Bussmann®

HIGH SPEED FUSES

Applications Guide

Bussmann®

WORLD-WIDE CIRCUIT PROTECTION SOLUTIONS

Bussmann manufacture a wide range of products for the protection of electrical and electronic circuits... Fuse Links, Fuse Holders, and Fusegear, all readily available from manufacturing sites in the United Kingdom, Denmark, United States, Brazil and Mexico.

Bussmann is a division of Cooper Industries Inc.,

a diversified world-wide manufacturer of electrical products and power equipment.

Bussmann has grown through both organic growth and acquisition.

Acquisitions have included the fusegear division of LK-NES, Beswick which added UK Domestic fuses as well as IEC and UL Electronic fuses, Hawker Fusegear *(formally Brush Fusegear Ltd.)* which strengthened our range of power fuses and Fusegear.

Bussmann circuit protection solutions comply with major international standards and agency requirements such as: BS, IEC, DIN and UL, CSA..... Our manufacturing operations have earned ISO 9000 certification, ensuring the utmost quality across every product.

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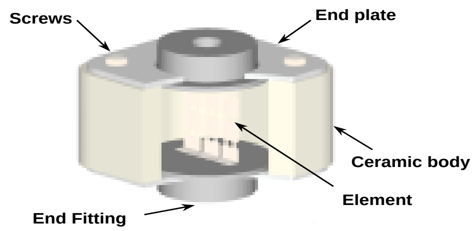
Preface

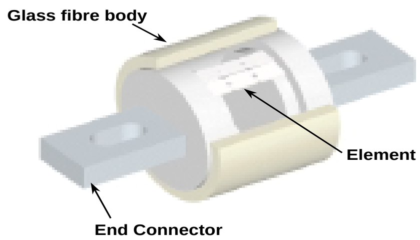
The history of the Bussmann High Speed Fuse products discussed in this Guide is long and proud. Since the first international acquisition in 1984, Bussmann has expanded its activities in order to service customers with fuses in all recognised standards of the world. Based on three different global standards and with manufacturing locations worldwide - all certified according to the ISO 9000 standard - Bussmann today provides the industry with a truly global program of High Speed Fuses and Accessories for the protection of Power Semiconductors.
With local Sales and Technical presence in all regions of the world, and with R&D facilities in the manufacturing locations for all fuse standards, Bussmann is able to provide the industry with optimum fuse solutions. In addition, when needed and practical, Bussmann offers to perform tests at our Gubany Test Centre at the Bussmann Headquarters in St. Louis, where test currents up to 300 kA can be obtained.
The objective of this Guide is to give engineers easy access to Bussmann data for High Speed Fuses. The document will provide detailed information on the Bussmann reference system for High Speed Fuses.
The various physical standards will be discussed. Some examples of applications are shown, and various considerations are discussed on how to select Rated Voltage, Rated Current and similar main data for fuses for the protection of power semiconductors. Guidelines for the mounting of fuses will be discussed, with explanations on how to read and understand Bussmann data sheets and drawings.
This document does not aim to be a complete Guide for all applications of power semiconductors requiring protection by High Speed Fuses. The market is simply too complex to make such a document, and in many cases the actual fuse selection will have to be based upon detailed technical discussions between the engineers specifying the equipment for the application, and Bussmann Technical Application Services.
However, we hope that the data presented here will be of help in the daily work, and that it will provide the reader with tools to facilitate the understanding of our products. Bussmann will appreciate all feedback on subjects that could be added to this document, in a continued effort to make this Guide even more useful.

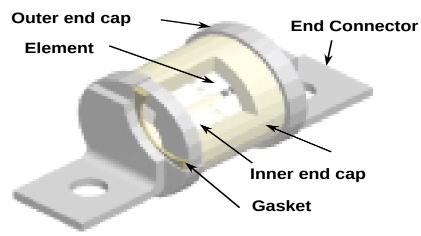
Background

The fuse-link in one form or other has been around since the earliest days of electric telegraphs and then later in different forms for the protection of power distribution and other circuits.
Like many other products the fuse-link has undergone considerable evolution since those early days. The modern High Breaking Capacity (h.b.c.) fuse-link provides an economical and reliable protection against over current faults in modern electrical systems.
The basic operation of a fuse is a simple process - the passage of excess current through specially designed fuse elements causes them to melt and isolate the faulty circuit. However fuse-links have now developed for many applications from current ratings of only a few milli-amperes to many thousands of amperes and for use in circuits of a few volts to those for high voltage distribution systems of 72kV.
The most common use of fuse-links is in distribution networks where they are graded carefully with others in the system to give protection to the cables, transformers, switches, control gear and equipment. As well as different current and voltage ratings, it is possible to change the operating characteristics of fuse-links to meet specific application areas and protection requirements.
The definitions on how fuses especially designed for a certain purpose (fuse class) are included in the »Glossary of terms« later in this guide.
Modern fuse-links are made in many shapes and sizes however there are key features common to all h.b.c. fuse-links. Although all the components used influence the total performance of the fuse-link the key part of the fuse-link is the fuse element; this will be made from a high conductivity material and will be shaped to produce a number of reduced sections commonly referred to as ’neck’ or ’weak-spots’. It is mainly these reduced sections that will control the operating characteristics of the fuse-link. The element is surrounded with an arc quenching material, usually graded quartz, which quenches the arc formed when the reduced sections melt. It is this function that gives the h.b.c. fuse-link its current limiting ability.
To contain the quartz will be an insulating container usually of ceramic or engineering plastic often referred to as the fuse body. Finally, to connect the fuse element to the circuits there are end connectors, usually of copper. The other component parts of a fuse-link vary depending on the type of fuse-link and the manufacturing methods used.

Typical fuse link constructions





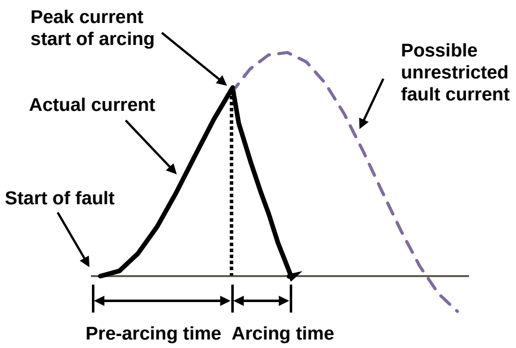


Operation of the fuse-link

The operation of a fuse-link depends primarily on the balance between the rate of heat generated within the element and the rate of heat dissipated to external connections and surrounding atmosphere. For current values up to the continuous maximum rating of the fuse-link the design ensures that all the heat generated is dissipated without exceeding the pre-set maximum temperatures of the element or other components. Under conditions of sustained overloads the rate of heat generated is greater than that dissipated and this causes the temperature of the element to rise. The temperature rise at the reduced sections of the elements (restrictions) will be higher than elsewhere and once the temperature has reached the melting point of the element material, the element will break, thus isolating the circuit. The time taken for the element to break will naturally decrease with increasing values of current. The value of current that causes the fuse-link to operate in a time of 4 hours is called the minimum fusing current, and the ratio of minimum fusing current to the rated current is called the fusing factor of that fuse-link. Under conditions of heavy overloading, as can be obtained in short circuit conditions, there is little time for heat dissipation from the element and the temperature at the restrictions will reach the melting point almost instantaneously. In other words the element will commence melting well before the prospective fault current (ac) has reached its first major peak. The time taken from the initiation of the fault to the element melting is called the pre-arcing time. This sudden interruption of a heavy current will result in an arc being formed at each restriction.
The arc thus created offers a higher resistance, thus reducing the current. The heat generated vaporises the element material; the vapour fusing with the quartz to form a non-conductive rock like substance called »fulgurite«. The arc also tends to burn the element away from the restriction, thus increasing the arc length and further increasing the arc resistance. The cumulative effect is the extinction of the arc in a very short space of time and the final isolation of the circuit. Under such heavy overload conditions the total time taken from initiation of fault to the final clearance of the circuit is very short, typically in a few milliseconds.
The current through the fuse-link will thus have been limited. Such current limitation is obtained at values of current as low as only 4 times the normal continuous rating of the fuse-link
The time taken from the appearance of the arc to its final extinction is called the arcing time. The sum of the pre-arcing and the arcing time is the total operating time. During the pre-arcing and the arcing times a certain amount of energy will be released depending on the magnitude of the current and the terms pre-arcing energy and arcing energy are similarly used to correspond to the times. Such energy will be proportional to the integral of the square of the current multiplied by the time the current flows, formally written as $\int i^2dt$, but more often abbreviated to I^2t; where I is the RMS value of the current and t is the time in seconds for which the current flows.

For high values of current the melting time is too short for heat to be lost from the reduced section (is adiabatic) and pre-arcing I^2t is therefore a constant. The arcing I^2t, however, also depends on the circuit conditions. The published data quoted is based on the worst possible conditions and is measured from actual tests. These will be detailed later in this guide.
The creation of the arc causes a voltage across the fuse-link; this is termed the arc voltage. Although this depends on the element design it is also governed by circuit conditions. This arc voltage will exceed the system voltage. The design of the element allows the magnitude of the arc voltage to be controlled to known limits. The use of a number of reduced sections in the element in series assists in controlling the arcing process and also the resultant arc voltage

Thus, a well-designed fuse-link not only limits the value of the prospective current, but also ensures that the fault is cleared in an extremely short space of time. Thus the energy released to protected equipment is considerably smaller than that available.



Protection Requirements for High Speed fuses

Since the development of silicon based semiconductor devices began they have, in numerous forms (diodes, thyristors, Gate turn-off thyristors - (GTO), transistors and more recently insulated gate bipolar transistors - (IGBT)), found an increasing number of applications in power and control circuit rectification, inversion and regulation.
Their advantage over other types of rectifiers and control elements lies in their ability to handle considerable power within a very small physical size. Due to their relatively small mass, their capacity to withstand overloads and overvoltages is rather limited.
In normal industrial applications of such devices, fault currents of many thousands of amperes could occur if an electrical fault were to develop somewhere in the circuit. Semiconductor devices can withstand these high currents only for extremely short periods of time.
High values of current cause two harmful effects on semiconductor devices. Due to non-uniform current distribution at the p-n junction(s) in the silicone, damage is caused by the creation of abnormal current densities. Secondly, a thermal effect is created, proportional to the product I^2, (RMS value of current)^2, x t, (time for which the current flows). The protection equipment chosen, therefore, must:

- **a** interrupt safely very high prospective fault currents in extremely short times
- **b** limit the value of current allowed to pass through to the device
- **c** limit the thermal energy ($\int i^2dt$ or I^2t) let through to the device during fault interruption

Unfortunately, ultra fast interruption of such large currents leads to the creation of high overvoltages. If a silicon rectifier is subjected to this, it will fail due to breakdown phenomena. The protective device selected must, therefore, also limit the overvoltage during fault interruption.
So far, consideration has mainly been given to protection against high fault currents. In order to obtain maximum utilisation of the device, coupled with complete reliability, the protective device selected must:

- **d** not require maintenance
- **e** not operate at normal rated current or during normal transient overload conditions
- **f** operate in a predetermined manner when abnormal conditions occur.

The only device to possess all these qualities at an economical cost is the modern High Speed fuse-link.
Normal fuse-links (e.g. those complying with IEC60269-2) designed primarily to protect industrial equipment, are found to be lacking when used for protecting such sensitive devices. They do possess all the qualities mentioned above, but not to the degree required.
For these reasons special types of fuse-links have been developed to protect semiconductor devices, they are characterised by their high speed of operation and are referred to as either semiconductor fuse-links or more accurately High Speed fuse-links - but both terms mean exactly the same.
As we will see the term semiconductor fuse is miss-leading as there is in fact no semiconductor material involved within the fuse-link.

How High Speed fuse-links are different to other fuse types.

High Speed fuse-links have been developed from the methods used to produce »industrial« fuse-links. However, to minimise the I^2t, peak currents let-through and arc voltages the fuse-links designs have to be modified.
To ensure rapid melting of the elements, the necks have a different design than a similarly rated industrial fuse.
High Speed fuses are typically operated at more elevated temperatures that other fuse types.
High Speed fuse-links also typically operate with higher power dissipations than other fuse types because of the higher element temperatures; often they are also in smaller physical dimension packages. For this reason the body or barrel materials used are often higher-grade materials than those used in other fuse types.
High Speed fuse-links are primarily for short circuit protection of semiconductor devices, the high operating temperatures often restricts the use of low melting point alloys to assist with low over current operation. The result is that High Speed fuse-links often have more limited capability to protect against these low over current conditions
Many types of High Speed fuse-links are physically different to the standard sizes used for other protection systems. Although this requires additional mounting arrangements for High Speed fuse-links, it does avoid use of incorrect fuse-links in a graded system.

Characteristics required / provided

For the protection of semiconductors with fuse-links a number of parameters of the devices and fuse-links need to be considered. Of the parameters there are a number of influencing factors associated with each one. The manner in which these are presented and interpreted will be shown below. These parameters and associated factors will need to be applied and considered with due reference to the specific requirements of the circuits and application.
Some of these factors are explained below. Others are described in the sections on voltage dimensioning, current dimensioning and applications.

Table 1 Factors to consider in fuse-link selection

	Factors Affecting Parameter		Data Provided	
PARAMETER	Fuse-Link	Diode or Thyristor *)	Fuse-Link	Diode or Thyristor *)
STEADY STATE RMS CURRENT	Ambient, attachment, proximity of other apparatus and other fuse-links, cooling employed	Ambient, type of circuit, parallel operation, cooling employed	Maximum rated current under specified conditions, factors for ambient, up-rating for forced cooling, conductor size	Comprehensive curves (mean currents generally quoted)
WATTS DISSIPATED FOR STEADY STATE	As for current	As for current	Maximum quoted for specified conditions	Comprehensive data
OVERLOAD CAPABILITY	Pre-loading, cyclic loading surges, manufacturing tolerances	Pre-loading, cyclic loading surges	Nominal time/current curves for initially cold fuse-links – calculation guidelines for duty cycles	Overload curves, also transient thermal impedance’s
INTERRUPTING CAPACITY	ac or d.c. voltage/short circuit levels		Interrupting rating	
I^2t RATINGS	Pre-loading; total I^2t dependent on: circuit impedance, applied voltage, point of initiation of short circuit	Pre-loading Fault duration	For initially cold fuse-links: total I^2t curves for worst case conditions, pre-arcing I^2t constant Fuse clearing time	Half cycle value or values for different pulse duration
PEAK LET THROUGH CURRENT	Pre-loading; fault current (voltage second order effect)	Pre-loading Fault duration	Curves for worst conditions for initially cold fuse-links	Peak current for fusing
ARC VOLTAGE	Peak value dependent on : applied voltage, circuit impedance, point of initiation of short circuit	P.I.V. voltage ratings (non- repetitive)	Maximum peak arc voltages plotted against applied voltage	P.I.V. voltage rating quoted (non-repetitive)

*) The protection of transistors is more complex and will be described in the section on IGBT protection

Ambient Temperatures

Fuse-links for the protection of semiconductors may have to be de-rated for external ambience in excess of 21°C. Ratings at other temperatures are shown on de-rating graphs.

Local Ambients

Poor mounting of fuse-links, enclosed fuse-links and proximity to other apparatus and fuse-links can give rise to high local ambient temperature. The maximum fuse rating in these cases should be determined for each application using the local ambient as described in the section on current dimensioning.

Forced Cooling

In many installations the diodes or thyristors are force-cooled in an air stream to achieve maximum ratings. Fuse-links can be similarly uprated if placed in the air stream. Air velocities above 5m/s do not produce any substantial increase in the ratings. For further information see the sections on current dimensioning and data sheets.

Mean, Peak and RMS Currents

Care must be taken in co-ordinating fuse currents with the circuit currents; fuse currents are usually quoted in RMS values whilst it is common practice to treat diodes and thyristors in terms of mean values.

Time / Current Characteristics

This is derived using the same test arrangement as used for the temperature rise tests, with the fuse-links at ambient temperature before each test. For standard fuse-links the nominal melting times are plotted against RMS current values down to melting times of 10 ms. For high speed fuse-links the virtual melting time is used and shown down to 0.1 ms.

Surges

Effects of cyclic loading or transient surges can be considered by co-ordinating the effective RMS current values and durations of the surges with the time current characteristics. The following points should be remembered when using these published characteristics:

1. The characteristics are subject to a 5% tolerance on current.
2. For times below 1 s, circuit constants and instants of fault occurrence affect the time/current characteristics. Minimum nominal times are published relating to symmetrical RMS currents.
3. Pre-loading at maximum current rating reduces the actual melting time. Cyclic conditions are detailed in the section on current dimensioning.

