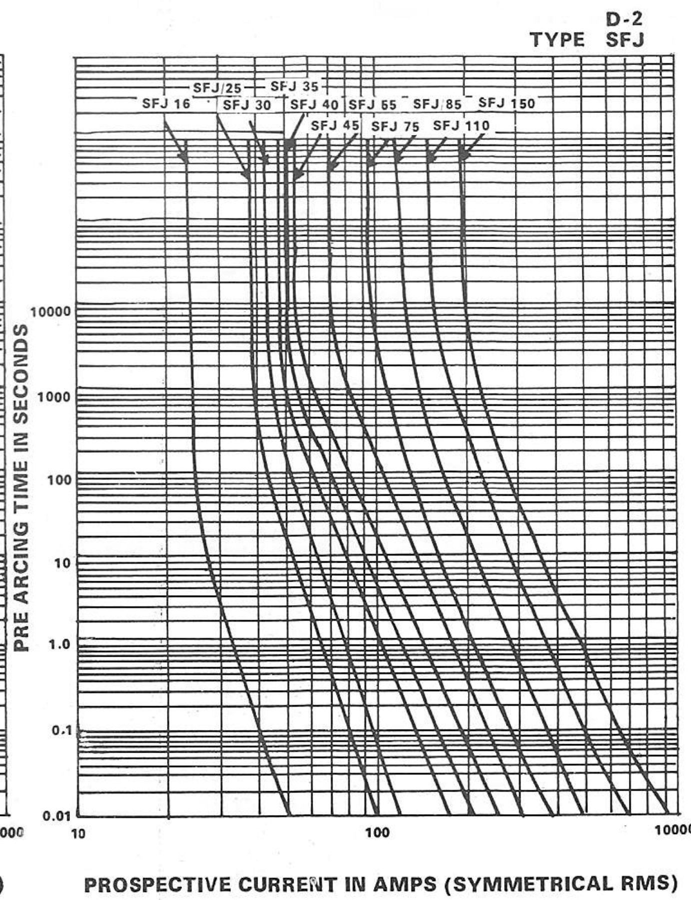


D-1
TYPE SFG-3



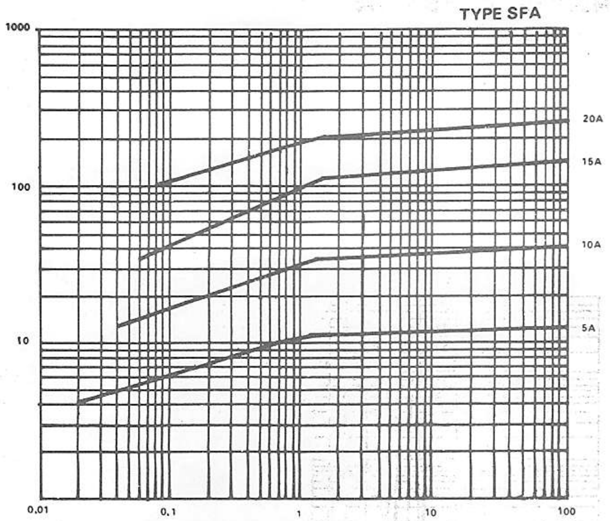
TIME CURRENT CHARACTERISTICS





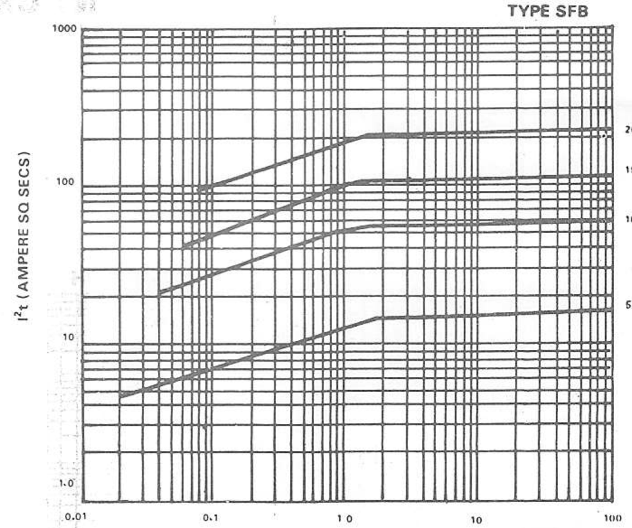
I² t VARIATION WITH PROSPECTIVE CURRENT

D-1
TYPE SFA

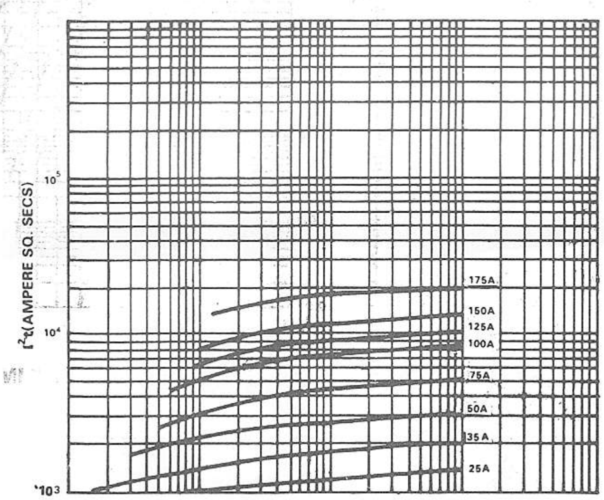


PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

D-1
TYPE SFB

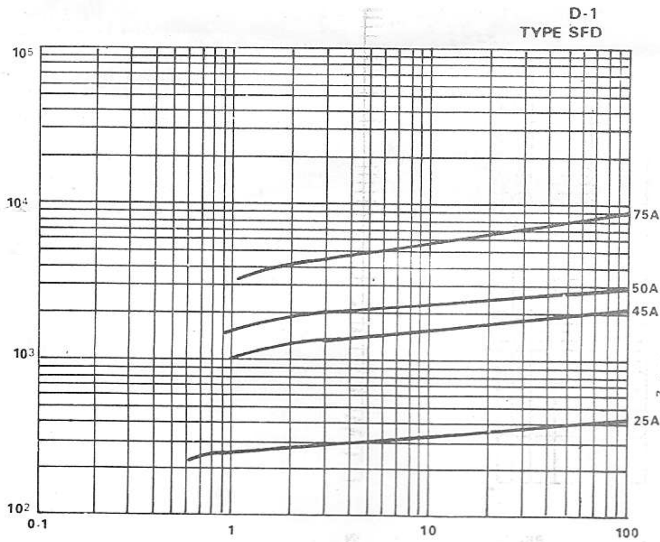


PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

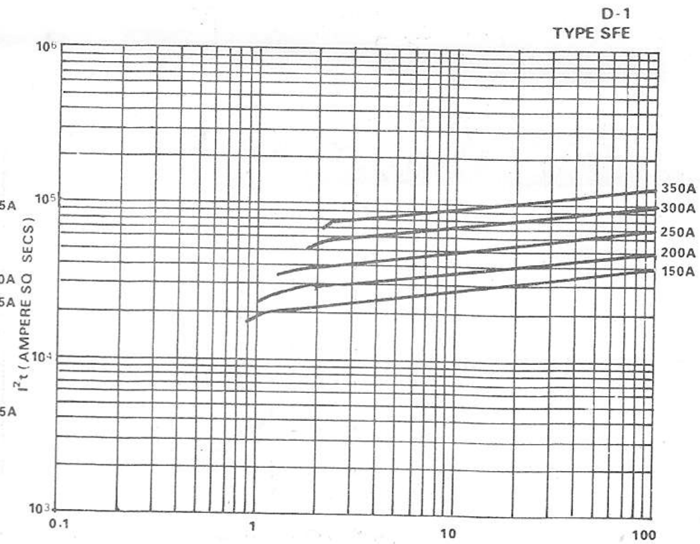


PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

