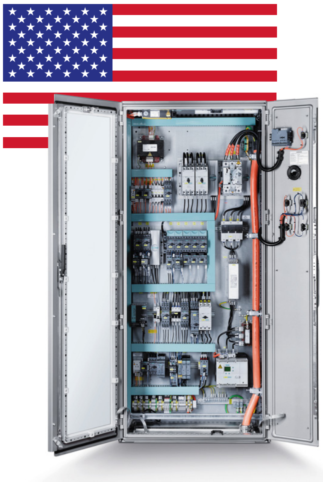
SIEMENS

Industrial Control Panels and Electrical Equipment of Industrial Machinery for North America

A Guide for Practical Use

Reference Manual



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indicates that death or severe personal injury **will** result if proper precautions are not taken.

⚠WARNING
indicates that death or severe personal injury **may** result if proper precautions are not taken.

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indicates that minor personal injury can result if proper precautions are not taken.

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indicates that property damage can result if proper precautions are not taken.

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The product/system described in this documentation may be operated only by **personnel qualified** for the specific task in accordance with the relevant documentation, in particular its warning notices and safety instructions. Qualified personnel are those who, based on their training and experience, are capable of identifying risks and avoiding potential hazards when working with these products/systems.

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Siemens AG
Industry Sector
Postfach 48 48
90026 NÜRNBERG
GERMANY

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℗ 08/2014 Subject to change

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Authors

Gerhard Flierl

Dipl.-Ing. **Gerhard Flierl** has been employed by Siemens AG in the area of low-voltage controls and distribution since 1996.

On qualifying as an industrial electronics engineer at Siemens AG, and after studying electrical engineering and business administration, he spent 4 years in the development department of low-voltage circuit protection systems.

Since 2008, he has worked in the areas of technical marketing and technical sales at Siemens AG in Germany, and also for many years at Siemens Industry Inc. in the USA.

His tasks include application consulting for North American regulations, UL / NFPA / ANSI and CSA standards, as well as the relevant IEC standards in the environment of low-voltage controls and distribution.

Email: gerhard.flierl@siemens.com

Martin Berger

Martin Berger has worked at Siemens AG since 1991 during which time he has been active almost exclusively in the area of low-voltage controls and distribution.

On completion of his training, he spent some years in industrial control equipment production. Completion of his advanced training to state-certified technician was followed by seven years developing distribution boards and industrial control equipment. For some of these years, he had project responsibility for new products.

Since 2010, he has worked in the area of technical sales at Siemens AG in Germany.

His tasks include global application consulting for North American regulations, UL / NFPA / ANSI and CSA standards, as well as the relevant IEC standards in the environment of low-voltage controls and distribution.

Email: bergermartin@siemens.com

1 Disclaimer of Liability

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If you use the information provided herein in your specific application, please double check its accuracy and applicability and be advised that you are using this information at your own risk.

Introduction 2

This manual is a supporting guide produced by Siemens experts working in the field of low-voltage controls and distribution.

Target group

This manual is intended for the following target groups:

- Plant manufacturers
- Industrial control panel builders
- Machine builders

The information in this manual is intended as an aid to users in practical issues.

Typical circuit diagrams and interpretations of standards

The typical circuit diagrams and interpretations of standards are not binding and do not claim to be complete regarding configuration, equipment or any other eventuality.

The typical circuit diagrams and interpretations of standards do not represent specific customer solutions, but are only intended to provide support when it comes to typical applications.

Every user is responsible for the correct operation of the products described.

The typical circuit diagrams and interpretations of standards do not relieve you of your responsibility to ensure safe handling when using, installing, operating, and maintaining the equipment. By using these typical circuit diagrams and interpretations of standards, you agree that Siemens cannot be held liable for possible damage beyond the scope of the liability outlined above. We reserve the right to make changes and revisions to these typical circuit diagrams and interpretations of standards without prior announcement.

Information about the sources used

Many of the tables and texts in this guide have been taken directly from the relevant regulations, standards, and codes. All users must always check whether the items quoted are still up to date and applicable or not.

The information provided in this manual will not, in most cases, be sufficient to attain approval, listing, certification, or authorization. Detailed knowledge of the corresponding regulations is needed for this.

Many of the terms and expressions used are explained in the Glossary (Page 387).

Provisions

The manual is based on ANSI, UL, and NFPA standards (originating in the USA), and contains primarily provisions from the following standards and codes:

- National Electrical Code, 2014 edition
- NFPA 79, 2012 edition
- UL 508A, February 2010

Industrial control panels and equipment for machinery manufactured for and circulated in the US market must comply with the relevant regulations as a minimum requirement. This document is designed to aid manufacturers and their suppliers, regardless of whether the manufacturer exports the goods to the USA, or manufactures them on-site in the USA.

Electrical installations are inspected by local authorized bodies who usually use the **N**ational **E**lectrical **C**ode® (see Chapter Standards (Page 35)) as the basis for their work. NEC® 2014, Art. 110.2, specifies that all devices, apparatus, accessories, machinery and conductors must be approved for electrical installation. This means all such equipment installed in the USA shall be approved by the **A**uthority **H**aving **J**urisdiction (AHJ – see Chapter Peculiarities (Page 41)).

In many application cases, however, the NEC does not specify all the necessary details. To meet the needs of the manufacturer in spite of this, this guide makes liberal use of provisions from other relevant standards and regulations. The applications described here are generally recognized practices.

3 Area of application for this documentation

This guide is mainly restricted to the design of electrical equipment for machinery, in other words, Industrial Control Panels, for general use according to the UL standard UL 508A, and general electrical equipment for industrial machinery and systems according to NFPA 79.

The NEC (National Electrical Code – NFPA 70), which is of higher importance, is also applicable in many respects and is referenced at various points in this guide.

Industrial control panels and items of general electrical machinery equipment are either built by the panel builder for the purpose of supplying them separately or incorporating them into other distribution systems, plants or machines, or they are otherwise produced by the machine manufacturers themselves.

As this guide is based heavily on specifications from standards, the area of application is, accordingly, based on these standards as well. Details of the area of application based on the key standards referred to (UL 508A, NFPA 79, and NEC) can be found in Chapter Standards (Page 35).

In addition, this guide is limited exclusively to information on the electrical safety required for industrial control panels and electrical equipment for machines and systems.
Other aspects such as machine safety, explosion protection, and electromagnetic compatibility are not the primary focus of this documentation.

4 General information for manufacturers of machinery and their associated electrical equipment

4.1 Organizations

This chapter deals primarily with organizations, authorities, and standardization bodies in North America. To provide a clearer picture of the variety of these organizations, some of the more significant ones are listed here individually along with an explanation of their roles.

ANSI (American National Standard Institute)

The American National Standards Institute (ANSI)[1)] is the US authority on the standardization of industrial practices. ANSI is a member of the International Organization for Standardization (ISO).

[1)] 1919 to 1928 AESC (American Engineering Standards Committee), 1928 to 1966 ASA (American Standards Association), 1966 to 1969 USASI (United States of America Standards Institute)

As the voice of US standardization and conformity assessment procedures, ANSI enables its members and clients to strengthen the US economy in the global marketplace. At the same time, it supports the health and safety concerns of its consumers as well as promoting environmental protection. To achieve this, ANSI monitors the development, publication, and use of thousands of standards and directives in nearly all sectors, including power distribution, construction machinery, milk and livestock production, and many more besides.

As an organization, ANSI itself does not actually create standards, but instead certifies and evaluates standards produced by private standardization bodies (including UL), for example.

Examples:

- ANSI/NFPA 70 (NEC), ANSI/NFPA 79 Industrial Machinery
- ANSI/UL 508 Industrial Control Equipment
- ANSI/NEMA Z535 Series

The UL 508A standard for Industrial Control Panels is one of the few exceptions in terms of standards that have not been certified by ANSI.

Additional information

You can find more information on the Internet at the website of the American National Standards Institute (http://www.ansi.org).

UL (Underwriters Laboratories)

UL was founded in 1894 and is an independent organization that inspects and certifies products in terms of their safety. The company is headquartered in Northbrook, Illinois.

UL International Germany GmbH is based in Neu-Isenburg near Frankfurt, Germany (headquarters for Europe and Latin America).

The primary focus for UL is on testing and certifying products, materials, components, and systems to ensure that they correspond to and fulfill the specific requirements.

In doing so, UL does not approve any products in the sense of meeting legal requirements; the UL mark is actually a voluntary one that is particularly widespread and accepted in the USA.

As part of its work, UL carries out tests according to its own UL standards, or on the basis of other standards, and issues the respective UL mark accordingly.

Alongside this objective, UL also creates many significant and necessary standards, such as UL 508A for Industrial Control Panels.

Additional information

More information is available on the Internet:

- UL (http://www.ul.com)
- UL - Online Certifications Directory (http://www.ul.com/database)
- UL - Scopes for UL Standards (http://ulstandardsinfonet.ul.com/scopes/)

CSA (Canadian Standards Association)

The CSA was founded in 1919 under the name "Canadian Engineering Standards Association (CESA)", and was officially renamed as CSA in 1944. Its headquarters are in Mississauga, Ontario.

For industrial control panel building, the standard "CSA 22.2 No.14-10 Industrial Control Equipment" published by the CSA is the approximate counterpart to "UL 508A Industrial Control Panels" published by UL.

Additional information

More information is available on the Internet:

- CSA Group (http://www.csagroup.org)
- CSA Group - Certified Product Listing (CPL) (http://www.csagroup.org/ca/en/services/testing-and-certification/certified-product-listing)
- CSA Group - Codes & Standards (http://www.csagroup.org/us/en/services/codes-and-standards)

NEMA (National Electrical Manufacturer Association)

NEMA is an American association with over 400 members, which both serves as a professional association for the North American electrotechnical industry and represents its interests. It was founded on September 1, 1926 and its headquarters are located in Rosslyn, Virginia.

Under the supervision of NEMA, a number of standards exist for the electrotechnical sector.

Examples:

- ANSI/NEMA MG 1: Motors and Generators
- ANSI Z535 series: Safety Signs, Labels and further information
- ANSI C12.1: Electric Meters-Code for Electricity Metering
- ANSI/NEMA 250: Enclosures for Electrical Equipment

Additional information

You can find more information on the Internet at the website of the National Electrical Manufacturer Association (http://www.nema.org).