Coordination with Semiconductor Characteristics

Short Circuit Performance

The short circuit zone of operation is usually taken as operating times less than 10 milliseconds (1/2 cycle on 50 Hz supply in AC circuits). It is in this region that High Speed fuse-links are current limiting. The performance data for fuse-links are usually given for AC operations since, in fact, the majority of the applications are fed from AC sources. Where applicable, prospective symmetrical RMS currents are used.

I^2t Ratings

The pre-arcing (melting) I^2t tends to a minimum value when the fuse is subjected to high currents, it is this value that is shown on the data sheet.

The arcing I^2t varies with applied voltage, fault level, power factor and the point on wave of the initiation of the short circuit. The total I^2t figures quoted are for the worst case of these conditions. The majority of semiconductor manufacturers give I^2t ratings for their power semiconductors which should not be exceeded during fusing at all times below 10 ms. These are statistically the lowest values for when the device has been pre-loaded.

For protection of the device the total I^2t of the fuse-link must be less than the I^2t capability of the device.

Peak Fuse Currents

Under short circuit conditions High Speed fuse-links are inherently current limiting; that is the peak current through the fuse-link is less than the prospective peak current. The 'Cut-off' characteristic, i.e. the peak fuse current against symmetrical prospective RMS current, are shown in the data sheets. Peak fuse currents should be co-ordinated with diode or thyristor data in addition to I^2t.

Arc Voltage

The arc voltage produced during fuse-link operation does vary with the applied system voltage. Curves showing variations of arc voltage with system voltage are included in the data sheets. Care must be taken in co-ordinating the peak arc voltage of the fuse-link with the peak transient voltage capability of the device.

Conductor Size

The RMS current ratings assigned to Bussmann fuse-links are based upon standard sized conductors at each end of the fuse during rating tests. These will be based on between 1 and 1.6 A/mm^2. Using smaller or larger conductors will affect the current rating of the fuse-link.

Package protection

Some of the semiconductor devices are extremely sensitive to over-currents and over-voltages and fuse-links may not operate fast enough to prevent some or even complete damage to the function of the device. High Speed fuse-links are still employed in such cases to minimize the consequences when the silicon or small connection wires are melting. Without these fuses the packaging surrounding the silicon will open, maybe violently, causing damage to equipment or injury to persons.

The Data sheet of the High Speed Fuse

The Electrical Data on our High Speed Fuses can be found from a range of various curves and written information. The following is a short description of this:

The Time Current Curve

The Time Current Curve, also called the melting curve, will enable the user to find vital information in the selection and dimensioning phase. See fig.1.

The axes are the prospective short-circuit current (Ip) in Amp symmetrical RMS and virtual Pre-Arcing time (tv) in seconds, as specified in IEC 60269.

Thus the melting time of a given fuse can be found, based upon a known short-circuit current value. In practice virtual times longer than approx. 100ms are equivalent to real time.

Using Ip and tv direct from the time current curve of a fuse enables the calculation of its melting integral in A^2s (Ip^2 x tv) for the actual value of prospective current.

The following method shows two examples (i_1 and i_2) with guidelines to determine the effect from an overload or short-circuit current on a fuse:

- First, the actual overload/short-circuit current must be known, either in the form of a curve (see Fig 2, $i_1=f(t_r)$ and $i_2=f(t_r)$) or as an equation.
- Calculate the RMS value of this current during time. The RMS value at a given time is found from the following formula:

$$I_{RMS}(t_r) = \sqrt{\frac{\int_0^{t_r} i^2 dt}{t_r}}$$

- Plot the values as coordinates i_{RMS},t_r onto the fuse time/current curve like shown in Fig I
- If the plotted curve crosses the fuse melting curve (like $i_{RMS,2}$ in the example shown in Fig 1), the fuse melts to the time which can be found from the crossing point (real time).

  If the plotted curve does not cross the fuse melting curve (like $i_{RMS,1}$ in the example shown in Fig1), the fuse will survive.

  In this case, the minimum distance (horizontally) between the plotted curve and the fuse melting curve gives an expression of how well the fuse will manage a given overload.

  The above method together with the guidelines given on overloads in the chapter »Rated Current dimensioning« will determine if in the long run the fuse can survive the type of overload in question.

This can be done even if the axes of the melting curve are in Ip and tv. It can be shown that a relabeling of the axes-designation: Ip=>I_{RMS} **and** tv=>tr can be done without changing the shape of the melting curve.

Fig 1

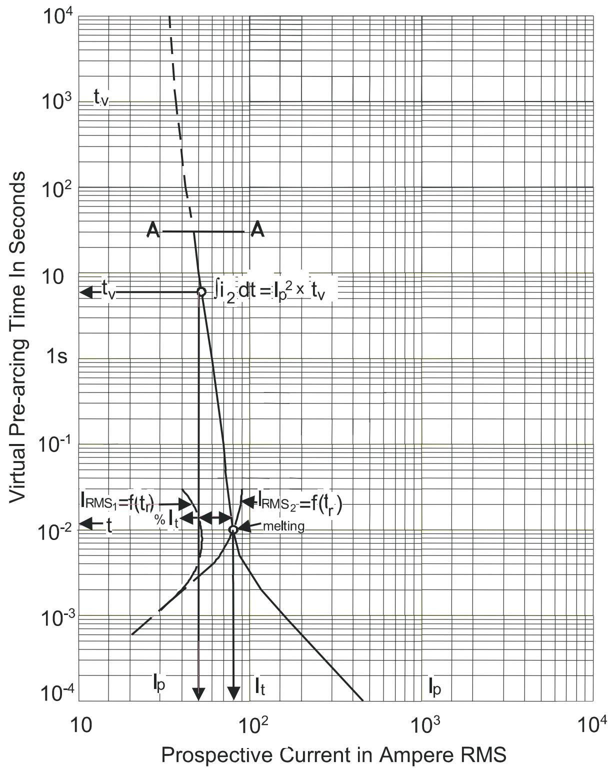
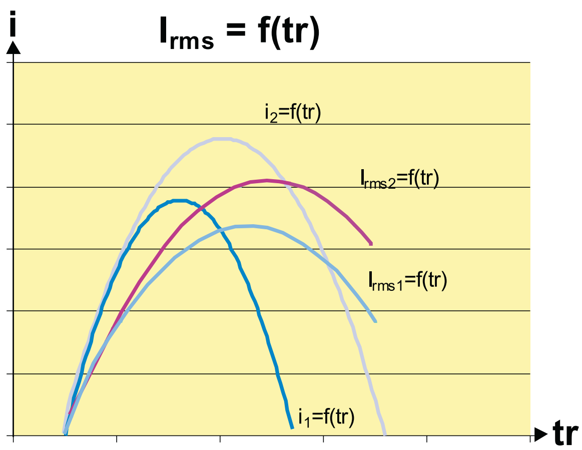


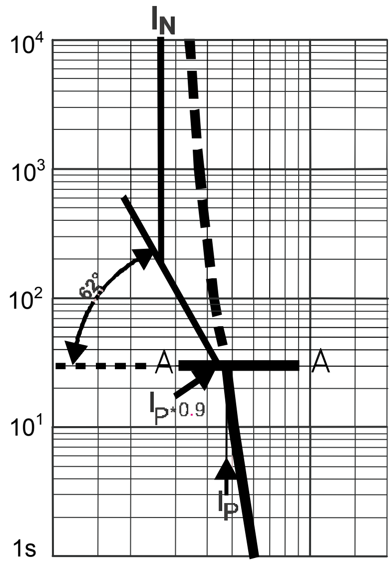
Fig 2



The AA-curve

In connection with the melting curve an AA-designation is given (for aR fuse types only). Melting or loading beyond this curve is forbidden. This is due to the risk of thermal overload, which might reduce the breaking capacity of the fuse.
Often the AA-curve is only indicated by a horizontal line, and in order to be able to draw the complete curve for a given fuse the following guidelines should be used:
The Ip found for the time equal to the crossing between the horizontal AA-curve and the actual melting curve should be multiplied by 0.9 (Ip x 0.9) and this point is marked on the horizontal AA-curve, see fig. 3. From here rises a 62 degree line to be connected with the Ip=IN vertical line. (IN being rated fuse current). This finalizes the complete AA-curve (Note 62º, only valid if decade relation is 1:2.

Fig 3



Clearing integral information

Normally the maximum I^2t under short-circuit conditions will be the 10ms clearing integral I^2t_{cl} of the fuse, which is given at applied working voltage equal to rated fuse voltage at power-factor cos φ = 0.15 and at a short-circuit level of 10-15 times rated current.
This fuse I^2t_{cl} (based upon 20ºC) should be compared with the equivalent 10ms fusing integral I^2t-scr of the semiconductor (normally given at 125ºC) to see if protection is ensured, and even for I^2t_{cl} = I^2t-scr a reasonable safety margin can be expected (cold fuse versus warm SCR).
If the fuse is clearing at a lower voltage than stated above and perhaps also at a different power factor, this means that two correction factors should be used in conjunction with the given I^2t_{cl} . The resultant clearing integral will be equal to:
I^2t_{cl} xKxX, which factors can be found from figs.4 & 5, and the I^2t_{scr} of the device should be compared with this result.

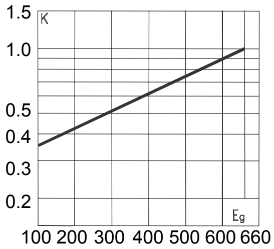


Fig 4

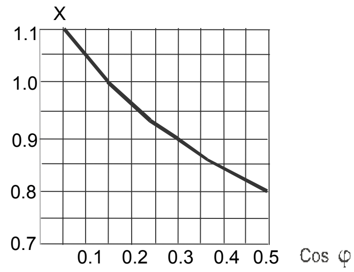
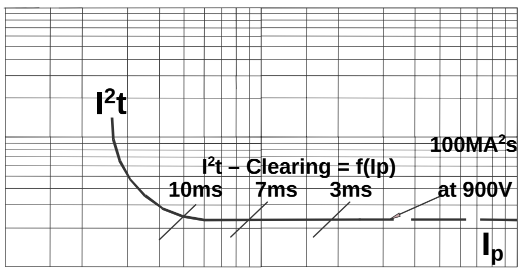


Fig 5

The I^2t Curve

On request an I^2t Curve can also be furnished, showing the clearing I^2t and time as a function of the prospective short-circuit current for a given system voltage, see fig. 6.
This can ease the selectivity coordination between fuse and semiconductor to be protected or other devices in the short-circuit path.

Fig 6

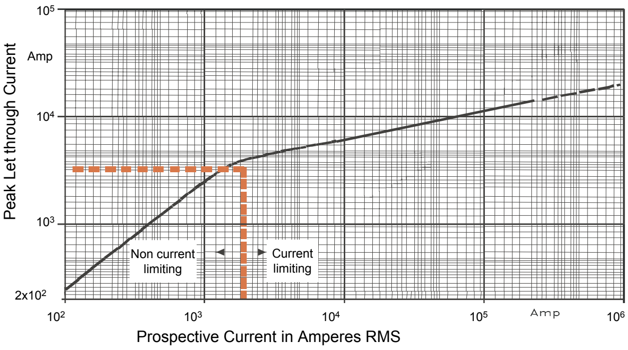


Cut Off Current Curve

The fuse is a short-circuit current limiting device. This means that the fuse will reduce the prospective, destructive thermal and mechanical forces in modern equipment to an acceptable level if a short should occur. In practice the short-circuit current is given as the **RMS** value of the **symmetrical** short-circuit current available, called Ip. How high the **actual** max peak (asymmetrical condition) of this current can be, only depends on the power factor in the circuit. For cos φ =0.15 the peak value will lie between

$$\sqrt{2}\ \mathrm{x}\ I_P \text{ and up to } 2.3\ \mathrm{x}\ I_P.$$

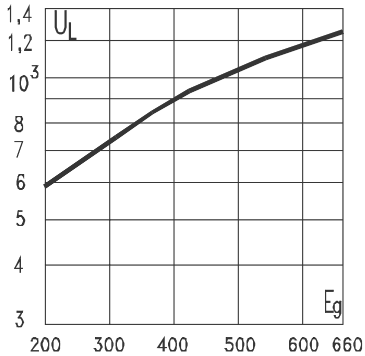
From the cut-off curve fig. 7 it can be seen that a certain magnitude of I_P, relative to the I_N of the fuse, is needed before the current-limiting effect will take place. The higher the short-circuit level, the lower the Icut-off of the fuse will be, relatively.



The Arc Voltage Curve

The peak arc voltage of the fuse and peak reverse voltage of the semiconductor should always be coordinated.
When the fuse melts, the current has reached a given level during the melting time. But due to the specially designed weak spots, which are packed in sand, an **arc voltage** is generated. This forces the current to zero during the arcing time, and finally isolation is established. This permanent isolation is built up at the weak spot areas which are converted into fulgurite, a composition of metal and sand made during the arcing process.
(The melting time plus arcing time is called clearing time, and for long melting times the arcing time is negligible).
For a given fuse voltage rating the **peak arc voltage** U_L mainly depends on the applied working voltage level Eg in RMS, according to fig.8.

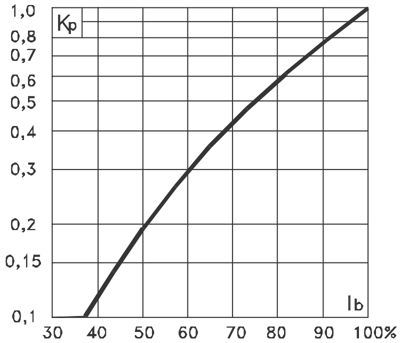
Fig 8



Watt loss correction Curve

The rated watt loss is given for each fuse under specified conditions, and to calculate the loss at a load current lower than rated current, the rated watt loss is to be multiplied by correction factor Kp. This factor is given as a function of the RMS load current Ib, in % of the rated current, ref. to fig.9.

Fig 9



Temperature conditions

Temperatures of the porcelain body and fuse terminals are normally not given, but can be furnished upon request. Temperature measurements can be misleading as an indication of whether a fuse is well suited or not in a given set-up, see the chapter dealing with rated current dimensioning. Generally, for fuses with a porcelain body, the temperature rise lies from 70-110ºC on the terminals and from 90-130ºC on the porcelain full loaded under IEC conditions.

Rated Voltage Dimensioning

Voltage Rating

The voltage rating of a fuse indicates the AC or DC system voltage at which it is designed to operate. Most commercial fuses are rated for AC RMS voltages (45-62Hz), unless otherwise stated on the fuse label.
To properly protect any system, the fuse voltage rating must be at least equal to the system voltage in question.
All Bussmann High Speed Fuses are designed to either the UL 248-13, IEC 60269 1&4 or the BS 88 standards. This allow designers to select a High Speed Fuse that can be used anywhere around the world.

International Voltage Ratings

IEC Voltage Ratings

IEC usually requires AC voltage tests to be performed at 110 percent of the rated voltage, with power factors between 10 and 20 percent.
This enables the fuse to be used at rated voltage virtually anywhere without fear of exceeding the severity of the test conditions. The extra percentages will take into account the supply voltage fluctuations found in some converters.

North American Voltage Rating

North American Voltage rating requires that all fuses should be tested at their rated voltage only, with power factors between 15 and 20 percent. In many instances, a fuse is chosen with a voltage rating well above the system requirement.
Under some circuit conditions, there can be normal circuit fluctuations of +10%, so be mindful of this factor when investigating North American style fuses these have not been tested for any voltages above their rating.

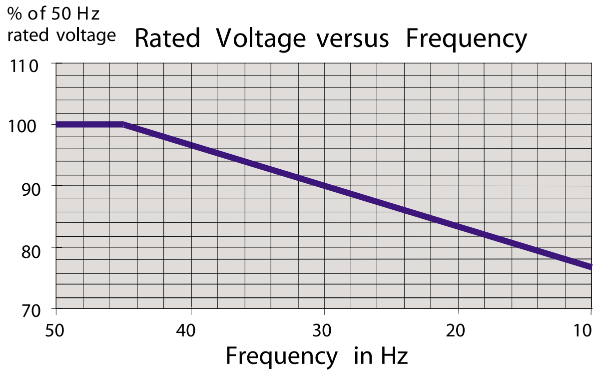
Simple Rated Voltage Dimensioning

In most converter circuits the size and nature of the dimensioning voltage is evident, and the voltage selection can be done right away.
Generally it can be said one fuse on its own should be able to clear against the maximum system voltage, and even if two fuses are in series in the same short-circuit path each fuse must be rated at the system voltage.

