Control Circuits in acc. with UL508A

- Definition of Control Circuits
- Disconnecting Means
- Protection of Control Circuits
- Dimensioning of the wires and cables
- Loads in the Control Circuit
Definition of Control Circuits

**Definition of a Control Circuit: (UL508A)**

A circuit that carries the electric signals directing the performance of a controller, and which does not carry the main power circuit. A control circuit is, in most cases, *limited to 15 amperes.*

With UL, the control circuits are usually connected to the load side of the branch circuit protection device (BCPD).

The circuit itself is not considered as branch.

If connected to the line side of the BCPD a separate BCPD is required.
Disconnecting Means

**UL508A §39**

- Control circuits connected to the line side of the main disconnecting means need to have their own main disconnecting means.

- Possible are all devices which can be used as main disconnecting means for the power circuits. UL508A; §30

- Door interlocking mechanism is not required.
Branch circuit protection and disconnecting means provided via a UL489 C.B.
Door interlocking mechanism is not required!
Definition of Control Circuits
Class 1 Control Circuits

Definition acc. to UL508A §2.6
- Control Circuits connected to
  - Load side of the Branch Circuit Protective Device (BCPD)
  - Secondary side of an power transformer
  - Secondary side of an control transformer or control power supply
- Max. Voltage
  - Acc. to UL 508A: $U_N = 600V$
  - Acc. to NFPA 79: $U_N = 120V$
  - Max. Current: in most cases limited to 15A

Possible „devices“ for the power supply
- Direct connected to the supply
- Power Transformers / Control Transformers
- Power Supply units for DC
Definition of Control Circuits
Class 2 Control Circuits

Have to be used, if control devices require a Class 2 control circuitry (e.g. Sensors) with terms like: „for use in class 2 circuits only“

Definition acc. to UL508A §2.8
- Control circuits with limited power, supplied by an specific source with max. 30V rms and limited power (e.g. Class 2 transformer).

Possible power supply devices
- Need to be approved acc. to UL 1310; UL 1585; UL 60950-1

Additional note
- Wires should be laid and routed separately
- Field wiring terminals for Class 2 circuits should be separated as well

Note: Components and wiring located entirely within an „Class 2 circuit“ are not required to be investigated (by e.g. AHJ, UL-Inspector)!
⇒ Unlisted devices and wiring could be used!
Definition of Control Circuits
Low-voltage limited energy circuit

Control circuit with low-voltage limited energy
- Circuit with max. 42.4 V peak voltage or DC voltage
- Max. power 100 VA or 5A with a voltage of 20V or lower
- Circuit must be protected against overcurrent
- Tap-off of load voltage by means of a voltage divider is not permissible
- Direct connection to the power circuit is not permissible!

Possible devices:
- Transformers acc. to UL506 or UL1561
- Power supply units (isolated secondary) acc. To UL508; 508C; UL1012 or UL1950
- Lithium battery acc. to UL1642
- Sealed battery acc. to UL1989
- Current transformer acc. to UL506 or current transformer with max. sec. current of 5A

Note: Components and wiring located entirely within an „limited energy circuit“ are not required to be investigated (by e.g. AHJ, UL-Inspector)!
⇒ Unlisted devices or wiring could be used!
Protection of Control Transformer / Power Supply Unit

Protection on primary side only, if

- The load on the secondary side is not higher than the primary side protective device
  (Ratio of primary to secondary side has to be observed)

Primary plus Each Secondary branch has to be protected separately, if

- Above condition is not given
- The total sum of all consumers is higher than the nominal rated current of
- the transformer / power supply unit
- The secondary wiring "leaves" the "Industrial Control Panel"
- The transformer / power supply unit has several secondary windings / tap offs

**Attention:** Standard power supply units can only be used for up to 50% of their nominal rated secondary current (UL508A - §42.2.3)!

**Exception:** Power supply units approved acc. to UL508, can be used for up to 100% of their nominal rated secondary current!
Protection devices in *dc control circuits above 32V* shall be *approved for the rating equal or greater*

40.1.5 Where a branch circuit fuse, inverse-time circuit breaker, miscellaneous or miniature type fuse, or supplemental protector is applied in a dc circuit with a voltage above 32 V, it must be evaluated in accordance with the appropriate product standard to have a dc voltage rating equal to or greater than the circuit voltage.

Excerpt from *Certificate of compliance of Siemens supplementary protectors 5SY...*

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Type</th>
<th>UG</th>
<th>FW</th>
<th>Max Volts</th>
<th>Max Amperes</th>
<th>TC</th>
<th>OL</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>5SY4, 5SY6, 5SY7, 5SY8</td>
<td>OC</td>
<td>A</td>
<td>0</td>
<td>480</td>
<td>63</td>
<td>2</td>
<td>0</td>
<td>5kA U2, 7.5kA U2, 14kA U2</td>
</tr>
<tr>
<td>5SY4, 5SY6</td>
<td>OC</td>
<td>A</td>
<td>0</td>
<td>60 Vdc</td>
<td>1A - 63</td>
<td>2</td>
<td>0</td>
<td>3.5kA U2</td>
</tr>
</tbody>
</table>
Protection of Control Circuits
Possible Devices

Primary side tapped off the line side of the BCP
- Inverse Time Circuit Breaker (UL489), e.g. 3RV, 3VL, 5SJ…HG
- Fuses (UL 248-4 … UL 248-12)

Primary side tapped off the load side of the BCP, additionally to above
- Miniature Circuit Breaker acc. to UL1077 (= supplementary protector); e.g. 5SJ
- Supplemental Fuse acc. to UL248-14

Secondary side for each ungrounded „conductor“ - Control circuit does not extend beyond the Industrial Control Panel
- Miniature Circuit Breaker acc. to UL1077 (= supplementary protector); e.g. 5SJ
- Supplemental Fuse acc. to UL248-14

Secondary side for each ungrounded „conductor“ - Control circuit extends beyond the Industrial Control Panel (recommendation)
- Inverse Time Circuit Breaker (UL489), e.g. 3RV, 3VL, 5SJ…HG
- Fuses (UL 248-4 … UL 248-12)
Miniature Circuit Breaker instead of Circuit Breakers

UL differentiates between
- Circuit Breaker acc. to UL489

and Supplementary Protectors acc. to UL1077

Example:

**Supplementary Protector:** Miniature Circuit Breaker acc. to UL1077; Supplementary Protectors are UL Recognized (r/c) – not useable as BCPD.
Only to protect e.g. control circuits.
E.g. 5SY made by Siemens; CCN = QVNU2

**Circuit Breaker (C.B.):** also named as Inverse Time C.B., are “Listed” acc. to UL489. Use in e.g. Branch- or Feeder Circuit as Overcurrent Protection Device
E.g.: 3VL; 3RV17; 3RV18; 5SJ4 made by Siemens; CCN = DIVQ

➤ Please be sure to use „suppl. Protectors“ at the correct position.
➤ Same applies also to supplemental (miniature) fuses acc. to UL248-14 (r/c)
Protection of Control Circuits
Dimensioning

UL508A; §40 following
- Max. 20A for the Branch Circuit Protection of the feeder to the control circuit
- Ampacity of the wire
- Max. permissible power consumption of the devices

If devices or wires require a smaller overcurrent protection device, this has to be installed additionally

Receptacle in the control circuit
- Requires overcurrent protection which does not exceed the rated current of the receptacle
- May only used for programming devices

Attention: When using supplementary protectors (UL1077), the control circuit is not allowed to „leave“ the Industrial Control Panel!
Protection of Control Circuits
Dimensioning

The following applies in general:
The protective device for the control wires have to be in acc. with the cross section of the control wires!