NFPA (National Fire Protection Association)

The NFPA is an international, not-for-profit organization that was founded in 1896. The headquarters are in Quincy, Massachusetts.

The aim of the NFPA is to reduce the effects of fires and other hazards. This is essentially promoted by developing standards and regulations, education and training, and carrying out investigations.

In the area of standards and regulations, the NFPA is in charge of approximately 300 documents on fire protection. This includes establishing criteria in the fields of building construction, procedures, and processes for service and installation work in the USA and many other countries.

One of the most fundamental regulations of the NFPA when it comes to electrical aspects of installation is the NEC (NFPA 70). Not only is the NEC (NFPA 70) compulsory in the USA, it has also been accepted and adopted almost in its entirety in many other countries too.

Additional information

You can find more information on the Internet at the website of the National Fire Protection Association (http://www.nfpa.org).

IAEI (International Association of Electrical Inspectors)

The IAEI was founded in 1928 and is a leading industrial organization in the electrical sector, with its headquarters in Richardson, Texas, USA. One of its primary responsibilities is to promote safe products and installations.

Its members include testing laboratories, standardization bodies, manufacturers, wholesalers, fitters, and, of course, inspectors.

The IAEI is a not-for-profit organization run by its members, whose main objectives include training and certifying inspectors as well as developing standards and regulations.

Additional information

You can find more information on the Internet at the website of the International Association of Electrical Inspectors (http://www.iaei.org).

OSHA (Occupational Safety and Health Administration)

OSHA is an authority in the USA that was founded in 1971 for the purpose of enforcing occupational health and safety laws. The primary objective of OSHA is to reduce the number of accidents in the workplace.

OSHA works under the supervision of the US Department of Labor. The laws and specifications of this federal authority are applicable in all US states, unless individual state specifications are stricter than OSHA's federal specifications. 22 states have their own laws, while OSHA specifications apply in 29 states.

These include OSHA 29 and, therefore, the essential CFR 1910[1)] "Safety and Health Standards", which covers topics such as electrical and mechanical safety, as well as hazardous materials. As a result, CFR 1910 is particularly important for machine manufacturers and ICP manufacturers.

[1)] CFR – Code of Federal Regulation

Further to these laws and specifications, OSHA also certifies and accredits NRTLs (Nationally Recognized Testing Laboratories). Among OSHA requirements are that equipment in electrical installations (e.g. on machinery and in plants) must be tested and listed in accordance with American product safety standards. Only those testing organizations that have been accredited accordingly by OSHA (NRTLs) are permitted to carry out these tests and certifications.

Additional information

You can find more information on the Internet at the website of the Occupational Safety and Health Administration (http://www.osha.gov).

The NRTLs recognized by OSHA can be found online at Nationally Recognized Testing Laboratories (NRTLs) (http://www.osha.gov/dts/otpca/nrtl/).

AHJ (Authority Having Jurisdiction)

In the USA, "Authority Having Jurisdiction" (AHJ) is used to define an organization, office, or individual that is responsible for implementing the following requirements:

- Requirements from legislation and standards
- Requirements for certifying equipment and materials
- Requirements for installations and procedures

The AHJ plays a crucial role in the North American safety concept. Its most important role in respect of electrical safety is checking electrical installations in compliance with the National Electrical Codes (NEC).

The phrase "authority having jurisdiction", or its acronym AHJ, is used in NFPA documents in a broad manner, since local jurisdictions and approval agencies vary, as do their responsibilities.

In matters of public safety, the authority having jurisdiction may be a federal, state, local, or regional authority. In this particular case, the AHJ may even be an individual. Examples: competent expert; fire chief; head of a fire safety, labor, or health authority; site manager; electrical inspector; or another person with legal responsibility.

For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction.

In many cases, the product owner or their authorized representative assumes the role of the authority having jurisdiction. In government institutions, the Head of Service can act as the authority having jurisdiction.

4.2 Laws, general requirements, and rules

Many products in the USA are subject to what are known as the Codes of Federal Regulations (CFR). The CFRs are federal laws that, in some cases, require products to be approved before they can be launched on the market.

The USA has many federal authorities in place, including:

- FDA ("Food and Drug Administration", Website FDA (http://www.fda.gov))
- FCC ("Federal Communications Commission", Website FCC (http://www.fcc.gov))
- OSHA ("Occupational Health and Safety Administration", Website OSHA (http://www.osha.gov))

OSHA is a particularly important authority that is associated with the Department of Labor. It issues the binding statutory regulations for occupational safety that are common to all US states. These statutory regulations are essentially requirements that are aimed at operators (occupational safety).

Alongside many other requirements, the OSHA Safety and Health Standards in Article 29, Part 1910 of the CFR are particularly relevant to operators of electrical and mechanical systems. It is therefore worth highlighting the following two subdivisions as especially important for machines and electrically operated equipment:

- **Machine Safeguarding,** Article 29 CFR Part 1910, Subpart O
- **Electrical,** Article 29 CFR Part 1910, Subpart S

In conjunction with certain applications, OSHA requires that all electrical Equipment be authorized by an OSHA-accredited NRTL for the specific application.

Essentially, all electrical systems must obtain a construction license. This is provided by the local authority having jurisdiction. It is regulated on a federal level and responsibility for it lies with various departments in each of the individual states; in many cases, this may be the State Electrical Commission, the State Fire Marshal, or the Department of Public Safety. Also refer to AHJ (Authority Having Jurisdiction) in Chapter Organizations (Page 27). These departments are responsible for monitoring and implementing standards and laws; certifying devices, materials, and systems; and for correct installation. However, the departments do not themselves test the devices to be installed, but instead have this carried out by the responsible Third-Parties, the NRTLs. In the USA, the best-known Third-Party organization providing these kinds of approvals and testing services for accession to the market is UL. Also refer to UL (Underwriters Laboratories) in Chapter Organizations (Page 27).

The "Electrical Inspection Manual" is based on the NEC (NFPA 70) and is regularly used when checking and approving electrical installations. Its introduction includes the following two statements which should be emphasized:

Approved

Acceptable to the authority having jurisdiction. [Approval is a primary responsibility of an electrical inspector. Investigations by a third-party and the listing and labeling that result are a great aid to inspectors in this responsibility (see "Labeled" and "Listed").]

⇒ The inspector decides what is accepted and what is not. The UL marks provide a valuable point of reference and assistance for the inspector.

AHJ function

The key to a successful and correct electrical inspection lies in applying the rules of the Code, not the personal preferences of the inspector. To reiterate, if the installation meets the Code requirements (including any local amendments) and is safe, the installation should pass inspection.

⇒ The application and fulfillment of the NEC (the Code) perform a key function in helping the inspector to reach a decision concerning acceptance and approval.

The figure below shows an overview of the relevant authorities, laws, and codes, going right down to the level of the key standards in each case for constructing industrial control panels and machines, along with the connections between them. This diagram is only intended to serve as a guide and does not include all federal authorities, rules, laws, or relevant standards. Further applicable standards for machine construction can be found in Chapter Standards (Page 35).

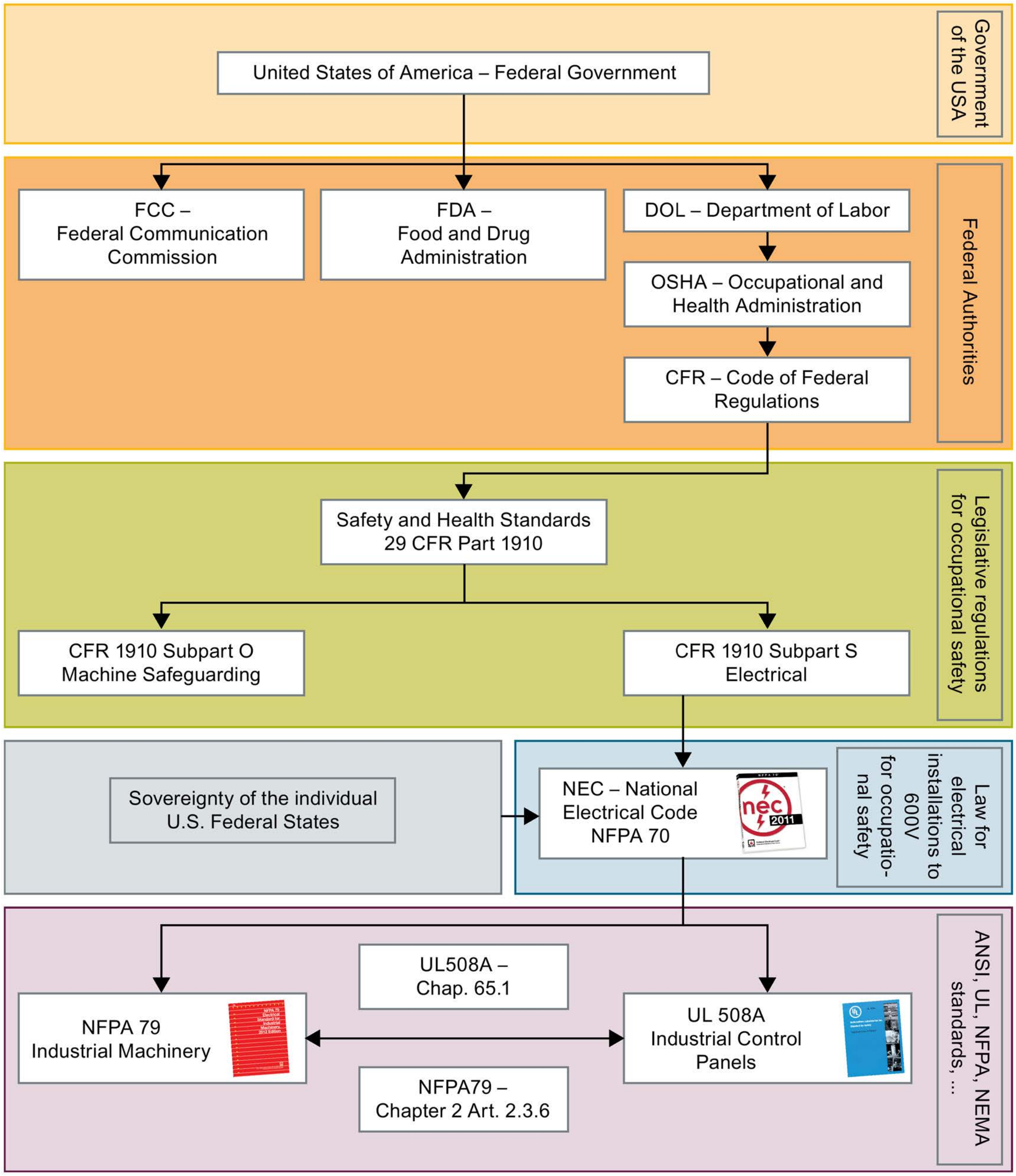

Figure 4-1 Overview of the connections between the relevant authorities, laws, codes, and standards for building industrial control panels and machines

4.3 Standards

This chapter provides an insight into the world of standards in the USA. It also includes a list and explanation of the standards substantially referred to in this documentation.

