Harmonization of IEC and North American Safety Standards

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Agenda

• UL 508C, UL 61800-5-1 and transition
• UL 508C & 61800-5-1 differences
• NEC Requirements
• Branch Circuit Protection Device Options
UL 508 Series

• UL
  • Industrial Control Panels
    • UL 508A SUPPLEMENT SB - SHORT CIRCUIT CURRENT RATINGS FOR INDUSTRIAL CONTROL PANELS
  • Drives & Power Conversion Equipment
    • UL 508C now transitioning to UL 61800-5-1 (harmonize with IEC) – adds requirements for testing ALL outputs and specific requirements for break-down of components test.
  • Control Components
    • UL 508 now transitioning to UL 60947-1 (harmonize with IEC), no major changes
UL 508C

• UL Standard for Safety for Power Conversion Equipment, UL 508C
  • Open or enclosed equipment that supplies power to control a motor or motors operating at a frequency or voltage different than that of the input supply.
  • Power-supply modules, input/output modules, Silicon Controlled Rectifier (SCR) or Transistor output modules, dynamic braking units, and input/output accessory kits for use with power conversion equipment.
  • 1500 volts or less.
UL 61800-5-1

- Harmonizes the IEC 61800-5-1 with UL 508C standards, with National Differences as noted in the Standard.

- National Differences can be based on
  - National regulatory requirements (DR)
  - Basic safety principals and requirements (D1)
  - Safety practices (D2)
  - Component standard (DC)
  - Editorial comments/corrections (DE)
  - They can add, modify or delete requirements.
UL 61800-5-1


  • Requirements for adjustable speed power drive systems, or their elements, with respect to electrical, thermal and energy safety considerations.

  • Does not cover the driven equipment except for interface requirements.

  • Applies to adjustable speed electric drive systems which include the power conversion, drive control, and motor or motors. Excluded are traction and electric vehicle drives.

  • Applies to d.c. drive systems connected to line voltages up to 1 kV a.c., 50 Hz or 60 Hz and a.c. drive systems with converter input voltages up to 35 kV, 50 Hz or 60 Hz and output voltages up to 35 kV.
UL 61800-5-1 Deviations

  - DV.1.1 This document is only applicable to the power conversion and drive control equipment, servo drives and integral servo drive/motor combinations.
  - DV.1.2 Only devices connected to line voltages of up to 1,5 kV a.c. are covered.
  - DV.1.3 A component of a product covered by this standard shall comply with the requirements for that component. See Annex DVA for a list of additional standards covering components used in the products covered by this standard.
UL 61800-5-1 & Transition Timeline

• First edition published June 2012.
• Current revision March 2015.
• All new (series or models for existing series) power-conversion products required to be investigated to UL 61800-5-1 February 2016.
• UL 508C is withdrawn – all products required to be evaluated to UL 61800-5-1 February 2020.
Benefits

• Harmonization of IEC and North American Safety Standards that brings the standards closer together.

• Moving toward one standard for adjustable speed drives for IEC or NA applications.
Design Implications

- Products previously tested may require redesign, retest or additional marking requirements.
- Product design cycle time may increase due to selection and testing of components and overcurrent protection.
Differences of UL 508C vs 61800-5-1

- Requirements for creepage and clearance distances and methods of reducing clearances have been revised.
- Short-circuit testing of all power outputs (not just main power output) is required.
- Specific requirements and changes to the procedure for the breakdown of components standard and high fault current test have been added.
- Protective bonding test now required for products with accessible conductive parts.
## Differences of UL 508C vs 61800-5-1

<table>
<thead>
<tr>
<th>UL 508C</th>
<th>UL 61800</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only required the motor output to be short circuit tested</td>
<td>All outputs must be short-circuit tested</td>
</tr>
<tr>
<td>No specific requirements for the short-circuit testing of internal components (breakdown of components testing).</td>
<td>Internal components must be tested for standard and high fault currents based on manufacturer’s short circuit current rating; unless analysis shows a different value is more severe.</td>
</tr>
<tr>
<td>Testing with cotton not required during short circuit and breakdown of components testing with circuit breakers.</td>
<td>Cotton indicator is required for all short circuit and breakdown of components tests when testing with circuit breakers.</td>
</tr>
<tr>
<td>Monitoring of secondary circuit voltage during short-circuit and break down of components test not required as part of pass/fail criteria.</td>
<td>Secondary circuit voltages are required to be monitored and not exceed specified levels during the short circuit and breakdown of components tests, or the AC/DC voltage test must be conducted after the short circuit test and breakdown of component test.</td>
</tr>
</tbody>
</table>
Additional Challenges

• Testing in high fault current laboratories will be required to achieve high SCCR, with limited facilities and resources to conduct the testing.