Frequency dependency

The stated AC rated voltage of Bussmann fuses are valid at frequencies from 45Hz to 1000Hz, below 45Hz please refer to fig 1. At even lower frequencies the breaking process tends to be more like DC, and here the voltage dimensioning should be in accordance with what is described in »DC Applications« in this Guide.

Fig 1



Extended Rated Voltage Dimensioning

Possible AC/ DC combinations

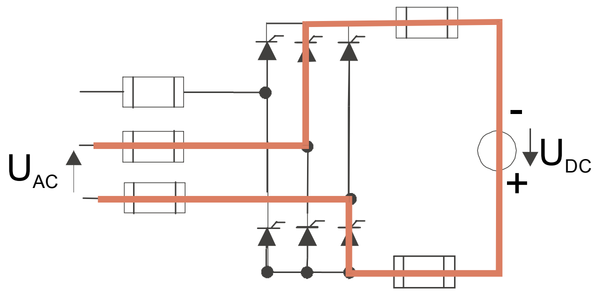
Even in relatively simple converters like the six-pulse bridge etc. (see Fig. 2) the possibility exists that the dimensioning voltage for the selection of rated voltage of the fuse is much higher than the AC-supply voltage itself.

This is true if the converter is regenerative, meaning that it is able to return energy to the supply. Here, in case of a commutation fault, the AC-supply voltage U_{AC} and the output DC voltage will be superimposed, and to be able to cope with this increase in voltage, the rated voltage UN of the fuse must be:

$$U_N \geqq 1.8 \times U_{AC}$$

For further details please refer to »Selection of Fuses for the Protection of Regenerative DC-Drives«

Fig 2



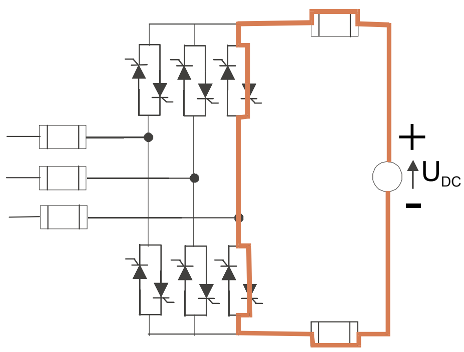
AC fuses in DC Circuits

If AC fuses are used in DC motor and drive application circuits etc. the selection process tends to be more complex (see Fig 3).

The dimensioning parameters will be the system DC-voltage, the minimum short-circuit current, and the associated max. time constant (L/R).

For details please refer to the »DC Application of Bussmann Typower Zilox AC Fuses«

Fig 3

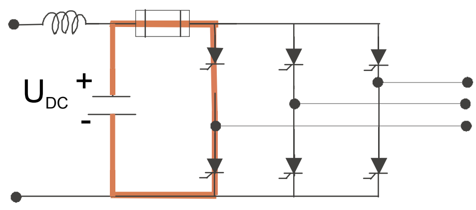


Fuses under oscillating DC

AC fuses can be used for the protection and isolation of GTO's and IGBT's on the DC side of voltage commutated inverters (see Fig 4).
Due to the very high di/dt of the short-circuit current in case of a DC shoot-through, it may be possible for the DC rating to be greater than the AC voltage rating (to IEC or UL).

For further information, please contact Bussmann Application Engineering.

Fig 4



Fuse-Links in Series

It is not common that fuse-links are connected directly in series. Under low overcurrent conditions only a small variation in fuse-link performance would cause one of the fuse-links to open the circuit before the other and thus this fuse should be capable of clearing the full system voltage. Under higher fault currents both fuse-links will operate but it is unlikely the voltage will be shared equally.
Therefore, if fuse-links are connected in series the following should be observed.

i) Fault currents sufficient to cause melting times of 10 ms or lower should always be available.
ii) The voltage rating of each fuse-link (Un) should be at least 70% of the system voltage.
iii) If the available fault current may only cause melting times more than 10 ms then the voltage rating of the fuse-link must be minimum the same as the applied voltage.

Rated Current Dimensioning

The rated current of a fuse is the RMS current that the fuse can continuously carry without degrading or exceeding the applicable temperature rise limits under well-defined and steady-state conditions. This in contrast to semiconductors, whose rated current is given as a mean or average value. Many conditions can effect the current carrying capability of the fuse, and to prevent premature ageing, the following parts 1-2 & 3 will allow the rated current selection to be on the safe side

Part 1.
Basic Selection

This part covers the basic selection criteria for the rated current of the fuse only, and not the influence from overload and cyclic loading. The actual RMS steady-state load current through the fuse should be lower or equal to the calculated maximum permissible load current called I_b.

$I_b = I_N \times K_t \times K_e \times K_v \times K_f \times K_b$

- I_b: The max permissible continuous RMS load current *.
- I_N: Rated current of a given fuse
- K_t : Ambient temp. correction factor acc. to fig 1
- K_e: Thermal connection factor acc. to fig 2
- K_v : Cooling air correction factor acc. to fig 3
- Kf : Frequency correction factor acc. to fig 4
- K_b : Fuse load constant. For fuses with porcelain body it is normally 1.0 (see data sheet) For fiber body fuses the factor is normally 0.8.

In case of water cooled fuse terminals, please consult Bussmann Application Engineering.

*NB: For any periods of 10 minutes duration or more the RMS-value of the load current should not exceed this.

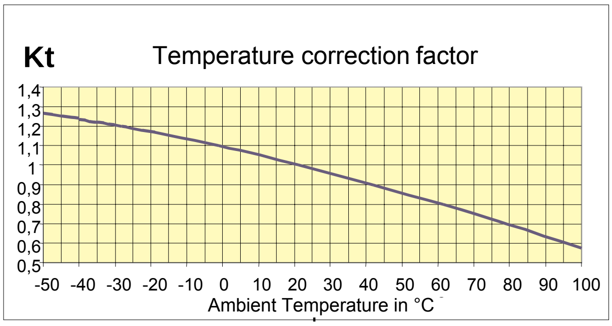


Fig 1

The curve shows the influence of the ambient temperature on the current carrying capability of the fuse.

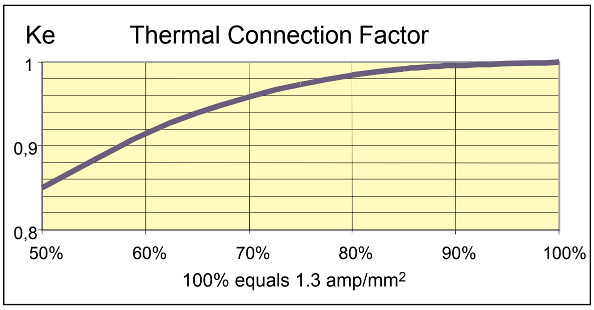


Fig 2

The minimum cross section area of the busbar or cable connections should be 1.3 amp/mm^2, in accordance with IEC 60269 part 4.

If the cross section of the connection is less then the fuse shall be derated as per above graph.

If the two connections are not equal, find the respective KE factor (example: K_1 & K_2) and calculate the combined effect: KE = $K_1 x K_2/2$

Fuse mounting inside a box etc. will reduce the convection cooling compared with IEC/UL-conditions, and based upon simple judgement an **additional** Ke factor should be chosen here. Often box mounted fuses are given an additional Ke of 0.8.

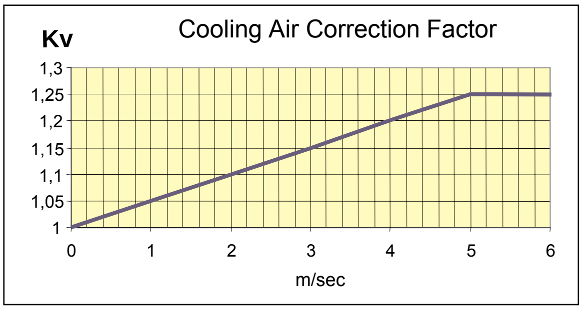


Fig 3

The curve shows the influence of forced air cooling on the fuse.

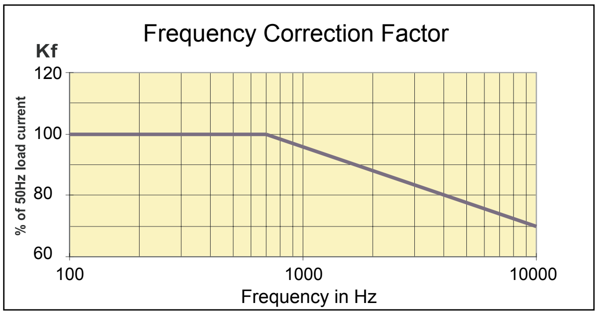


Fig 4

Fuses under high frequency load like in voltage commutated inverters etc. call for special attention. At these frequencies the current carrying capability can be reduced due to the imposed skin and proximity effect on the current carrying elements inside the fuse. Using the curve given in Fig 4 normally ensures a sufficient margin

Example 1:
A 200A rated square body fuse is applied at an ambient temperature of 40C°, and wired with cables with a cross sectional area of 120 mm² which is only 78% of the recommended size (1.3A/mm^2). Forced air cooling is established at a rate of 4 m/s. The frequency of the load current is equivalent to 3000 Hz.
What would be the max allowed steady-state RMS current I_b ?:

$I_b = I_n \times K_t \times K_e \times K_v \times K_f \times K_b \geq$

$I_b = 200 \times 0.9 \times 0.98 \times 1.2 \times 0.85 \times 1 = 180$A RMS

Based upon:
I_n = 200A
K_t = 0.9 , Fig.1 for 40C° ambient temperature.
K_e = 0,98, Fig. 2 for 0,78xIEC
K_v = 1.2, Fig. 3 for 4m/s forced air cooling
K_f = 0.85, Fig. 4 for a frequency of 3000 Hz
K_b= 1

In other words the 200A fuse should be subjected to max 180A RMS only, under the described steady-state conditions.

Control of the fuse amperage

The maximum permissible steady-state load current I_b of a fuse can be checked empirically by making simple voltage measurements under actual operating conditions after the fuse has been installed in its operating location and loaded at the calculated Ib value :

E2/E1 x (0.92 + 0.004 x t) ≤ N

where
E1 = Voltage drop across fuse after 5 secs.
E2 = Voltage drop across fuse after 2 hours.
t = Air temperature at start of test in C°.
N = Constant (if available, from data sheet, normally 1.5 or 1.6)

Part 2.
Influence of overloads

The maximum overload current Imax which can be imposed on the fuse found under Part 1. depends upon the duration and frequency of occurrence.
Time durations fall into two categories:
1) Overloads longer than one second
2) Overloads less than one second, termed impulse loads.

The following table gives general application guidelines. In the expression Imax < (% factor) x It, It is the melting current corresponding to the time »t« of the overload duration as read from the time/current curve of the fuse. The limits given permit the determination of Imax for a given fuse rating or, conversely, the fuse current rating required for a given overload, expressed by : Imax < (% factor) x It.

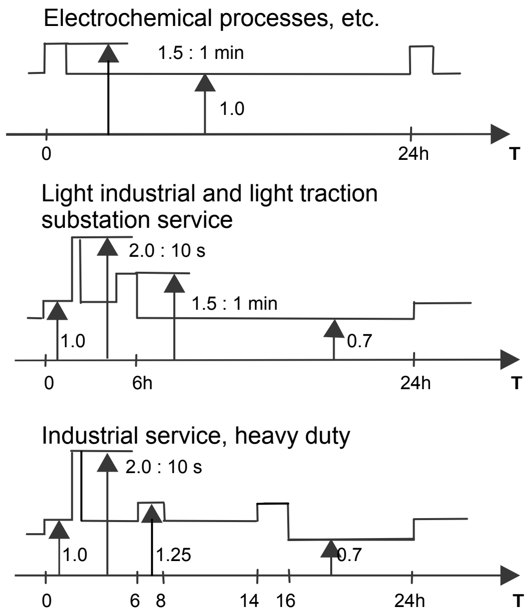
Fig 5

Frequence of Occurence	Overloads (> 2 sec)	Impulse Loads (< 1 sec)
Less than one time per month	Imax< 80% x It	Imax < 70% x It
Less than twice per week	Imax < 70% x It	Imax< 60% x It
Severel times per day	Imax < 60% x It	Imax <50% x It

Typical examples of load cycles including overload currents are given below:
The % factor for each overload should be checked against the melting curve of the selected fuse in question, based upon the guidelines in Part 1.

There is a grey area between a sole overload and a pure cyclic load situation, in particular, the last of the three examples shown is typical of this dilemma, and for safety reasons, treat a cycle like this based upon the guidelines in Part 3 of this chapter.

Fig 6



Example 2:

A 200A fuse has been selected and will be subjected to temporary overloads of 300 Amps of 5 sec duration each. These overloads occur 3-5 times a day. From the time current curve of the fuse we find It: the melting current corresponding to the time t=5sec of the overload duration to be: It=600A.
From Fig 5 we therefore find the actual limit:
Imax < 60% x It = 60% x 600 = 360A.

This means that temporary overloads of up to 360A can be accepted and thus the 200A fuse selected and subjected to the 300A for 5 sec 3-5 times a day, will work correctly in this application.

Part 3.
Cyclic Loading

Cyclic loading which will lead to premature fuse fatigue can be defined as regular or irregular variations of the load current, each of a sufficient size and duration large enough to change the temperature of the elements inside the fuse in such a way that the very sensitive weak spots will fatigue. In order to avoid this when selecting a fuse, certain calculations can be made to ensure that there is an appropriate safety margin.

Using the following empirical rules will cover most cyclic loading situations, but it is impossible to set up general rules for all situations, so please contact our technical department for further advice.

$$I_b \geqq I_{RMS} * G$$

Ib is the max permissible load current found based upon the criteria laid out in Part 1, and I_{RMS} is the RMS value of the cyclic loading. Some cyclic load Factors G can be found from the example profiles below (see fig.7) or can be provided by our technical department upon request.
In many cases, however, a sufficient safety margin is assured by using the following value:

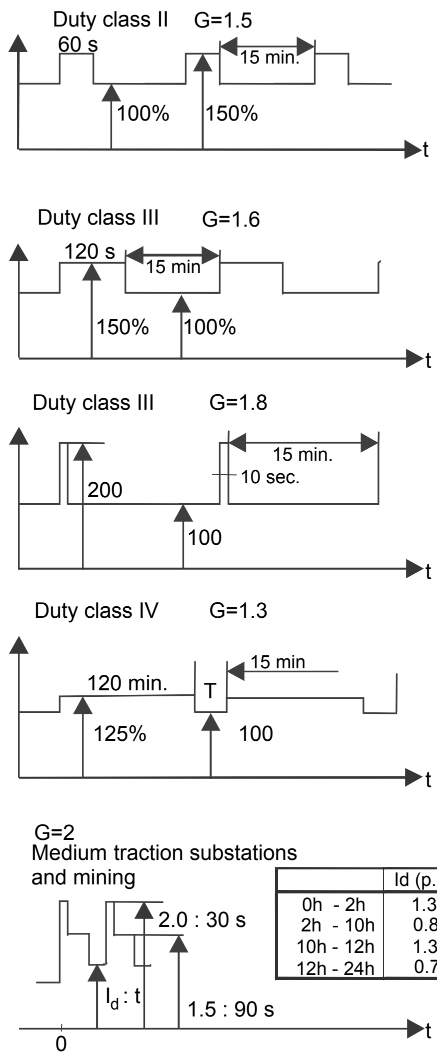
G = 1.6

This should be followed by a check to see if the individual load pulses each expressed in (I_{pulse}, t_{pulse}) coordinates have a sufficient safety margin B in relation to It of the melting curve of the fuse found based upon G above, where It is the melting current of the fuse corresponding to $t=t_{pulse}$, and B to be found according to Fig 8

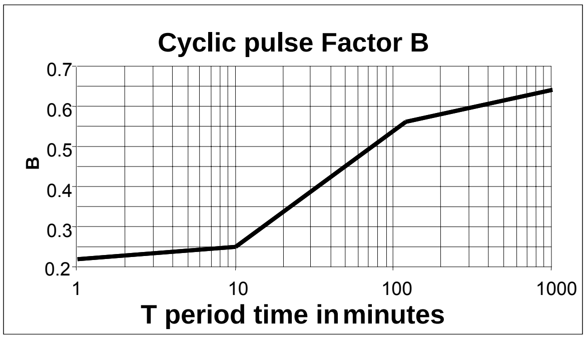
$$I_{pulse} < It * B$$

When both conditions are OK, this should ensure a sufficient lifetime of the fuse subjected to the given loadings.