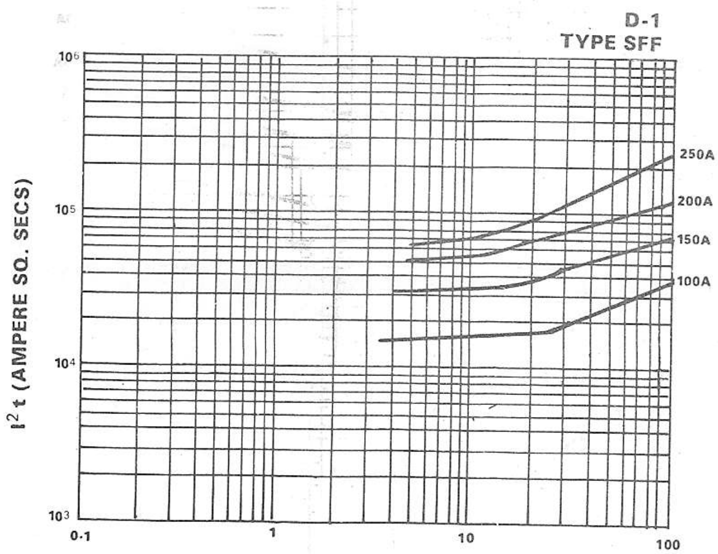
$I^2 t$ VARIATION WITH PROSPECTIVE CURRENT



PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)



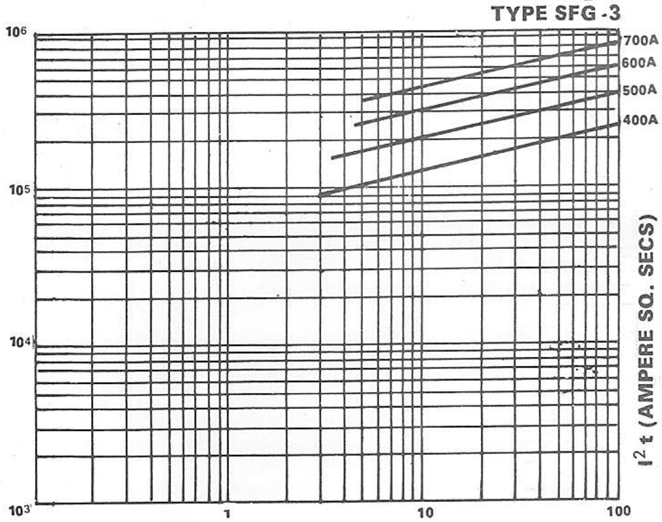
PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)



PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

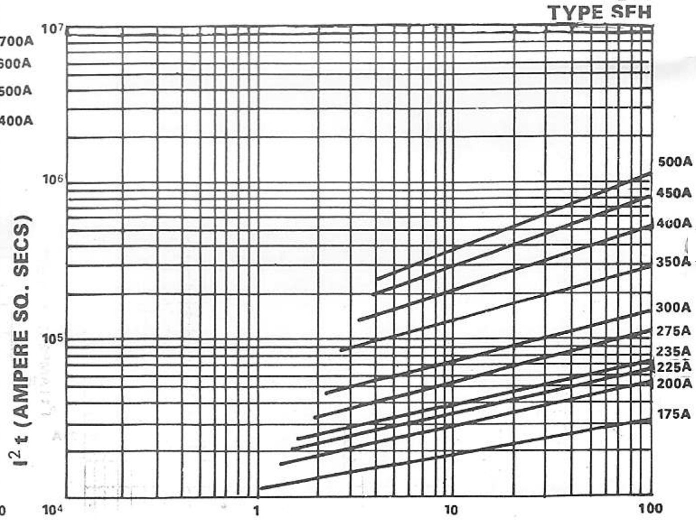
I^2t VARIATION WITH PROSPECTIVE CURRENT

D-1
TYPE SFG-3



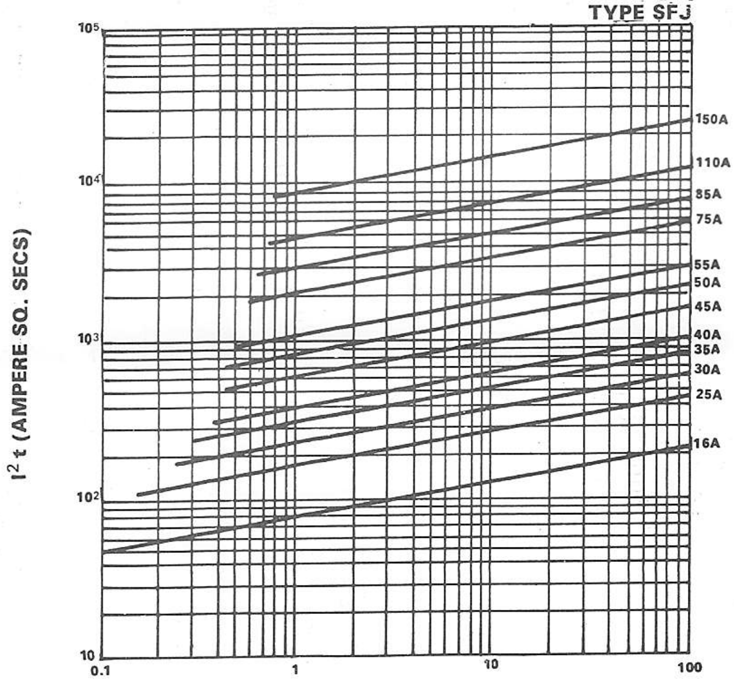
PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