1st Exception:
Control circuit connected to the load side of the Branch Circuit Protection and entirely inside the Industrial Control Panel
→ Wire cross section acc. to UL508A, Tab.41.1

2nd Exception:
Control circuit connected to the load side of the Branch Circuit Protection and not entirely inside the Industrial Control Panel
→ Wire cross section acc. to UL508A, Tab.41.2
### Table 41.1
Motor branch circuit protection of common control circuit without remote control devices
Table 41.1 effective April 25, 2003

<table>
<thead>
<tr>
<th>Control circuit wire size</th>
<th>Maximum protective device rating, amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG</td>
<td>(mm²)</td>
</tr>
<tr>
<td>22</td>
<td>(0.32)</td>
</tr>
<tr>
<td>20</td>
<td>(0.52)</td>
</tr>
<tr>
<td>18</td>
<td>(0.82)</td>
</tr>
<tr>
<td>16</td>
<td>(1.3)</td>
</tr>
<tr>
<td>14</td>
<td>(2.1)</td>
</tr>
<tr>
<td>12</td>
<td>(3.3)</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

### Table 41.2
Motor branch circuit protection of common control circuit with remote control devices
Table 41.2 effective April 25, 2003

<table>
<thead>
<tr>
<th>Control circuit wire size</th>
<th>Maximum protective device rating, amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG</td>
<td>(mm²)</td>
</tr>
<tr>
<td>22</td>
<td>(0.32)</td>
</tr>
<tr>
<td>20</td>
<td>(0.52)</td>
</tr>
<tr>
<td>18</td>
<td>(0.82)</td>
</tr>
<tr>
<td>16</td>
<td>(1.3)</td>
</tr>
<tr>
<td>14</td>
<td>(2.1)</td>
</tr>
<tr>
<td>12</td>
<td>(3.3)</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>7</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>45</td>
</tr>
<tr>
<td>120</td>
<td>60</td>
</tr>
</tbody>
</table>
Conductor Cross-Sections
Acc. to UL508A

Dimensioning of the cross section for internal wires acc. to the:

- Nominal rated current of the overcurrent protective device
- Nominal rated current of the secondary side of the transformer / power supply unit

Selection of the cross section for internal wires acc. to:

- UL 508A, Tab. 38.1 – if rated less than 10A
- UL 508A, Tab. 28.1 – if rated for more than 10A

<table>
<thead>
<tr>
<th>Wire size</th>
<th>60°C (140°F)</th>
<th>75°C (167°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWG</td>
<td>Copper</td>
<td>Aluminum</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>14</td>
<td>(2.1)</td>
<td>–</td>
</tr>
<tr>
<td>12</td>
<td>(3.3)</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>(5.3)</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>(6.4)</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>(13.3)</td>
<td>55</td>
</tr>
<tr>
<td>4</td>
<td>(21.2)</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>(26.7)</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>(33.6)</td>
<td>95</td>
</tr>
<tr>
<td>1</td>
<td>(42.4)</td>
<td>110</td>
</tr>
<tr>
<td>10</td>
<td>(53.5)</td>
<td>–</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ampacity, amperes</th>
<th>AWG</th>
<th>Conductor size (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>16</td>
<td>(1.3)</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>(0.62)</td>
</tr>
<tr>
<td>5</td>
<td>20²</td>
<td>(0.52)</td>
</tr>
<tr>
<td>3</td>
<td>22²</td>
<td>(0.32)</td>
</tr>
<tr>
<td>2</td>
<td>24²</td>
<td>(0.20)</td>
</tr>
<tr>
<td>1</td>
<td>26²</td>
<td>(0.13)</td>
</tr>
<tr>
<td>0.6</td>
<td>29²</td>
<td>(0.09)</td>
</tr>
<tr>
<td>0.5</td>
<td>30²</td>
<td>(0.05)</td>
</tr>
</tbody>
</table>

*Where these conductors are contained in a jacketed multi-conductor cable assembly.

* These sizes of conductors are only for connection of control circuits for electronic programmable input/output and static control (having no moving parts).
Consumers in the Control Circuit
Requirements

Possible devices:
- Signalling lamps acc. to UL508 (lamp sockets acc. to UL496)
- Electrical operated valve acc. to UL429
- Solenoid shall be evaluated for the intended use
- Time-indicating or time-recording device (e.g. hourmeter) acc. to UL863
- Audible signaling appliance (e.g. bell, buzzer) acc. to UL464
- A coil or input to another control circuit switching device or to a load controller need to comply with other component requirements of UL508A

Determination of the power:
- Ratings on the device (A; VA; W)
- The power of devices without indicated ratings has to be determined acc. to UL508A, Table 46.1
Note / Disclaimer

The circuit examples and interpretations of the standard are non-binding and do not claim completeness concerning configuration, equipping and contingencies. They do not represent customized solutions but merely provide support for typical tasks.

Every user of this presentation assumes full responsibility for the proper operation of the described products. This presentation does not relieve you of your obligation to ensure safe application, installation, operation and maintenance.

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Many tables and texts in this description were directly taken from NEC 2011 and the UL standards. Every user has to regularly check whether the quoted references are still up-to-date.

The final decision as to whether an application complies with the corresponding American standards and regulations lies with the end customer or any organization respectively authorized by him (e.g. authority having jurisdiction, AHJ).
Enclosure Types acc. to NEMA/UL

- Overview and Definitions
- Degrees of Protection and Rules
- Comparison of “IP” and “Enclosure Type Ratings”?
- Detailed “Enclosure Type Rating”
<table>
<thead>
<tr>
<th>IP – degree of protection (IEC)</th>
<th>Enclosure types (UL)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>International Protection</em> (DIN)</td>
<td>Sometimes also called “NEMA type”.</td>
</tr>
<tr>
<td><em>Ingress Protection</em> (intl.)</td>
<td>NEMA is, however manufacturer-dependent, whereas UL is manufacturer-independent</td>
</tr>
</tbody>
</table>

1. Figure: protection against contact and foreign bodies

2. Figure: protection against water

---

**Details**

**In principle:**

The higher the digits, the higher the level of protection

**In principle:**

A high enclosure type does not automatically mean a higher level of protection
Enclosure Types acc. to UL

The rating code of enclosure types cannot be systematically encoded. Instead, every digit/letter is assigned to a defined degree of protection.

Sub-categorization of the enclosure ratings for

- **non-hazardous locations:**
  - Acc. to UL50 / UL50E
  - Type Ratings for **Indoor use:** 1, 2, 5, 12, 12K, 13
  - Type Ratings for **Outdoor use:** 3, 3R, 3S, 4, 4X, 6, 6P

- **hazardous locations (classified locations):**
  - Type 7: Indoor -- Class I; Group A, B, C or D
  - Type 8: Indoor / Outdoor -- Class I; Group A, B, C or D
  - Type 9: Indoor -- Class II; Group E, F or G
  - Type 10: Mine safety and Health administration (30 CFR, Part 18.)
  - Classification acc. NEC 2011

**Attention:** A higher digit does not automatically mean a higher level of protection but implies other protective features!
Overview and Definitions
Enclosure types in acc. with NEC / NFPA

- Every component being mounted to an enclosure or through the enclosure sheet must have the same rating as the enclosure or a higher rating.
- If devices with lower ratings are used, the rating of the entire industrial control panel is identical to the lowest rating of all devices applied.
- If devices are used which do not provide for an enclosure rating, the rating of the entire industrial control panel is type 1.
- Some ratings can be compared to IP degrees of protection.

**Attention:**
IP degrees of protection can never converted to UL enclosure type ratings!

UL Enclosure Type Ratings may need further additional tests which are not covered by the possible IP degrees of protection.
**Degrees of Protection and Rules**
Comparison of enclosure types versa IP-Degree

<table>
<thead>
<tr>
<th>UL / NEMA</th>
<th>Properties</th>
<th>Installation site (typical application)</th>
<th>Comparable IP degree of protection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>General use</td>
<td>Indoors</td>
<td>IP 20</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Protection against dripping water</td>
<td>Indoors</td>
<td>IP 20</td>
</tr>
<tr>
<td><strong>3R</strong></td>
<td>Rain, hail, ice</td>
<td>Outdoors (starter for pump)</td>
<td>IP 54</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Dust-tight, water-tight</td>
<td>Indoors outdoors (food industry)</td>
<td>IP 65</td>
</tr>
<tr>
<td><strong>4x</strong></td>
<td>Water-tight, corrosion-resistant</td>
<td>Indoors, outdoors (sewage plants, fertilizer production)</td>
<td>Not available</td>
</tr>
<tr>
<td><strong>12</strong></td>
<td>Drip-tight, dust-tight, oil- and cooling water-tight</td>
<td>Indoors (machine tools)</td>
<td>IP 54 (IP 55)</td>
</tr>
<tr>
<td><strong>13</strong></td>
<td>Drip-tight, dust-tight, oil- and cooling water-tight</td>
<td>Indoors (commanding devices on machine tools)</td>
<td>IP 54+</td>
</tr>
</tbody>
</table>