Fig. 7



	Id (p.u.)	t (min.)
0h - 2h	1.3	10
2h - 10h	0.8	15
10h - 12h	1.3	10
12h - 24h	0.7	30



Example 3

The following cyclic load exists:
150A for 2 minutes followed by 100A for 15 minutes, which gives I_{RMS}=107A as RMS-value of the cyclic loading. Period time of T=17 minutes. This requires a cyclic load factor of G = 1.6 (refer to the example profiles), and to see if a given fuse is suitable, the following expression should be used:

Ib $\geqq$ I_{RMS}*G = 107*1.6 = 171A

(Ib as the max permissible load current (from Part 1).

Using a 200A fuse under the conditions described in example 1, we have: Ib = 180A which means this fuse should be OK.

Now only a check by factor B remains in order to secure that the pulse keeps a sufficient safety distance to the melting curve:

Ipulse < It * B = 440A * 0,32 = 141A

It=440A can be found from the time current curve of the actual 200A fuse for t=2 minutes (melting current for t= 2 minutes), and B=0.32 from fig. 8 based upon period time T=17 minutes. In the actual case Ipulse=150A, and therefore the above equation is not fulfilled, thus a bigger fuse should be selected, in this case a 250A. Due to the small 6% margin (150/141), a 200A fuse would still do a good job here too.

Fuse-Links in Parallel

There are many applications where fuse-links are used in parallel.
As the surface area of two smaller fuse-links is often greater than an equivalent rated larger fuse-links, the cooling effects will also be larger. The result may provide a lower I^2t solution, giving closer protection to the devices or a lower power loss solution.
Only fuse-links of the same type or part number should be used in parallel, excepting that only one may be required to provide indication.
All the fuse-links would be mounted to allow equal current and heat flow to the connections.
In larger installations it is best to parallel fuse-links of close cold resistance values.
The I^2t value of parallel fuse-links are given by:-
$i^2t \times N^2$
where N is the number of parallel fuse-links connected together.
Mountings should ensure at least 5 mm between the adjacent parallel fuse-links.

Application Areas - General

Semiconductors and associated High Speed fuses are used in many application areas:
AC drives, DC drives, traction, soft starters, solid state relays, electrolysis, induction furnaces and inverters just to mention some. The power source for these may be grid supply, local generator or battery.
The circuit configuration for these application areas varies a lot, and some of the most typical circuits are found on the following page, together with information on how to find relevant RMS-load current level for fuse installation.
All of these types may operate at just a few amperes or at many thousands of amperes. The principles of the circuit operation are usually the same for all ratings whereas the level of protection depends on issues like the need to protect against accidents and personal injuries, security of components etc.
Some aspects of the circuits and their protection are common to many application areas, these will be covered here, and more specific details will be explained in following sections.

Applications are broadly grouped into those that are AC and those that are DC, however in modern circuits many systems involve AC and DC.
The applications such as variable speed AC drives, un-interruptible power supplies (UPS) that utilises inverters (DC to AC) can usually be considered in two parts for fusing. Firstly the AC to DC converter and then the inverter section. This guide will describe the »ac« part first and consider the rectifier systems and switches.

RMS currents in common bridge arrangements.

The most common circuits involve rectifiers converting AC to DC. There are a number of ways in which the supply transformers and rectifying devices may be arranged. For the purposes of the following diagrams diodes are shown, however thyristors or GTO's could also be used; these would give control over the output voltage or power.

There are common places to fit fuse-links in rectifier circuits. The RMS current at these positions varies depending on the amount of a cycle the current will be flowing. This is described for diodes, but for controlled circuits these values may be different. But they will not exceed those shown, as this is the same as the controlled device being permanently in an On state. The most common arrangements are shown in the diagrams below.

The pros and cons of positioning fuse-links in each of the positions will be considered in the detail for each of the configurations later.

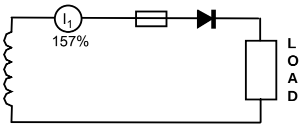
Circuit1 is not often encountered in power electronics systems. The half wave output will be inefficient and much distortion will be reflected to the supply.
Of the two methods (circuits 2 and 3) of single-phase bridge arrangements, circuit 2 is less common but it does have advantages in terms of earthing and the isolation voltages if the centre tap point of the transformer is earthed.
It is of course energy efficient to use three phase systems where possible, so the single-phase arrangements are usually only found in lower power applications involving currents below 50 amperes (supply primary).
However for low voltage battery systems and electroplating this can represent several hundred amperes on the secondary side.
The most common three-phase system is that shown in the 5th diagram.

The other rectifier systems shown are more often restricted to extremely high power applications that require the maximum efficiency possible for power conversion but they may also require special voltages that are not normal supply voltages. In these cases the need for special transformers can then be exploited by the complex bridge arrangements.
The final two diagrams are those used for AC switching and phase control, the most common applications being soft starting and solid state relays

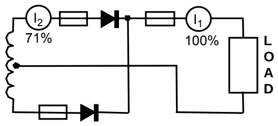
Typical Rectifier Circuits

Fuses are RMS-devices and based upon the 100% output DC-load current in average, the relevant RMS-load currents I_1, I_2, and I_3 can be found.

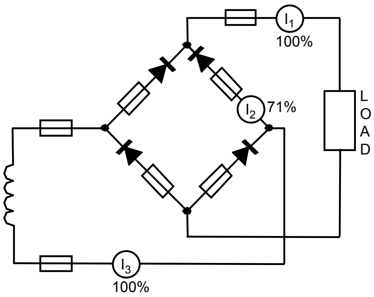
1. Single phase, Half Wave



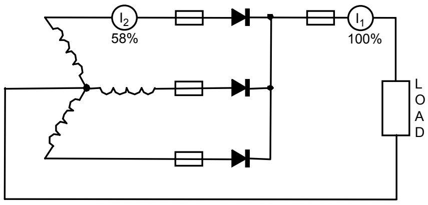
2. Single-Phase, Full Wave, Center Tap



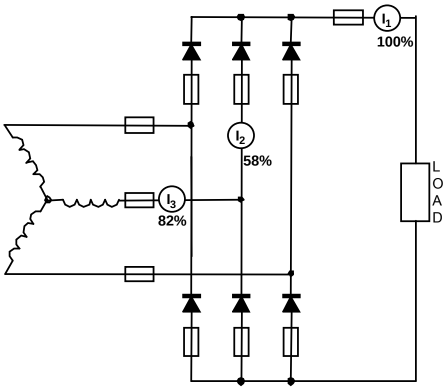
3. Single Phase, Bridge



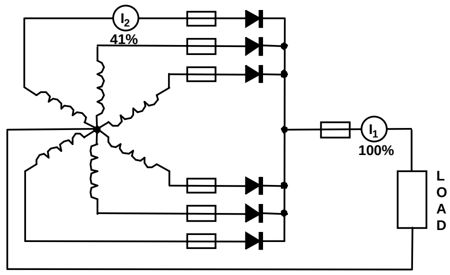
4. Three-Phase, Wye



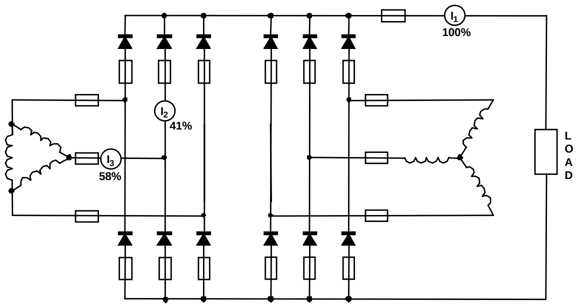
5. Three-Phase, Bridge



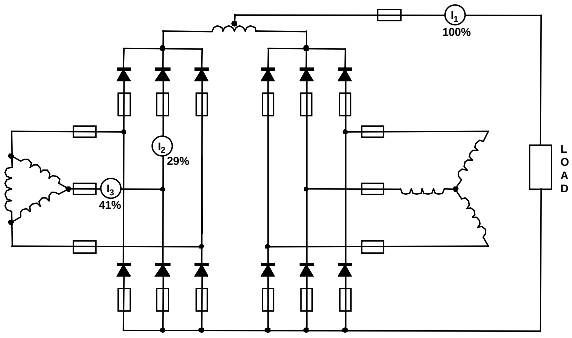
6. Six-Phase, Star



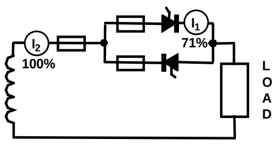
7. Six phase parallel (without IPT)



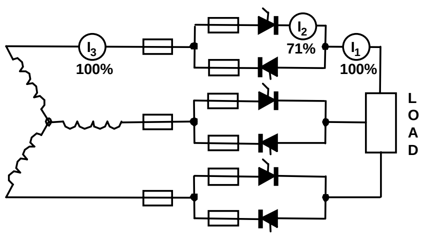
8. Six phase parallel (with IPT)



9. Single Phase, Anti Parallel, AC Controller



10 Three-Phase, Anti-Parallel, AC Control



Protection by Fuse-Links

In principle, the fuse-link should carry all the required continuous current and any expected overload currents and when a fault occurs should limit the energy passing through the semiconductor to a value that prevents damage to the semiconductor.

Internal and External Faults

As can be seen in the diagrams fuse-links may be placed in different positions in the circuit. Fuse-links may be placed in series with the semiconductor devices or in the supply lines, and sometimes in the output lines. Only the fuse-links in the legs of the bridge will allow maximum semiconductor steady state current carrying capacity as the minimum fuse-link RMS current is in this position.
In the design of high power rectifier equipment, there are two types of fault that must be catered for:

a) Failure to short circuit of an individual rectifier cell; generally termed an 'internal fault'
Failure to open circuit of silicon power rectifiers is rare, this type of fault, however, can be ascertained by the use of detection circuitry

b) The appearance of a short circuit or excessive load at the output terminals of the equipment; generally termed 'external fault'

Protection from an internal Fault

In order to protect healthy rectifier cells in the event of an internal fault, fuse-links should be placed in series with each rectifier cell.

Further consideration for rectifiers with parallel paths

It is important to point out at this stage, in the design of high power rectifier equipment; continuity of supply in the event of an internal fault is often a desired feature.
The equipment must therefore be designed to provide the required output under all load conditions with one or more semiconductor devices non-operative according to the manufacturer's specification.
To ensure continuity in the event of an internal fault, the fuse-link connected in series with the faulty arm of the bridge must clear without damaging fuses connected in series with healthy rectifier cells.
In order to satisfy this condition, the total I^2t of the single fuse-link must be less than the combined prearcing I^2t of all the fuse-links of one arm of the equipment, namely :
$I^2t_2 < I^2t_1 \times n^2$
where - I^2t_2 total I^2t of the single fuse-link
I^2t_1 - pre-arcing I^2t of each fuse
n the number of parallel paths in each arm of the equipment
Strictly, to allow for non-uniform current sharing in the parallel paths n should be replaced by: n/(1+S) where S is the uneven sharing in percent usually between 0.1 and 0.2 (10% and 20%).

In addition, should the design specify that continuity of supply must be maintained in the event of one or more devices being non-operative, the 'n' in the above formula must be replaced by (n - x), where x is the required number of non-operative cells.
Experience has shown that the protection of the above nature is often difficult where 'n' is less than 4.
In applications utilising both line and individual cell fuse-links a check must be made to ensure that the cell fuse-link discriminates with the line fuse-link in the case of an internal fault, i.e:
The total I^2t of the cell fuse-link must be less than the pre-arcing I^2t of the line fuse-link
$I^2t_1 < I^2t_2$
where I^2t_1 = total I^2t of cell fuse-link
I^2t_2 = pre-arcing I^2t of line fuse-link

Protection from an External Fault

In the event of an external fault, it is undesirable that all the individual rectifier fuse-links operate. It is practice, therefore, to include a fuse-link in series with the supply line.
To ensure that the line fuse-link clears before the individual cell fuse-link the following conditions must be satisfied:
the total I^2t of the line fuse-link must be less than the combined pre-arcing I^2t of the fuse-links utilised in one arm of the equipment, i.e.
$I^2t_1 < I^2t_2 \times n_2$
where I^2t_1 - total I^2t of line fuse-link
I^2t_2 - pre-arcing I^2t of each cell fuse-link
n: cell fuse links in parallel.

Service Interruption upon Device Failure

The majority of faults in low and medium power rectifying and converting equipment falls into this category. Fuse-links in series with the semiconductor devices or in the supply lines are used for protection against internal and external faults. Applications include:

1 Variable speed motor drives
2 Heater controls
3 Invertors
4 Low power rectifiers

Care must be taken in inverter circuits that correct DC voltage ratings are chosen for each application. Also DC faults can occur upon device failure in bridge circuits when other power sources feed the same DC bus or when the load consists of motors, capacitors or batteries.
Example 1 in the worked examples section, illustrates the protection of a typical DC thyristor drive.

Non-Interrupted Service upon Device Failure

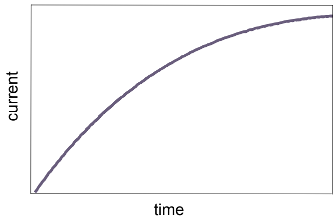
Service interruptions cannot be tolerated in large rectifying plant such as DC supplies for electro-chemical applications.

As discussed earlier, in such applications several parallel paths ($n > 4$) are employed in each leg of the rectifier and each of these parallel paths are individually fused to isolate faulty devices (see worked example section). In applications where a large number of fuse-links are used, the detection of the blown fuse-link is made easier by indicators on the fuse-links, which in addition can be made to actuate a micro-switch for distant warning.

Fuses under DC Conditions

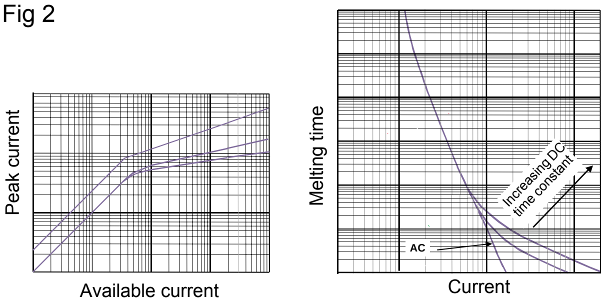
The inductance in a DC circuit limits the rate of rise of the current, and the time spent for the current to rise to 63% of the final value is called the time constant also referred to in terms of L/R.

Fig 1



The rate of rise of current influences the rate of energy input to melt the fuse elements. This will influence both the melting time-current characteristic and the peak current let-through of the fuse-link. For long operating times (greater than 1 s) the heating effect of an alternating current is the same as DC and the characteristics will merge. See Fig 2

Fig 2



Many circuits have the time constant of between 10 and 20 milliseconds and thus IEC specifications require testing between those values. Time constants longer than 20 ms are not often found outside of third rail railway applications, where the long rail lengths give extremely high inductance to resistance ratios. For short circuit considerations, the value of the circuit time constant under fault conditions should be used; this may be different to the time constant during »normal« operating conditions.

In many rectifier circuits, even under fault conditions, a fuse link will be subjected to an alternating voltage or when only unidirectional the voltage will reduce to zero or close to zero on a regular basis as defined by the supply frequency.
In these conditions, the extinguishing of the arc internal to the fuse-link, under fault conditions is assisted by the voltage reducing to zero.
When a fuse-link is involved in a purely DC situation the fuse arc extinction process will not be assisted by the reducing voltage or the voltage zeros of an AC situation.

The inductance in the circuit stores electircal energy. This influences the manner in which the fuse arcing process reduces the current in the circuit, for reasons that are beyond the scope of this guide.
The voltage, under which the fuse-link can safely operate is thus dependent on circuit time constants.
It should be noted that when the time constant is short, it may be possible for the DC voltage rating to be greater than the AC voltage rating (to IEC or UL); but for most fuse-links the DC voltage rating is 75% or less than the AC voltage rating and this DC rating will decrease further as the circuit time constant increases.
The arc voltage generated by the fuse-link during operation will also vary with respect to the system voltage. The variation of arc voltage with respect to applied voltage will be different between AC and DC systems. However in most cases it is acceptable to use the data provided for AC conditions.
Unless special design features are included, fuse-links should not be asked to clear against low over currents in DC circuits. The performance in this area may be a limiting factor on fuse-link selection.

DC fed systems

The vast majority of applications involving DC fall into the type where an AC supply is rectified to supply a load. This load may be passive such as an electrolysis cell or complex as regenerative drive.
There are a number of circuit types that require special consideration. These include those with batteries or capacitors and those where the motor drive is regenerative. In large electrolysis systems there are often considerations of parallel devices and fuses, this is covered elsewhere in this guide, as are regenerative drives.