D-1
TYPE SFH



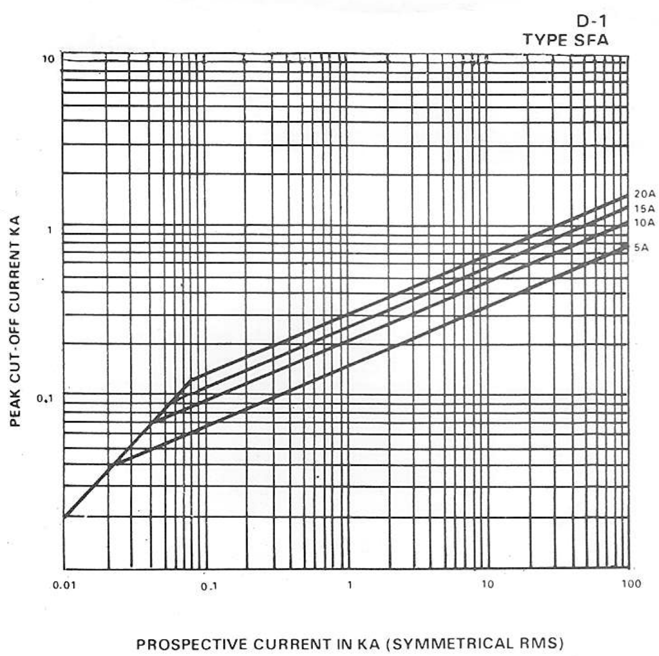
PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

