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FUSE CHARACTERISTICS

Overview

- **Overview of protection classes**
  - General Purpose
  - Motor Protection
  - High Speed
- **Time current Curves**
- **I2t values**
- **Let through current and cut-off curves**
- **Rated voltage dimensioning**
- **Rated current dimensioning**
  - Derating factors
- **Dimensioning I2t Values**
- **Influence of overloads**
- **Cyclic loading**

General Purpose Fuses

- **Fuse class refers to the designed breaking capacity of the fuse**
- **gG/gL – full range for general applications**
- **Full range – protection against low overloads and short circuit protection**
- **Elements have standard notched design and have M-effect**

Motor Protection

- Specifically designed for motor protection
- Thicker element for thermal stress
- gM – full range breaking capacity
  – M-effect
- aM – partial range breaking capacity
  – Short circuit protection only
  – No M-effect

High Speed Fuse-links

Semiconductor Protection

- Designed for the protection of semiconductor devices and applications using semiconductors – diodes, thyristors, IGBTS
- Semiconductor devices are sensitive to over voltages and over currents – require very fast acting protection
- Specially designed necks to ensure rapid melting

Features of HSF

- High breaking capacity
- Compact size
- High operating temperature - restricts the use of m-effect to assist with low over current protection
- High grade body ceramic
- Primarily for short circuit protection

IEC Protection Class

- aR
  - partial range breaking capacity
  - No m-effect
  - A-A curve
- gR
  - full range breaking capacity
  - aR fuses with m-effect