Battery as a load

In principle, battery-charging circuits are similar to electrolysis systems.
»Standard« bridge configurations are normally used for these systems; Fuse-links may be positioned in AC line, arm or DC line. The use of arm fuse-links not only gives closest protection to the semiconductor device but also protects the bridge against internal bridge faults and faults in the DC system.
In high current circuits the control of the current is often by phase control using thyristors. In lower power systems the fault current may be limited only by the impedance of the secondary side of the transformer and the rectifier will be only diodes.
In the former, high fault currents can occur if the control to the thyristors fail. Selection of fuse-links for this type of circuit is like that for a DC drive. (Detailed elsewhere in this guide)
However, in a diode only system, in the event of a battery being connected in reverse polarity, the fault current will be passing directly through the diodes. The resulting fault current will only be limited by the internal impedance of the battery; Fast isolation is required to protect the diodes and to limit the I^2t in the diode.
Due attention has to be paid to the possible pulse duty a battery charger may be used for. Many controlled circuits will have a high charge rate for a short time before a lower continuous rate is applied. Guidance on this aspect is given in the section on cyclic loads

Battery as only source

Fault currents are usually only limited by the internal impedance of the battery. This will depend on the type of cells being used. However the internal impedance of the battery will vary with the state of charge of the battery. In some cases if the battery is in a part discharged condition there may not be sufficient current available to operate a fuse-link.
High Speed fuse-links are often used to protect batteries, as they limit the peak current to lower values than other fuse types and this will better protect the battery from damage. Cable protection should be by appropriate fuse-links that provide protection against overload faults. Full co-ordination is often difficult with battery systems, please contact Bussmann application engineers for assistance.

Whatever the application, care must be taken with circuits that are regenerative (supply energy back to the source e.g. vehicle braking conditions). In DC fed circuits such as traction propulsion systems care must be taken to ensure fuse-links on the DC supply are of a sufficient voltage rating for the regenerative voltage that will be higher than the system voltage by up to 10% or more.

DC Application of Bussmann Square Body AC Fuses

The information below applies specifically to the Square Body fuses of the 660V, 690V, 1000V, and 1250V AC standard series. For DC application on other High Speed fuses, please refer to the High Speed fuse catalogue.

These fuses can be used also in circuits where DC-faults occur. However, due care must be taken in the selection process.

The breaking capacity of the fuses depends on the combination of:
- the maximum applied DC-voltage
- the time constant L/R
- the prospective short-circuit current Ip of the circuit

Figures 1 and 2 show the dependency of the maximum applied DC-voltage on L/R, with 3 levels of Ip as parameter indicated as 1, 2, and 3.

In order to determine factor F in fig. 3, use the curves in figure 1 or 2. Which curve number to use depends on the coordinate point, if no such curve exist a fuse with a higher AC rating than 1250V must be chosen.

Note:
Fuses with reduced AC voltage:
Having found the max. applicable DC-voltage a reduction of this value is necessary if the given fuse has a rated AC-voltage lower than nominal for the series. The reduction of max. applicable DC-voltage should be equivalent to the derating in rated AC-voltage, (example: 690V series, but rated voltage 550VAC => 20% reduction of max appl. DC-voltage).

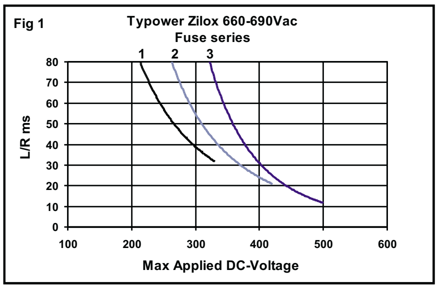
To check if the minimum level of Ip in the actual DC-circuit is in accordance with the selections made in fig. 1 or fig. 2,

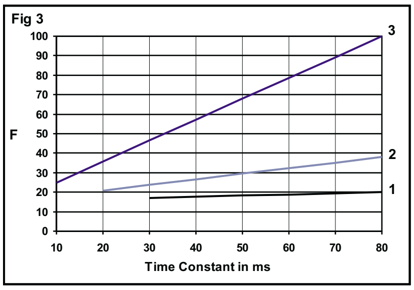
$$Ip\ ^{3}\ F\ x\ \sqrt{I^2t}\quad [A]$$

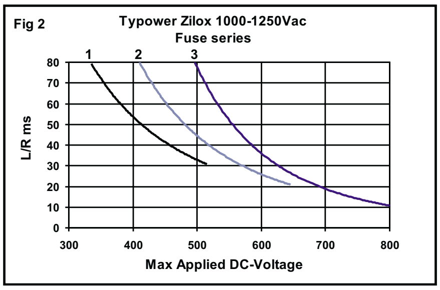
the following condition must hold true:

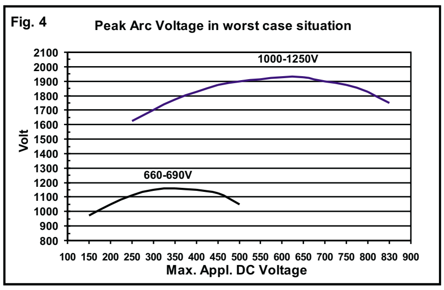
i^2t is the pre-arcing integral (from cold) in A^2s of the fuse in question, and F is found in fig. 3 as a function of actual L/R and the selected curve 1, 2, or 3 as parameter.

In fig. 4 the peak arc-voltage of the fuse in worst case situation can be found as a function of applied DC-voltage.







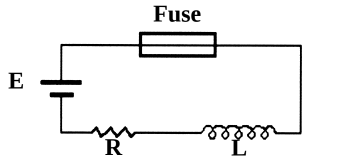


Calculation example:

Typower Zilox 1100A, 1250V, AC, 3/110, 170M6149, 575.000 A^2s (pre-arcing integral).

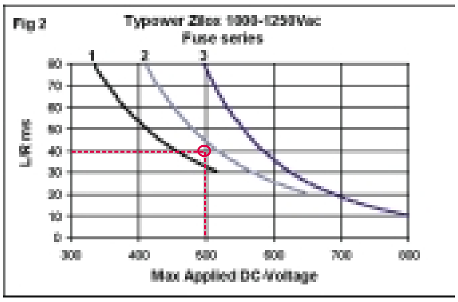
Applied voltage E = 500V DC,
Prospective current Ip = E/R = 500/16 = 31.3 kA
Time constant L/R = 40 ms (0.64/16)

Fig 1



R = 16mΩ   L = 0,64mH

Using fig. 2. it is found that having 500V as applied DC voltage with L/R = 40ms, curve 1 has been passed, and this leaves us with curve 2 in order to be on the safe side.



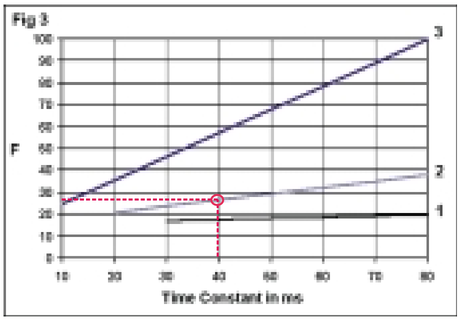
From fig. 3 we find F=26,5 based upon the combination L/R = 40ms and curve 2.
Together with the prearcing I^2t = 575.000 A^2s of the actual fuse this calls for.

Checking with the actual circuit parameters, it can be seen

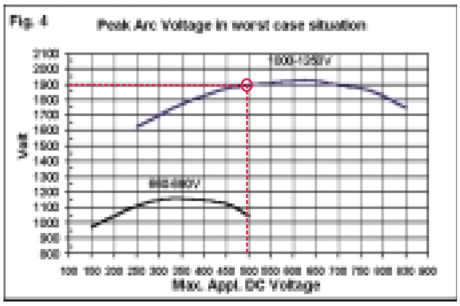
$$\text{min. Ip} = 20\text{KA} \ (26{,}5 \ \text{x} \ \sqrt{575.000})$$

that the breaking capacity of the selected fuse holds true, having the following main parameters fulfilled:

1. The max applied DC voltage is 500V
2. The time constant L/R is 40ms, up to 46ms could be allowed, OK and
3. Minimum of Ip= 20 kA is needed, having actually 31.3 kA is OK.



The peak Arc voltage generated by the fuse can be found to be lower than 1900V, according to fig. 4.

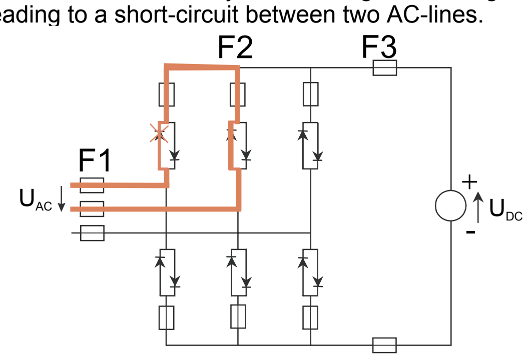


Selection of fuses for the protection of regenerative DC-drives

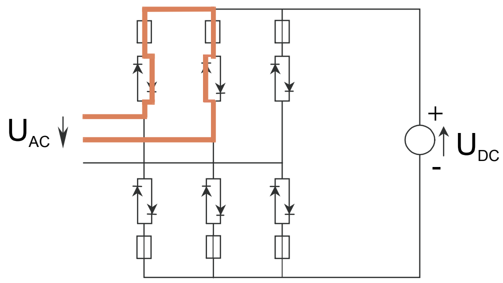
To select the rated fuse voltage the types of faults that can occur in the equipment must be known.
The fuses could be situated as F2 fuses only or as F1+F3 fuses.

In rectifier operation there are three possible fault types:

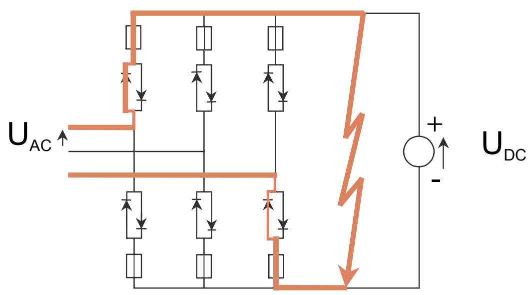
Internal fault
This fault is due to a thyristor loosing its blocking capacity, leading to a short-circuit between two AC-lines.



Cross-over fault
This fault occurs in case of a misfiring of one of the thyristors in the inverter bridge, resulting again in an AC line-to-line short-circuit.



External fault
This fault is due to a short-circuit on the DC output side, a motor flash-over for example. The applied fault voltage is again equal to the AC line-to-line voltage.



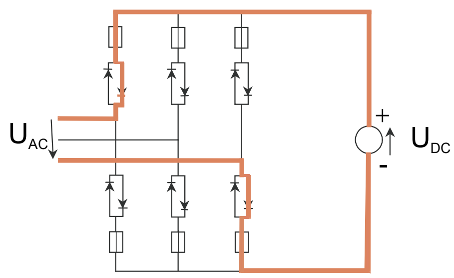
Conclusion on the rectifier mode

In all these three fault types the short-circuit current will pass through two fuses in series. This means that the two fuses will normally help each other in clearing the fault. Nevertheless, for safety reasons, as a minimum the rated voltage of the fuse U_N has to be selected according to $U_N \geq U_{AC}$ (please pay attention to the commutation fault situation). When it comes to the protection of the semiconductor and the I^2t calculation, it is an advantage to have two fuses in series. In the short circuit path this means that if the prospective current is very large, the I^2t can be calculated with almost equal sharing of the fault voltage. At smaller fault current levels it is not considered safe to use total equal voltage sharing: Normal procedure is to use 1.3 as a security factor. Hence, the **I^2t values** are calculated at

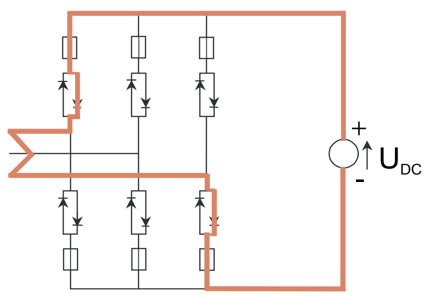
$$U_{AC} \times 0{,}5 \times 1{,}3 \sim 0{,}65 \times U_{AC}$$

During operation in the regenerative mode there can also be three types of faults:

Commutation fault
This fault is due to a thyristor losing its blocking capability while there is a direct line-to-line voltage across it. This leads to a short-circuit where the AC voltage is superposed to the DC voltage.

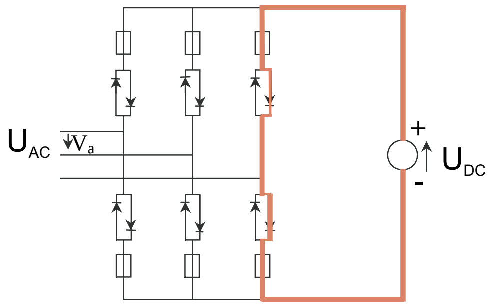


Loss of AC-power
If the AC voltage fails, a short on the motor acting as a generator occurs through the thyristors and the transformer.



DC shoot-through

This fault occurs due to the misfiring of one thyristor leading to a DC short-circuit.



Conclusion on the regenerative mode

As it can be seen from the fault circuit, there will also in all these three fault types be two fuses in series, but the fault voltage differs a lot.

During the commutation fault, the fault voltage is the AC voltage added to the DC voltage. In the worst case, the peak voltage will be about:

$$0{,}8 \times 1.35 \times U_{AC} + U_{AC} \times \sqrt{2} \approx 2.5 \times U_{AC}$$

As a rule of thumb, the fault voltage is half a sine wave at a lower frequency. E.g. the RMS value of the fault voltage will be about

$$2.5 \times U_{AC} \times 1/\sqrt{2} \approx 1{,}8 \times U_{AC}$$

Though this type of fault is very rare, it will dictate the dimensioning voltage for the rated voltage of the fuse in this system, meaning that the rated fuse voltage should be in accordance with;

$$U_N \geq 1{,}8 \times U_{AC}$$

If an I^2t calculation is needed here (mainly done for internal fault only), the dimensioning I^2t voltage having two fuses in the same short-circuit path will give

$$U_N = 1{,}8 \times 0{,}5 \times 1{,}3\ U_{AC} = 1{,}2 \times U_{AC}$$

For the other two types of faults under operation as an inverter, the fault voltage will be a pure DC-voltage. Normally, the max. voltage will be

$$0{,}8 \times 1{,}35 \times V_{AC} = 1{,}1 \times U_{AC}$$

A normal AC-fuse can operate under DC-conditions with some limit to the supply voltage, the minimum available fault current, and the time constant.

Please refer to the section »DC Application on Bussmann AC Fuses«.

During the DC shoot-through fault, the only impedances in the circuit are in the motor and in the inverter branch. The minimum prospective fault current is normally very large and the time constant in the circuit is small (e.g. 10-25 ms). Under this condition having two fuses in series, the I^2t value is normally equal to the value obtained under AC at a voltage level of

$$U_{DC} \times 1/\sqrt{2} = 1{,}1 \times U_{AC} \times 0{,}5 \times 1{,}3 \approx 0{,}5 \times U_{AC}$$

In order to be certain, all data should be available for the motor and other impedance in the circuit.

In case of a reduced or total loss of the AC-power, the condition is worse. The fault current level can be very low and the impedance of the transformer gives large time constants.

In order to suggest fuses that can function under these conditions it is necessary to have information not only on the motor and the inverter impedance but also on the transformer.

Summary of Voltage Selection for Regenerative Drives: (4Q-Service)

Combination of line voltage and load voltage requires:

Fuse voltage U_N 1,8 x U_{AC} (line to line)

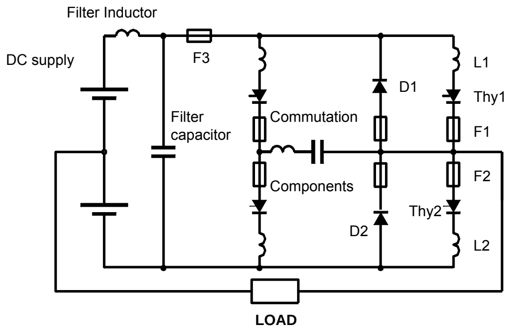
e.g.	110V System:	200V Fuse
	380V System:	690V Fuse
	690V System:	1250V Fuse

For further guidance please contact Busmann technical services.

Protection of inverters

There are now many equipment types that are used to convert direct current to alternating current (the direct current may have been created from alternating current by a rectifier).
Such applications include variable speed AC drives and un-interuptible power supplies (UPS).
All these inverters work by switching the DC on and off in a predetermined manner. Early inverters using thyristors were often of the »McMurray« form (see diagram). As thyristors continue to pass current, once they are turned on, until the voltage across them is reversed, numerous components were required to »commutate« the devices. These devices were often physically large. The commutation thyristors also required protection.