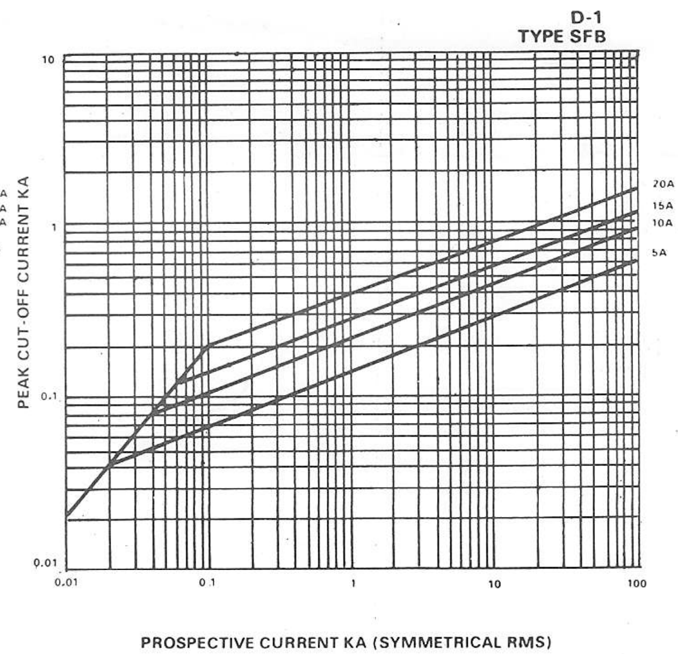
D-1
TYPE SFJ

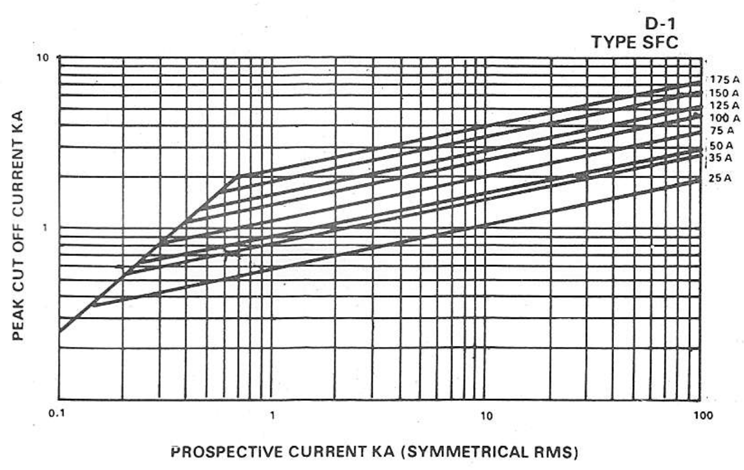


PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

CUT OFF CURRENT CHARACTERISTICS

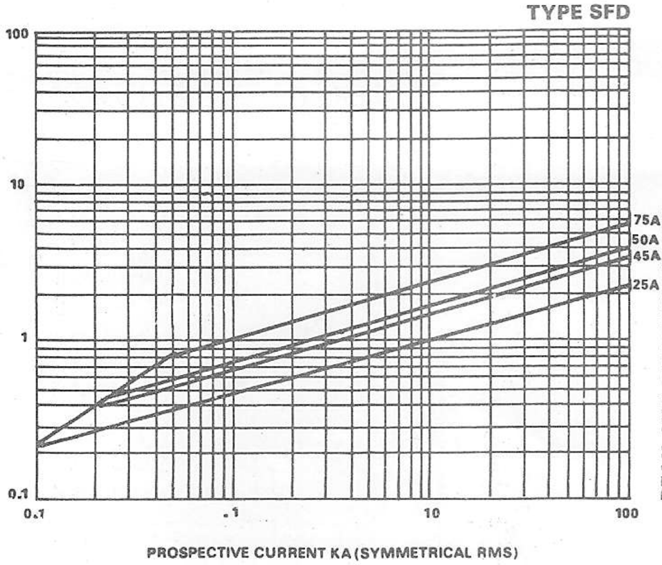






CUT OFF CURRENT CHARACTERISTICS

D-1
TYPE SFD



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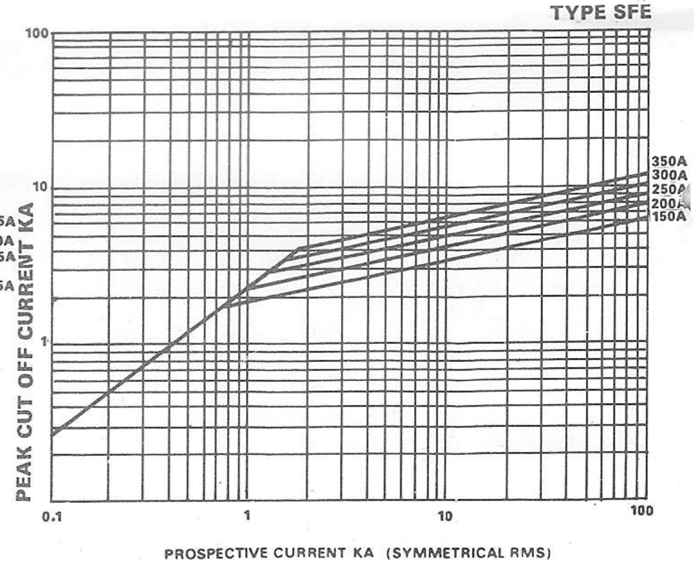
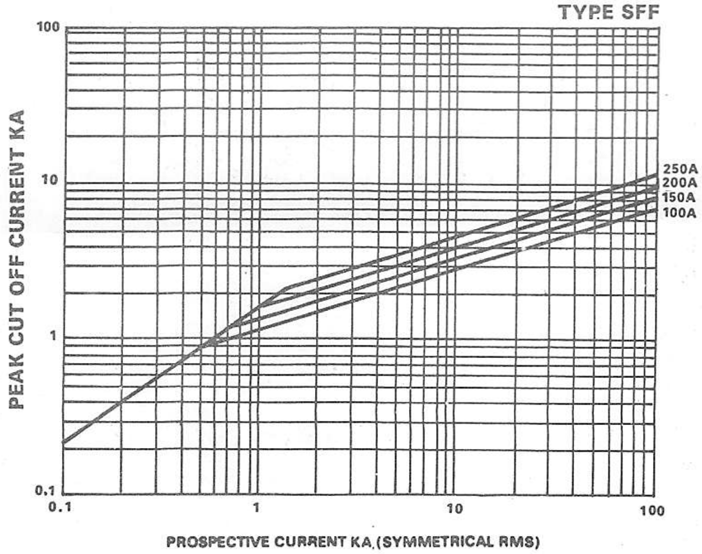
TYPE SFE

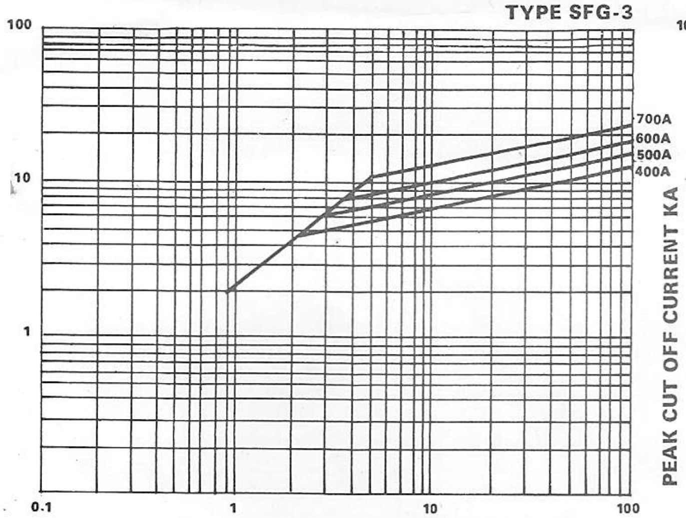


D-1
TYPE SFF



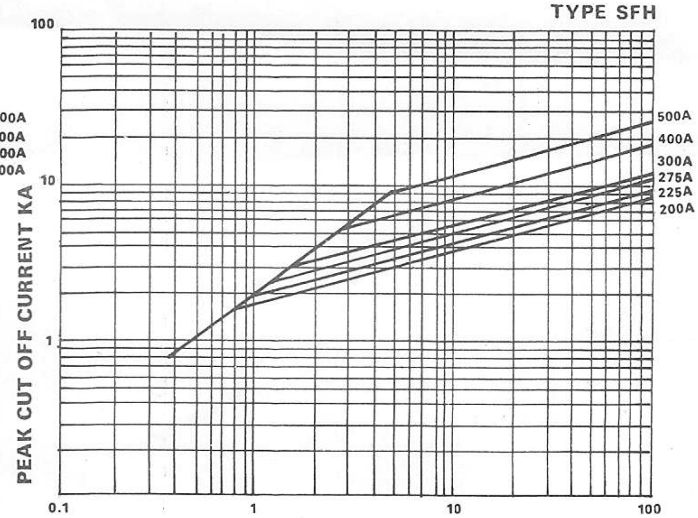
CUT OFF CURRENT CHARACTERISTICS

D-1
TYPE SFG-3



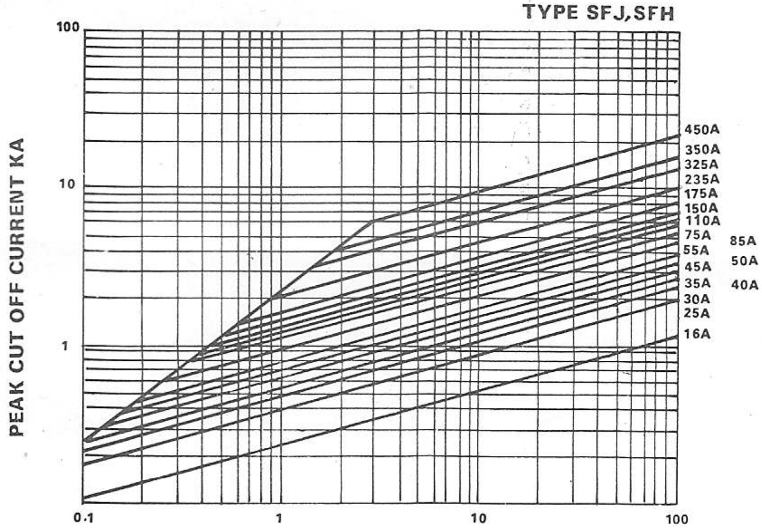
PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