HSF Families

BS88

North American

Ferrule

Square Body

Time-Current Characteristics

Example: aR

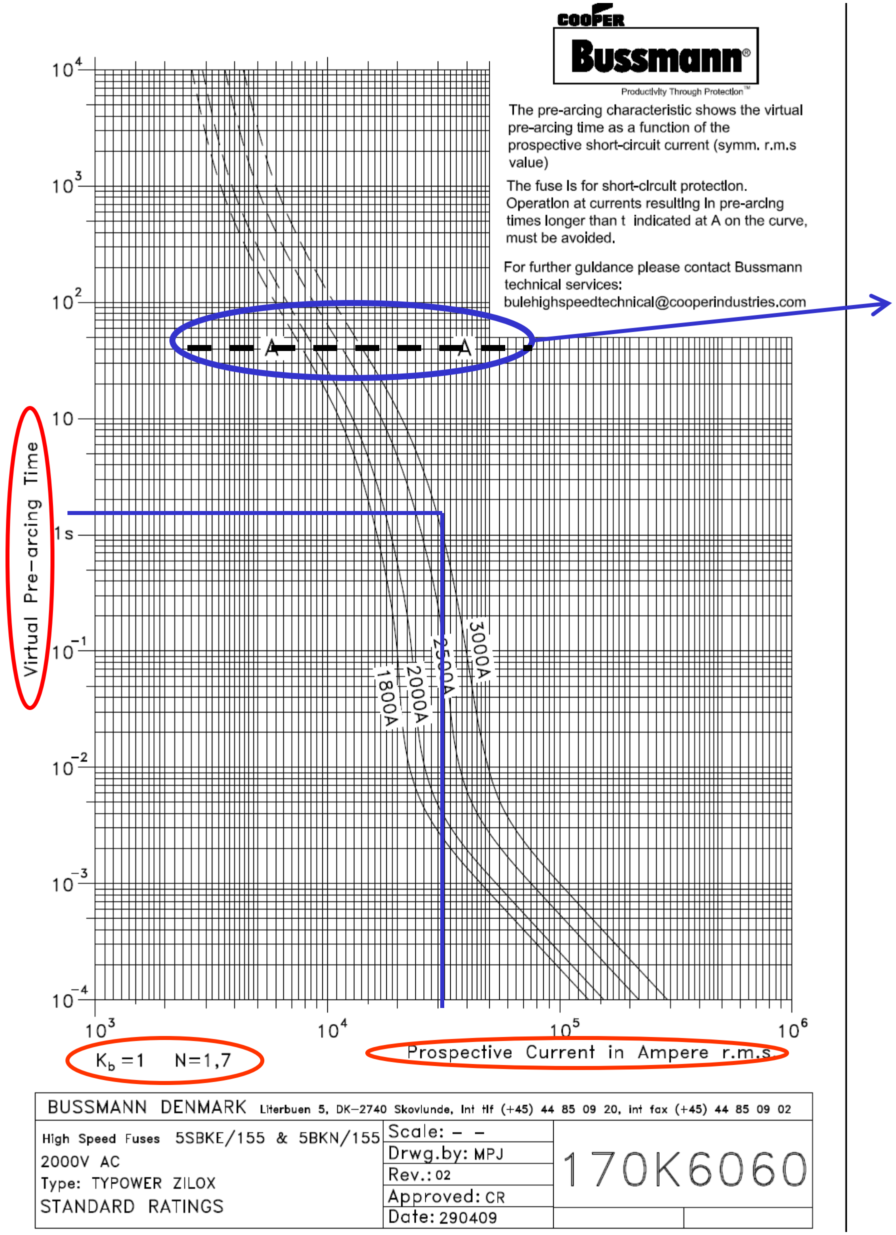
2000V AC

• Top rating – test for minimum of 6 points

• Other ratings – test for a minimum of 3 points

Kb = capability of the fuse to meet rated current at 21°C

N factor = ratio of cold resistance to hot resistance



A-A Curve

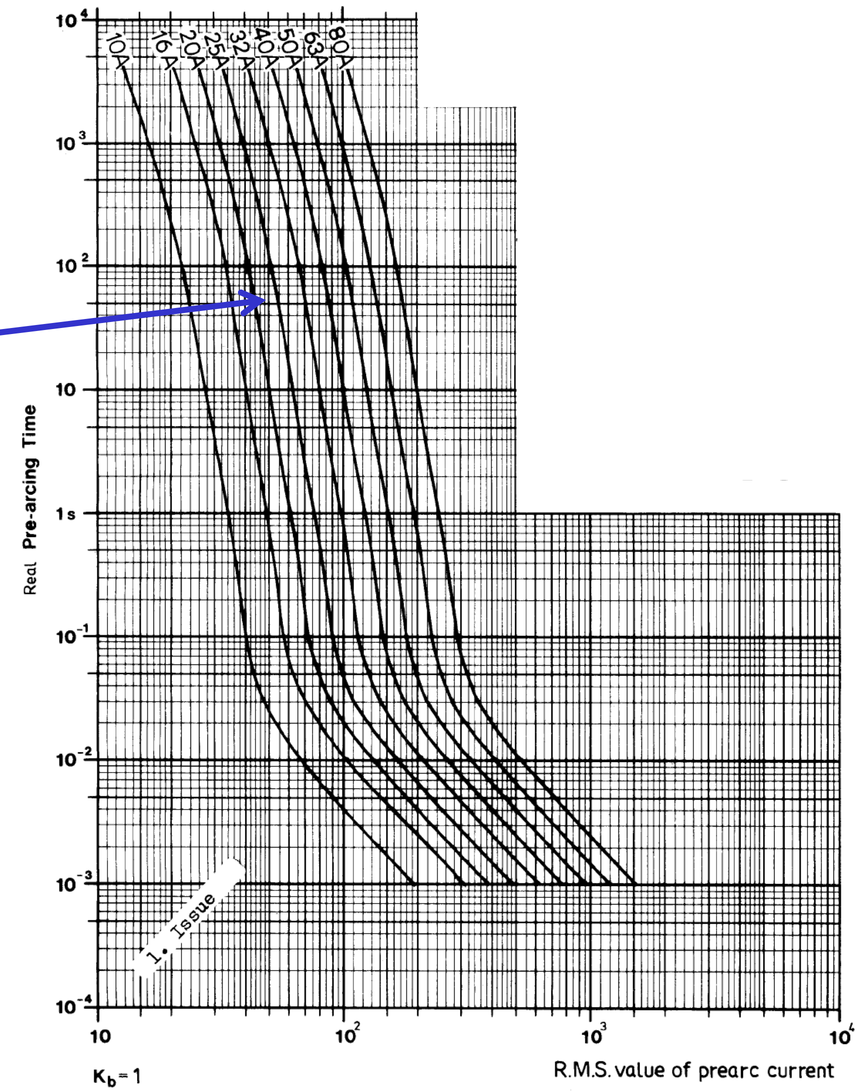
A-A Curve

- **aR fuse-link is for short circuit protection only – it must not be allowed to operate at overload conditions above the A-A line**
- **Overload within this region will cause the fuse-link temperature to exceed the maximum allowed for that level**
- **Thermal stress may cause the ceramic to crack - even if the fuse-link survives the overload, it may rupture violently if later subjected to a short circuit current.**
- **A-A curve often only indicated by a horizontal line**

Time Current Characteristics

Example: gR

- No A-A Curve
- Fuse can operate in any given situation
- Relatively slow fuse compared to an aR type



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I2t - energy integral

- Short circuit conditions – heat generated is far greater than heat dissipated – temperature of restrictions reach melting point almost instantaneously