The Figure 4-3 Overview diagram showing the use of different standards (Page 42) provides an overview of the application area of the standards described in this guide.

In the USA, the standards listed below are important for manufacturers of machinery, systems, and industrial control panels for electrical safety and the relevant areas of application.

NEC (National Electrical Code, Edition 2014)

Area of application

The NEC covers the installation of electrical wires, equipment, and associated cable ducts, as well as the configuration and routing of signal and communication lines and their equipment in the following areas:

- On private and public land including buildings, vehicles, houses, mobile homes and houseboats, farms, land, fairs, and industrial connection stations
- Installation of conductors and equipment for the electrical supply
- Installations for the electrical utility company, e.g. in buildings, warehouses, offices, and workshops that are not part of the power plant or its industrial control panel buildings and controls.

The NEC **does not cover**, for example, installations on ships or watercraft (with the exception of house boats), trains, airplanes, or automobiles. Other exceptions can be found in NEC 2014, Art. 90.2 (B).

The NEC is **the definitive** regulation for low-voltage installations and, unlike standards, it is prescribed by law in the USA.

The first edition of the NEC was printed as early as 1897, and it is updated and published every three years.

The NEC can be viewed online for free on the Website of the NFPA (http://www.nfpa.org).

UL 508A Industrial Control Panels

Area of application

- Industrial control panels for industrial use
  - Installed in accordance with the NEC (NFPA 70) in a conventional, industrial environment
  - Max. 40 °C ambient temperature
  - Max. supply voltage of 600 V
- Industrial control panels for cranes or lifting machinery, elevator controls, air conditioning systems, cooling devices, safety installations for monitoring inflammable fuel assemblies, and industrial control panels for the incoming supply circuit
- Controls for stationary, motor-actuated machines and systems

In this case, the definition of Industrial Control Panels covers at least two or more components in the main and/or control circuit. Examples of these include circuit breakers, control devices, commanding and signaling devices, fuses with the corresponding conductors, electrical and mechanical connections, and construction parts. The components can be installed on or inside an enclosure, or on a mounting panel.

In this regard, the specifications in the standard are limited exclusively to the industrial control panel itself and do not make any stipulations for incoming supply circuit conductors or outgoing conductors of the industrial control panel. Only the interfaces for the connected electrical circuits and their markings, for example, are described.

NFPA 79 Standard for Industrial Machinery

Area of application

Within its area of application, NFPA 79 covers the electrical equipment of machines, starting from the point of the incoming supply circuit and proceeding all the way through to the end consumer. The maximum supply voltage is 600 V, and the standard applies to conventional industrial ambient conditions. The actual machines are generally motor-actuated, permanently installed, and unable to be transported manually during operation.

Alongside the specifications of the NPFA 79, those of the NEC always apply across the board. This means that the protective devices for supplying machines, for example, shall have supply conductors, fuses, and configurations in accordance with the NEC (NFPA 70).

NFPA 79 represents a minimum requirement within its area of application. However, additional measures can be requested at any time in order to ensure a sufficient level of safety for the machines and systems in question.

The definition of Industrial Machinery covers machines that are used to shape, press, or cut material. This also includes electrical, thermal, or optical processes for handling materials, or a combination of all these. In this sense, machines also include equipment that is provided for transporting materials, preparing tools, assembling or dismantling parts (including accessories), packaging goods, and testing or inspection purposes.

The associated electrical equipment, such as the industrial control panel or other distributed components, is considered part of the machine.

Examples of Industrial Machinery

Annex C of the standard lists examples of industrial machines that are covered by the standard. The following machine categories are mentioned:

- Machine tools for cutting/forming metals
- Plastics machinery
- Wood machinery
- Assembly machines
- Material-handling machines
- Inspection/testing machines
- Packaging machines

Other standards

Other standards that this document refers to in part are listed below. A detailed explanation of the area of application is not included in this information.

ANSI/NEMA Z535.1 to 6 (Safety Labels and Signs, Colors, Criteria, Product Safety Tags, Product Safety Information in Manuals)

Important standard for safety information, safety symbols, and labels, and their design, color coding, selection criteria, etc.

NFPA 70E (Standard for electrical safety requirements for employee workplaces)

This standard is primarily aimed at the operators and users of electrical equipment.

Above all, it covers specifications for electrical safety in the workplace, which ensure that staff members are safeguarded using practical means and are still able to work in favorable conditions.

NFPA 70B (Recommended Practice for Electrical Equipment Maintenance)

These specifications denote recommended practice for servicing and maintaining electrical equipment in order to prevent malfunctions and potentially hazardous situations for both people and objects. The specifications are not intended to replace the manufacturer's instructions, such as the equipment manual.

Important US standards for the construction of machines and systems

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Note

As already mentioned in the introductory chapters of this guide, machine safety is not the focus of this guide. The following list of U.S. standards is only intended to provide an overview of the wide diversity of basic safety standards for machine safety. However, practice shows that international IEC and ISO standards are enjoying increasing acceptance on the U.S. market. Within the explanations in Annex A, NFPA 79 recommends both IEC/ISO and ANSI standards. Close agreement on this topic in advance between suppliers and customers is therefore recommended

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Basic safety standards for general requirements

Standards	Description
OSHA 29CFR1910	Safety and Health Standards
OSHA 29CFR1910.212	General requirements for (Guarding of) All Machines

Generic safety standards for aspects of safety

Standards	Description
ANSI / NFPA 70	The National Electrical Code (NEC)
ANSI / NFPA 70E	Electrical Safety Requirements for Employee Workplaces
ANSI / NFPA 79	Electrical Standard for Industrial Machinery
OSHA 29CFR1910.333	Selection and Use of Work Practices (Electrical Safety)
OSHA 29CFR1910.147	The Control of Hazardous Energy (Lockout/Tagout)
ANSI Z244.1	Lockout/Tagout of Energy Sources
ANSI Z535.1	Safety Color Code
ANSI Z535.2	Environmental and Facility Safety Signs
ANSI Z535.3	Criteria for Safety Symbols
ANSI Z535.4	Product Safety Signs and Labels
ANSI Z535.5	Accident Prevention Tags and Labels
ANSI Z136.1	Safe Use of Lasers
ANSI B11.21	Machine Tools Using Lasers - Safety
OSHA 29CFR1910.219	Mechanical Power Transmission Apparatus
ANSI / ASME B15.1	Mechanical Power Transmission Apparatus
ANSI B11.19	Safeguarding (Machine Tools)
ANSI B11/TR1	Ergonomic Guidelines
ANSI B11/TR3	Risk Assessment / Risk Reduction
MIL-STD-882D	U.S. DOD System Safety Program (Risk Assessment)
OSHA 3071	Job Hazard Analysis

Safety standards for specific machine applications

Standards	Description
Machine tools	
OSHA 29CFR1910.217	Guarding of Mechanical Power Press
ANSI B11.1	Mechanical Power Presses
ANSI B11.2	Hydraulic Power Presses
ANSI B11.3	Power Press Brakes
ANSI B11.4	Shears
ANSI B11.5	Iron Workers
ANSI B11.6	Lathes
ANSI B11.7	Cold Headers and Cold Formers
ANSI B11.8	Drilling, Milling and Boring Machines
ANSI B11.9	Grinding Machines
ANSI B11.10	Sawing Machines
ANSI B11.11	Gear Cutting Machines
ANSI B11.12	Roll Forming and Roll Bending Machines
ANSI B11.13	Automatic Bar and Chucking Machines
ANSI B11.14	Coil Slitting Machines / Systems
ANSI B11.15	Pipe, Tube and Shape Bending Machines
ANSI B11.16	Powder Metal Presses
ANSI B11.17	Horizontal Hydraulic Extrusion Presses
ANSI B11.18	Coil Processing Equipment
ANSI B11.20	Manufacturing Systems / Cells
ANSI B11.22	Numerically Controlled Turning Machines
ANSI B11.23	Automatic Drilling, Milling and Boring
ANSI B11.24	Transfer Machines
Conveyors	
ANSI / ASME B20.1	Conveyors and Related Equipment
Industrial Robots	
ANSI / RIA R15.06	Industrial Robots and Robot Systems
Injection Molding	
ANSI B151.1	Horizontal Injection Molding Machines
ANSI B151.21	Injection Blow Molding Machines - Safety
ANSI B151.26	Dynamic Reaction - Injection Molding Machines
ANSI B151.27	Plastics Machinery - Robots Used with HIM Machines - Safety
ANSI / SPI B151.29	Vertical Clamp Injection Molding Machines
Injection Molding	
ANSI B151.1	Horizontal Injection Molding Machines
ANSI B151.21	Injection Blow Molding Machines - Safety
ANSI B151.26	Dynamic Reaction - Injection Molding Machines
ANSI B151.27	Plastics Machinery - Robots Used with HIM Machines - Safety
ANSI / SPI B151.29	Vertical Clamp Injection Molding Machines

Standards	Description
Mills and Calenders	
OSHA 29CFR1910.261	Pulp, Paper and Paperboard Mills
OSHA 29CFR1910.216	Mills and Calenders in the Rubber and Plastics Industries
ANSI B28.1	Safety Code for Rubber Mills and Calenders
Packaging	
ANSI / PMMI B155.1	Packaging and Packaging-Related Converting Machinery - Safety
Cranes	
OSHA 29CFR1910.179	Overhead and Gantry Cranes
ANSI / ASME B30.5	Mobile and Locomotive Cranes
Printing	
ANSI / B65.1	Printing Press Systems
ANSI / B65.2	Binding and Finishing Systems
ANSI / B65.5	Stand Alone Platen Presses
Semiconductor	
SEMI S1	Safety Guideline for Equipment Safety Labels
SEMI S2	Environmental Health and Safety Guideline for Semiconductor Manufacturing Equipment
SEMI S3	Safety Guidelines for Heated Chemical Baths
SEMI S7	Safety Guidelines for Environmental, Safety, and Health Evaluation of Semiconductor Manufacturing Equipment
SEMI S8	Safety Guidelines for Ergonomics Engineering of semiconductor Manufacturing Equipment
SEMI S9	Safety Guideline for Electrical Design Verification Tests for Semiconductor Manufacturing Equipment
SEMI S10	Safety Guideline for Risk Assessment
SEMI S13	Safety Guidelines for Operation and Maintenance Manual Used with Semiconductor Manufacturing Equipment
SEMI S17	Safety Guideline for Unmanned Transport Vehicle Systems (UTV)
SEMI S19	Safety Guideline for Training of Semiconductor Manufacturing Equipment, Installation, Maintenance and Service Personnel
Woodworking, Lumber and Logging	
OSHA 29CFR1910.213	Woodworking Machinery Requirements
OSHA 29CFR1910.261	Pulp, Paper and Paperboard Mills
OSHA 29CFR1910.265	Sawmills
OSHA 29CFR1910.266	Logging Operations
ANSI O1.1	Woodworking Machinery Requirements

4.4 Peculiarities

Adoption of the NEC (NFPA 70) within the US states

The NEC is the recognized set of comprehensive regulations for low-voltage installations in the USA. However, the NEC does not become legally valid and applicable until it has been accepted into state law and by the regional AHJ (Authority Having Jurisdiction).