D-1
TYPE SFH



PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

D-1
TYPE SFJ,SFH

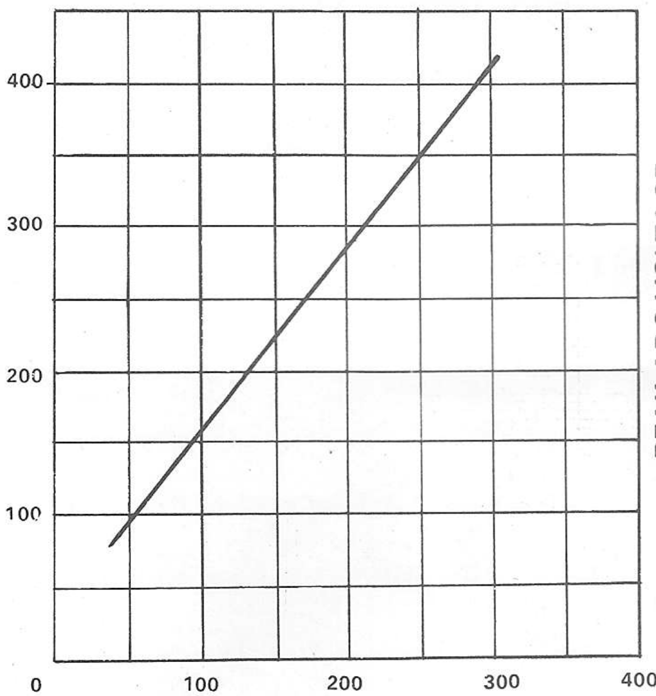


PROSPECTIVE CURRENT IN KA (SYMMETRICAL RMS)