- Pre-Arcing I2t – expresses the amount of energy required to melt the element before it begins to arc

- Arcing I2t – expresses the amount of energy generated from the arcing point to the point at which the over current is safely interrupted

- Clearing I2t – Sum of the pre-arc I2t and arcing I2t - expresses the total energy the fuse will let through during an operation

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I2t - energy integral

<u>Pre-arcing I2t</u>

- **The pre-arcing I2t value tends to a minimum when the fuse is subject to high currents**
- **Directly related to cross sectional area <u>squared</u>**
- **Min i2t = constant x (cross section)^2**
- **Constant depends on material properties**

<u>Arcing I2t</u>

- **The arcing I2t value varies with applied voltage, fault level and power factor**

I2t - energy integral

➢ <u>Clearing I2t</u>

- **The total I2t figures are quoted at worst case scenario**
  - Applied working voltage (rated fuse voltage)
  - Power factor cos φ = 0.15
  - Short circuit level 10-15 times rated current
- **Semiconductor manufacturers produce I2t ratings which should not be exceeded during fusing at all times below 10ms**

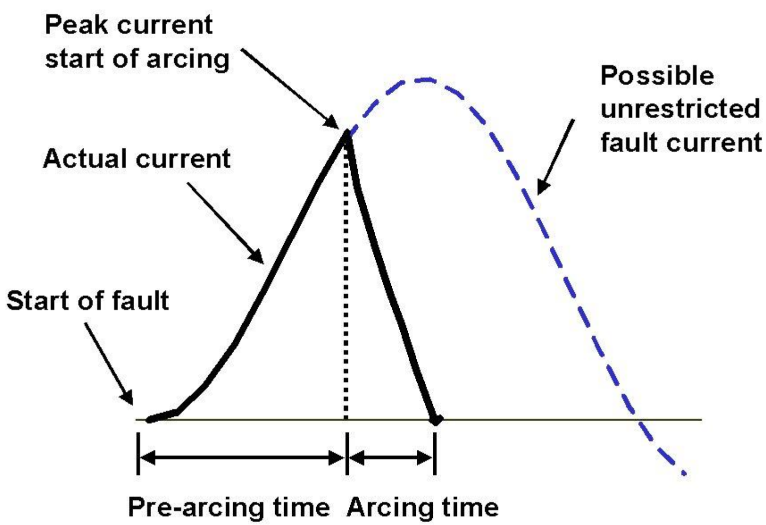
Total i2t value of the fuse-link must be less than the I2t capability of the device