• Design cycle time may increase or delay product launch

• To meet the requirements for short circuit and breakdown of components testing, damage to internal components must be either contained or reduced through the use of current-limiting overcurrent devices.

• Traditional current-limiting circuit breakers and fuses may not be able to provide adequate protection in larger horsepower drives – leading to the use of more semiconductor (high speed) type fuses.

• Need for higher AC/DC voltages (above 600V) drives to high speed fuses. UL fuses not listed above 600V.

• Protection of dc output/busses. Often not protected in the past, now will require protection.
NEC Requirements


(A) Circuits Containing Power Conversion Equipment.

Circuits containing power conversion equipment shall be protected by a branch-circuit short-circuit and ground-fault protective device in accordance with the following:

(1) The rating and type of protection shall be determined by 430.52(C)(1), (C)(3), (C)(5), or (C)(6), using the full-load current rating of the motor load as determined by 430.6.

(2) Where maximum branch-circuit short-circuit and ground-fault protective ratings are stipulated for specific device types in the manufacturer’s instructions for the power conversion equipment or are otherwise marked on the equipment, they shall not be exceeded even if higher values are permitted by 430.130(A)(1).

(3) A self-protected combination controller shall only be permitted where specifically identified in the manufacturer’s instructions for the power conversion equipment or if otherwise marked on the equipment.
NEC Requirements


(B) Bypass Circuit/Device. Branch-circuit short-circuit and ground-fault protection shall also be provided for a bypass circuit/device(s). Where a single branch-circuit short-circuit and ground-fault protective device is provided for circuits containing both power conversion equipment and a bypass circuit, the branch-circuit protective device type and its rating or setting shall be in accordance with those determined for the power conversion equipment and for the bypass circuit/device(s) equipment.
UL489 Molded Case Circuit Breaker

- **Device Overview**
  - UL Listed
  - 430.52(C)(1)
  - Single or group installations
  - ASD must be marked with:
    - For NCL circuit breakers: the voltage and current or voltage and percent of the motor full-load output current rating;
    - For CL circuit breakers: same as NCL CB plus the manufacturer and model number.
  - Limited SCCR and drive manufacturer

<table>
<thead>
<tr>
<th>Type</th>
<th>UL Std.</th>
<th>Spacings</th>
<th>Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>UL489</td>
<td>UL489</td>
<td>Majority of Circuits</td>
</tr>
</tbody>
</table>
UL 248 Branch Circuit Fuses

### Device Overview

- **UL Listed**
- **430.52(C)(1)**
- Single or group installations
- ASD must be marked with the fuse class, voltage and current or voltage and percent of the full-load motor output current rating.
- More options for drive manufacturer
- Current-limiting
- Standard fuseholders/switches

<table>
<thead>
<tr>
<th>Type</th>
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<tbody>
<tr>
<td>Thermal</td>
<td>UL248</td>
<td>UL4248/UL98</td>
<td>Majority of Circuits</td>
</tr>
</tbody>
</table>
Instantaneous Trip CB (MCP)

<table>
<thead>
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<th>Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>UL489</td>
<td>UL489</td>
<td>Motor</td>
</tr>
</tbody>
</table>

- Device Overview
- UL Recognized
- 430.52(C)(3)
- Single ASD applications
- Must be marked with manufacturer and model number and integrated into the overall assembly
- Limits options for drive manufacturers
Semiconductor (High Speed) Fuses

<table>
<thead>
<tr>
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<th>UL Std.</th>
<th>Spacings</th>
<th>Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>UL248</td>
<td>UL4248</td>
<td>Power Electronic Devices</td>
</tr>
</tbody>
</table>

- Device Overview
- UL Recognized
- 430.52(C)(5)
- Single ASD applications
- Must be marked with manufacturer and model number and integrated into the overall assembly
- Increased current-limitation
- Less options for holders/switches
Self Protected Type E Combination Starters

<table>
<thead>
<tr>
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<th>UL Std.</th>
<th>Spacings</th>
<th>Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>UL508</td>
<td>UL508</td>
<td>Motor</td>
</tr>
</tbody>
</table>

- Device Overview
- 430.52(C)(6)
- Single ASD applications
- Must be marked manufacturer, model number, rated voltage and rated HP
- Limits options for drive manufacturers
- Extra accessories typically required
- Often Slash Rated (i.e. 480/277)
Degrees of Current Limitation

- Varies by type of overcurrent device
  - Non-current limiting
  - Current-limiting circuit breaker typically similar in performance to RK5 fuse
  - Current-limiting fuse
Class L

• “Large”

• Class L – Low-Peak®
  • KRP-C-(AMP)SP
  • 600V, 601A – 6000A, 300kA

• Characteristics
  • Time Delay
  • Current limiting
  • The large the ampacity, the more fault current needed to be current-limiting.
Class T