Typical Invertor - thyristor
One phase of three phase unit



Although fuse protection may be in the »DC link«, F3, to protect the thyristors it is best to use device protection (F1& F2). To ensure protection in these circuits, it is essential to use the fastest fuses that are available (and still meet all the current dimensioning) which are also rated with a DC voltage capability at least as high as the DC link voltage.

The key to fuse-link selection in inverters is to select the highest speed available that will meet the current and voltage dimensioning requirements.

Voltage selection

Fuse-links in the inverter must have a DC voltage rating of at least the supply link voltage. Even though in most fault conditions there will be two fuse-links in series, these will not share the voltage equally. Also in some fault situations the voltage on the link may exceed the nominal value by up to 30% for a short time.

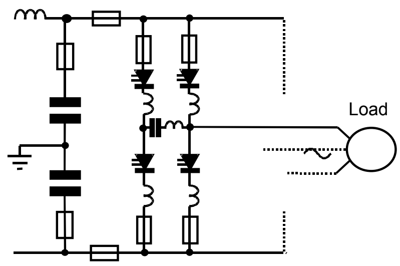
Current selection

As shown in the diagrams of inverter circuits, there are several positions to place fuse-links. As with DC drive circuits, the use of »link« fuses or DC line fuses results in the highest current rating and closest protection is by individual device protection.
As inverter circuits contain high frequency components to the current, and the physical arrangements are compact, proximity effects may influence the fuse-links and further allowance must be made for current carrying capability.

I^2t selection

Due to the magnitude of the fault current from the capacitor and small inductance in the circuit, the rate of rise of current may be very high. Selection of suitable I^2t criteria is not easy as device data may not be available for times below 3 ms and fuse-link information may not be provided for these conditions either. Fuse-link performance will also vary slightly depending on the size of capacitor, the circuit inductance and resistance and link voltage. Selection by choice of the lowest I^2t fuse-link that will meet the current dimensioning requirements will be the best way of ensuring device protection. But even if device protection is not ensured this fuse-link selection will certainly limit the damage to all the circuit components.
It is also important to select a low I^2t fuse-link for the following reason, especially if the capacitor is a low value. When a short circuit occurs in the inverter the current rises rapidly to a peak and will then decay, the waveform is classical of capacitor discharge. It is important that the fuse-link has completed operation before the voltage on the capacitor has decayed to a low value. If the fuse-link was to operate at a low voltage on the capacitor, the fuse-link may not have developed sufficient insulation resistance to resist the DC link voltage when it is replenished from the supply.

GTO inverter

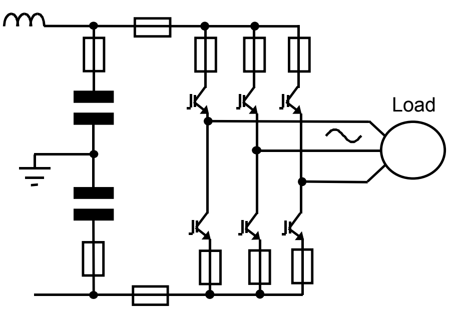


With the developments of GTOs, it was possible to switch off the current without the use of commutation components. It should be noted that as well as reducing the complications for trigger (firing) circuits considerable, space and costs were to be saved as the commutation components were both bulky and expensive, and of course they also contributed energy losses.
Although GTOs are more expensive than thyristors the reduction in component count more than compensates for this. In terms of protection there is little difference in the selection parameters, however the GTO circuits are inherently more reliable and there are fewer power components to protect.

IGBT as Switching Device

The advent of the IGBT as the switching device has made the control circuits much easier and the power dissipation of the power switching sections can be much reduced. The higher switching frequency capability and ease of control has allowed the more efficient use of the pulse width modulation techniques, as well as improved quality of the output waveform.

IGBT inverter



However the IGBT circuit has brought some different problems to the protection system.
In order to reduce switching losses the inductance of the filter capacitor and IGBTs has to be as low as possible. This is achieved by careful busbar arrangements that often preclude the addition of fuse-links.
Due to the design of the silicon switching element, an IGBT module can limit current for a short period. In addition it is often possible to detect fault currents and switch off the IGBT before damage is caused to it. However, if the IGBT is not switched off before the device is damaged, the silicon will melt and vaporise, like other semiconductors will when subjected to sufficient over current.
In the case of plastic IGBT modules there is a further failure mode that occurs before the silicon melts. The internal connections to the IGBTs and other components are thin aluminium wires. Under fault conditions, these wires melt, and the resulting arc causes the module case to become detached from the base, and in some cases there is damage to the module case. Protection must therefore be about protecting the wires and the module case as well as the devices. Unfortunately, there is often no I^2t data provided for IGBT modules.

Protection of drive circuits.

If damage is caused to the IGBT device or connecting leads, the gate control circuits may become »involved« with the high voltages and power of the power circuit.
To avoid, or at least limit, damage to the control circuits, miniature HBC fuse-links should be used in the drive circuits. Low breaking capacity glass fuse-links are not suitable.

Bi-polar Power transistors and darlingtons

It is difficult to protect power transistors using fuse-links. The power transistor is usually operated extremely close to its power limits of current and voltage. Only a short excursion beyond the safe operating area will damage the functional aspect of the transistor and even High Speed fuses will not react fast enough to protect the device. However, like IGBTs, when the function of the transistor is lost the current is only limited by the low resistance of the damaged silicon and very high currents result. These will melt any connecting wires; and will in the case of press-pack configuration eventually melt the silicon. The resultant arcs will cause the packaging to fail with catastrophic results. Hence even though device protection cannot be offered by using fuse-links it is still essential to use fuse-links to prevent case rupture and to provide circuit isolation.

Worked Examples

The foregoing can perhaps be best understood by studying typical examples and seeing how appropriate Bussmann fuse-links can be selected to meet the necessary requirements.

Example 1. DC Thyristor Drive

Basic Information:
500 hp drive variable speed.

- i. Motor, nominal DC voltage-660 V
- ii. Motor, maximum DC current-600 A
- iii. Supply transformer 750 kVA, 5% impedance
- iv. Supply voltage - 480 V RMS
- v. Overload protection is provided by current limit circuit (direct control of the firing of the thyristors) with a response time of 25 milliseconds
- vi. The equipment has to operate at a maximum ambient of 40°C, natural ventilation.
- vii. The circuit used is a 3-phase thyristor bridge, using one thyristor per leg
- viii. Thyristor particulars: I^2t rating 120,000 amp^{2}sec, Peak reverse voltage withstand Urrm=1600V.
- ix. No details of cyclic loading are to be included for this example
- x. Application is for northern europe.

Basic Design

For best protection, device protection utilising 6 fuse-links will be examined, one each Thyristor.
Since the fuse-links are used for short circuit protection only, this is simply a question of co-ordinating the I^2t, peak current, and maximum RMS fuse current ratings.
Maximum RMS current through each thyristor is given by the appropriate factor for the circuit layout multiplied by the DC load current
= 0.58 x 600 (Fig 5 in the section Typical Rectifier Circuits)
- 348 A
From the fuse catalogue a fuse link of around 400A of an appropriate physical type is selected. For the application a fuse from the square fuse types is required. From the data sheet for size 00 fuses rated at 690V and 400A is initially chosen. From the temperature rating graph, Fig 1 in the section "Rated Current Dimensioning", a derating to 90% is required at 40 deg C. No other thermal derating factors will be required.
0.9 x 400 = 360 A.
As this is above the required 348 A, this rating would be appropriate.
Next, the fuse-link I^2t has to be confirmed as less than the withstand of the device.
For the 400 A fuse of body size 00 the total I^2t is 125,000 at 660V. By observing the factor for I^2t with respect to applied voltage on the data sheet it can be seen that the I^2t at 480V will be only 0,7 of the value at 660 V, i.e. 87,500, which is well below that of the thyristor withstand,
A check of the arc voltage graph on the data sheets confirms that the fuse arc voltage of 1000V will be below the 1600V voltage rating of the thyristor.
Thus the selection of the type 170M2621, a body size 00, 690V 400A, 80mm fixing centre fuse-link can be made.
If the power loss of the equipment is critical and there are no physical constraints it may be possible to utilise an alternative solution:
By selecting a higher current rating fuse-link and using it at a current well below its capability it will give considerable lowering of the power dissipation.
For this example we can chose a body size 2 fuse-link of 500A rating. Although the I^2t is 145,000 at 660V this will be reduced to 101,000 at 480 volts as described above.
The power dissipation of the 400 A fuse at 348 A (87%) will be reduced to 80% of the 70W shown on the data sheet i.e. 56W.
If the 500A body size 2 fuse link is used at 348 (70%) the 75 watts shown on the data sheet will be reduced to 45% or 34 W.
As 6 fuse-links are to be used the total power saving by using physically larger fuse-links will be 132W

Example 2. DC supply with redundant diodes

Rectifier to provide a 7500 A, 80 V DC supply from a 50 Hz supply

Basic Information:

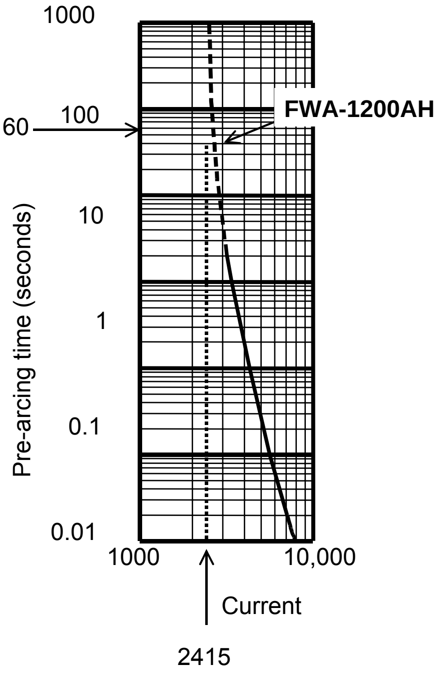
- i. 3-phase diode bridge, 6 parallel diodes per leg
- ii. 100% overload for 1 minute
- iii. 55°C ambient-maximum. Air-flow of 4 m/s supplied
- iv. Bus-bars based on 1 A /mm^2
- v. Diode rating :
  - A. Maximum mean rating (free convection, specified heat sink) 1000A
  - B. I^2t rating, 10 milliseconds - 1,000,000 A^{2}s, Peak reverse voltage withstand Urrm=500V.
- vi. Maximum prospective AC fault current = 125,000 RMS symmetrical amps

Protection requirements

Fuse-links must protect the diodes against internal faults, isolating faulty diodes without interrupting the supply.

Design Details

To protect this application we require device fuse-links.
Maximum RMS fuse current (allowing for one defective diode, n-1=5 ; and sharing factor of 90%)
Load current x factor for rectifier circuit / 0.9 / number of good paths
7,500 x 0.58 / 0.9 / 5 = 966 A
Therefore selected fuse must have a current rating above 966 after any other thermal de-ratings are applied.
We require to apply factors for high ambient temperature and air cooling. The 1 Amm-1 busbar does not need any adjustment.
From the section on Rated Current Dimensioning we find factors of Kt=0.85 due to amb.temp. and Kv=1.2 for 4m/s air flow.
The rated current In of the selected fuse-link must be greater than
In>= 966 / 0.85 / 1.2 = 947A
For the low voltage application, with a low peak reverse voltage diode a fuse-link from the low voltage »British« or USA ranges is required.
To achieve 950 A in the 240 volt »British« range it would be necessary to use three fuse-links of 350A rating.
To avoid using parallel fuse-links, the FWA product should be chosen. It is this option that will be considered for the overload considerations.



Overload

The selected fuse must also carry extra 100% (or twice rated) current for 60 seconds, once a month. As this is only an occasional overload it should be possible to select a fuse up to 80% of the time current curve at the 60 second operating time. Put an alternative way: the fuse must have an operating current greater than
966 x 2 / 0.8 = 2415A
at the 60 second operating time, clearly the FWA-1200AH is suitable for this application.

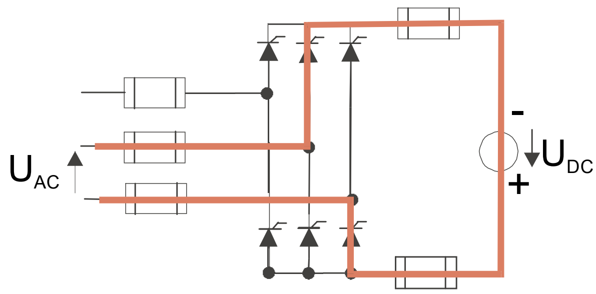
Arc Voltage

From the data sheet for the chosen fuse-link, the arc voltage of 190V can be seen to be less than the 500V reverse voltage capability of the diodes chosen.

Short Circuit Protection

The I^2t of the FWA-1200AH is 730.000 A^2s at 130 volts, the I^2t will reduce with lower voltages. From the data sheet it can be seen that the reduction at 80 volt is to 75%, 548.000 A^2s.
To ensure continuity of supply when a device fails, the total I^2t of the fuse-link in series with the faulty device must be less than the combined pre-arcing I^2t (240.000 A^2s each) of all the 6 fuse-links in series with the fault (in a different arm of the bridge)
That is 548.000 < 6^2 x 240.000= 8.640.000 A^2s confirming the suitability to protect the devices suggested.

Example 3. Regenerative Drive Application



Typical application

High inertia drive, using a 500HP DC motor, supplied from a three phase 380V AC grid.
To simplify the application - assume the busbars are adequately rated at between 1 and 1.6 A/mm^2.
Assume air cooled system with ambient temperature of 35ºC with no additional air flow.
Although expected overloads will be cyclic, regenerative drives would not be cost effective if the load was not stopped regularly. For the purpose of this example the cyclic loading details will not be included so as to simplfy the example. In practice the rules for cyclic loading explained in this guide should be followed and applied to the current rating as well as the ratings described here.
A 380 V supply will give a nominal DC voltage of 500 V from a six-pulse bridge.
A 500 V DC, 500 HP motor will have a motor current of approximately 750A.
The best place to fit fuse-links will be in series with each device (device or arm fusing). The current in each arm will be 0.58 x 750 = 435A.
For ambient de-rating we find Kt= 0,94 thus the minimum current rating of the fuse-link should be 435 / 0,94 = 426A.
The next rating available above this should be chosen. In most product ranges this will be 500A.

Consideration of voltage rating

The worst case for voltage rating in a regenerative drive is that of a commutation fault. Therefore a fuse-link is required with an AC voltage rating of at least 1.8 x 380 = 640 V (see section Selection of the fuse for the protection of regenerative DC-drives) for this we would select a 690 volt fuse-link.
Selection of fuse-link is then based on mounting arrangements, physical constraints, approvals required etc.

Note on voltage rating
If the drive system was to align with the international standard voltage (not the old voltages) then the drive should be rated to be supplied with a 400-volt supply, the d.c voltage could be maintained at the same voltage by phase angle control of the bridge devices. In this case the use of a 690-volt fuse in the application would then be unsuitable and selection form a higher voltage range would be required.

Appendix 1
International Standards and Bussmann Product Range

For many years there were no specific international standards for High Speed fuse-links. Over a period of time, as more manufacturers produced these fuse-links, a number of dimensional arrangements became common practice. High Speed fuse-links are now becoming a mature product and international standards have been developed to include the test methods and dimensions.
In Europe, the test requirements of BS88 part 4 (1976) were the same as IEC269-4, with dimensions included for High Speed fuse-links in common use in the UK. IEC 269-4 included test conditions for AC and DC circuits that were more suitable for High Speed fuses than those for industrial circuits. The German VDE specification 0623 part 23 was specific to the testing of High Speed fuse-links, dimensions were included in DIN 43620 (the same as industrial fuse-links) and DIN 43653 (European High Speed square-body). Cylindrical fuse-links were usually dimensionally to French NF C63211.
The EURONORM EN60269 now supersedes all these.

In the USA, common dimensions became an »industry norm« but until these commonly used dimensions were included in EN60269, they were not included in a published standard. Testing was performed to either customer specifications or when UL component recognition was required the tests performed would be similar to those of various UL specifications.The specifications now define test conditions and methods. Although these conditions are similar there are some differences that are beyond the scope of this guide. The major difference between the UL and IEC specifications is that of voltage rating. This difference is common to many electrical specifications and is based on long historical background. Briefly, European standards require testing at voltages at some tolerance above the rated voltage of the components thus proving a safety margin. Practice in the USA requires testing at the rated voltage. Hence, it is design practice to use the max. voltage available for dimensioning the rated voltage of components.