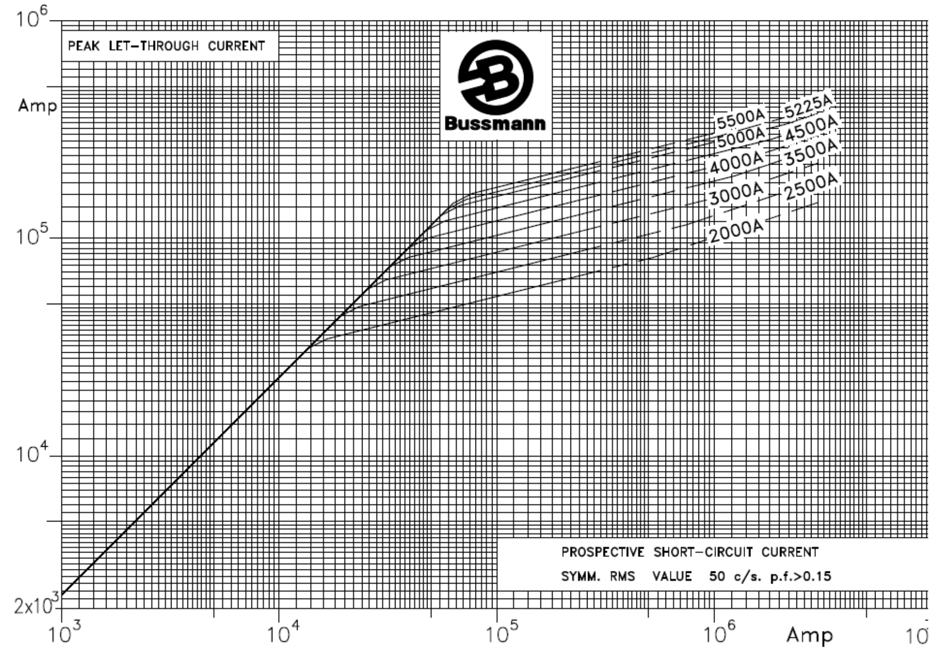
Current limiting

- ➢ **Initiation of fault to final clearance of the short circuit – *<u>milliseconds</u>***

- ➢ **Current through the fuse-link is limited**

- ➢ **Minimum short circuit level needed before current limiting effect will take place**





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Rated Voltage Dimensioning

➢ Rated Voltage

- Voltage at which the fuse is designed to operate
- Nominal voltage of the fuse must be higher than any other voltage in the application

➢ IEC

- Tests performed to at least +10% of the rated voltage
- Allows for fluctuations found in some converters

➢ North American

- Only tested to rated voltage

➢ Commutation fault

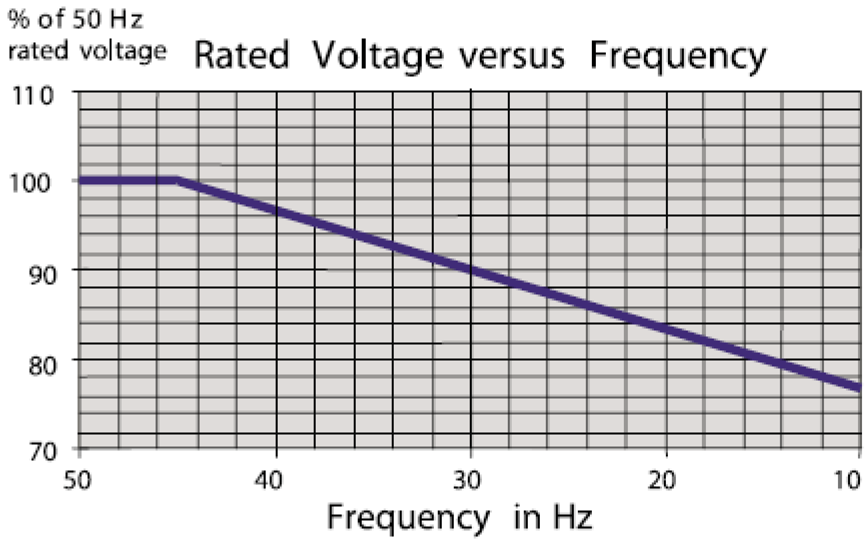
- Regenerative drive
- AC supply voltage and DC output voltage is superimposed
- $U_N \geq 1.8 \times U_{AC}$