**Attention:** NEMA ratings may be converted to IP degrees of protection, however, IP degrees of protection cannot be converted to NEMA ratings!
## Degrees of Protection and Rules

**UL50E (UL50) Enclosure Type Rating for general applications**

<table>
<thead>
<tr>
<th>Provides a degree of protection against the following environmental conditions</th>
<th>Type of enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Incidental contact with the enclosed equipment</td>
<td>X</td>
</tr>
<tr>
<td>Falling dirt</td>
<td>X</td>
</tr>
<tr>
<td>Dripping and light splashing of non-corrosive liquids</td>
<td>X</td>
</tr>
<tr>
<td>Rain, snow, and sleet&lt;sup&gt;d&lt;/sup&gt;</td>
<td>X</td>
</tr>
<tr>
<td>Rain, snow, and sleet&lt;sup&gt;e&lt;/sup&gt;</td>
<td>X</td>
</tr>
<tr>
<td>Circulating dust, lint, fibers, and flyings&lt;sup&gt;f&lt;/sup&gt;</td>
<td>X</td>
</tr>
<tr>
<td>Settling airborne dust, lint, fibers, and flyings&lt;sup&gt;g&lt;/sup&gt;</td>
<td>X</td>
</tr>
<tr>
<td>Windblown dust</td>
<td>X</td>
</tr>
<tr>
<td>Hosedown and splashing water</td>
<td>X</td>
</tr>
<tr>
<td>Oil and coolant seepage</td>
<td>X</td>
</tr>
<tr>
<td>Oil or coolant spraying and splashing</td>
<td>X</td>
</tr>
<tr>
<td>Corrosive agents</td>
<td>X</td>
</tr>
<tr>
<td>Occasional temporary submersion</td>
<td>X</td>
</tr>
<tr>
<td>Occasional prolonged submersion</td>
<td>X</td>
</tr>
</tbody>
</table>

<sup>a</sup> These enclosures may be ventilated.

<sup>b</sup> External operating mechanisms are not required to be operable when the enclosure is ice covered.

<sup>c</sup> External operating mechanisms are operable when the enclosure is ice covered. See 8.5.2.

<sup>d</sup> These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings. (For Class III type ignitable fibers or combustible flyings, see the Canadian Electrical Code, Part I, Section 18, the National Electrical Code, Article 500, or Mexico’s NOM-001-SEDE, Electrical Installations (utility), Article 500.

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**UL 50E valid in the field of:**
- CEC (CSA22.1) - NEC;
- NOM-001-SEDE

Valid for general applications at non-hazardous locations
### Degrees of Protection and Rules

**Openings in enclosures with enclosure type >1**

<table>
<thead>
<tr>
<th>Enclosure type (Column 1)</th>
<th>Openings are able to be closed by equipment marked (Column 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>2, 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, “Wet Location”, or “Raintight”</td>
</tr>
<tr>
<td>3</td>
<td>3, 3S, 3SX, 3X, 4, 4X, 6, 6P</td>
</tr>
<tr>
<td>3Rb</td>
<td>3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, 6P, “Wet Location,” or “Raintight”</td>
</tr>
<tr>
<td>3RX</td>
<td>3RX, 3SX, 3X, 4X</td>
</tr>
<tr>
<td>3Sx</td>
<td>3, 3S, 3SX, 3X, 4, 4X, 6, 6P</td>
</tr>
<tr>
<td>3SXx</td>
<td>3SX, 3X, 4X</td>
</tr>
<tr>
<td>3X</td>
<td>3SX, 3X, 4X</td>
</tr>
<tr>
<td>4</td>
<td>4, 4X, 6, 6P</td>
</tr>
<tr>
<td>4X</td>
<td>4X</td>
</tr>
<tr>
<td>5</td>
<td>3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, “Wet Location,” or “Raintight”</td>
</tr>
<tr>
<td>6</td>
<td>6, 6P</td>
</tr>
<tr>
<td>6P</td>
<td>6P</td>
</tr>
<tr>
<td>12, 12K</td>
<td>12, 12K, 13</td>
</tr>
<tr>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

*Type 1 components, ventilation openings, or observation windows are able to be installed when their profile outside the enclosure is completely protected by the drip shield from water dripping vertically downward from above.*

*Components marked “Weatherproof” or “Rainproof” are able to be installed below all other live parts within the enclosure.*

*Components with external operating mechanisms shall be Type 3S or 3SX for use on a Type 3S enclosure, or Type 3SX for use on a Type 3SX enclosure.*

---

**Note:**

Column 2 shows the required enclosure type for the device/component, which is provided for the opening.
### Degrees of Protection and Rules

Openings in enclosures with enclosure type >1

---

**Table 19.3**

Alternate enclosure ratings

Table 19.3 revised September 1, 2005

<table>
<thead>
<tr>
<th>Enclosure type (including components and fittings that comply with Tables 19.1/19.2)</th>
<th>Component/fittings ratings that do not comply with Tables 19.1/19.2</th>
<th>Resulting enclosure rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Enclosure</td>
<td>(Column 1)</td>
<td>Rating of an add. device</td>
</tr>
<tr>
<td>3, 3RX, 3S, 3SX, 3X, 4, 6, 6P</td>
<td>3R, “Wet Location”, “Raintight”, “Weatherproof”, “Rainproof”</td>
<td>3R&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4X</td>
<td>3RX, 3SX, 3X, 4X</td>
<td>3RX&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>4X</td>
<td>3, 3S</td>
<td>3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6, 6P</td>
<td>3X, 3SX</td>
<td>3X&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6P</td>
<td>4, 4X</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>12, 12K, 13</td>
<td>12, 12K</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>3, 3S, 4, 4X, 5, 6, 6P, “Wet Location”, “Raintight”</td>
<td>5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

---

<sup>a</sup> When a drain is added.

<sup>b</sup> When provision is made for locking the door (such as loop for padlock, key-locking type handle or latch) or tools are required to open the enclosure.

<sup>c</sup> Components marked “Weatherproof” or “Rainproof” shall be installed below all other live parts within the enclosure. Openings for conduit or conduit fittings shall comply with note a, b, or c in Table 19.1 for type 3R enclosures.
Degrees of Protection

- Appropriate degree of protection against the intrusion of solids and liquids in dependence of the ambient conditions (e.g. location, dust, cooling water, chips, etc.)
- Minimum degree of protection: NEMA type 1

Exception: Replaceable collection pieces with busbar systems or terminal strips; appropriate protection must be ensured (e.g. raised mounting, covers)

Recommendation: Degrees of protection against the intrusion of water and other liquids are specified in NEMA250; NFPA79, Annex F
<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPFirstCharacter</td>
<td>NEMAEnclosureType</td>
</tr>
<tr>
<td>IP0_</td>
<td>AB AB AB AB AB AB AB AB AB AB</td>
</tr>
<tr>
<td>IP1_</td>
<td>A AB AB AB AB AB AB AB AB AB</td>
</tr>
<tr>
<td>IP2_</td>
<td>B AB B AB AB AB AB AB AB AB</td>
</tr>
<tr>
<td>IP3_</td>
<td>AB B AB AB AB AB AB AB AB AB</td>
</tr>
<tr>
<td>IP4_</td>
<td>AB AB AB AB AB AB AB AB AB AB</td>
</tr>
<tr>
<td>IP5_</td>
<td>AB AB AB AB A AB AB A A A</td>
</tr>
<tr>
<td>IP6_</td>
<td>A A AB AB AB AB</td>
</tr>
<tr>
<td>IP7_</td>
<td>B B</td>
</tr>
<tr>
<td>IP8_</td>
<td>B</td>
</tr>
</tbody>
</table>

**Notes:**

1. Type-rated enclosures for hazardous locations and potentially explosive areas have been excluded from the table. Additional and supplementary fields for IP ratings have also been excluded from the table (see NEMA 250, ANSI/IEEE 508, and IEC 60529).

2. This table should be used only to assign an IP rating to a type-rated enclosure, and not to assign a type-rating to an IP rated enclosure. This table is not intended to provide specific enclosure ratings and should not be used as a definitive guide. For example, if the conditions of installation require an IP65, this table includes data for a Type S, 3S, 4S, 6, or 6P enclosure; it can be utilized. However, if the conditions of installation require a NEMA Type 4, it is an enclosure that is only IP-rated cannot be used as a substitute.