The time scale for this varies from one state to another. Furthermore, some states adopt the NEC with additional supplements and/or amendments. This can even vary between the individual towns and cities of a state (as is the case in Texas, Arizona, and Nevada, for example).

NEMA provides regular online updates on this subject on the Internet (http://www.nema.org).

Example showing how the NEC has been adopted in different ways

(As of September 2012, source: NEMA Website (http://www.nema.org))

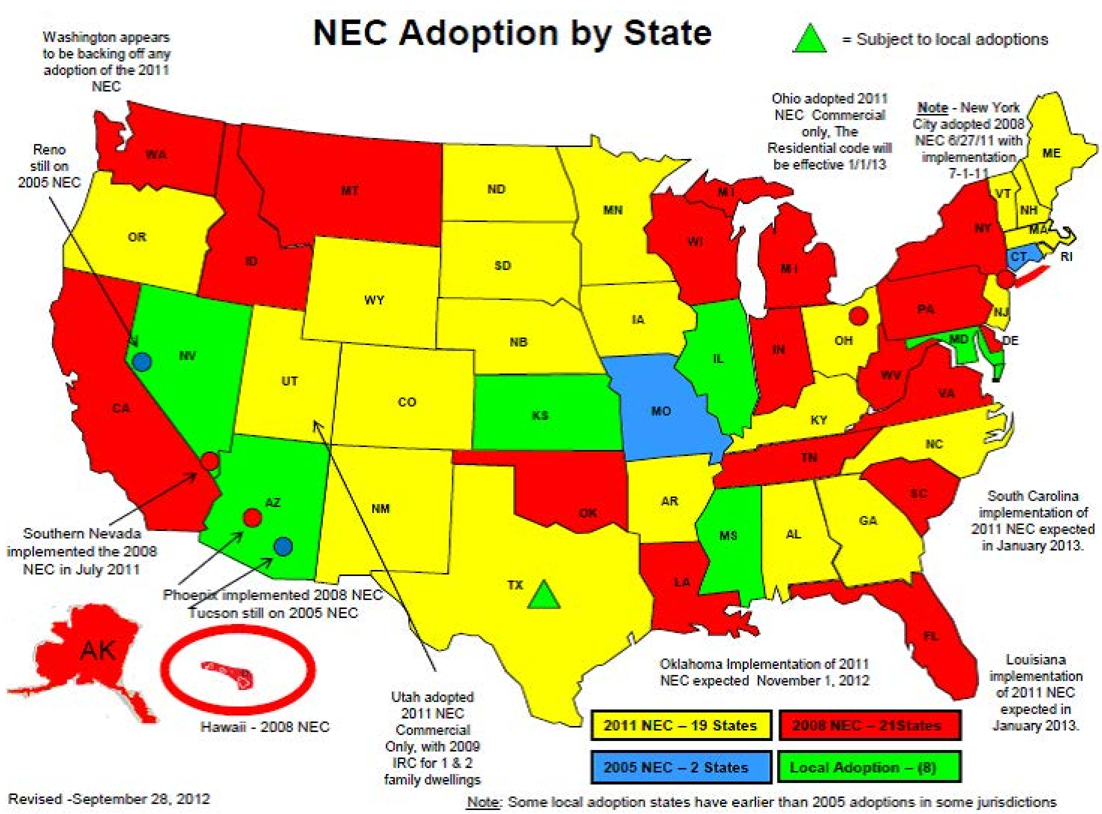


Figure 4-2 Example showing how the NEC has been adopted in different ways

Differences between NFPA 79 and UL 508A

In various chapters, the NEC refers to additional standards that outline further specifications on certain subjects in detail.

For example, UL 508A is referred to in Article 409 of the NEC as a leading standard for Industrial Control Panels. Article 670 of the NEC discusses the subject of Industrial Machinery and makes reference to NFPA 79.

These two standards overlap in many of the technical topics they cover, and are even identical in several cases. There are topics, however, that have different requirements as far as the standards are concerned.

This includes the area of application in the case of each standard (see Chapter Standards (Page 35)):

In this respect, UL 508A only covers industrial control panels and, in the additional requirements of Chapter 65 "Industrial Machinery", machine control panels too.

However, the area of application as far as NFPA 79 is concerned is applicable to all electrical equipment for machines and therefore covers not only the requirements for industrial control panels, but also all the electrical equipment in the machinery field.

Both standards are explained and interpreted in equal measure in this guide. Nevertheless, it is strongly recommended that the standard(s) to be applied in each case are agreed with the users and operators in advance.

The machine diagram below is provided as an example to illustrate the application of various standards and regulations for electrical safety.