Voltage across the fuse during fault must be known

Rated voltage Dimensioning cont…

- AC rated voltage of Bussmann fuses applicable between 45Hz and 1000Hz

- Below 45Hz – derate the voltage rating of the fuse using the curve as shown



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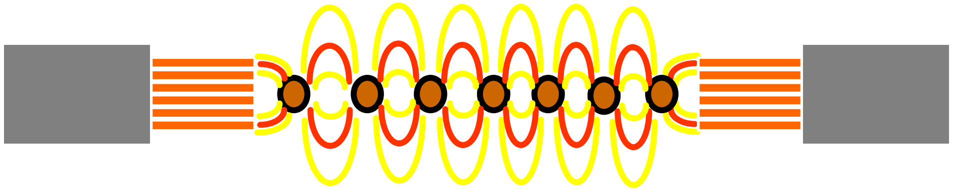
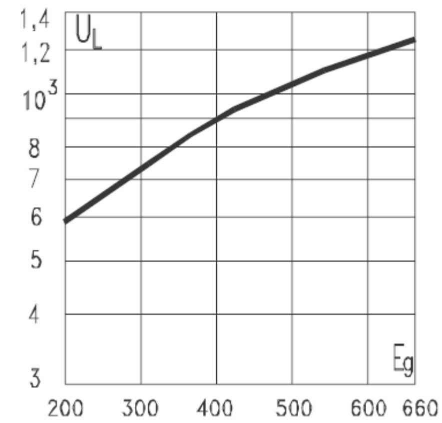
The Arc Voltage

- ➢ Arc formed across each restriction – **ARC VOLTAGE**
- ➢ Exceeds the voltage rating of the fuse
- ➢ Element design and restrictions controls magnitude of the arc voltage to a known voltage



- ➢ Peak arc voltage U_L depends on applied voltage
- ➢ Datasheet displays curve showing variance of arc voltage with system voltage
- ➢ **Coordination with semiconductor** – the arc voltage should be less that the peak reverse voltage of the semiconductor



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Rated Current Dimensioning

- **Current Rating –** the current the fuse will continuously carry without deterioration

- **HSF**
  - fast acting
  - high power losses
  - high working temperature

- Current carrying capability dependent on thermal conditions of applications

- **Correction Factors**
  - Ambient Temperature
  - Thermal Connection
  - Forced Cooling
  - High Frequency
  - High Altitude

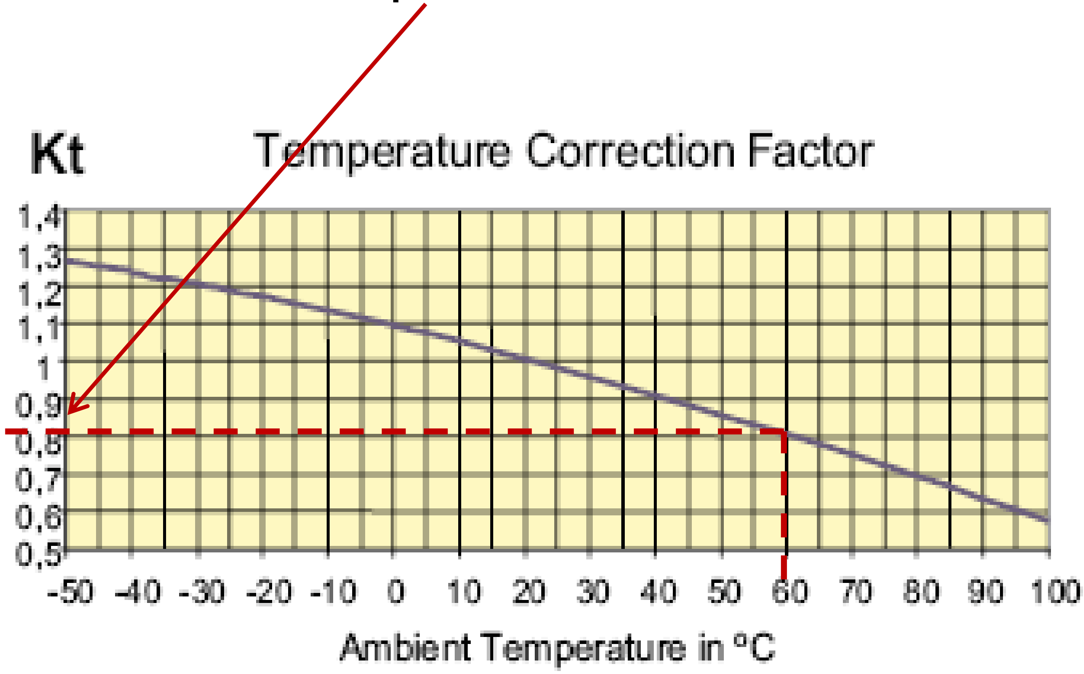
- **Derating will ensure that the lifetime of the fuse is not compromised**