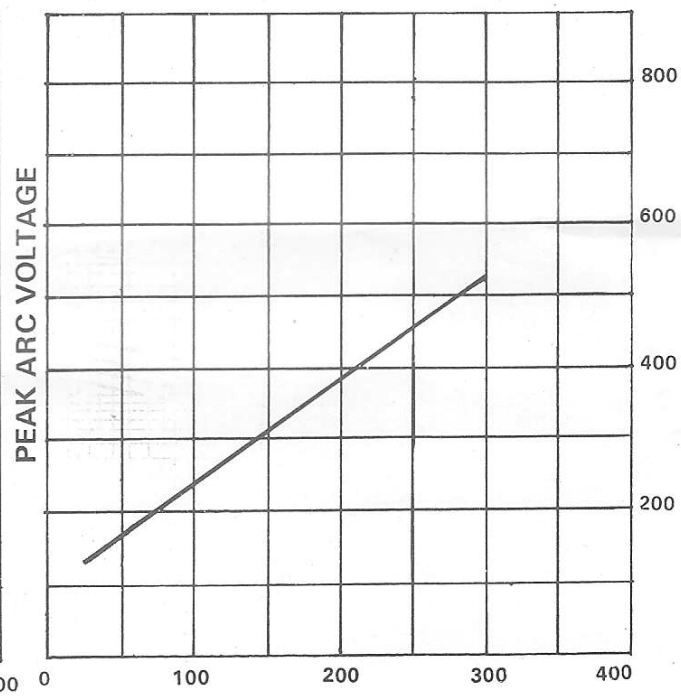
NOTE SFJ-16A TO 150A
SFH-175A TO 500A

ARC VOLTAGE CHARACTERISTICS

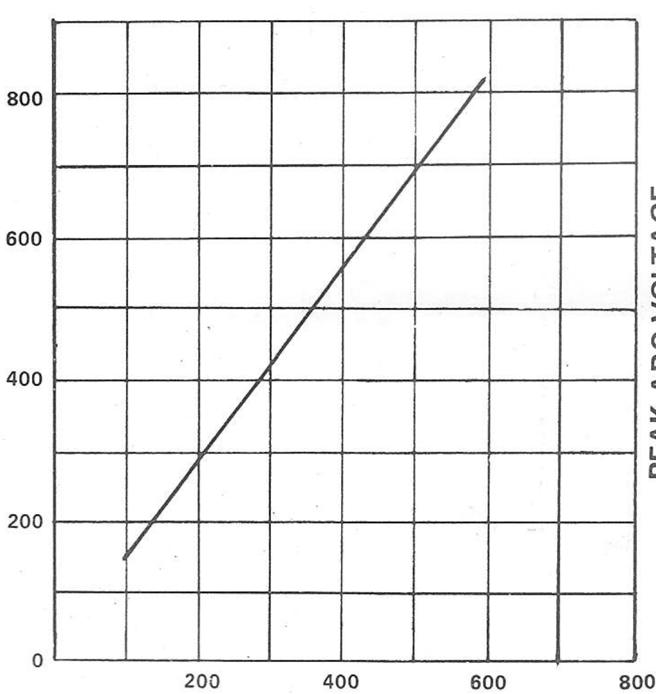
D-1



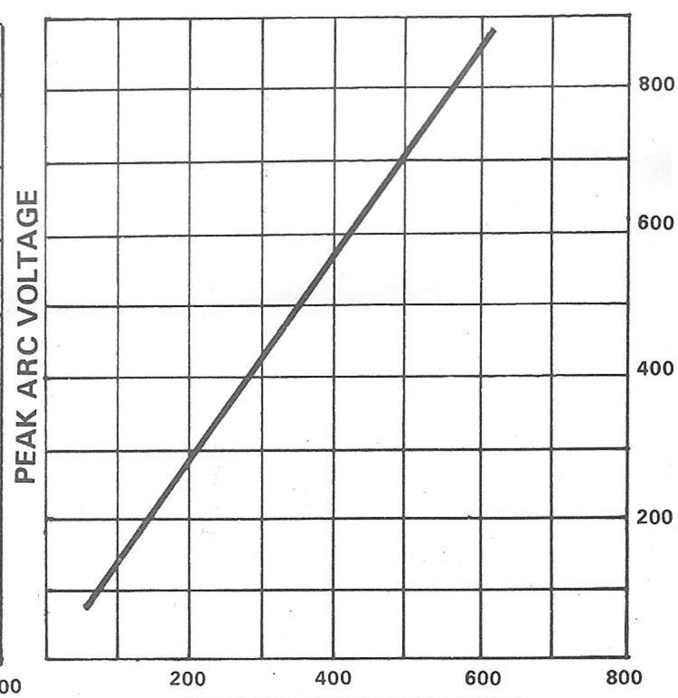
APPLIED VOLTAGE R.M.S.
FUSE TYPE: SFA



APPLIED VOLTAGE RMS
FUSE TYPE: SFC



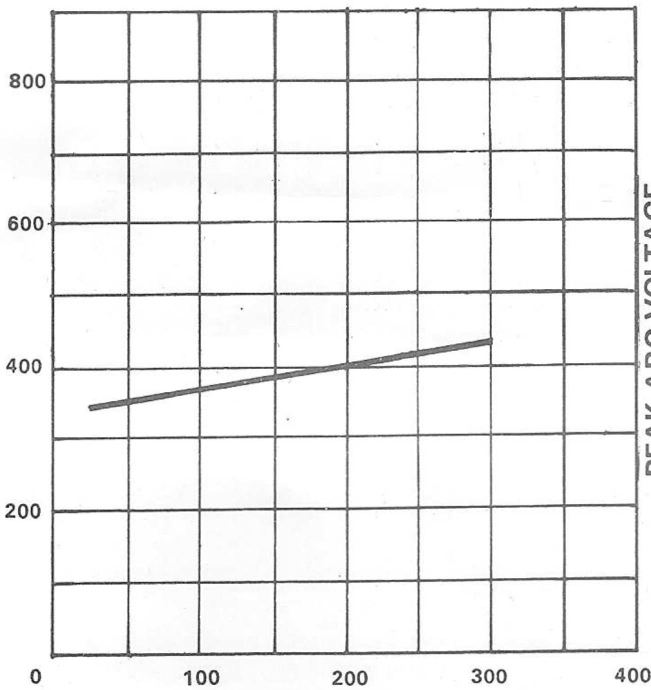
APPLIED VOLTAGE R.M.S.
FUSE TYPE: SFB



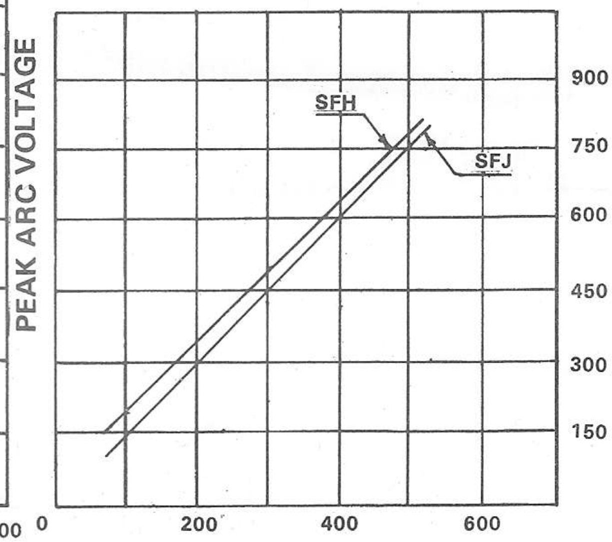
APPLIED VOLTAGE RMS
FUSE TYPE: SFD

ARC VOLTAGE CHARACTERISTICS

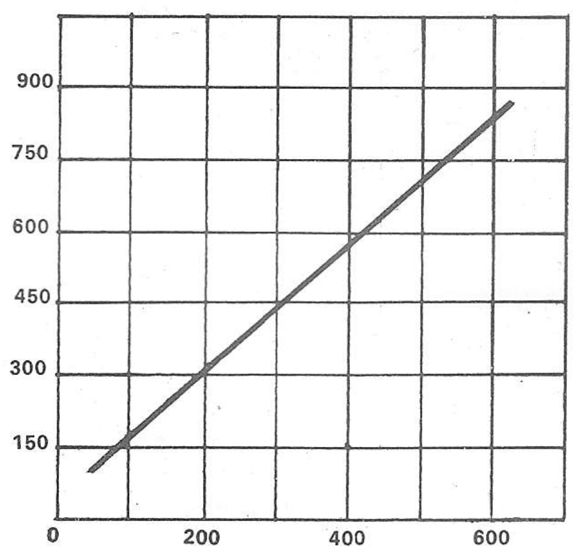
D-1



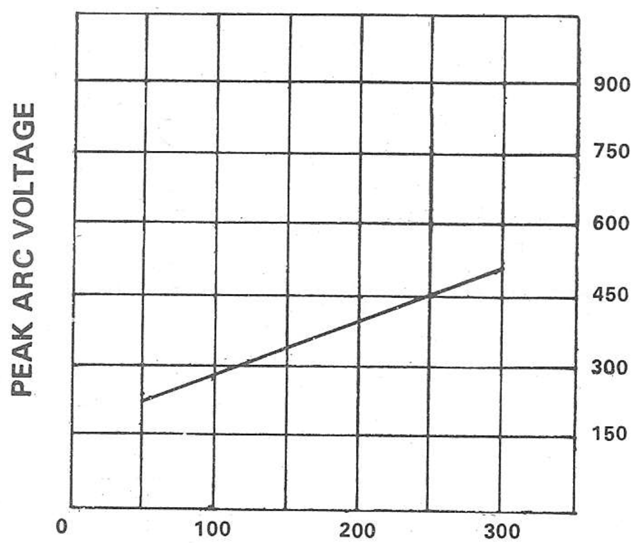
APPLIED VOLTAGE RMS
FUSE TYPE : SFE3



APPLIED VOLTAGE RMS
FUSE TYPE: SFH, SFJ

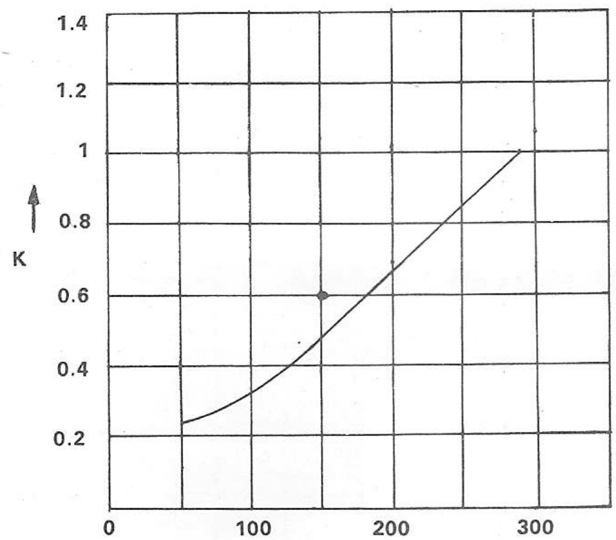


APPLIED VOLTAGE RMS
FUSE TYPE: SFF

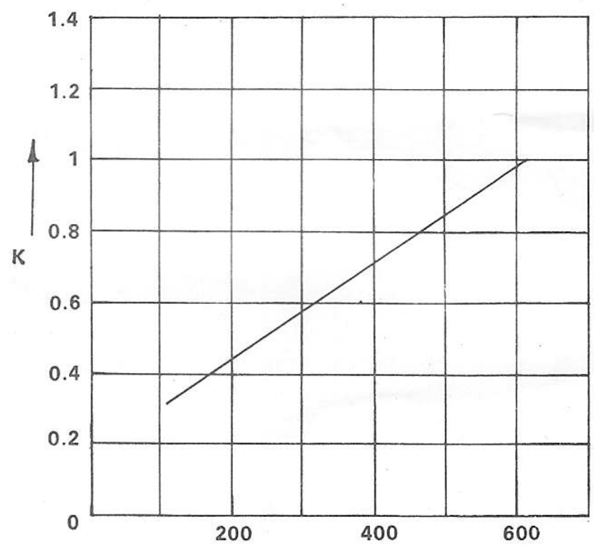


APPLIED VOLTAGE RMS
FUSE TYPE: SFG3

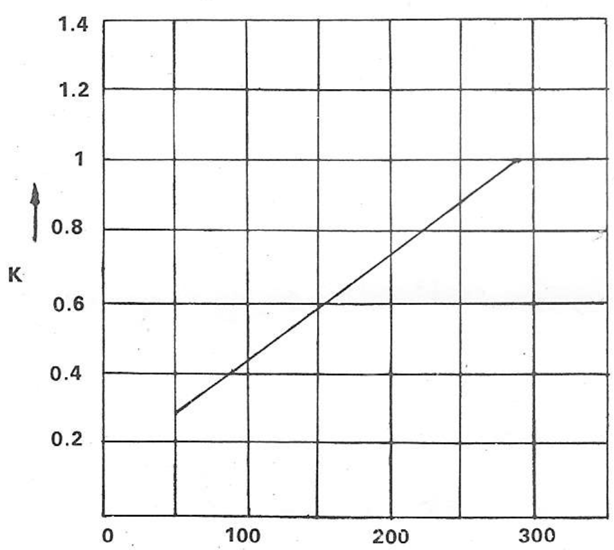