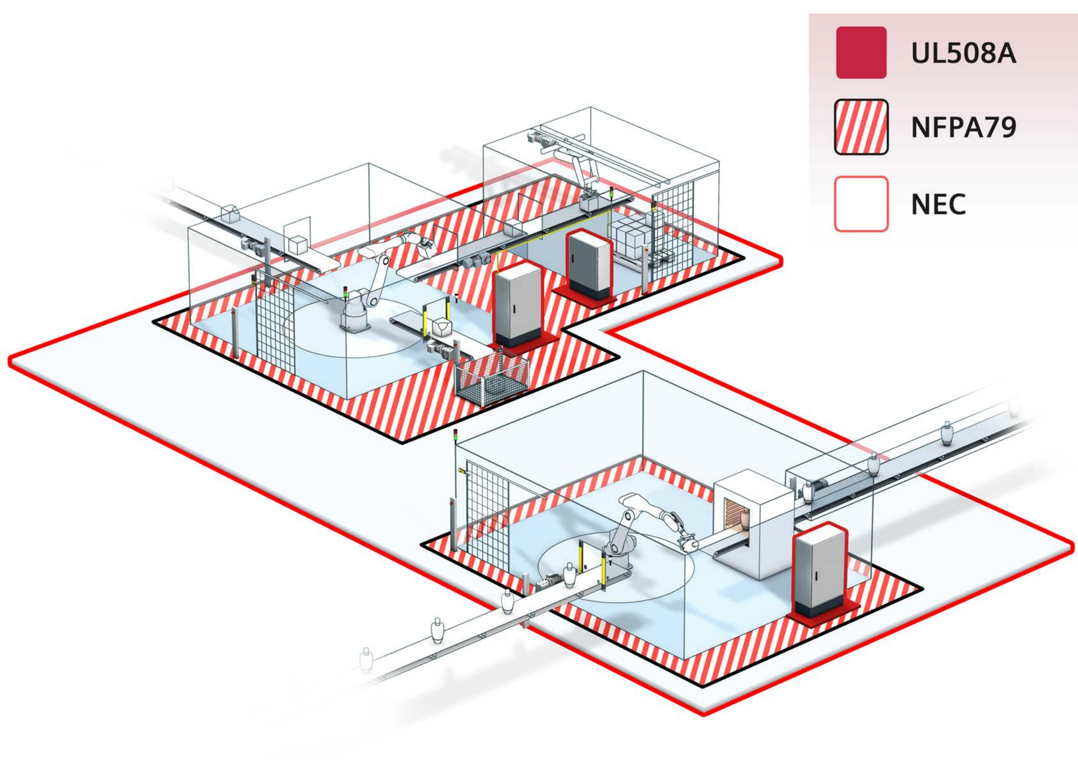


Figure 4-3 Overview diagram showing the use of different standards

Peculiarities about acceptance and commissioning in the USA

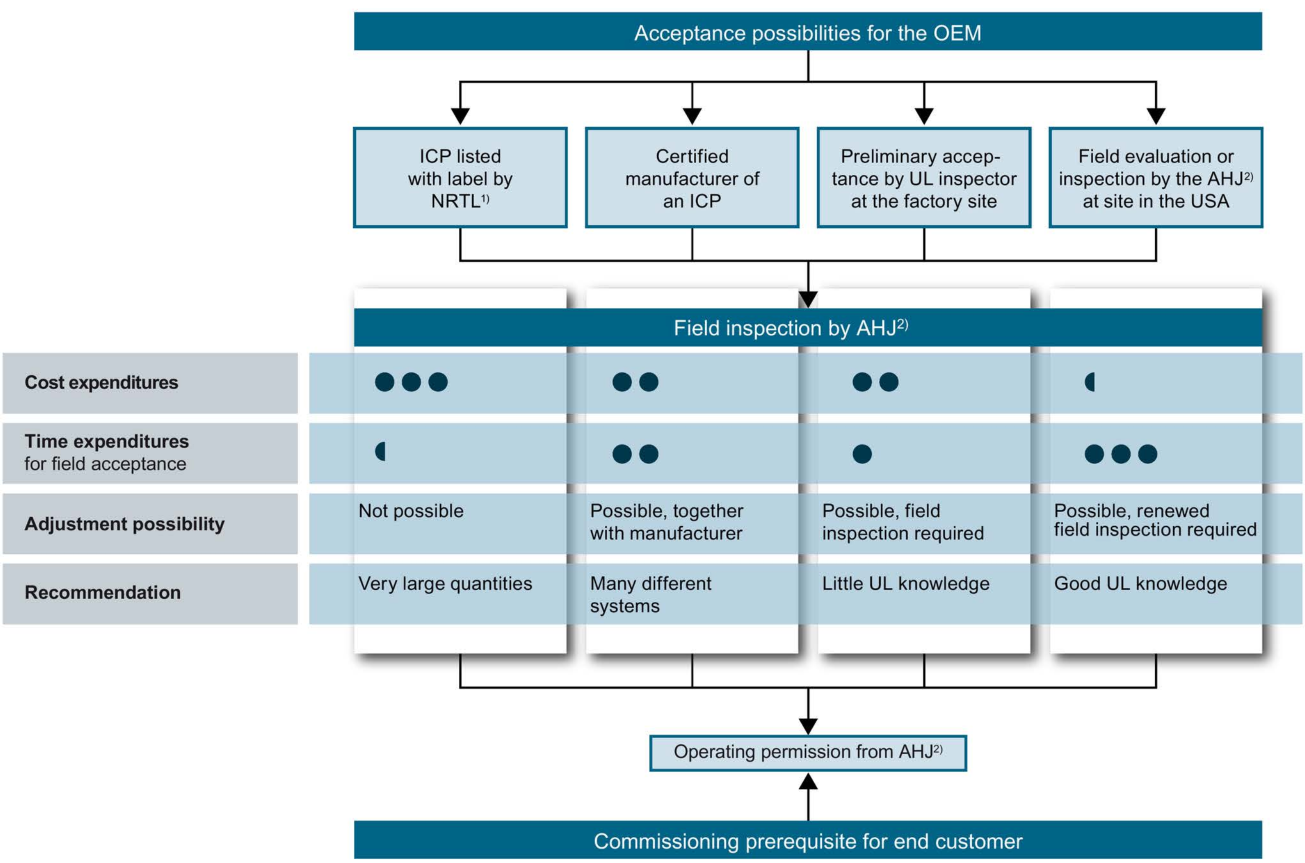
Every electrical machine or system in the USA is checked by an inspector known as the AHJ (Authority Having Jurisdiction) before it can be commissioned.

Acceptance is based on the NEC (National Electrical Code, NFPA 70), the relevant application-specific standards such as NFPA 79 and UL 508A, as well as any local standards or specifications.

Acceptance is required by law in the USA. Operators failing to have their machines or systems inspected by an AHJ risk loss of both insurance and electrical power supply.

For successful field acceptance, a correct configuration according to the applicable standards is essential. The diagram shown below outlines four possible ways of achieving successful acceptance.

Manufacturing an industrial control panel that meets the requirements of UL 508A is more than a question of simply using UL-approved products. The interaction of devices in accordance with the relevant application standard, as well as the acceptance of the industrial control panel in its actual application environment, are critical too.



1) Nationally Recognized Testing Laboratories

2) Authority Having Jurisdiction

Figure 4-4 Acceptance possibilities for OEMs

1st possibility: ICP listed with label by NRTL

Industrial control panel approved by a recognized testing organization – Third-Party Certification:
(see also NEC 2014, Art. 90.7).

In this case, the system does not need to be inspected again by the local inspectors. Only the connections and installation conditions in the Certification Report need to be observed. This system would be advantageous when exporting individual industrial control panels, especially where series production is involved.

This does not mean that final acceptance and assessment by the AHJ is not required in the USA, but there is some scope for simplifying this process since a listed industrial control panel (see glossary entry "Listed") finds a high level of acceptance among inspectors (AHJ) and because of this, a detailed inspection is no longer required.

2nd possibility: Certified manufacturer of an ICP

Certified manufacturers of industrial control panels

Panel builders who produce a range of different systems for the various areas of application according to UL 508A can obtain certification from an NRTL offering this service. Listed industrial control panels can thus be built and also provided with a Panel Listing mark on the manufacturer's own responsibility.

The panel builder needs to comply with various conditions in order to do this. The manufacturing site is then visited several times a year by an NRTL inspector and checked in accordance with UL 508A. Some of these visits will be announced, but others will not. The panel builder pays an annual fee plus the charges for the inspector's visits.

See also the section "Label Service (Type L)" in Chapter UL-listed (Page 49).

Manufacturer certification is offered by different NRTLs. Examples are:

- UL (listed Panel Shop)
- Intertek (Panel Shop listing)

Here too, acceptance testing by the AHJ is necessary in the USA. However, acceptance by the AHJ can be significantly simplified since a labeled control panel (see glossary entry "Labeled") finds a high level of acceptance among inspectors (AHJ), and consequently, a detailed inspection is no longer required.

3rd possibility: Preliminary acceptance by UL inspectors at the factory site

Every machine and panel builder can obtain a preliminary acceptance. By contracting a suitable NRTL approved for the respective application, the panel or parts thereof can undergo a preliminary inspection at the manufacturer's factory site. This allows any necessary modifications or adjustments to be made prior to delivery. Under certain circumstances, the NRTL can also approve deviations from the standard and certify these in what is known as a "Deviation Note".

This does not mean that acceptance by the AHJ is not required in the USA. However, acceptance by the AHJ can be significantly simplified since these acceptance reports enjoy a high level of acceptance among the local inspectors (AHJ).

4th possibility: Field evaluation or inspection by the AHJ at site in the USA

In this case, the electrical equipment of the machine including the industrial control panels shall be inspected and accepted at its site of installation by a local inspector. In other words, the manufacturer relies on the opinion of each inspector. Complaints then have to be remedied on site. This can often lead to additional costs and delays in commissioning. The costs of a general Third-Party Certification are, however, eliminated. This could be of benefit when installing individual systems.

Note

The decisions of the individual AHJs can be disputed. For this to take place, an appeal shall be submitted in writing to the relevant Electrical Board within 15 days of the negative decision being received. NEC 2014 Annex G, 80.15 (G)

Note

The local inspectors are not authorized to negotiate with the manufacturer on deviations from the standard. The AHJs are permitted to apply a certain leeway in making technical decisions. See also NEC 2014, Art. 90.4.

Important definitions (extracts from the NEC 2014)

Mandatory requirements - NEC 2014, Art. 90.5 (A)

Mandatory rules of this Code are those that identify operations that are specifically required or prohibited and are characterized by the use of the terms "shall" or "shall not".

Permissive requirements - NEC 2014, Art. 90.5 (B)

Permissive rules of this Code are those that identify operations that are permitted but not required, are normally used to describe options or alternative methods, and are characterized by the use of the terms "shall be permitted" or "shall not be required".

Explanatory material - NEC 2014, Art. 90.5 (C)

Explanatory material, such as references to other standards, references to related sections of this Code, or information related to a Code rule, is included in this Code in the form of fine print notes (FPN).

Informational notes are used for information only and are not enforceable as requirements of this Code.

Note

The format and language used in this Code follow guidelines established by NFPA and published in the NEC Style Manual. Copies of this manual may be obtained from NFPA.

Approval - NEC 2014 Art. 90.7

The conductors and equipment required or permitted by this Code shall be acceptable only if approved.

Note

See Section 90-7 of the "Examination of Equipment for Safety", and Section 110-3 of "Examination, Identification, Installation, and Use of Equipment".

Identified - NEC 2014 Art. 100

Identification attached to equipment

Recognizable as suitable for the specific purpose, function, use, environment, application, etc., where described in a particular Code requirement.

Note

Suitability of equipment for a specific purpose, environment, or application may be determined by a qualified testing laboratory, inspection agency, or other organization concerned with product evaluation. Such identification may include labeling or listing (see definitions of "Labeled" and "Listed").

Labeled - NEC 2014 Art. 100

Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed - NEC 2014 Art. 100

Equipment, materials, or services included in a list, published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services.

Such listing states that either the equipment, material, or services meets identified standards or has been tested and found suitable for a specified purpose.

Note

The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. Use of the system employed by the listing organization allows the authority having jurisdiction to identify a listed product.

Useful extracts from the Electrical Inspection Manual*

* Manual for the acceptance of electrotechnical installations, based on the NEC (NFPA 70)

Approved

"Acceptable to the authority having jurisdiction."

Note

Approval is a primary responsibility of an electrical inspector. Investigations by a third-party and the listing and labeling that result are a great aid to inspectors in this responsibility (see "Labeled"' and "Listed").

Meaning: The inspector decides what is accepted and what is not. The UL approvals provide a valuable point of reference and assistance for the inspector.

AHJ function

Note

The key to a successful and correct electrical inspection lies in applying the rules of the Code, not the personal preferences of the inspector. To reiterate, if the installation meets the Code requirements (including any local amendments) and is safe, the installation should pass inspection.

Meaning: The application of standards helps the inspector to reach a decision concerning acceptance.

4.5 UL-specific definitions and identification

The following chapter deals with definitions, peculiarities, and the generally accepted identification specifications provided by UL (Underwriters Laboratories).

4.5.1 Marks

UL has introduced a variety of different marks. The most important of these, along with their meanings, are listed and explained below. For the marking of UL-certified products, a general distinction is made between Listed Devices and Recognized Components. Further variants exist for the Canadian market.