Ambient Temperature

- Current ratings are valid for ambient temperatures of ~ 21°C

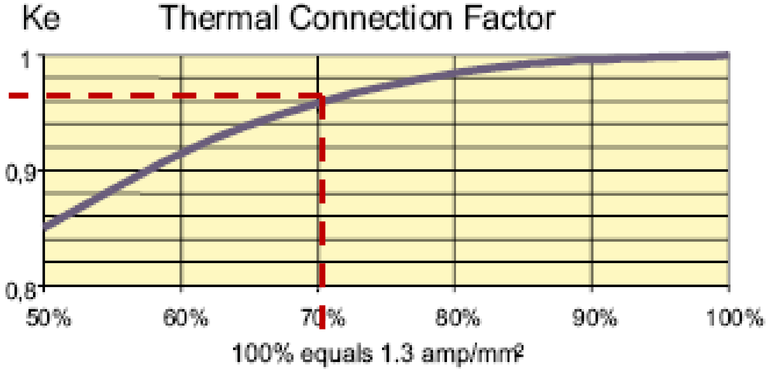
- Ratings at other temperature will require derating using the temperature correction coefficient , K_T

- Example: Ambient 60°C, K_T = 0.8



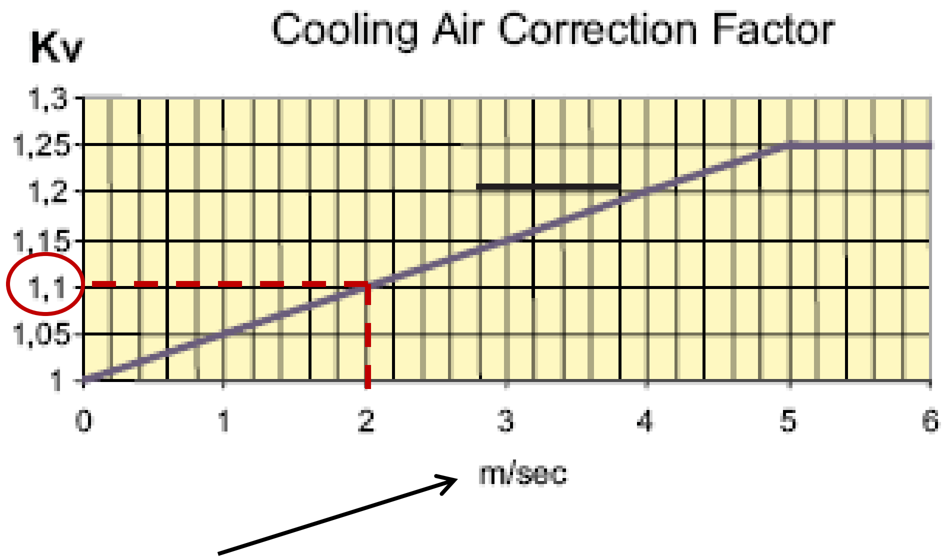
Thermal Connection Factor

- **Minimum current density of the busbars should be 1.3A/mm^2 (IEC 60269 part 4)**
- **If application does not meet this condition – derate current rating**
- **Example:**
  - 200A square body fuse is mounted onto a busbar with cross sectional area 120mm^2
  - Minimum cross sectional area for 200A fuse: 200/1.3 = 154mm^2
  - 120mm^2 is only 70% of IEC recommended size
  - Thermal connection factor – 0.96
  - If the 2 connections are not equal, calculate the combined effect (0.9+0.96)/2 = 0.93