- “Tiny”
- Fast-acting
- 300V AC or 600V AC
- Up to 1200A
- Amperage case sizes include:
  - 30, 60, 100, 200, 400, 600, 800, 1200
- 200kA Interrupting rating
- Current limiting
- Rejection feature – class or size rejecting
- Best space saving design of any power fuse
Class RK5

• “Rejection”

• Class RK5 – Fusetron®
  • FRN-R-(AMP) / FRS-R-(AMP)
  • 250V/600V, 1/10A – 600A, 200kA

• Characteristics
  • Dual Element Time Delay
  • Good current limitation
  • Optional Open Fuse Indication
Class RK1

• “Rejection”

• Class RK1 – Low-Peak®
  • LPN-RK-(AMP)SP/LPS-RK-(AMP)SP
  • 250V/600V, 1/10A – 600A, 300kA

• Characteristics
  • Dual Element Time Delay
  • Better current limitation
    (better Type2 and Arc Flash protection)
  • Less time delay than RK5
  • Optional open fuse indication
Class J

• “Junior”

• Class J – Low-Peak®
  • LPJ-(AMP)SP
  • 600V, 1A – 600A, 300kA

• Characteristics
  • Dual Element Time Delay
    • Better time delay than CC
    • Less time delay than RK1/RK5
  • Very current limiting
  • Smaller than RK1/RK5
  • Open fuse indication Optional
  • Finger-safe accessories
Class J – Drive Fuse (DFJ)

• “Junior”

• Class J – DFJ High Speed Fuse
  • DFJ-(AMP)
  • 600V, 1A – 600A, 200kA
  • 450Vdc, 100kA

• Characteristics
  • High speed performance: extremely current limiting (similar to high speed fuses)
  • 5X or more current-limiting than traditional time-delay Class J fuses
Class CF

• “CUBE FUSE”

• Class CF - TCF(amp), TCF(amp)RN or FCF(amp)RN
  • TCF - 600Vac/300Vdc, 1-100A, 300kA/100kA
  • FCF - 600Vac/dc, 1-100A 200kA/50kA

• Characteristics
  • DE Time Delay or Fast Acting
  • Class J Performance
  • Very Current Limiting
  • Small physical Size
  • Finger safe IP20
  • Optional Indicating version time-delay only
Class CC

- “Control Circuit” or “Charlie Chaplin” (little hat)

- Class CC - General Features
  - 600V, up to 30A
  - 200kA Interrupting rating
  - Very Current Limiting
  - Space Saving Design - 13/32” X 1½”

- Grooved ferrule provides rejection feature from supplementary fuses with same dimensions (midget fuses) when Class CC fuseholders are used

- Offer 3 different fuse types
  - Time delay (for motor circuit: LP-CC)
  - Time delay (for control transformer primary: FNQ-R)
  - Non-time delay (Non-inductive loads: KTK-R)
High Speed Fuses

North American Round Body
Voltage: 150Vac – 1,000Vac
Current: 1A - 2,000A

BS 88
Voltage: 240Vac - 690Vac
Current: 16A - 700A

European Square Body
Voltage: 660Vac – 1,250Vac
Current: 10A – 10,000A

Ferrule
Voltage: 150Vac – 1,500Vac
Current: 1A - 100A

5 times or more current limiting than DFJ
North American Style

Round Body US Style Fuses
130 to 1000 Volts
FW and K Series
What is new in compact high speed fuses?

Eaton answers the call for compact drives, power conversion and UPS equipment with our new compact high speed fuses

48% smaller

Less space = more compact drives = lower cost drive

A platform that enables cost savings through smaller designs
Features and benefits summary

Most compact 500Vac/dc high speed fuse up to 400A

Using up to 48% less enclosure space allows for a reduction in the overall size of power conversion equipment.

Innovative design allows for size reduction without compromising performance

Available in three compact case sizes
• 50-100A
• 125-200A
• 250-400A

Global agency standards
• UL Recognized
• IEC aR – self certified
• CSA component acceptance
• RoHS compliant
• Reach declaration available

Bolt-on design with multiple mounting options
• Installed in fuse blocks
• Bolted directly to busbar
European Style

SPP, SPJ, and 170 Style of Fuses
DIN and US Style Mounting
690 to 1250 Volts - Typical
380 to 10,000 Amps Available
Open fuse indication/microswitch
British Style

BS 88 Style
240 to 690 Volts
Ferrule Style

6x32mm (1/4 x 1-1/4)
10x38mm (13/32 x 1-1/2)
14x51mm (9/16 x 2)
22x58mm
20x127mm
Selecting HSF’s