Bussmann Product Ranges

The origins of the various fuse link constructions are from different centres in the world, and Bussmann also manufactures High Speed Fuses in both UK, DK, and in USA. Since the late 50s, various standards have been developed in the above mentioned regions for fuses for the protection of semiconductors. As a result, Bussmann High Speed Fuses can today be grouped in four World Recognised standards:

- European Standard - Square Body
- European Standard - round body BS 88 or British Standard
- US Style - North American blade and flush-end style
- Ferrule Fuses - cylindrical

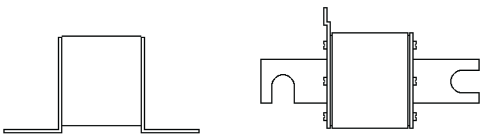
European Standard

In Europe, outside of the UK, two types of fixing have proved to be the preferred in applications requiring High Speed Fuses - namely blade type fuses and flush-end versions.

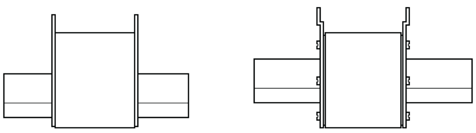
Blade type fuses

In Europe, two German standards for the mounting of fuses cover most normal styles used for Bussmann blade type High Speed Fuses. The two standards are:

DIN 43653



DIN 43620



The DIN 43620 style, used for gG fuses (previously referred to as gL fuses), is used also for High Speed Fuses. However, parts of a High Speed Fuse typically reach higher temperatures during continuous operation than a normal gG fuse. As a result, the DIN 43620 style High Speed Fuses cannot get a sufficient rating if the temperature limits for the holders in which the fuses are installed is to be respected. Knives with holes for mounting fuses directly on the busbar are the solution to this. The DIN 43653 standard came in 1973 with the possibility of mounting the fuse directly on the busbar. Also new holders appeared at the same time.

For the most common voltage ratings, fuses with blades according to DIN 43653 will always have fixing centres of 80mm or 110mm.

Flush-end contact type

Like the DIN 43653 style, the flush-end style has proved to be a very efficient and popular style for High Speed Fuses. The reason is its flexibility in installation. But the style is also selected because the current carrying capacity in this construction is the most efficient of all fuse types. This is now an industry standard style and is to be included in the international standard IEC 60269-4-1.

British Standard - BS 88

Not surprisingly, this type of fixing has found its use mainly, but not exclusively, in the UK and in British Commonwealth countries. Also in North America manufacturers have begun to specify British style fuses - particularly in applications like UPS equipment with voltages of 240V or less. The advantages are the size, performance, and cost benefit. Utilising the dimensions given in the BS 88 standard for High Speed Fuses, which are not physically interchangeable with Industrial fuses to the same standard, has proven to be a very popular and indeed a cost competitive solution also for High Speed Fuses.

Cylindrical Fuses

Often referred to as ferrule fuses, this style is internationally used and accepted. The program that Bussmann manufacture in most cases have dimensions that meet IEC standard 60269. The standard dimensions are 10x38mm, 14x51mm, and 22x58mm, and Bussmann supplies suitable modular fuse holders. The fuses with this particular housing has proven very popular for applications with ratings up to 660V/100A, due to their easy installation.

US Style - North American blade and flush-end style

Over the years, the North American market has adapted its own style for mounting High Speed Fuses. Although no published standard exists for these fixings as yet, the industry has standardised on mounting centres that accept Bussmann fuses.
In many ways, the US Style fuses are similar to the European Style. They are made in both blade and flush-end versions, but two major differences distinguish the two:
US Style fuses are usually made in mineral fibre tubes. The fixing centres for US Style fuses will vary, depending on both the rated voltage and the rated current.

Appendix 2
Fuse-link Reference System

Again, because of the variety of Bussmann High Speed Fuses, the reference system as contained in our program today is rather complex. The use of one particular reference system in Europe outside UK, another one in the UK, and a third system in the US has become a fact of life. Over the years, with the acquisitions made by Bussmann, it has of course been discussed on several occasions to change all references and to have only one system instead. However, all systems have been around for a long time, and the references today are so well known in the respective market concentrations for particular styles that we have decided to maintain the existing systems.
Below, we will therefore describe the Bussmann reference system in detail, - style by style.

Reference system for European High Speed Fuses

A typical fuse from our European Range could have a part number like for example 170M3473. However, this will not give any guide to what rating or what fixing this fuse will have. Here, the user will first of all need to know the rating. But the fixing is obviously also of interest, and here we use a Type Description to determine what style is in question. Fuses according to the German DIN 43620 standard are always listed by type, as for example DIN 3, DIN 00, etc. But for other fuses, according to DIN 43653, flush-end types, or special types, this description will reveal the actual type in question. For the reference given above, the type designation will be the following:

1*BKN/50

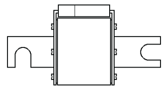
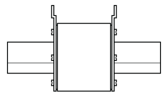
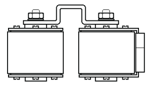
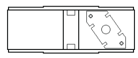
To interpret this Type Code we have made the following general guideline, which will cover most of the fuses in the European programme:

Primary Code **Pos. 1**	**Pos. 2** Body size	Optional **Pos. 3**	**Pos. 4** Mechanical fixing	Indicator Type **Pos. 5**	**Pos. 6** Indicator position		Centre distance **Pos. 7**
	1*		**B**	**K**	**N**	**/**	**80**

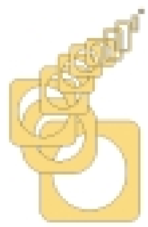
The following tables show the various options for all above positions in the Type Description:

Pos. 1 - Primary code

The primary code can be one of the following values:

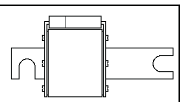
None	DIN 43653 or other style	3KN/110	
DIN	DIN 43620	DIN 3	
2//	Two fuses in parallel connected with fish joint	2//3BKN/100	
2	Two fuses in parallel integrated between plates	24BKN/85	

Pos. 2 - Body size

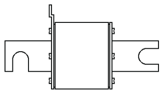
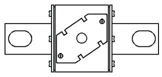
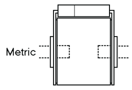
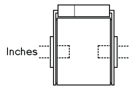
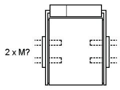
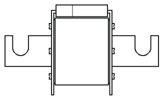
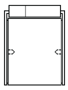
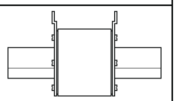
0000	17x17 mm	0000U/80	
000	21x36 mm	000/80	
00	30x47 mm	DIN 00	
0	35x45 mm	0S/55	
1*	45x45 mm	1*BKN/90	
1	53x53 mm	DIN 1	
2	61x61 mm	2TN/110	
3	76x76 mm	2//3SBKN/55	
4	105x105 mm	4PKN/150	
4+	115x115 mm	24+BKN/55	
5	159x159 mm	5BKN/65	

Pos. 3 - Optional

Over the years, Bussmann has become known as a supplier who is able to adapt to customer needs. Therefore, a lot of customised, special fuses are now a part of the product offering. Pos. 3 in the Type Description might therefore be an »S« for special. For all such references, please consult Bussmann for a mechanical drawing, if this is not already at your disposal.

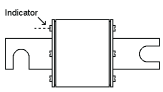
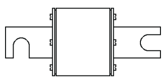
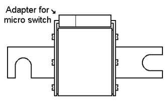
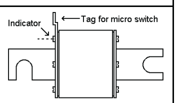
S	Customised fuse	2SKN/210	

Pos. 4 - Mechanical fixing

None	Slotted Blade type DIN 43653	2TN/110	
F	US or BS 88 blade style	1*FKE/78	
B	Flush-end version - metric thread	3BKN/50	
G	Flush-end version - US thread	1GKN/50	
D	Double Bolt, flush-end version - metric	3DKN/65	
E	French style blades	1EKN/86	
P	Press Pack	3PKN/85	
H	Blade, without slots (not DIN 43620)	3SHT	

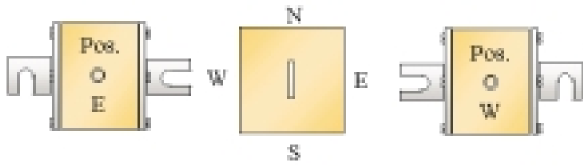
Pos. 5 - Indicator type

It is quite common that a fuse will have some type of indicator to show if it has operated. Some indicators are built in and some have to be fitted externally. Optionally they are able to trigger microswitches for remote operation. On the Indicator Pos. 5 in the Type Description, the following options are standard:

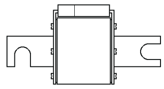
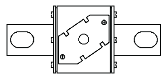
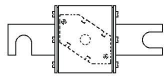
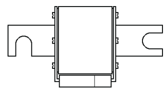
None	Standard visual indicator	1/80	
U	No indicator	2U/110	
K	Adapter type indicator mounted on the fuse prepared for microswitch	3KN/110	
T	Tag-type indicator prepared for microswitch	2TN/110	

Pos. 6 - Indicator position

The indicator position may vary from product to product. Standard fixation is the so-called Position N (North) and alternative positions are E (East), W (West), and S (South):

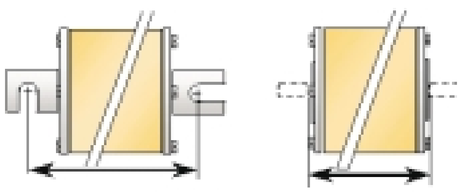


(European projection)

N	North position (standard fixation)	2KN/110	
E	East position	1FKE/78	
W	West position	2KW/110	
S	South position	2SKS/110	

Pos. 7 - Centre distance

Indicates centre distance for mounting, or overall length of fuses with flush end contacts, stated in millimetres.



Reference system for BS88 High Speed Fuses

Since fuse-links were first produced in the dimensions that became standardised in BS88 part 4, fuse-link technology has improved. It is now possible to manufacture fuses with many different operating characteristics. In these dimensions Bussmann High Speed fuses are available in two speed ratings. The T range and the F range.
Fuse-links can be selected according to the following codes.

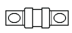
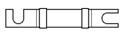
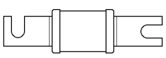
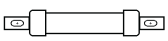
T Range

Current rating **Pos. 1**		Body size **Pos. 3**	
80	**L**	**E**	**T**
	Pos. 2 Voltage or style		**Pos. 4** T Range

Pos. 1 - Current Rating

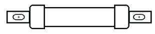
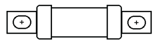
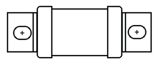
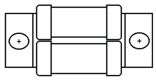
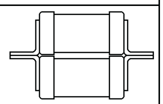
The continuous current rating in amperes

Pos. 2 - Voltage or style

L	Voltage rating 240 volts. Fixings as BS 88 part 4	80LET	
A	Voltage rating 660 volts. Fixings 80 mm	80AET	
C	Voltage rating 660 volts. Fixings 110 mm	250CMT	
None	Voltage rating 660 volts. Fixings as BS 88 part 4	20CT	

Pos. 3 - Body Style

In BS88 part 4, fuse-links have three diameters. Bussmann indicates which diameter the fuse-link has by use of a letter in position 3. To achieve additional current ratings of fuse-links, it is possible to place two fuse-links in parallel. Bussmann provides such fuse-links, and to indicate that two fuse barrels are used, the letter indicating the diameter is repeated.

C	8.4 mm	6CT	
E	18 mm	35LET	
M	38 mm	315LMT	
EE	2 x 18 mm	140EET	
MM	2 x 38 mm	710LMMT	

Pos. 4 - T range

The Bussmann T range has a T in this position. Some special purpose fuse-links in 'standard' dimensions or with special fixing arrangements may have an alternate letter in this position. Contact Bussmann for details.
For example, 80LET is an 80 ampere, 240 volt fuse-link, 18 mm diameter. 160AEET is a 160 ampere, 660 volt fuse-link with two 18 mm diameter barrels and 80 mm fixings.

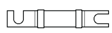
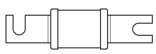
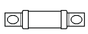
F Range

Current rating **Pos. 1**		F Range **Pos. 3**	
80	**A**	**F**	**E**
	Pos. 2 Voltage or style		**Pos. 4** Body Size

Pos. 1 - Current Rating

The continuous current rating in amperes

Pos. 2 - Voltage or style

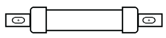
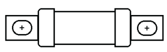
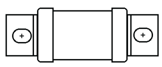
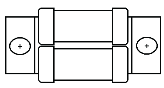
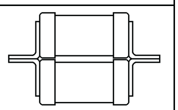
A	Voltage rating 660 volts. Fixings 80 mm	20AFE	
C	Voltage rating 660 volts. Fixings 110 mm	250CFM	
No mark	Voltage rating 660 volts. Fixings as BS 88 part 4	80FE	

Pos.3 - F range

The Bussmann F range (these fuse-links are faster acting than the T range) has an F in this position.

Pos. 4 - Body Style

In BS88 part 4, fuse-links have three diameters. Bussmann indicates the diameter of the fuse-links by means of a letter in position 4. To achieve additional fuse-link current ratings it is possible to place two fuse-links in parallel. Bussmann provides such fuse-links and to indicate that two fuse barrels are used, the letter indicating the diameter is repeated.

C	8.4 mm		
E	18 mm	35FE	
M	38 mm	200FM	
EE	2 x 18 mm	180FEE	
MM	2 x 38 mm	630FMM	

For example, 80FE is an 80 ampere, 660 volt fuse-link, 18 mm diameter.

Reference system for US High Speed Fuses

Like the fuse-links in European square and round bodies have descriptive type numbers, the US fuses in the Bussmann programme have descriptive part numbers. To date there is no recognised US dimensional standard for high speed fuse-links, but there are accepted industry standards. Bussmann fuse-links meet these standards. The following tables show the various options for all above positions in the Type Description.

Standard programme - type FW

Fuse-links can be selected by the following codes:

Primary Code **Pos. 1**			Current Rating **Pos. 3**		Fixing Style **Pos. 5**	
FW	**X**	**-**	**1000**	**A**	**H**	**I**
	Pos. 2 Voltage Rating			**Pos. 4** Technical Revision		**Pos. 6** Indicator Type

Pos. 1 - Primary code

All Bussmann US style high speed fuse-links in the standard program are designated by the prefix FW.

Pos. 2 - Voltage rating

The AC voltage rating of the fuse-link.

A	130 or 150	FWA-80A
X	250	FWX-1A14F
H	500	FWH-175B
C	600	FWC-12A10F
P	700	FWP-15A14F
K	750	FWK-5A20F
J	1000	FWJ-20A14F
L	1250	FWL-20A20F
S	1500	FWS-15A20F

Pos. 3 - Current Rating

For Bussmann high speed fuse-links this is usually the continuous current rating.

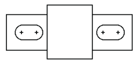
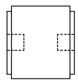
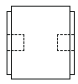
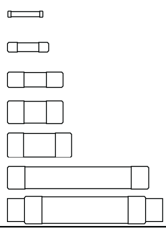
Pos. 4 - Technical Revision

Bussmann constantly improves the performance of its products. The Bussmann FW range also represents a range consolidated after several acquisitions. When this occurs with products in the main programme, it is necessary to distinguish each technical revision without changing all the part numbers. In common with the semiconductor industry, Bussmann uses a letter code for this purpose. For technical reasons it may be necessary to maintain more than one of these revisions for some applications.Most applications should use the latest revision, however.

No mark	The first version of this product	
A, B, C etc.	Later improved version	FWP-10B

Pos. 5 - Fixing style

Most of the FW type fuse-links have centre blades with fixing holes. However, flush end fixings (often called Hockey Puck) are common and so are the cylindrical bladeless types.

Empty	Standard blade	FWX-90A	
H	Flush end fixings – imperial thread	FWX-1000AH	
BB	Flush end fixings – metric thread	FWA-2000ABB	
****F**	Cylindrical blade- less (ferrule) where ** is the diameter in mm of the end cap	FWH-30A6F FWC-20A10F FWH-30A14F FWA-35A21F FWP-100A22F FWK-25A20F FWK-60A25F	

Note: Where F is in position 5, the first version of the product will be designated with an A

Pos. 6 - Indicator

As standard, the FW range products do not have visual indication of fuse operation.

Empty	Standard product
I	Indication by additional external type TI indicating fuse that also takes MA type microswitch (see BS style accessories)
SI	Indication by external indicator that also takes 170H0069 microswitch.

Special Programme - types SF and XL

In addition to the standard programme of FW fuse-links, Bussmann offers special purpose fuse-links and also a range of higher speed versions as an alternative to some of the FW range.