Cooling Air Correction Factor

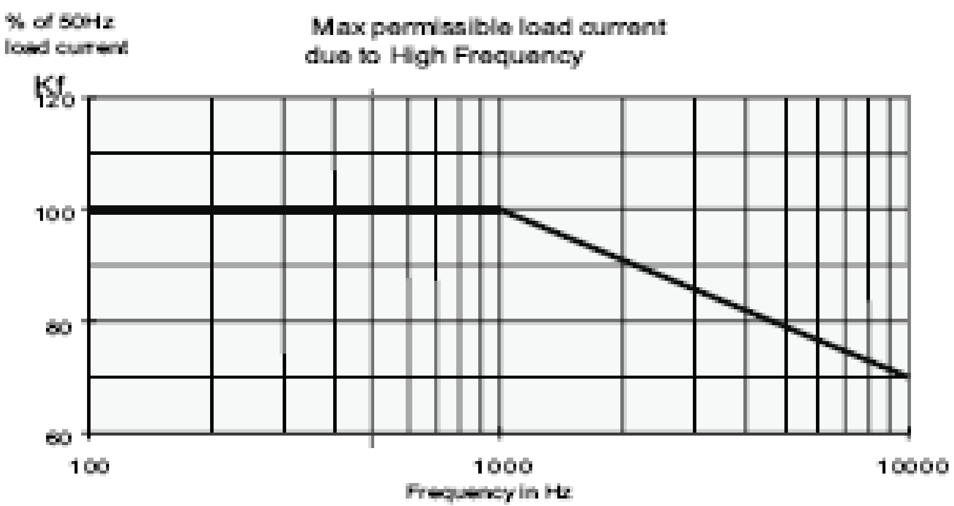
- Fuses may be placed in a cabinet ventilated by an electric fan – provides additional cooling for the fuse
- Can improve the current carrying capability of the fuse
- Example: Air speed across the fuse given as 2m/s



Air speed across the fuse not the air speed of the fan

Frequency Correction

- Fuses under high frequency load call for special attention as current carrying capability may be reduced
- Correction curve ensures a sufficient safety margin



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High Altitude

- Reduced convection and radiation of heat away from the fuse-link at heights over 2000m above sea level

- Current derating of 0.5% for every 100m above 2000m above sea level is required, Ka:

$$I = I_N * \underbrace{(1-((h-2000)/100)*0.005)}_{\text{Ka} = 0.88}$$

Example: 15A fuse would de-rate to 13A at 4500m above sea level

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Example

- **Application:**

  - **690V AC, 250A rms. The ambient temperature of the application is 50°C and selected fuse will be connected with cables of cross sectional area 120mm². Forced air cooling is established at 3m/s. The frequency of the load current is 500Hz. The fuse will be situated at sea level. What current rating should be selected?**