3. Although the corresponding NEMA type ratings meet or exceed the corresponding IP ratings as indicated in the table, NEC does not currently accept these type ratings without further NEC wording.
Note / Disclaimer

The circuit examples and interpretations of the standard are non-binding and do not claim completeness concerning configuration, equipping and contingencies. They do not represent customized solutions but merely provide support for typical tasks.

Every user of this presentation assumes full responsibility for the proper operation of the described products. This presentation does not relieve you of your obligation to ensure safe application, installation, operation and maintenance.

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The final decision as to whether an application complies with the corresponding American standards and regulations lies with the end customer or any organization respectively authorized by him (e.g. authority having jurisdiction, AHJ).
Protection Against Electric Shock

- Protection against direct contact
- Protection against electric shock in case of indirect contact (fault case)
- Protection through protective extra-low voltage (PELV)
- Protection against residual voltages
Protection Against Direct Contact

**General:**
Energized parts must be protected against direct contact when:

- AC: $U \geq 50 \, \text{V}$
- DC: $U \geq 60\, \text{V}$

**Measures:**

1. Insulation
2. Enclosure
3. Interlocking of enclosures
4. Restricted access to the enclosure
Protection Against Direct Contact

(1) Insulation

Energized parts must meet the following conditions:

- Complete insulation (only removable through disassembly!)
- Mechanical, chemical, electrical and thermal resistance
- Paints, varnishes and coatings do not offer sufficient protection against electric shock
Protection Against Direct Contact
(2) Enclosures

Enclosures and enclosure openings must comply with the requirements according to:

- UL508
- UL508A
- UL50 or NEMA 250.

Exception:
Unapproved enclosures can be checked by means of a test finger; checking of all openings after disassembly of all parts removable without tools

→ Touching of energized parts with the test finger must not be possible
Protection Against Direct Contact
(3) Interlocking of Enclosures

**General:** Main disconnecting means of enclosures / industrial control panels must be interlocked with the door when energized parts are contained with
- AC ≥ 50 V
- DC ≥ 60 V

**Exceptions:**
1. Main disconnecting means for industrial control panel lighting inside the industrial control panel
2. Main disconnecting means for memory elements for the retention of information

**Note:**
Qualified persons may implement measures for defeating the interlocking (see NFPA 70E "Standard for Electrical Safety in Workplaces")
Protection Against Direct Contact
(3) Interlocking of Enclosures – Conditions

- The interlocking must be defeatable by means of a tool
- With the door open and the "ON" position, the interlocking must be enabled upon closing
- With the door is open, switch-on must be mechanically blocked; defeat must be possible without tools ("deliberate action")

Caution:
Devices on the inside of industrial control panels must be protected against unintended contact when $U \geq 50$ V; either by means of *device characteristics* or through *barriers in a range of 50 mm* (2 inches)
Protection Against Direct Contact
(3) Interlocking of Enclosures – Solutions

Mechanical solutions:
UL-compliant with UL508A, NFPA 79, JIC and NEC

Max-flex drive
Enclosure type: 1, 3R, 12

Interlocking module 8UC
Enclosure type: 1

Standard references:
UL508A: 30.4 / 66.1.5 / 66.6.3
NFPA79: 5.3.3 / 6.2.3 / 6.2.5
Protection Against Direct Contact
(3) Interlocking of Enclosures – mechanical solutions

Examples for mechanical interlocking solutions provided by Siemens
Protection Against Direct Contact
(3) Interlocking of Enclosures – Solutions

Electrical solutions:
- 1 key switch for defeat
- 1 timing relay
- 1 undervoltage release per main disconnecting means
- Diverse auxiliary relays
- 1 limit switch per door, preferably with tumbler
- Motorized operating mechanism

Note:
The electrical interlocking must meet the same conditions as the mechanical interlocking!
Protection Against Direct Contact

(4) Access to Industrial Control Panels

When **qualified skilled persons** with respective experience open an industrial control panel **without main disconnecting means**, the following conditions must apply:

- the door can be opened by means of a key or tool,

  or

- the door can be opened without defeat, key or tool when all energized parts are covered or encapsulated in a finger-safe manner.
Protection Against Indirect Contact (Fault Case)  

**General:**
Protection against indirect contact is to prevent hazardous states in *case of faults* (e.g. due to insulation faults between energized and exposed parts)

**Measures:**
1. Protection through double insulation
2. Protection through automatic supply disconnection
Protection Against Indirect Contact

(1) Double Insulation

- Double insulation is to prevent the occurrence of hazardous touch voltages due to faults in the basic insulation.

- Operating equipment must be *respectively marked*.

- Operating equipment either must be *listed or tested in a comparable manner*.

"Double insulation" symbol (protection class 2)
Protection Against Indirect Contact
(2) Protection Through Automatic Supply Disconnection

**General:**
Protection through automatic supply disconnection of affected circuits by means of the respective overcurrent protective device in case of faults

**Prerequisites for the safety measure:**
1. Exposed, conductive parts must be grounded
2. Application of overcurrent protective devices for automatic disconnection
Note / disclaimer

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Grounding

- General
- Protective conductor circuit
- Control circuits
- Lighting circuits
Protective Conductor Circuit

The **protective conductor circuit** must consist of:

- separate terminals
- protective conductor and jumpers

**Grounding of systems:**

- All conductive, exposed, non-current-carrying parts must be grounded
- The grounding conductor must be suitable for the respective mechanical and thermal loads as well as overcurrent

**Exception:** Small parts, e.g. screws, rivets and rating plates, need not be grounded if energization of these parts is very unlikely
Protective Conductor Circuit
Grounding Terminals

- Every infeed line requires **separate** grounding terminals near the corresponding phase terminals – **grounding point**
- Grounding conductors of additional concrete-footing ground electrodes [auxiliary electrodes] also must be connected to the grounding terminal
- Wires must be made of copper and approved for the application (e.g. finely stranded, flexible, etc.)
- Dimensioning of the conductor cross-section at least according to Table 8.2.2.3

**Marking**

- "GROUND", "GND", "GRD", "G" or ⬇️
- Protective conductor color for wires / terminals: **green** (or optionally: green/yellow)
<table>
<thead>
<tr>
<th>Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of the Equipment (Not Exceeding Amperes)</th>
<th>Copper Conductor Size (AWG or kcmil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>16</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
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<tr>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>300</td>
<td>4</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
</tr>
<tr>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td>800</td>
<td>1/0</td>
</tr>
<tr>
<td>1000</td>
<td>2/0</td>
</tr>
<tr>
<td>1200</td>
<td>3/0</td>
</tr>
<tr>
<td>1600</td>
<td>4/0</td>
</tr>
<tr>
<td>2000</td>
<td>250</td>
</tr>
<tr>
<td>2500</td>
<td>350</td>
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<tr>
<td>3000</td>
<td>400</td>
</tr>
<tr>
<td>4000</td>
<td>500</td>
</tr>
<tr>
<td>5000</td>
<td>700</td>
</tr>
<tr>
<td>6000</td>
<td>800</td>
</tr>
</tbody>
</table>
Protective Conductor Circuit

Continuity

- The protective conductor connection must be continuously available
- Removal of a component must not lead to an interruption (no daisy-chaining – max. within the industrial control panel)
- Ground studs (e.g. doors, covers) are permitted  
  Prerequisite: Effective removal of color and dirt from the contact surface
- Movable machine parts connected by means of metal bearings are considered grounded  
  Exception: Movable parts in non-conductive, pressurized liquids
- Cable routes and cable ducts made of metal must not be used as protective conductor!

Example of a protective conductor connection
NFPA 79 Ed. 2012
Grounding

NFPA79 Ed. 2007
8.2.3.1 The continuity of the equipment grounding (protective bonding) circuit shall be ensured by effective connections through conductors or structural members.

NFPA79 Ed. 2012
8.2.3.1 The continuity of the equipment grounding (protective bonding) circuit shall be ensured by effective connections through conductors
Protective Conductor Circuit

- Doors and covers with mounting parts must be grounded

- If required, covers and doors must be grounded with the enclosure
e.g. connector, separate PE conductor within the enclosure

- Suspended or movable / spring-loaded operator stations must be grounded *separately*

  *Exception:* When using multi-core wires, one core (green) may be used as grounding conductor

- Protective conductors leading to doors and covers must be protected against damage

**Caution:** The protective conductor circuit must not be routed through industrial control equipment

→ *no* disconnection of the protective conductor connection!!!