MULTIPLICATION FACTOR (K) FOR I^2t VALUE AT DIFFERENT VOLTAGE



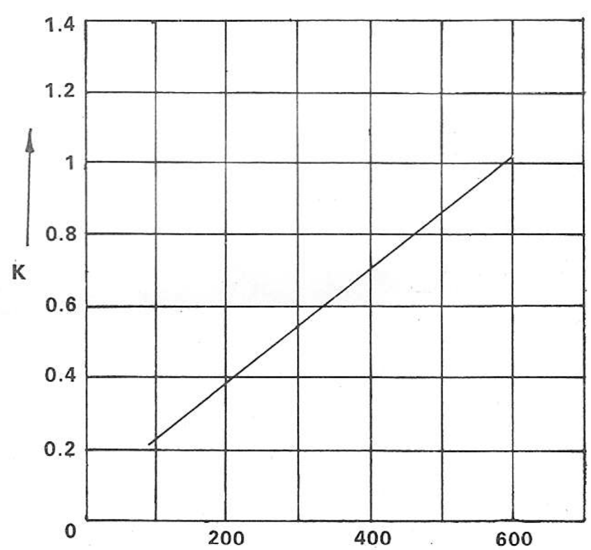
APPLIED VOLTAGE (RMS)
FUSE TYPE: SFC



APPLIED VOLTAGE (RMS)
FUSE TYPE: SFD

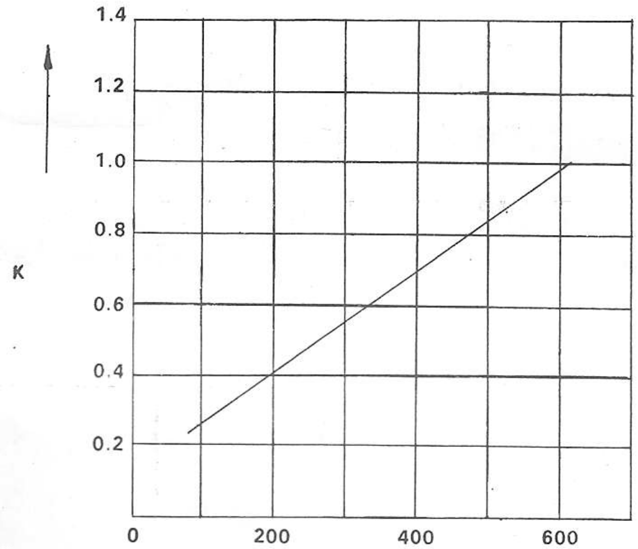


APPLIED VOLTAGE (RMS)
FUSE TYPE: SFE

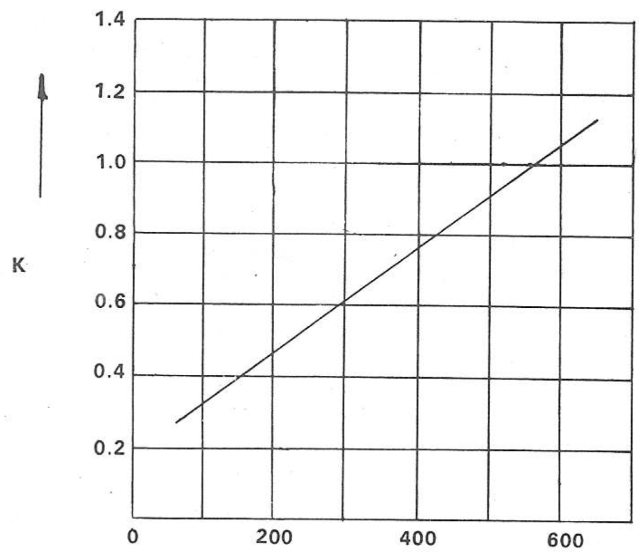


APPLIED VOLTAGE (RMS)
FUSE TYPE: SFF

MULTIPLICATION FACTOR (K) FOR I^2t VALUE AT DIFFERENT VOLTAGE



APPLIED VOLTAGE (RMS)
FUSE TYPE: SFJ



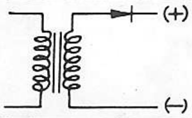
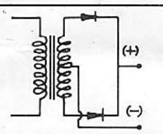
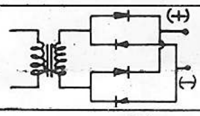
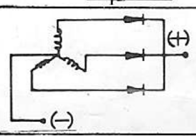
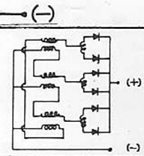
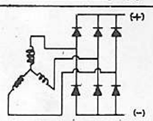
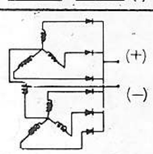
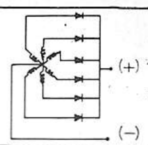
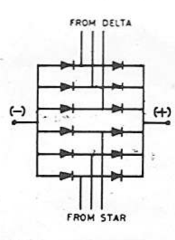
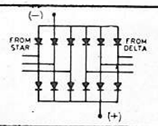
APPLIED VOLTAGE (RMS)
FUSE TYPE: SFH