Table 4- 1 UL marks

Mark	Applications
	UL Listing Mark: This is one of the most common UL Marks. Products carrying this mark (e.g. washing machines, computers, electrical control panels, fire extinguishers, life belts, etc.) meet all UL safety requirements and can be installed universally, without further instructions, and without restrictions on the relevant applicability. The Siemens portfolio, for example, offers contactors in accordance with UL 508 or circuit breakers in accordance with UL 489.
	C-UL Listing Mark: This mark is applied to products for the Canadian market. The products with this type of mark have been evaluated to Canadian safety requirements, which may be somewhat different from U.S. safety requirements. You will see this type of Mark on appliances and computer equipment, vending machines, household burglar alarm systems, lighting fixtures, and many other types of products.
	C-UL-US Listing Mark: UL introduced this new Listing Mark in early 1998. It indicates compliance with both Canadian and U.S. requirements. The Canada/US UL Mark is optional. UL encourages those manufacturers with products certified for both countries to use this new, combined Mark, but they may continue using separate UL Marks for the United States and Canada.
	Recognized Component Mark: This mark is used on components or devices used in machinery, systems or products, such as washing machines. These components may have restrictions on their performance or may be incomplete in construction. The Recognized Component Mark is found on a wide range of products, including switches, power supplies, printed circuit boards, some kinds of industrial control equipment, and many other products. They shall only be installed by experts, as the "Conditions of Acceptability" (CoA) apply to these devices. The UR Mark is carried, for example, by Siemens miniature circuit breakers according to UL 1077, Siemens time switches according to UL 917, and SITOR fuses.
	Canadian Recognized Component Mark: Similar as the Recognized Component mark - see above): Products intended for Canada carry the Recognized Component mark "C".
	Recognized Component Mark for Canada and the United States: This new UL Recognized Component Mark, which became effective April 1, 1998, may be used on components certified by UL to both Canadian and U.S. requirements. Although UL had not originally planned to introduce a combined Recognized Component Mark, the popularity of the Canada/US Listing and Classification Marks among clients has led to the new Mark.
Certifications such as and are issued by the NRTLs (Nationally Recognized Testing Laboratories) after successful testing. OSHA has accredited Underwriters Laboratories as an NRTL.	

Note

UL and CSA are authorized to grant approval certificates in accordance with Canadian and North American regulations. This option of mutual recognition is based on the Memorandum of Understanding between these two organizations.

4.5.1.1 UL-listed

General rule

Devices which are considered to be "complete assemblies" feature this mark. They are labeled with the company name, all specified and approved data and the UL mark. Such devices can be installed and used in accordance with the approval by a technician without any special tools and without further instructions. (Examples: magnetic motor controller, circuit breaker)

UL-listed variations

There are various versions:

- **Reexamination Service (Type R):** One or more devices are tested by UL, inspected and described in detail in a report. UL inspectors visit the production facilities periodically and check that the product is being produced in accordance with the description. (Examples: magnetic controller, coffee maker)
- **Label Service (Type L):** A special UL-Label that is placed on a product once it has passed a specified check.

  Examples:

  – All circuit breakers (UL 489) shall pass a specified test during production (such as Type R + Reassessment Tests).

  – Industrial Control Equipment (UL 508A) are tested and accepted by a UL inspector.

  These labels are bought directly from UL, or via one of the UL-registered printers. They are administered by the manufacturer, but checked by the UL inspector in accordance with production.

Application example

An "Industrial Control Panel" with this form of label will have been manufactured according to UL regulations by an approved, UL-listed ICP manufacturer (Listed Panelbuilder).

Figure 4-5 Example: Label for a panel including devices and wiring

4.5.1.2 UL-recognized

General rule

This mark is used for components, in other words devices which are assembled in a factory together with other parts and components and which gain UL approval in the form of an end product.

UL-Recognized handling

UL-Recognized components only need to feature a type and manufacturer's identification mark. Their design and application are not therefore complete.
The user shall pay attention to additional information and operating conditions which are specified in detail in the UL certificate (known as **C**onditions **o**f **A**cceptability, CoA).

Note

Use of UL-approved devices:

Devices which are UL-approved (listed or recognized) cannot be automatically installed in "Industrial Control Panels" unless their intended use (approval) is known. A 3LD25 LISTED MAN MTR CNTR type switch (according to UL 508) cannot, for example, be used as a disconnecting means. A switch with the label RECOGNIZED OPEN SWITCH, on the other hand, would comply with this requirement. Particular attention should be paid to the "Type Listings"; a listed plastic conduit (nonmetallic conduit) is not also automatically listed as "Liquidtight" – even if it is classified as IP65 according to IEC.

You can find more detailed explanations of this in Chapter Categorization using the Category Code Number (CCN) (Page 52).

Note

UL-approved devices shall always be approved by one of the NRTLs.
These NRTLs are approved by OSHA. In this case, approval only applies to specific products/applications. You are therefore recommended to note the purpose for which the respective NRTL is approved.

4.5.1.3 Practical use of "Listed" and "Recognized"

Use of the marks

In some categories, you have the choice of approving a device as "Listed" or "Recognized".

Application examples for "Recognized" components

A magnetic controller for a special application without any rated data, but which features manufacturer identification and order number, can be UR approved.
Some devices can only be approved as components, i.e. with "UR", e.g.:

- Instantaneous trip circuit breakers see NEC 2014 430.52 (C) (3).
- Terminal blocks according to UL 1059
- Miniature circuit breakers according to UL 1077:
  These devices can only be used as a "supplementary protector" (see NEC 2014, 430.72 (A)).

Example application of UL-Listed and UL-Recognized

Washing machine

A washing machine consists of the most diverse individual components. Many of these individual components are often UL-Recognized since the application area is limited, or use only with certain other individual components is possible.

It can therefore happen that the individual components are provided with a UL-Recognized label, but the assembled complete washing machine bears a UL-Listed label.

4.5.2 Categorization using the Category Code Number (CCN)

UL provides a number of approvals. However, "Listing" and "Recognized" are the most common of these.

A product category cannot, however, necessarily be determined uniquely by means of a label. Added to this is the fact that many UL standards cover a host of products. To enable differentiation and classification, UL has introduced the "Category Code Number" (CCN). With the help of the CCN, inspectors can check the proper use of a component.

UL classifications contain 4 letters; they may also contain a digit in some cases. The 4 letters are used fairly randomly. The additional digit, however, is always used in a consistent way.

A list of all UL-approved products can be found in the UL database, The database can be viewed on the Internet (http://www.ul.com/database).

Different search parameters can be specified in the database, such as company name, UL File No., CCN, address, postcode/zip code, country, keyword.

Table 4- 2 Significance of the additional digit (in fifth position)

No digit 4 letters only		**Listed product for the USA** Inspection/acceptance is performed by an approved NRTL according to the relevant standards.
4 letters plus the number 7		**Listed product for Canada** Inspection/acceptance is performed by an approved NRTL according to the relevant UL standards for Canada (these are different from the USA).
4 letters plus the number 2		**Recognized product for the USA** Inspection/acceptance is performed by an approved NRTL according to the relevant standards.
4 letters plus the number 8		**Recognized product for Canada** Inspection/acceptance is performed by an approved NRTL according to the relevant UL standards for Canada (these are different from the USA).

Some **CCNs** are listed below to indicate how these products can be found under particular classifications.

Table 4- 3 Examples of product classifications (Category Code Numbers - CCN)

Classification – Extract	**UL-listed**	**UL-recognized**
UL Industrial Control Panels (Panel Builder Program UL 508A)	NITW	
UL Industrial Control Components (UL 508)	e.g. NLDX	e.g. NLDX 2
Circuit breakers (UL 489)	DIVQ	
Miniature circuit breakers (UL 489)	DIVQ	
Combination starters (UL 508A)	NKJH	----
Switch units	----	WHTY2
Miscellaneous switches	WPZX	----
Terminal blocks	----	XCFR2
Magnetic motor controllers	NLDX	NLDX2
Supplementary protectors (UL 1077)	----	QVNU2
Auxiliary devices (overcurrent relay, contactor relay, etc.)	NKCR	NKCR2
Classification – Extract	**c-UL-listed**	**c-UL-recognized**
UL Industrial Control Panels (Panel Builder Program UL 508A)	NITW 7	
UL Industrial Control Components (UL 508)	e.g. NLDX 7	e.g. NLDX 8
Circuit breakers (UL 489)	DIVQ 7	
Miniature circuit breakers (UL 489)	DIVQ 7	
Combination starters (UL 508A)	NKJH 7	----
Switch units	----	WHTY 8
Miscellaneous switches	WPZX 7	----
Terminal blocks	----	XCFR 8
Magnetic motor controllers	NLDX 7	NLDX 8
Supplementary protectors (UL 1077)	----	QVNU 8
Auxiliary devices (overcurrent relay, contactor relay, etc.)	NKCR 7	NKCR 8

Note

Devices that can be installed in industrial control panels in accordance with UL 508A are listed in UL 508A, Table SA1.1 List. Most of Siemens' low-voltage controls and distribution devices are, of course, UL-approved. An overview and summary of the UL, CSA and IEC approvals with helpful information (e.g. E-File number, CCN identifier) can be found in the overview "Standards and Approvals" on the Siemens Support Website. See Chapter Further information and support (Page 380).

4.5.3 New marking with the UL "Enhanced Certification Marks and Badges"

In 2013, UL presented and introduced new marks for the future. The "Enhanced UL-Marks" will replace the previous UL listed and UL classified marks in the medium to long term, without the previous marks losing their validity in the meantime. Manufacturers are not obliged to introduce these future, new marks immediately for their respective products and device.

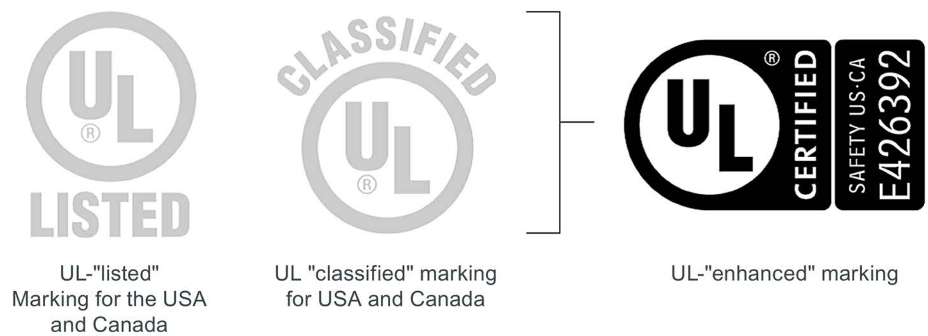


Figure 4-6 Future transition of the previous marking to the UL "enhanced" marking (source: http://www.ul.com)

Example of a UL "enhanced" marking and explanation

① E-file number for manufacturer reference
② Property
③ Country code

Figure 4-7 Example of UL enhanced marking

Electrical equipment for machines and their associated industrial control panels 5

5.1 General information

According to the **NEC**, **NFPA 79**, and **UL 508A**, electrical components for machines and their associated industrial control panels shall be approved and suitable for their intended use. This means there are various criteria that have a say in which components are the right ones to choose. See Chapter UL-specific definitions and identification (Page 48).

Examples

- Is the component approved for the intended use?
- Are additional accessories required in order to use the component in a way that conforms to standards?
- Does the component meet the required ratings (e.g. SCCR-Rating, rated current)?