*Exception:* Disconnectable connections (connectors, receptacles) require a "first make – last break" (leading / lagging contact) connection of the PE conductor

**Note:** If interlocking with connectors / receptacles prevents plug-in *without* protective conductor connection,
no "first make – last break" contact is required
Control Circuits
Grounding

General:
NFPA79 §8.3: Control circuits may be grounded or ungrounded

With grounded control circuits, the following conditions apply:
- With AC, the secondary transformer side must be grounded
- With DC, the secondary power supply unit side must be grounded

Exceptions:
1. PELV control circuits must always be grounded
2. Contacts of overload relays may be connected between coils of magnetic devices and the N-conductor when the wire between contact and device is routed within the industrial control panel
Control Circuits
Grounding

**Ungrounded** control circuits must be equipped with insulation monitoring which:

- indicates ground faults
  
  faults must be rectified after an *appropriate* period of time ➔ (risk analysis!)

  or

- automatically interrupts the circuit

**Exception:** Class 2 control circuits do not require insulation monitoring (§725 NEC)
Example of Ungrounded Control Circuits

**Note:** Whether ground fault indication is sufficient or immediate interruption is required must be determined within the scope of the risk analysis.
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UL-Compliant Marking

- Name Plate
- Panel Marking – Overview
- Information concerning the power supply
- Technical Documentation acc. NFPA79
- Conductor Marking
- Graphic Symbols ANSI – IEC
- Device Marking
- Examples of Diagrams and electrical Drawings acc. to ANSI
Panel Marking
General Markings – UL508A §52

- Name Plate should contain:
  - Manufacturer’s data or approved designation
  - Complete electrical data (e.g. rated current, voltage, number of conductors, frequency, hp-rating of the largest motor, etc.) acc. to UL508A §49.1
  - The voltage rating may not be higher than that of any devices directly connected to the main power
  - All supply terminals shall have an SCCR value acc. UL508A, SB4
  - Schematic diagram of external wiring acc. to UL508A, §52, 54, 60
  - Designation of the origin if the OEM has more than one manufacturing places
  - Indication of enclosure type rating
  - Current rating of the largest heater load
  - Short circuit current rating of the Industrial control panel

- The markings shall be made according to the Table 52.1
- The markings shall be clearly visible after installation at site
What is not proper indicated on this nameplate?

Plastics Processing Machine

- Serial Number: 12388-77
- Current: 50 Amperes
- Voltage: 460 - 480 volts
- Phase & Freq.: 3 φ, 60 Hz
- Diagram Numbers: CM 12.1 THRU CM 12.5
- Fuse: 63 Amperes

AAA Machine Company, Anywhere, Germany
Panel Marking
Nameplate – Failures – Example

- Current should be changed to Full Load Amps
- Phase and Frequency: could be integrated at the Voltage marking. But 3~ is not an valid sign in the USA
- Fuse: missing is
  - Note „Field provided“
  - Indication of the needed Fuse Class and Voltage
- General missing (as minimum)
  - Largest Motor in hp
  - Largest heater load in Amperes
  - SCCR-Value
- For Machines covered by NFPA 79, or for which UL508A chapter 66 and following are valid, the name plate shall contain additionally:
  „Industrial Control Panel for Industrial Machinery“
Panel Marking
Nameplates – better

Much better Version

AAA Machine Company, Anywhere, Germany

Serial Number 12388-77
Full-load Amperes 50 Amperes
Largest Motor 2 Horsepower
Largest Heater Load 15 Amperes
Voltage, phase, freq. 460 - 480 V, 3 phase, 60 Hz
Max. short circuit current 50 kA rms symmetrical, 480 V max.
Supply fuse (field provided) Class RK5, 600 Vac / 60 A
Enclosure Type rating Type 1
Diagram Numbers CM 12.1 THRU CM 12.5

Industrial Control Panel For Industrial Machinery
## Marking of Conductors

NFPA 79 Chapter 13.2. and UL 508A Chapter 66.9

<table>
<thead>
<tr>
<th>Marking of conductors</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective conductor</td>
<td>Green or green / yellow</td>
</tr>
<tr>
<td>Ungrounded line voltage circuit (power &amp; control)</td>
<td>Black</td>
</tr>
<tr>
<td>Ungrounded AC control current (operating voltage &lt; line voltage)</td>
<td>Red</td>
</tr>
<tr>
<td>Ungrounded DC control current (operating voltage &lt; line voltage)</td>
<td>Blue</td>
</tr>
<tr>
<td>Ungrounded conductor &quot;excluded circuits&quot;</td>
<td>Orange (or yellow)</td>
</tr>
<tr>
<td>Grounded conductor of an AC line voltage circuit</td>
<td>White, gray or three continuous white stripes</td>
</tr>
<tr>
<td>Grounded conductor of a DC control circuit</td>
<td>White with blue stripes</td>
</tr>
<tr>
<td>Grounded conductor of an &quot;excluded circuit&quot;</td>
<td>White with orange or yellow stripes</td>
</tr>
</tbody>
</table>
## Panel Marking
according UL508A – Table 52.1

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>General description</th>
<th>Location categories (see notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.1</td>
<td>General markings</td>
<td>Enclosed Open</td>
</tr>
<tr>
<td>52.1</td>
<td>Nameplate stating: manufacturer, maximum voltage, total FLA, largest motor FLA, phase, frequency, field wiring diagram, short circuit current rating</td>
<td>a or b f</td>
</tr>
<tr>
<td>52.2</td>
<td>External load ratings</td>
<td>a, b, or e e or f</td>
</tr>
<tr>
<td>53.1</td>
<td>Enclosure markings</td>
<td>a or b –</td>
</tr>
</tbody>
</table>

### Table 52.1
Locations of required markings

Table 52.1 revised December 28, 2007

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Schematic Wiring Diagrams</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.1, 61.2</td>
<td>Complete schematic</td>
<td>e e</td>
</tr>
</tbody>
</table>

### NOTES
a) Marking shall be visible without opening the door or cover of the enclosure.
b) This marking is able to be provided on the door or cover of the enclosure or on the inside walls of the enclosure.
c) Marking shall be on or adjacent to the component in question. Fuse replacement markings are able to be on a chart displayed as specified in (b) when each fuseholder is marked with a distinctive designation, such as F1. For open panels, the chart is able to be supplied as described in (d).
d) Marking shall be shipped separately on a self-adhesive label with the device (this is intended to be placed on or in the ultimate enclosure).
e) Marking shall be on the field wiring diagram, prints, or instructions that are referenced on the panel nameplate and is to be shipped with the panel (either loosely, in the “print pocket,” or adhered to the inside of the enclosure).
f) Marking shall be on the subpanel component mounting plate.
Panel Marking
According UL508A – § SB5

- The SCCR value shall be indicated on the name plate.
  E.g.: „Short Circuit Current: …..kA r.m.s. symmetrical, ….V maximum“

- If the panel is marked with an „high“ SCCR value and the BCPD is not installed in the panel, the needed BCPD has to be indicated clearly on the name plate.