• Basic Process:
  • Determine duty cycle of load current ($I_{rms}$) based on configuration and placement of fuse protection
  • Select fuse (type, terminations, etc)
  • Determine required ampacity of fuse ($I_n$)
  • Analyze overload and pulse (such as inrush) characteristics with fuse selected
  • Analyze protection level of device
Fuse Sizing

• \[ \ln \geq \frac{I_b}{(K_t \times K_e \times K_v \times K_f \times K_b)} \]

\( I_b = \) Maximum allowed Steady-State RMS Current
\( \ln = \) Fuse Current Rating

\( K_t = \) Ambient temp. correction factor (From Chart)
\( K_e = \) Thermal Connection Correction (From Chart)
\( K_v = \) Cooling Air Correction (From Chart)
\( K_f = \) Frequency Correction (From Chart)
\( K_a = \) High Altitude Correction (From formula)

\( K_b = \) 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.
Influence of Overloads and Pulses

- Select Fuse and verify with TCC That it will withstand overloads and pulses

<table>
<thead>
<tr>
<th>OCCURRENCE</th>
<th>OVERLOADS</th>
<th>PULSES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>duration &gt;1 sec</td>
<td>duration &lt;1 sec</td>
</tr>
<tr>
<td>Less than once a month</td>
<td>$I_{ovr} &lt; 80% I_{TCC}$</td>
<td>$I_{pulse} &lt; 70% I_{TCC}$</td>
</tr>
<tr>
<td>Less than twice a week</td>
<td>$I_{ovr} &lt; 70% I_{TCC}$</td>
<td>$I_{pulse} &lt; 60% I_{TCC}$</td>
</tr>
<tr>
<td>Several times a day</td>
<td>$I_{ovr} &lt; 60% I_{TCC}$</td>
<td>$I_{pulse} &lt; 50% I_{TCC}$</td>
</tr>
</tbody>
</table>
Cyclic Loading – G Factor

- Determine G Factor

\[
I_n \geq \frac{I_{RMS} \cdot G}{K_t \cdot K_e \cdot K_v \cdot K_f \cdot K_a \cdot K_b}
\]

- Determine required fuse rating

\[
\text{Duty Class II } G=1.5
\]

\[
\text{Duty Class III } G=1.6
\]

\[
\text{Duty Class IV } G=1.3
\]

\[
\text{Medium Traction Substations and Mining } G=2
\]

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Cyclic Loading – B Factor

- Determine B Factor

- Adjust Fuse TCC
- Plot Pulse
- Compare to Fuse TCC
Critical Data for High Speed Fuses

I\(^2\)t Derating

Fuse operating on a 480V System will allow the clearing I\(^2\)t to drop 30%

<table>
<thead>
<tr>
<th>Catalog Numbers</th>
<th>Electrical Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN Type T Ind</td>
<td>Rated Current</td>
</tr>
<tr>
<td>Indicator for Micro</td>
<td>RMS-Amps</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>170M3808D</td>
<td>40</td>
</tr>
<tr>
<td>170M3809D</td>
<td>50</td>
</tr>
<tr>
<td>170M3810D</td>
<td>63</td>
</tr>
<tr>
<td>170M3811D</td>
<td>80</td>
</tr>
<tr>
<td>170M3812D</td>
<td>100</td>
</tr>
<tr>
<td>170M3813D</td>
<td>125</td>
</tr>
<tr>
<td>170M3814D</td>
<td>160</td>
</tr>
<tr>
<td>170M3815D</td>
<td>200</td>
</tr>
<tr>
<td>170M3816D</td>
<td>250</td>
</tr>
<tr>
<td>170M3817D</td>
<td>315</td>
</tr>
<tr>
<td>170M3818D</td>
<td>350</td>
</tr>
<tr>
<td>170M3819D</td>
<td>400</td>
</tr>
<tr>
<td>170M4863D</td>
<td>450</td>
</tr>
<tr>
<td>170M4864D</td>
<td>500</td>
</tr>
<tr>
<td>170M4865D</td>
<td>550</td>
</tr>
<tr>
<td>170M4866D</td>
<td>630</td>
</tr>
<tr>
<td>170M4867D</td>
<td>700</td>
</tr>
</tbody>
</table>
Critical Data for High Speed Fuses

Arc Voltage

Watts Loss

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Typical Fuses recommended for ASDs

- Drives (5HP or less) – Type E Self-Protected Starters or Class CC, J, T fuses
- Drives (50HP or less) – Class J or T Fuses
- Drives (200HP or less) – High Speed Class J fuses or Compact High Speed fuses.
- Drives (above 200HP) – UL/IEC Square Body Fuses
- Servo Drives and DC Outputs – UL/IEC Cylindrical/IGBT Fuses
Questions?

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