To enable the correct components to be selected, it is absolutely crucial that the basic and ambient conditions are clearly defined in advance.

Annex B of NFPA 79 contains an inquiry form in which many necessary and helpful basic conditions are examined. Manufacturers and operators are recommended to reach agreements in advance, and to make these agreements an integral part of the contract award process.

The detailed inquiry form is based on NFPA 79 and can be found in the Annex under Checklists (Page 328).

Table 5- 1 Inquiry form (extract)

INQUIRY FORM FOR THE ELECTRICAL EQUIPMENT OF MACHINES			
Name of manufacturer/supplier			
Name of end user			
Tender/Order No.		**Date**	
Type of Machine/Serial Number			
1. Are there to be modifications as allowed for within this standard?	☐ Yes ☐ No		
Operating Conditions – Special requirements (see Section 4.4)			
2. Ambient temperature range			
3. Humidity range			
4. Altitude			
5. Environmental (e.g., corrosive atmospheres, particulate matter, EMC)			

Source: NFPA 79, Annex B

5.1.1 Through air and over surface spacings

The **NEC**, **NFPA 79**, and **UL 508A** generally differentiate between the following two circuits in the power circuit:

- Feeder circuit
- Branch circuit

Note

In control circuits, there is a distinction between a Feeder and a Branch Circuit .

Definitions

Definition according to the NEC and NFPA 79

- Feeder circuit: All conductors between the incoming supply and the branch circuit protective device.
- Branch circuit: The circuit conductors between the branch circuit protective device and the outlets.

Definition according to UL 508A

- Feeder circuit: The conductors and circuitry on the supply side of the branch circuit protective device.
- Branch circuit: The conductors and components following the last branch circuit protective device protecting a load.

A simpler way of defining the boundary between the feeder circuit and the branch circuit is to take the reverse approach:

- Feeder circuit: Starting from the load, all products above the first branch circuit protective device.
- Branch circuit: Starting from the load, all products up to the first branch circuit protective device.

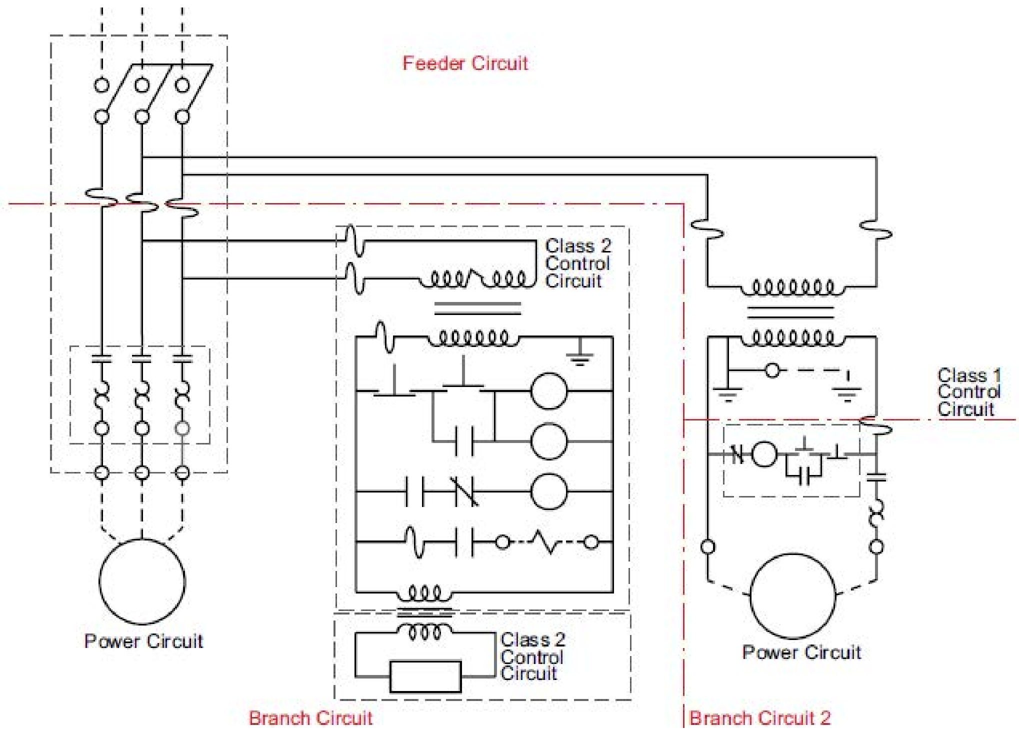


Figure 5-1 Illustration Feeder Circuit – Branch Circuit

Source: UL 508A, Fig. 6.2/3

The supply terminal of the branch circuit protective device forms the exact boundary. The supply terminal belongs to the feeder circuit. All conductors and components below the supply terminal belong to the branch circuit.

Minimum through air and over surface spacings

a) Minimum spacings for feeder circuits

The minimum through air and over surface spacings between the phases for feeder circuits feeder circuits are specified in the NEC, Table 430.97 and UL 508A, Table 10.2. The spacings in the NEC, Table 430.97 correspond to those in UL 508A, Table 10.2.

No minimum through air and over surface spacings are described in NFPA 79. Since electrical installations shall always take place in agreement with the NEC, the requirement is thus also valid for the application area of NFPA 79.

Table 5- 2 Extract from UL 508A, Table 10.2: Feeder circuits

	125 V or less		126 - 250 V		251 - 600 V	
	inch	mm	inch	mm	inch	mm
Through air	1/2	12.7	3/4	19.1	1	25.4
Over surface	3/4	19.1	1-1/4	31.8	2	50.8
Between live parts and enclosures	1/2	12.7	1/2	12.7	1 *1/2	25.4

*) For details and exceptions, see UL 508A, Table 10.2

In some devices, the necessary through air or over surface spacings for feeder circuits shall be ensured by using an appropriate accessory. Example: Some manual self-protected combination motor controller sizes based on UL 508 Type E, which can be used as motor protective devices according to UL 508A, shall be equipped with additional supply terminals or phase barriers on the supply side.

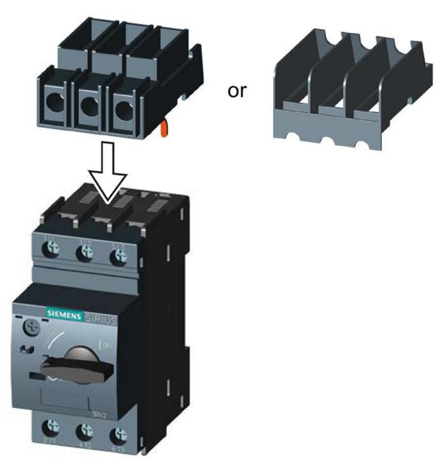


Figure 5-2 Example of "manual self-protected combination motor controller according to UL 508 Type E"

On the other hand, other devices such as a Circuit Breaker in accordance with UL 489, comply with the required through air and over surface spacings depending on design.

Note

According to UL 508A, Section 10.8, the through air and over surface spacings for branch circuits in Table 10.1 always apply to fuse holders, regardless of whether these involve feeder circuits or branch circuits.

---

b) Minimum spacings for branch circuits

The minimum required spacings for branch circuits are defined in UL 508A, Table 10.1 . There are no minimum required spacings for branch circuits defined in the NEC.

Table 5- 3 Extract from UL 508A, Table 10.1: Branch circuits

	51 - 150 V		151 - 300 V		301 - 600 V	
	inch	mm	inch	mm	inch	mm
Through air	1/8	3.2	1/4	6.4	3/8	9.5
Over surface	1/4	6.4	3/8	9.5	1/2	12.7
Between live parts and enclosures	1/2	12.7	1/2	12.7	1/2	12.7

For details and exceptions, see UL 508A, Table 10.1

The required through air and over surface spacings for branch circuits are met by all approved components (e.g. industrial control equipment, terminal blocks) depending on design.

5.1.2 Plastic materials

Approvals

According to the NEC, UL 508A, and NFPA 79, any plastic materials used (such as insulating material, cable ducts, and barriers) shall always possess specific technical properties (e.g. flame resistance).

Plastic components, or components that include plastic materials, which are approved for a particular application (e.g. machine tool wire according to UL 1063 or cable ducts according to UL 870) must demonstrate that they meet the requirements for their intended use by means of the available approval.

Plastics that are not approved for a specific purpose must provide other kinds of evidence that they possess the required technical properties. Examples of these include self-built plastic covers for uninsulated live components (e.g. bus bars).

One possible way of demonstrating this is the "Plastic Recognition Yellow Card".

Plastic Recognition Yellow Card

Each plastic inspected and approved by UL is issued with a "Plastic Recognition Yellow Card". This lists not only the "Category Control Number" and the "UL File Number", but also technical properties that have been tested; for example:

- Flame class (according to UL 94)
- HWI (hot-wire ignition)
- HAI (high amp arc ignition)
- RTI (relative temperature index)

You can find additional information on the UL website at Plastics and components (http://www.ul.com/plastics).

QMFZ2 Component - Plastics E12345

Plastics Company, Ltd.
1285 Walt Whitman Road, Melville, NY 11747 USA

ABC123
Polyamide 66 (PA66), furnished as pellets

Color	Min Thk (mm)	Flame Class	HWI	HAI	RTI Elec	RTI Imp	RTI Str
ALL	0.40	HB	-	-	65	65	65
	0.71	V-2	-	-	125	80	80
	1.5	V-2	3	0	125	80	85
	3.0	V-2	2	0	125	80	90

Comparative Tracking Index (CTI): 0
High-Voltage Arc Tracking Rate (HVTR): 0
Dielectric Strength (kV/mm): 15
Dimensional Stability (%): 1.0
High Volt, Low Current Arc Resis (D495): 4
Volume Resistivity (10xohm-cm): 14

UL94 small-scale test data does not pertain to building materials, furnishings and related contents. UL94 small-scale test data is intended solely for determining the flammability of plastic materials used in the components and parts of end-product devices and appliances, where the acceptability of the combination is determined by Underwriters Laboratories Inc.

Report Date: 6/19/1999 Underwriters Laboratories Inc®

Figure 5-3 Example Plastic Recognition Yellow Card

Source: UL - Plastic Recognition Yellow Card (http://www.ul.com/global/eng/pages/offerings/industries/chemicals/plastics/card/)

Insulating barriers and insulating material

UL 508A provides details regarding material and minimum dimensions for the case of required "insulating barriers" and "insulating materials".