- If an „high“ SCCR value is indicated due to „Series rating“ or „Combination Tests“ (acc. to SB4.2.3), than the panel shall be marked additionally with „WARNING – Risk of fire of Electric Shock“ (or similar)
  „The opening of the branch-circuit protective device may be an indication that a fault current has been interrupted. All current-carrying parts and other components protected by this device should be examined and replaced“
Panel Marking
According UL508A – § SB5

WARNING - Risk of Fire or Electrical Shock

The opening of the Branch Circuit Protective Device may be an indication that a fault current has been interrupted. All current-carrying parts and other components protected by this device should be examined and replaced if damaged. If burnout of a current element of an overload relay occurs, the complete overload relay shall be replaced.
Panel Marking
(1) Field Wiring Terminal Markings – UL508A §54

- The terminal marking shall be conform to the diagrams
- Field wiring terminals shall be marked with
  - The neccessary wiring material
  - The neccessary wiring temperature
    Exceptions: Other than motor loads with max. 15A
- Torque
  Exceptions 1: wire binding screws
  Exceptions 2: control circuit terminals with 7 inch-lb (0,8 Nm)
- Marking of the grounding terminal with one of the following
  a. Green, not easy to removeable Screw (hexagonal type)
  b. Green, not easy to removeable Nut (hexagonal type)
  c. Terms „Ground“ or „Grounding“
  d. Letters „G“, „GR“, „GRD“, „GND“, „GRND“
  e. IEC-Grounding Symbol is allowed

Note: if the grounding terminal is within a housing (e.g.: terminal block),
the marking shall be either c, d, e or green/yellow color
Panel Marking
(1) Field Wiring Terminal Markings – UL508A §54
Panel Marking
(2) Field Wiring Terminal Markings – UL508A §54

- Low Voltage Limited Energy or Voltages of max. 30V r.m.s. connected to an „isolated secondary“ shall be marked with „Class 1 control circuit“ or „Use class 1 conductors“ or similar
- Class 2 control circuits shall be marked with „Class 2 control circuit“ or „Use class 2 conductors“ or similar
- If an enclosure contains „Class 2“ and „Class 1“ or Power terminals, not provided with „Barriers“, it shall have instructions how to make the separation
- Terminals for control circuits less than 14 AWG are to be marked with the needed wire size
- Transformers feeding circuits leaving the panel from a secondary winding shall be marked how the secondary neutral conductor shall be grounded
Panel Marking
(3) Field Wiring Terminal Markings – UL508A §54

- Each terminal shall be marked additionally with one of the following
  - Use Copper Conductors Only“ if the terminals allows only Cu
  - „Use Aluminum Conductors Only“ if the terminals allows only Al
  - „Use Copper or Aluminum Conductors“ or „Use Copper, Copper-Clad Aluminum or Aluminum Conductors“ if the terminal allows both, Cu and Al
  - „Use Copper, Copper-Clad Aluminum“ if the terminal allows both, Cu and Cupal

- Marking of the supply terminal if the panel shall be used on „slash rated voltages“ „For use on a solidly grounded wye source only“ or similar
Panel Marking
(1) Cautionary Markings – UL508A §55

- Markings shall not be easily removable and shall be legible and visible
- Cautionary markings shall start with „CAUTION“ or „WARNING“ and this shall be not less than 1/8 inch (3.2mm) in size, all other words shall be not less than 1/16 inch (1.6mm)
- Cautionary marking to instruct operators shall be visible during normal operation
- Marking that provides servicing instructions shall be visible when servicing.
- If more than one supply source is used, it shall be marked as following or similar „CAUTION – Risk of Electric Shock, more than one Disconnecting means“

Exception: This marking is not required for an isolated control circuit contact that is separately supplied
If the BCPD is an „Instantaneous-trip circuit breaker“ the following „WARNING“ shall be made (§55.6)

- All necessary protection measures shall be made according to the manufacturer (Overload, short circuit, ground fault, adjustments)
- That a tripping of the Circuit Breakers indicates a possible short circuit and that all parts in this particular circuit shall be checked and if necessary replaced

**WARNING**
To maintain overcurrent, short-circuit, and ground-fault protection, the manufacturer’s instructions for selecting current elements and setting the instantaneous-trip circuit breaker must be followed.

**WARNING**
Tripping of the instantaneous-trip circuit breaker is an indication that a fault current has been interrupted. Current-carrying components of the magnetic motor controller should be examined and replaced if damaged to reduce the risk of fire or electric shock. If burnout of the current element of an overload relay occurs, the complete overload relay must be replaced.
If a "Self-protected Combination Motor Controller" is used the following "WARNING" shall be made (§55.7)

- All necessary protection function are to be made according the manufacturer (Overload, short circuit, ground fault, adjustments)
- That a tripping of the Circuit Breakers indicates a possible short circuit and that all parts in this particular circuit shall be checked and if necessary replaced

**WARNING**

To maintain overcurrent, short-circuit, and ground-fault protection, the manufacturer’s instructions for selection of overload and short circuit protection must be followed to reduce the risk of fire or electric shock

**WARNING**

If an overload or a fault current interruption occurs, circuits must be checked to determine the cause of the interruption.

If a fault condition exists, the current-carrying components should be examined and replaced if damaged, and the integral current sensors must be replaced to reduce the risk of fire or electric shock.
A safety sign shall be provided adjacent to the main supply circuit disconnect operating handle to warn qualified persons of potential electric arc flash hazards.
110.16 Arc-Flash Hazard Warning

Electrical equipment, such as switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers, that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field or factory marked to warn qualified persons of potential electric arc flash hazards.

The marking shall meet the requirements in 110.21(B) and shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

110.21 Marking (B)
Field-Applied [during of after the installation] Hazard Markings. Where caution, warning, or danger signs or labels are required by this Code, the labels shall adequately warn people of the hazards, be permanently and of sufficient durability.
A **branch circuit fuseholder** that accepts a fuse having a rating larger than the maximum specified rating and all **control circuit fuseholders** shall be marked with the voltage and current rating of the replacement fuse.
Panel Marking
Switch Markings – UL508A §57

- The position „ON“ and „OFF“ of each disconnecting means shall be indicated clearly

- Switches which are not approved for switching under load shall be marked with “Do not operate under load“

- Disconnects on which also in the OFF position voltage may exist (back-fed), shall be marked which disconnect will be necessary to switch off this voltage.
Panel Marking
Receptacle Markings – UL508A §59

- If the BCPD has a lower ampacity as the receptacle, the receptacle shall be marked with the lower ampacity. This receptacle also shall be marked with the foreseen application.

- A receptacle in the control circuit intended for control circuit load, shall be marked with the ampacity of the overcurrent protection device and with the intended load.

- „Multiple pin“ receptacles or a common receptacle with more than 20A shall be marked as following:
  „For disconnecting use only, not for current rupturing“
Panel Marking
Field Provided Components – UL508A §60

Panels needing field provided components provided by the installer shall be marked, if:

1. Disconnecting means, BCPD and / or Motor overload are not installed

2. If for separated circuits the disconnecting means and / or the BCPD are not installed

3. If devices included in the panel diagrams are not installed in the panel

**Supply fuse (field provided)**
- Class RK5, 600 Vac / 60 A

**Enclosure Type rating**
- Type 1

**Diagram Numbers**
- CM 12.1 THRU CM 12.5

*Industrial Control Panel For Industrial Machinery*
Panel Marking  
Supply Ratings

1. Full load amp. rating acc. to UL508A, 49.2  
   This value shall contain the total sum of all loads which can be operated simultaneously plus all  
   primary currents of all control power units / transformers  
   → simultaneous factor!

2. Voltage rating acc. to UL508A, 49.6  
   If devices are market with „slash voltage rating“ (e.g. 480Y/277; 600Y/347V), the following  
   applies for the panel:  
   a. Marking of the complete „slash voltage“ for the supply  
   b. Marking of the lower voltage value of the slash rating for connection to a different type of  
      supply
49.2 The full-load ampere rating of the panel shall, at a minimum, include the sum of the ampere ratings of all loads that are able to be operated simultaneously plus the primary ampere rating of all control transformers connected to the input voltage.

49.2 effective April 25, 2003

Note for a „simultaneous factor“

49.6 The voltage rating of an industrial control panel shall not exceed the voltage rating of any component connected to the source of supply. When an industrial control panel contains components marked with a slash voltage rating, such as 120/240, 480Y/277, or 600Y/347, the voltage rating of the industrial control panel shall be:

a) The complete slash voltage rating, when intended for connection to the higher voltage; or

b) Not more than the lower voltage rating.

49.6 added September 1, 2005
Wire Marking
acc. to UL508A §66.5 and NFPA 79 Chapter 13.2

Possibilities:
1. Termination-number to where the wire belongs
2. Device plus termination designation to where the wire belongs
3. Circuit numbers

Objective: Definite corresponding of wires and termination

No matter which possibility is chosen, the marking shall also correspond to the electrical drawings. Which documents shall be delivered with the machine, is regulated by NFPA79 – Kap. 13.2 and UL508A §17.

Remark: It shall exist a definite indication and conformity of the diagrams and the panel wiring!
Conductor Marking
Excerpt from UL508A and NFPA 79

UL 508A §66.5

66.5.2 All conductors shall be identified at each termination by letter(s) or number(s) corresponding with the wiring diagrams provided with the industrial control panel.