$$I_N = \frac{Irms}{K_T \cdot K_e \cdot K_v \cdot K_f \cdot K_a}$$

- $K_T = 0.85$
- $K_e = 0.93$
- $K_v = 1.15$
- $K_f = 1$
- $K_a = 1$

$I_N = 275A$

Influence of overloads

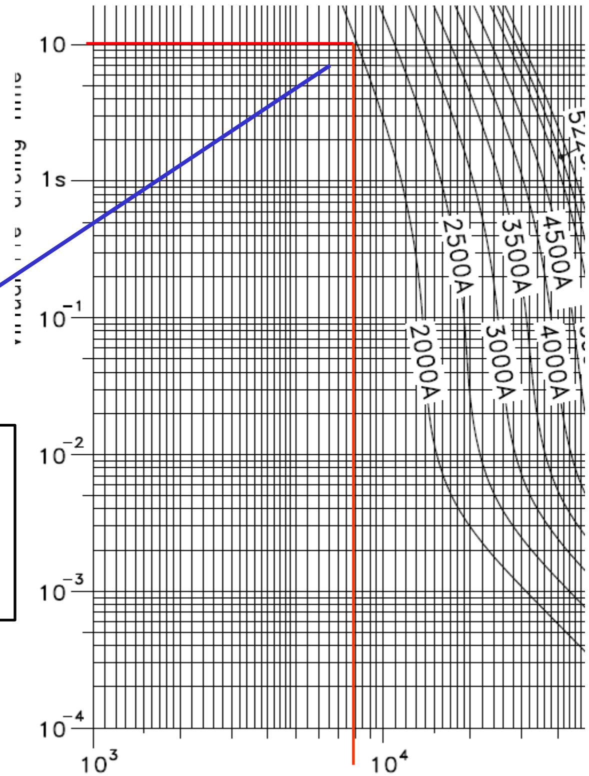
- **Must know: *frequency* and *duration* of overload**
  - **Fuse rating 2000A**
  - **Irms = 1800A**
  - **Impulse load: 1.5*Irms for 10 sec, once per month**

To be safe the overload should be less than 80% It

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

***It = 8000A @10s**

Imax < 8000x0.8
2700A < 6400A



* It = melting current corresponding to the time of the overload duration

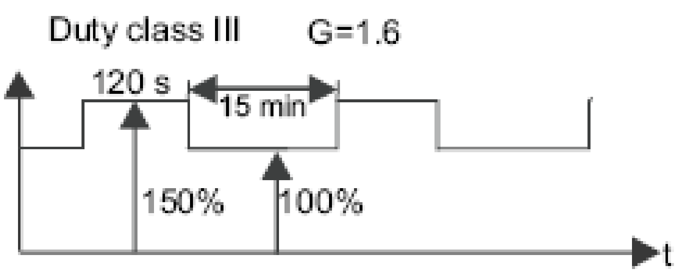
The lifetime of the fuse is not affected by this type of overload

Cyclic Loading – G Factor

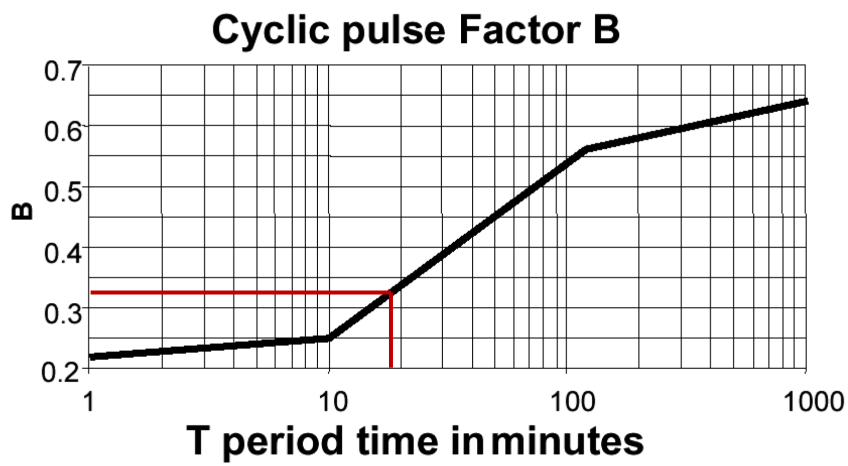
- Regular or irregular variations of the load current
- Causes the temperature of the fuse elements to fluctuate
- Heavy thermal cyclic loading leads to mechanical stress → premature aging/fatigue
- SOLUTION – Reduce ΔT of the fuse by selecting a higher rated fuse
- Use “G-factor” to apply a safety margin in the fuse selection – G=1.6 in most applications
- IN > Irms * G

Cyclic Pulse Factor B

- Once the fuse has been selected, the time current curve must be checked against the actual pulse
- The period time (T) of this cyclic load example is 17mins
- Corresponds to cyclic pulse factor B=0.32
- Find It from melting curve of the fuse for t=120s
- Rule: : I_{pulse} < It x B



Period T = 17 min



When both conditions are satisfied, the lifetime of the fuse will not be compromised when subject to the given loadings