Fuse-links can be selected by the following codes:

Primary Code **Pos. 1**		Style **Pos. 3**		Technical Revision **Pos. 5**		Indicator Type **Pos. 7**
SF	**75**	**X**	**1000**		**H**	**I**
	Pos. 2 Voltage Rating		**Pos. 4** Current Rating		**Pos. 6** Fixing Style	

Pos. 1 - Primary code

Bussmann's US style high speed and special purpose fuse-links are designated by the prefix SF or XL.

Pos. 2 - Voltage rating

Generally, this is one tenth of the AC voltage rating of the fuse-link. For special purpose fuse-links please check with Bussmann.

Pos. 3 - Style

F	High speed performance This often also means good dc voltage performance
X	Slow speed, often for traction applications

This is only an indication of the letters used, others may be used for special purpose fuse-links

Pos. 4 - Current Rating

For standard Bussmann high speed fuse-links this is usually the continuous current rating. For other types this position may only be an indication of capabilities, as many of these designations are agreed with OEMs for special applications.

Pos. 5 - Technical Revision

Bussmann constantly improves the performance of its products. When this occurs with products outside our main program, it is necessary to distinguish each technical revision without changing all the part numbers. In common with the semiconductor industry, Bussmann uses a letter code for this purpose. For technical reasons it may be necessary to maintain more than one of these revisions for some applications, however most applications should use the latest revision.

No mark	The first version of this product
A, B, C etc.	Later improved versions

Pos. 6 - Fixing style

Most of the SF and XL type fuse-links have centre blades with fixing holes.

Empty	Standard blade
HP	Flush end fixings – imperial thread
BB	Flush end fixings – metric thread
others	Agreed with OEM

Pos. 7 - Indicator

Empty	Standard product
I	Indication by additional external type TI indicating fuse that also takes MA type microswitch (see BS style accessories)
M	Microswitch fitted

Appendix 3. Installation Issues

High Speed Fuses are highly sophisticated electrical devices and due care must be taken regarding proper installation and maintenance. This to ensure reliable function throughout the natural lifetime of the fuse. In this chapter we will cover various issues like:

- Tightening torque and contact pressure.
- Mounting Alignment.
- Surface materials of contacts.

Other issues of more general character will also be addressed:

- Resistance to vibration & shocle
- Service/maintenance
- Environmental issues.

Tightening torque and contact pressure

High Speed Fuses are electro-mechanical devices. Their function is very much dependent of the quality of the contact between the fuse and the connecting cables/ busbars or between the fuse and fuse-holder. This for several reasons: of course a proper electrical contact is needed, but it is also important to remember that High Speed Fuses generate a lot of heat, which is partly to be removed through the connections. A poor thermal connection can result in overheating of the fuse and reduced lifetime. The number one rule is therefore to observe the right tightening torque when mounting the fuse.

Fuses with flush end contacts.

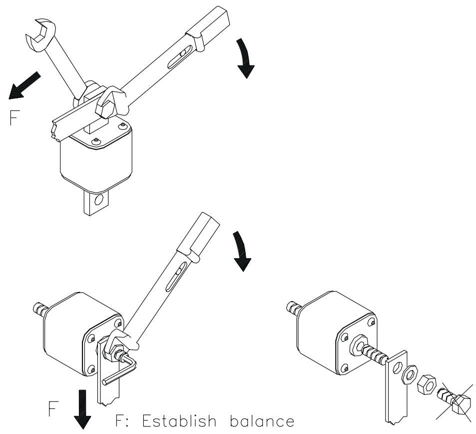
For all kinds of flush end fuses Bussmann recommends (screw in) studs according to DIN 913. The studs must be tightened carefully applying a torque of 5-8Nm.
As a general rule the tightening torque for the nuts relates to the dimension of the threaded hole in the fuse contact. In the following the recommended nut tightening torques are given:

Size/type	Threaded hole mm - inch	Tightening torque Nm *)	Nm**)
00B	M8	20	10
1*B - 1*G	M8 - 5/16	20	10
1B - 1G	M8 - 5/16	20	10
2B - 2G	M10 - 3/8	40	20
3B - 3G	M12 - 1/2	50	40

Size/type	Threaded hole mm - inch	Tightening torque Nm *)	Nm**)
23B - 23G	2xM10 - 2x3/8	40	20
4B - 4G	4xM10 - 4x1/2	40	20
24B - 24G	3xM12 - 3x1/2	50	40
5B - 5G	5xM12 - 5x1/2	50	40
FWX,FWA, KBC	3/8	40	20

*) Ungreased thread
**) Thread greased with Rhodorsil Paste 4 (Rhone-Poulenc) etc.

Bussmann recommends a calibrated torque wrench with a tolerance of max. ±4%.



Special flush-end types

Special types like for example 4SB or 24SB normally have threaded holes in one end only and a plate in the other for mounting on (water cooled) busbars. In such cases the screw-in studs and nuts are used for the threaded holes as indicated in the above table. The plates are mounted on busbars at torque of 50Nm.

Fuses with contact knives

In general this type of fuses can be divided into two main groups. Fuses with slotted knives according to the DIN 43653 standard for mounting direct on busbars or in special fuse holders and fuses with solid knives according to the DIN 43620 standard for mounting in spring-loaded fuse bases.

DIN 43653 - on busbars

Fuses for mounting on busbars are to be tightened with the biggest possible bolts/studs, nuts and washers. Use of washers is recommended. The bolts/nuts are tightened with a torque of 50Nm.

DIN 43653 - in fuse bases.

Fuses for mounting in special made fuse bases must be tightened according to the specification provided with the base. Maximum tightening torque for some Bussmann bases are given below:

Part number	Bolts for holder Nm *)	Bolts for cables/fuses Nm *)
170H1007	4 (M6)	12 (M8)
170H3003 – 170H3006	10 (M8)	20 (M10) **)
	Conductor set screw lbs-in	Fuse Mounting Bolt lbs-in
1BS101	120	70
1BS102	275	120
1BS103	275	170
1BS104	375	170
BH-1,2,3	---	---

1 lbs-in x 0.11298 = 1 Nm

*) Note: Thread greased with Rhodorsil Paste 4 (Rhone-Poulenc) etc.
**) Note: For 170Hxxxx bases the above values can be raised by 25% if no plastic parts are stressed.

DIN 43620

This kind of bases is equipped with one or more springs providing the correct contact pressure when the fuse is pressed into the base. For this reason no tightening recommendations are given. For Bussmann bases 170H3040-47 a maximum tightening torque of 10Nm can be used when mounting the holder itself into the equipment.

Press Pack fuses.

Some of the most common semiconductors must be stack mounted under a certain clamping force. A range of so-called press pack fuses in type 3P and 4P are available and enables the user to reduce the number of components by clamping the semiconductor and the fuse together with the water cooling boxes in a single mounting arrangement. The maximum clamping force a fuse can withstand depends on many details such as: length and cross section area of the fuse body, temperature gradient between the fuse contacts and also the electrical load conditions.

Example values for maximum clamping force can be found in the tables below.

Size	Single-sided cooling kN	Double-sided cooling kN
3P/55	22	30
4P/60	40	50
3P/80	30	40
4P/80	50	60

To ensure safe electrical and thermal contact between fuse-contact and cooling box or busbar and at the same time avoid the risk of damaging the fuse contact, the contact pressure (Pf) should lie between the following limits:

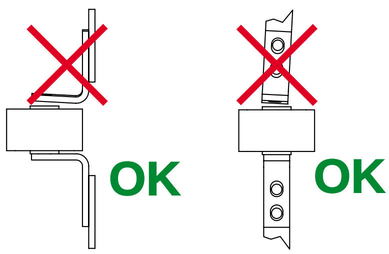
$$2 N/mm^2 < Pf < 15 N/mm^2$$

For fuses cooled in one end a maximum temperature gradient of 55K between the fuse contacts must be observed. For fuses used with double-sided water cooling, the temperature gradient between the fuse contacts is expected to be negligible.

Special made Press Pack fuses are also made in the double body construction type 24B or 24+B. Many details must be considered when using this kind of fuses under pressure - please consult Cooper Bussmann Application Services.

Mounting Alignment

Bussmann High Speed fuses are generally supplied in a ready-to-install condition.
The fuses are not meant as fixing isolators. Excessive push, pull and tensional forces due to misalignments between fuse and bus bars, which might occur like in below given example, should be avoided. If possible the mounting should be made starting with the fuse followed by the necessary adjustment and tolerance utilisation of the bus bar components, when mounting the rest of the fixing.



Surface material

The various electrical conducting metal parts of Bussmann High Speed fuses are usually plated to maintain longivity of the surface condition. The most common material for the fuse contacts today is tin.

Tin plated contacts

Most contact surface of Bussmann High Speed fuse-links are electro-plated with a 5mμ layer of tin. This surface treatment provides an excellent electrical and thermal interface to bases or cables/busbars of either pure copper or copper/aluminium plated with tin/nickel or silver.

	Concentration – duration PPM – h	According to standard
H_2S	12,5ppm – 96h	IEC 68-2-43 Kd
SO_2	25ppm – 504h	IEC 68-2-42 Kd

Many tests and more than 30 years of experience have shown that a tin, nickel or silver plated surface is both mechanically and electrically stable in the entire temperature area for High Speed fuses (typical maximum temperature rise of 130K).

Resistance to vibration and shock.

In general, High Speed fuses should not be submitted to excessive vibration. However, standard High Speed fuses can withstand vibration with a magnitude of maximum 5g on a long-time basis and 7g for short periods (shocks). Before using fuses in applications with stronger vibration please consult Cooper Bussmann Technical Applications Services.

Service and maintenance

The following points should be observed during maintenance.

Check points during routine maintenance of electrical cabinets and switchgear.

The tightening torque should be checked, and ceramic fuse bodies should be checked for visible cracks.
All blown fuse indicators must be checked. In case of any fuse operation the following procedure must be observed: Change all operated fuses AND fuses which have not operated but have been loaded with the fault current or a part of it. Please note that even if the ohmic resistance of the fuse is unchanged, the fuse may be damaged by the fault current and must be changed to avoid nuisance fuse operation.

Environmental issues
Basic materials

High Speed fuses are made from the following basic materials: ceramic/fibreglass, silver, copper, brass, steel, and sand. Accessories like micro switches and fuse holders are partly made of various plastic materials.
For futher information on materials, contact Bussmann technical services.

Storage

Fuses should be stored in their original boxes or containers and under typical warehouse conditions for electro-mechanical products, i.e. free from any dirt and dust. The relative humidity at long term storing must not exceed 70% and the storage temperature should be in the -40°C to +85°C range.

Appendix 4. Glossary of Terms

Arcing I^2t

Value of the I^2t during the arcing time under specified conditions.

Ampere

The measurement of intensity of rate of flow of electrons in an electric circuit. An ampere is the amount of current that will flow through a resistance of one ohm under a pressure of one volt.

Ampere Rating

The current-carrying capacity of a fuse. It is given in amps RMS (root mean square, also called the effective value).

I^2t , Ampere Squared Seconds

The measure of heat energy developed within a circuit during the fuse operation. »I« stands for effective let-through current (RMS), which is squared, and »t« stands for time of opening, in seconds. It can be expressed as »Melting I^2t«, »Arcing I^2t« or the sum of them as »Clearing I^2t«.

Arcing Time

The amount of time from the instant the fuse link has melted until the over current is safely interrupted (cleared).

Arc Voltage

This is the voltage, which occurs between the terminals of a fuse during operation. The size of the arc voltage for a given fuse is supply voltage dependent.

Breaking capacity / Interrupting rating/ Interrupting capacity

This is the maximum value of prospective current, RMS symmetrical, which a fuse is capable of breaking at stated conditions.

Classes of Fuses/Fuse class

National and International Standards have developed basic physical specifications and electrical performance requirements for fuses with voltage ratings that pertain to specific countries.
The fuse class refers to the designed breaking characteristic of the fuse. The following fuse class found in IEC 60269 applies to High Speed Fuses.
aR - Partial-range breaking capacity (short-circuit protection only) for the protection of Power Semiconductors (IEC Utilization category)

Other classes are:

gG (gL) - Full-range breaking capacity (overload and short-circuit protection) for general applications (IEC Utilization category)

gM - Full-range breaking capacity (overload and short-circuit protection)for the protection of motor circuits (IEC Utilization category)

aM - Partial-range breaking capacity (short-circuit protection only) for the protection of motor circuits (IEC Utilization category)

gR - Full-range breaking capacity (overload and short-circuit protection) for the protection of Power Semiconductors. (pending)

Clearing (Total operating) Time

The total time between the beginning of the over current and the final opening of the circuit at system voltage. Clearing time is the total of the melting time and the arcing time.

Current-Limitation

A fuse operation relating to short-circuits only. When a fuse operates in its current-limiting range, it will clear a short-circuit before the first peak of the current. Also, it will limit the instantaneous peak let-through current to a value substantially less than that obtainable in the same circuit if that fuse were replaced with a solid conductor of equal impedance.

Cut-off current/Peak-let-through current

The maximum value reached by the fault current during the breaking operation of a fuse.
In many cases the fuse will be current limiting.

Electrical Load

That part of the electrical system which actually uses the energy or does the work required.

Fast Acting Fuse

A fuse which opens on overload and short circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads, when sized near the full load current of the circuit.

Fuse

An over current protective device with a fusible link that operates and opens the circuit on an over current condition.

High Speed Fuses

Fuses with no intentional time-delay in the overload range and designed to open as quickly as possible in the short-circuit range. These fuses are often used to protect solid-state devices.

Inductive Load

A load which has inductive properties. Common forms are motors, transformers, wound control gear. This type of load pulls a large amount of current when first energised.

Interrupting Capacity

Refer to Breaking Capacity

Interrupting Rating

Refer to Breaking Capacity

Melting (Pre-arcing) Time

The amount of time required to melt the fuse element during a specified over current. (See Arcing Time and Clearing Time.)

Ohm

The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one ampere to flow under a pressure of one volt.

Overcurrent

A condition which exists on an electrical circuit when the normal load current is exceeded. Over currents take on two separate characteristics - overloads and short-circuits.

Overload

This is a condition in which an over current exceeds the normal full load current of a circuit that is in an otherwise healthy condition.

Peak Let-Through Current

The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Power Factor

The ratio of active power (kW) to apparent power (kVA) drawn by a load. It corresponds to the cosine of the phase angle between the voltage and current (cos φ)

Power Losses/Watts losses

The power released in a fuse when loaded according to stated conditions.

Prospective short-circuit current

This is the current that would flow in the fault circuit if the fuse was replaced by a link with an infinitely small impedance. Normally it is given as symmetrical RMS value, also called IP.

Recovery voltage

This is the voltage which can be measured across the fuse connections after operation.

Resistive Load

An electrical load which is characteristic of not having any significant inductive or capacitive component. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS Current

Also known as the effective value, it corresponds to the peak instantaneous value of a sinusoidal waveform divided by the square root of two. The RMS value of an alternating current is equivalent to the value of direct current which would produce the same amount of heat or power.

Semiconductor Fuses

Fuses used to protect solid-state devices. See »High Speed Fuses«.

Short-Circuit Current

Can be classified as an over current which exceeds the normal full load current of a circuit by a factor many times.

Short-Circuit Current Rating

The maximum short-circuit current an electrical component can sustain without the occurrence of excessive damage when protected with an over current protective device.

Threshold Current

The symmetrical RMS available current at the threshold of the current limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off of a peak let-through chart where the fuse curve intersects the A-B line. A threshold ratio is the relationship of the threshold current to the fuse's continuous current rating. This current is used during testing to UL specifications

Time-Delay Fuse

A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Virtual Melting Time

Is a method of presenting melting times in a manner independent of the current waveform. It is the time that it would take a DC-current equal to IP to generate the Melting I^2t. The definition is:

$$t_V \qquad \frac{i^2 dt}{I_P^{\,2}}$$

Total operating (Clearing) I^2t

The total operating I^2t value is the total of the pre-arcing and the arcing I^2t values under specified conditions.

UL

UL stands for Underwriters Laboratories Inc., an independent, non-profit, and non-governmental organization focusing on product safety.
UL issues standards and provides third party testing.

Voltage Rating

The maximum open circuit RMS voltage in which a fuse can be used, yet safely interrupt an over current. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.

Withstand Rating

The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage.

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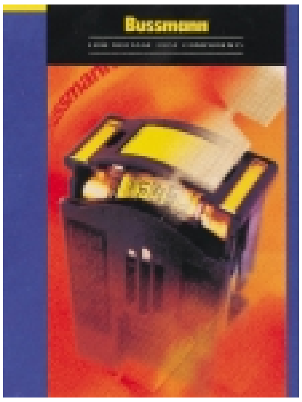

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