66.5.2 effective April 25, 2003

NFPA 79

13.2 Identification of Conductors.

13.2.1 General Requirements.

13.2.1.1 Conductors shall be identified at each termination by number, letter, color (either solid or with one or more stripes), or a combination thereof and shall correspond with the technical documentation. Internal wiring on individual devices purchased completely wired shall not require additional identification.

13.2.1.2 Where numbers are used to identify conductors, they shall be Arabic; letters shall be Roman (either upper or lower case).
Conductor Marking

Examples

[Images of electrical panels with conductor markings]
UL does not provide any specifications as to the use of graphic symbols in the documents. This has to be agreed between OEM and “enduser”.

Either

- **ANSI symbol**

- or

- **IEC symbol**

“Cross reference” excerpt from NFPA79, annex D

**Note:** Please enclose cross-reference when using IEC symbols!
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Unlisted Components UL508A, Appendix B

- Application requirements
- Principle sketch
- Remarks
- Power supply
- Input signals
- Output signals
- Documents
- GFCI / GFPE

UL guideline, chapter 4.3.9
Unlisted Components
Application Requirements acc. to UL508A, Appendix B

Scope of Appendix B
For components neither „listed“ nor „recognized“

Appendix B shall NOT be applicable for components,
a) Which interrupts circuits due to overload, Motor overload, Short circuit, Ground fault
b) If further safety aspects shall be considered,
   e.g. flammable gases and liquids, high pressure, vacuum tubes, etc.
c) Already inspected and for other applications and/or with other ratings approved components.
d) Which are directly connected to the power circuits
e) Which are completely located inside an isolated circuit or protected by an GFCI

Possible components
Switch, Relay, Measuring device, Recording devices or similar, which are controlling only loads or signals inside the control circuit, but which do not have any direct connection to other circuits
Unlisted Components
Application Requirements acc. to UL508A, Appendix B

Application Requirements

- The component shall be completely enclosed in the industrial control panel.
- If this additional enclosure has ventilating openings this shall be considered as arc flash hazardous device.
- The component shall be used only in control circuits.
- All Inputs to the component shall be connected with control circuit components only, which comply with the conditions specified in SA1.1 – SA2.5.
- All Outputs of the component shall be connected with control circuit components only, which comply with the conditions specified in SA1.1 – SA2.5.
Exceptions of the Requirements

- The component may be extended through the panels, if the enclosure of the component is made of
  - Polymeric material and the outer surface is not bigger than 30 sqinch (194 cm²)
  - Metal or glass and the outer surface is not bigger than 100 sqinch (654 cm²)

- Components used in an open type industrial control panel
  - The component shall be completely enclosed
    Or
  - The component is protected by barriers.
    This barriers shall comply with the conditions for barriers of ventilating openings
Unlisted Components
UL508A, Appendix B

A – Primary overcurrent protection for isolation transformer
B – Isolation transformer
C – Secondary overcurrent protection for isolation transformer
D – Secondary ground connection
E – Control of load inside control panel and not protected by GFCI. Also see K.
F – Ground-fault circuit interrupter (GFCI)
G – Coil of isolating relay input from switching device operating at over 30 Vrms. Also see M.
H – Control of load outside control panel from isolating relay contacts. Also see L.
I – Power supply input to component under evaluation
J – Control of control circuit load inside control panel and on load side of GFCI
K – Control of internal load on line side of GFCI via isolating relay
L – Control of external load operating at over 30 Vrms via isolating relay
M – Input from external switching device operating at over 30 Vrms
N – Low-voltage connections without fusing
O – Low-voltage connections with fusing
Q – Accessible part of component under evaluation
Unlisted Components
Remarks and Warnings acc. to UL508A, Appendix B

- If unlisted components are used a clear warning shall be made to indicate this and how these components shall be protected by an Protection Device.
  Example:
  "WARNING – Use of the following components is dependent upon the additional protection afforded by the ground fault circuit interrupter and the overcurrent protective device provided. Do not remove or defeat these protective devices."

  plus an additional table which devices need to be protected by an GFCI

<table>
<thead>
<tr>
<th>Example:</th>
<th>Component</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relay, K1</td>
<td>Acme, p/n 508</td>
</tr>
</tbody>
</table>

- All documents of how this components shall be applied have to be kept safe in place.
Unlisted Components
Powersupply acc. to UL508A, Appendix B

- Transformer with isolated secondary
- Secondary voltage of 115-120V or 230-240V
- Secondary winding shall be solidly grounded
- Secondary circuits shall be protected by an GFCI (Ground Fault Circuit Interrupter acc. to UL943 -- Class A, 6mA or receptacle type)

If a Receptacle Type is used,
- The component shall be connected directly, not via an plug. Components having a cord with plug, the plug needs to be cut off.
- A mark shall be made adjacent to the receptacle that this receptacle shall not be used for devices outside the panel
- The receptacle shall be installed that it is not accessible from outside
Unlisted Components
Powersupply INPUTS acc. to UL508A, Appendix B

**U > 30V rms (42.4 peak or DC)**
- The input signals shall be connected via an listed device (SA1), e.g. Relay.
- This device shall be installed inside the panel.
- The power supply shall be taken from the load side of an GFCI

**U ≤ 30V rms (42.4 peak or DC)**
- If power supply installed inside the panel, by either one of the following
  - Low Voltage Limited Energy
  - Class 2 Power supply / Transformer
- If power supply installed outside the panel a 0.5A fuse shall be installed inside the panel for each ungrounded conductor
  - Adjacent to the fuse a caution mark shall be made, „CAUTION“ and the remark, “To reduce risk of electric shock, connection to these terminals shall not involve voltage potential of greater than 30V rms (42.4V peak or DC)“ or similar.

**Voltage of measuring devices (Tachometer, Thermoelement, etc.)**
- If this signal is isolated of the supply voltage no other measurments are neccessary.
Unlisted Components
Powersupply OUTPUTS acc. to UL508A, Appendix B

**U > 30V rms (42.4 peak or DC):**
- The output signals shall be connected via a listed device (SA1), e.g. Relay.
- This device shall be installed inside the panel.
- The power supply shall be taken from the load side of a GFCI.

**U ≤ 30V rms (42.4 peak or DC):**
- If power supply installed inside the panel, by either one of the following:
  - Low Voltage Limited Energy Circuit
  - Class 2 Power supply / Transformer
- If power supply installed outside the panel a 0.5A fuse shall be installed inside the panel for each ungrounded conductor
  - Adjacent to the fuse a caution mark shall be made, "CAUTION" and the remark, "To reduce risk of electric shock, connection to these terminals shall not involve voltage potential of greater than 30V rms (42.4V peak or DC)" or similar.
### Unlisted Components

**Responsibility of the Manufacturer acc. to UL508A, Appendix B**

- Testing of the GFCI acc. to the provisions specified in B3.2 UL508A
- All documents on applied and examined devices must be recorded
- The documents must be kept ready at all times for review by UL inspectors
- Availability of the documents must be ensured for at least 6 months

The documents should be recorded as follows:

<table>
<thead>
<tr>
<th>Component Designation</th>
<th>Component Manufacturer’s Name</th>
<th>Catalog Designation</th>
<th>Number Used</th>
<th>Panel Identification</th>
<th>Ground Fault Date Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ground Fault Protection acc. to UL

1. **Ground Fault Circuit Interrupters (GFCI) acc. to UL943**
   - Application for personal protection
   - Application only in grounded networks
   - Application mainly in the residential sector (up to 120/240 VAC)
   - Tripping between 4 - 6 mA

2. **Ground fault sensing and relaying equipment acc. to UL1053 (GFPE)**
   - Application for system protection
   - Application as *detector* for fault currents against ground (low currents)
   - Application together with, e.g. circuit breakers, fused circuit breakers, fused switches or separately (depending on type)
   - Application range from 150 VAC to max. 600VAC
   - Application for conventional tasks

*UL provides different types of “ground fault interrupters”*
Ground Fault Circuit Protection by Siemens

Ground fault circuit interrupter (GFCI) acc. to UL943
- 1-pole 120V AC and 2-pole 120V / 240 V AC
- 1-pole from 15 – 30 A, 10kA IR
- 2-pole from 15 – 60 A, 22kA IR
- Class A, 5mA

Ground fault equipment protection (30mA) acc. to UL1053 (GFPE)
- 1-pole 120V AC and 2-pole 120V / 240 V AC
- 1-pole from 15 – 30 A, 10kA IR
- 2-pole from 15 – 60 A, 22kA IR
Questions?