Pre Arcing I^2t for different ratings of fuses

Fuse Type reference	Current rating (amps)	Prearcing I^2t
SFA	5	1.5
	10	5.0
	15	10.5
	20	26.0
SFC	25	140
	50	250
	75	540
	100	700
	125	1150
	150	2600
	175	5040
SFE 3	150	3300
	200	7500
	250	11,300
	300	14,670
	350	18,600
SFG 3	400	18,000
	500	36,000
	600	42,000
	700	70,000
SFB	5	1.8
	10	6.0
	15	13.0
	20	30.0
SFD	25	51
	45	110
	50	185
	75	520
SFJ	16	13
	25	25
	30	42
	35	58
	40	84
	45	110
	50	180
	55	260
	75	480
	85	600
	110	770
	150	1850
SFH	175	1600
	200	2500
	225	2800
	235	3700
	275	5100
	300	6900
	350	11,000
	400	14,400
	450	33,000
	500	54,000

ANNEXURE I

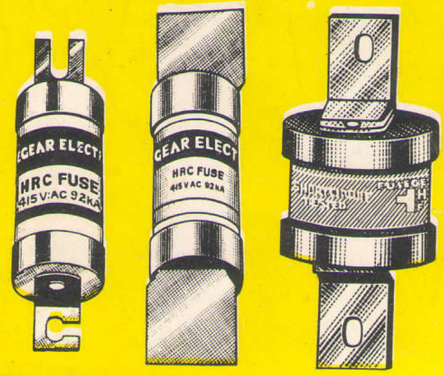
VARIOUS CIRCUIT ARRANGEMENT AND THE RELATIONSHIP BETWEEN DIFFERENT PARAMETERS

LINE DIAGRAM OF THE CIRCUIT	Vac / Vdc	Iav / Idc	I_{ac1} / Idc	I_{ac2} / Idc	Vr / Vdc	Vr / Vac	NAME OF THE CIRCUIT
	2.22	1.0	1.57	1.57	3.14	1.41	SINGLE PHASE HALF-WAVE RECTIFIER
	2.22	0.5	0.707	0.707	3.14	2.82	SINGLE PHASE FULL-WAVE RECTIFIER
	1.11	0.5	0.707	1.00	1.57	1.41	SINGLE PHASE BRIDGE CIRCUIT
	1.48	0.33	0.577	0.577	2.09	2.45	THREE PHASE WYE CONNECTION
	2.22	0.167	0.236	0.236	3.14	2.83	THREE PHASE TRIPLE DIAMETRIC
	0.74	0.333	0.577	0.816	1.05	2.45	THREE PHASE BRIDGE CIRCUIT
	1.48	0.167	0.289	0.289	2.00	2.45	THREE PHASE DOUBLE WYE CIRCUIT
	1.48	0.167	0.408	0.408	1.05	2.83	SIX PHASE STAR CONNECTION
	0.715	0.167	0.408	0.577	1.05	2.83	SIX PHASE PARALLEL BRIDGE (WITHOUT INTER PHASE TRANSFORMER)
	0.74	0.167	0.289	0.408	1.05	2.83	SIX PHASE PARALLEL BRIDGE (WITH INTER PHASE TRANSFORMER)
	0.37	0.334	0.578	0.816	1.05	2.45	SIX PHASE SERIES BRIDGE

Details of Notation used

Vac	:	No load r.m.s ac Voltage (line)
Vdc	:	No load d. c. Voltage
Iav	:	Average value of rectified current per arm
Iac1	:	Arm Current Value in r.m.s.
Iac2	:	Line Current Value in r.m.s.
Idc	:	DC Output current
Vr	:	Reverse voltage across the rectifier

Our Other Products

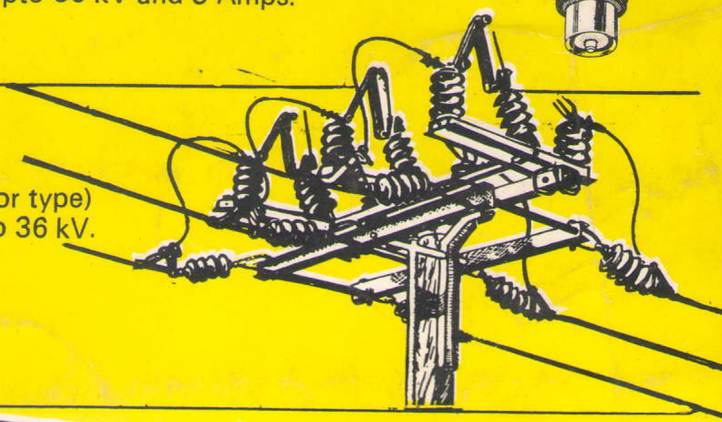


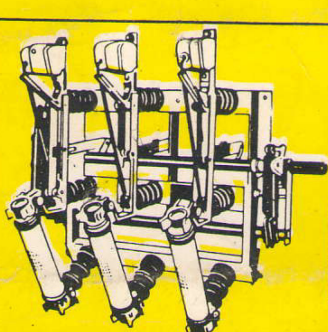
General Purpose Fuse Link from 2 Amp to 630 Amp in bolted type and knife blade type tag version. Tested to 92 kA short circuit level.

High Voltage Fuse Links upto 36 kV and upto 500 Amps.

Potential Transformer fuses upto 36 kV and 3 Amps.

High Voltage Isolators (indoor/outdoor type) upto 36 kV.





High Voltage Load Break Switches (indoor/outdoor type) upto 36 kV and 630 Amp.

Due to continuous development, data given are likely to change.

FUSEGEAR ELECTRIC

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OFFICE: 349, Poonamallee High Road, Aminjikarai, Madras-600 029 Tel: 424647
Telex: HRC IN 041-7725 Grams: FUSEGEAR