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Summary

- Information and recommendations
- Cax Online Generator and My Documentation Manager
- Frequent mistakes in connection with NFPA79
Information and Recommendations
Further Information Sources

Further information
- Configuration document;
- UL Guidelines “Industrial control panels for North America”
- Product catalog “Industrial controls”
  www.usa.siemens.com/controls

Safety applications / Safety Evaluation Tool:
- www.siemens.com/safety-evaluation-tool
- www.usa.siemens.com/safety

Further UL links:
- www.ul.com
- www.ul.com/database
- www.nfpa.org

Siemens UL website
- www.usa.siemens.com/controlpaneldesign
Information and Recommendations
Further Information Sources

Important numbers:

Technical Support:
800-333-7421

Training, Spare Parts, Field Service:
800-241-4453
Information and Recommendations
SCCR – Information for Siemens control products

C Ax online generator – Your information archive
C Ax data types – Types of information

- Product graphic
- Operating travel diagram (only relevant for position switches)
- Terminal connection diagram
- 2D dimension drawing
- Internal circuit diagram
- 3D model
- EPLAN macros

Product: C Ax data

- Product data sheet
- Operating instructions
- Commercial data

Technical data
- Characteristic curves
- Certificates/approvals

Manual
MDM
My Documentation Manager – Function

Compile product documentation effectively and appropriately in a separate structure and manage it comfortably

1. Select a contribution – e.g. select a manual (configurable) using the search

2. Call a contribution in MDM – e.g. select a particular chapter of a manual

3. Create / expand a separate library – add, compile, rename or delete separate folders / subject areas

4. Transfer a contribution to a separate composition – integrate contents into a separate structure using "drag and drop"

5. Export function – export a separate library wholly or partially as a file (.pdf, .xml, .rtf, etc.)
Frequent Mistakes
Application of the Wrong Standard

- Requirements not defined in due time, e.g. hazardous location
- Relevant standards such as NFPA 79 and UL 508A and their contents not known by suppliers

**Caution:**
Wrong standards are frequently applied due to insufficient advance research; the scope of the respective standard must always be considered!

→ **The end use application always serves as the decisive factor for the standard to be applied!**
Frequent Mistakes
Delta Networks Compared to Slash Networks

Examples:

Slash rating:
e.g. 480 Y / 277 V

→ Industrial control equipment must be dimensioned for at least 480 Y / 277 V;
   industrial control equipment with 600 Y / 347 V may also be used!!!

Straight rating:
e.g. 480 V

→ Industrial control equipment must be marked with at least 480 V;
   industrial control equipment with e.g. 600 Y / 347 V must not be used!!!

Caution:
There is a great variety of different network types; the differentiation between slash and straight rating is important when dealing with network types; this may have considerable effects on the selection of industrial control equipment!
Frequent Mistakes

Difference between feeder circuit and branch circuit not known
→ Non-compliance regarding distances through air and over surfaces
→ Incorrectly protected control circuits
→ Faulty SCCR rating determination (according to UL508A)
Frequent Mistakes
Components

Difference between circuit breaker and supplementary protector not known
With regard to MCBs, a differentiation between auxiliary protective devices (supplementary protectors UL1077) and overcurrent protective devices (circuit breakers UL489) is made

Example:

- **Supplementary protector**: Miniature circuit breaker according to UL1077; MCBs (suppl. protection) are UL Recognized (R/C) according to UL1077 – not applicable as BCPD; protection, e.g. of control circuits, possible

- **Circuit breaker**: Circuit breakers (C.B.) feature a UL label and are listed according to UL489; application e.g. in branch or feeder circuits as overcurrent protective device → miniature circuit breakers according to UL489

Note:
The application of miniature circuit breakers or miniature fuses (R/C) instead of a BCP (branch circuit protection) is considered a **severe installation fault** by all AHJs!
Frequent Mistakes
Components

Application of AC breakers in 24 V DC circuits

<table>
<thead>
<tr>
<th>Short Circuit current [kA]</th>
<th>Voltage</th>
<th>Tripping Characteristic</th>
<th>rated current [A]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>240Vac</td>
<td>all</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>60Vdc</td>
<td>all</td>
<td>Up to 63</td>
</tr>
<tr>
<td>15</td>
<td>240Vac</td>
<td>B (see Ill 8 and 9)</td>
<td>6 through 63</td>
</tr>
<tr>
<td>15</td>
<td>240Vac</td>
<td>C (see Ill 8 and 9)</td>
<td>0.3 through 40</td>
</tr>
<tr>
<td>15</td>
<td>240Vac</td>
<td>D (see Ill 8 and 9)</td>
<td>0.3 through 20</td>
</tr>
<tr>
<td>10</td>
<td>60Vdc</td>
<td>all</td>
<td>Up to 63</td>
</tr>
</tbody>
</table>

Excerpt from the Siemens report on miniature circuit breakers 5SJ
CCN: DIVQ
UL489 circuit breaker
Application of unapproved components

**General:** All employed components require an approval for the North American market, e.g. ![UL Listed](image) or ![cULus Listed](image)

**Exceptions:**
1. Components are completely installed in a class 2 circuit
2. Components are completely installed in a LVLE circuit (low-voltage limited-energy)
3. Installation of components according to UL508A, Appendix B

**Caution:**
According to UL508A, components installed in the power circuit imperatively require the suitable approval! (observe CCN!)
Component selection and dimensioning

**UL-Listed:**
Devices bearing this sign can be installed without any restrictions in terms of applicability and without any further instructions
- Free replaceability
- Observance of few exceptions; see Table SA1 (UL508A)

**UL-Recognized:**
Devices bearing this sign are employed as components or as part of a complete device; installation must be carried out by qualified personnel only as the **COAs (conditions of acceptability)** must be considered

**Caution:** Always observe the respective COAs when employing products and devices!
Frequent Mistakes

Components

These COA (conditions of acceptability) explain and specify the requirements to be met for application of such components.

The COAs are included in the components’ UL Reports and are listed on the first 3 to 4 pages of the respective report.

<table>
<thead>
<tr>
<th>Listed</th>
<th>R/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANADA</td>
<td>xxxx7</td>
</tr>
<tr>
<td>USA</td>
<td>xxxx</td>
</tr>
</tbody>
</table>
Frequent Mistakes
Components

Application of service receptacles without GFCI

1. Receptacles for service purposes generally require a ground fault circuit interrupter according to UL943 GFCI for operator protection.

2. Tripping with $I_{\Delta n} = 4 \ldots 6$ mA
Frequent Mistakes in Connection with NFPA79
Control Circuits

- Transformers without overcurrent protection on the secondary side
- Secondary transformer side not connected with PE
- Ungrounded control circuits not equipped with insulation monitoring
- Ungrounded control circuits without two-pole protection
**Frequent Mistakes in Connection with NFPA79**

**Cables and Conductors**

- Insufficient conductor marking
- Wrong colors for zero conductors and excluded circuits
- Plastics and foamed plastics without fire class proof (yellow card!)
- Wires without approval or with incorrect approval, e.g. AWM (style number!)
- Routing of signal, data and control wires with supply wires (basic insulation) in the same cable duct, Uinsu unapparent
- Filling degree of cable ducts > 50%
- Cross-section reduction by >2 AWG without corresponding protection element
Frequent Mistakes in Connection with NFPA79
Cables and Conductors

- Protective conductor concept unapparent (complete machine)
- Protective conductor connections unmarked
- Protective conductor resistance > 100 mOhm
- Enclosure covers not connected to protective conductor
- Equipotential bonding over varnished surfaces, no contact washers
Frequent Mistakes in Connection with NFPA79 Documentation

- Incomplete or incorrect data on the rating plate
- SCCR rating: Mostly read off the main disconnecting means or circuit breaker or switching capacity of the protection element
- Circuit diagram according to IEC without cross-reference list
- Lack of warning notes
- Warning notes according to IEC (mostly not accepted / unknown)
- Lack of data sheets and certificates
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