Insulating barriers, UL 508A, Section 12

One of the reasons insulating barriers are constructed is to increase the over surface or through air spacings between phases. See Chapter Through air and over surface spacings (Page 56).

The insulating material shall comply with all the following requirements:

- The insulating material shall either be a material included in the table "Generic materials for use as barriers" below, or it shall comply with one of the following requirements:
  - Electrical sleeving according to UL 1441
  - Insulating tubing according to UL 224
  - Wrapping consisting of at least two layers of insulating tape according to UL 510
- The rated values of the insulating material are suitable for direct contact with the relevant live parts.
- The insulating material itself is only used for insulation purposes and not as a load-bearing design part.

Exception: A material that does not comply with the conditions specified shall be investigated as an insulating barrier in accordance with UL 508 (Industrial Control Equipment)

Table 5- 4 Generic materials for use as barriers

Generic material	Minimum thickness	
	inches	(mm)
Aramid paper	0.010	(0.25)
Electrical grade paper	0.028	(0.71)
Epoxy	0.028	(0.71)
Mica	0.006	(0.15)
Mylar (PETP)	0.007	(0.18)
RTV	0.028	(0.71)
Silicone rubber	0.028	(0.71)
Vulcanized fiber	0.028	(0.71)

Source: UL 508A, Table 12.1

Insulating material, UL 508A, Section 13

In many applications it may be necessary to support exposed, uninsulated live parts structurally. Examples of such applications include spacer bolts or insulating bases for bus bars or terminals.

The materials used for this shall be listed in the table "Generic materials for direct support of uninsulated live parts" below.

Exception: A material that does not comply with the conditions specified shall be investigated as an insulating material in accordance with UL 508 (Industrial Control Equipment).

In the case of such self-produced structural parts, the through air and over surface spacings as specified in the Chapter Through air and over surface spacings (Page 56) shall still be complied with.

Table 5- 5 Generic materials for direct support of uninsulated live parts

Generic material	Minimum thickness	
	inches	(mm)
Diallyl phthalate	0.028	(0.71)
Epoxy	0.028	(0.71)
Melamine	0.028	(0.71)
Melamine-phenolic	0.028	(0.71)
Phenolic	0.028	(0.71)
Unfilled nylon	0.028	(0.71)
Unfilled polycarbonate	0.028	(0.71)
Urea formaldehyde	0.028	(0.71)
Ceramic, porcelain and slate	no limit	no limit
Beryllium oxide	no limit	no limit

Source: UL 508A, Table 13.1

5.2 Operating conditions and ambient conditions

5.2.1 General information

The operating conditions and ambient conditions are crucial for planning and configuring industrial control panels and the electrical equipment of machines.

Implementation and configuring are substantially influenced by the operating conditions and ambient conditions:

- Which standards have to be observed?
- Which power supply system configuration is available?
- What is the maximum short circuit at the infeed (SCCR value)?
- What enclosure types shall be complied with?
- etc.

Operating conditions

The operating conditions (e.g. required short circuit current rating (SCCR), power supply system configuration, rated current, etc.) are comprehensively regulated and described in the NEC, and in NFPA 79 and UL 508A.

Ambient conditions

Specifications for the ambient conditions can be found to varying degrees in the NEC, and in NFPA 79 and UL 508A. Ambient conditions are described in detail in NFPA 79, Chapter 4. In contrast, UL 508A only describes the voltage and the maximum ambient temperature of 40 °C. No ambient conditions are defined in the NEC.

Non-hazardous locations

UL 508A and NFPA 79 are standards for non-hazardous locations and cover the low-voltage range up to 600 V.

Hazardous locations

Industrial control panels and machines for hazardous locations are described in the NEC, Article 500 ff. and Article 505 ff. and also in UL 698A with the additional requirements.

Applicability of the specified ambient conditions and operating conditions

Unless otherwise agreed between the manufacturer and the operator of the machine, the specified conditions from NFPA 79 Chapter 4 apply.

The inquiry form in the Annex (see Checklists (Page 328)) supports users in defining the existing ambient conditions at the later location of operation.

Some examples from Chapter 4 of NFPA 79 are listed below:

- **AC voltage for distributions and DC voltage for power supplies/transformers:**

  Continuous operating voltage: 0.9 to 1.1 of the nominal voltage

- **Frequency:**
  - 0.99 to 1.01 of the continuous nominal voltage
  - 0.98 to 1.02 short-time
- **Electromagnetic compatibility (EMC):**
  - This shall be taken into consideration in the event of disturbances.
  - Possible measures from NFPA 79, Chapter A.4.4.2 (for information): Filtering, shielding, RF suppression techniques, etc.
- **Ambient temperature:** for operation: +5 to +40 °C (41 °F and 104 °F)
- **Air humidity:** for operation: max. 50 % at max. 40 °C (max. 90 % at 20 °C)
- **Altitude:** up to 1,000 m (3,300 ft) above sea level
- **Transport and storage:** -25 °C to +55 °C (-13 °F to 131 °F), short-time, max. 24 h, up to 70 °C (158 °F)

5.2.2 Power supply system configurations

Different power supply system configurations occur in US industry and these must be observed when selecting short-circuit protective equipment. Power supply system configurations in the USA are described in ANSI C 84.1.

An important input variable for panel builders and machine manufacturers is not only the rated voltage, but also the specification of the electric power supply system. In the relevant US standards, NEC, NFPA 79 and UL 508A, a grounded wye power system is designated as "slash rating".

For power supply systems other than grounded wye systems, there is no superordinate official term in the standards. However, these power supply systems are frequently referred to in common parlance as "straight rating".

The power supply system for which the control panel or machine is to be configured shall be agreed in advance between the panel builder / machine manufacturer and the operator.

Note

The protective devices used shall be approved for the existing rating (slash or straight).

Slash rating

A "slash rating" refers to a solidly grounded wye. The following two voltages occur in such a power system:

- "Phase-to-phase"
- "Phase-to-ground"

Both voltages are specified in the case of a "slash rating". For example:

- 208Y/120V
- 240Y/131V
- 480Y/277V
- 600Y/347V

The term "slash rating" refers to the slash used.

The most frequently found industrial power system in the USA is the 480Y/277V system.

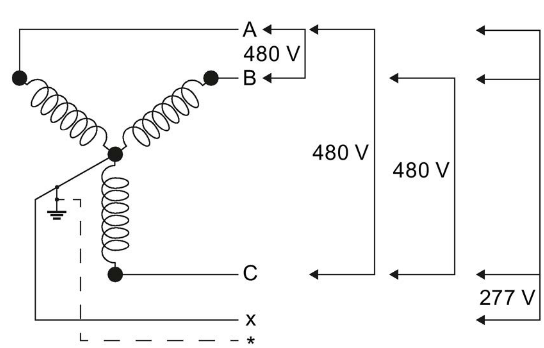


Figure 5-4 Grounded wye 480Y/277V

In the case of a "slash rating", the first single-pole short-circuit on phase-to-ground voltage (e.g. 277 V on a 480Y/277V power system) is switched. This means the protective devices used shall be approved **at least** for the phase-to-ground voltage.

Example

Approved devices for a 480Y/277V power system are devices with the following designation:

- 480Y/277V
- 480 V
- 600Y/347V
- 600 V

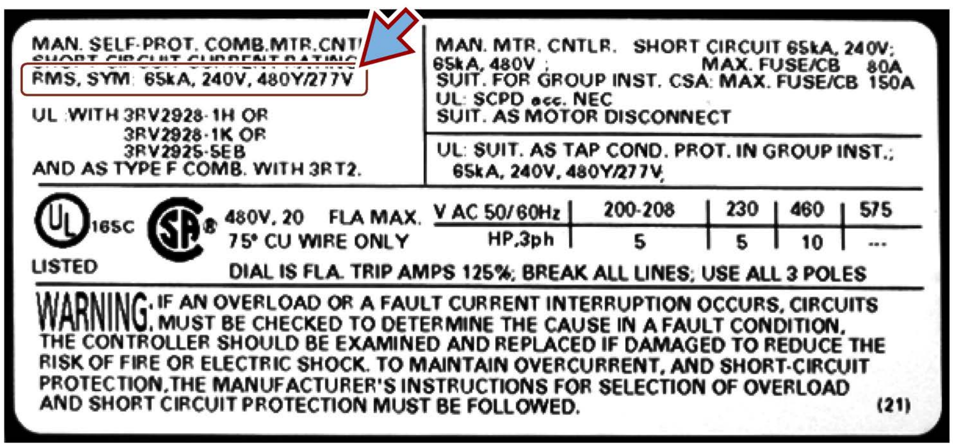


Figure 5-5 Sample nameplate of a motor circuit breaker approved for 65 kA at 240 V and 480Y/277V

Straight rating

A "straight rating" refers to power systems other than a solidly grounded wye.

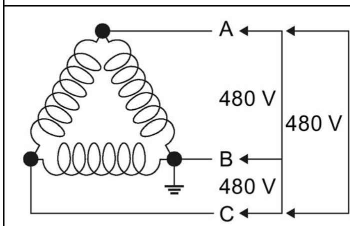
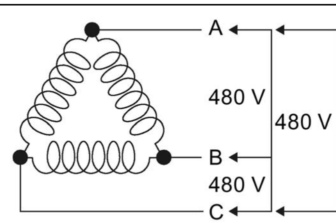
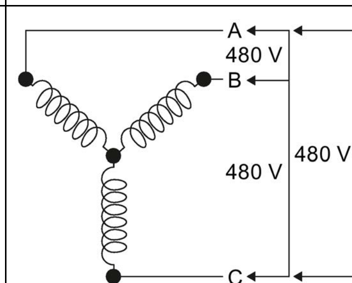
Only one voltage occurs in such power systems. The phase-to-phase voltage and the phase-to-ground voltage are equal in size if present.

Such power systems can include:

- Delta systems, grounded or ungrounded
- Ungrounded wye systems

If a "straight rating" is present, only one voltage will consequently be specified. For example:

- 240 V
- 480 V
- 600 V

Corner grounded delta 480 V 3 phase, 3 wire	Ungrounded delta 480 V, 3 phase, 3 wire	Ungrounded wye 480 V, 3 phase, 3 wire
		

Delta system, grounded and ungrounded 480 V, ungrounded wye system 480 V

With a "straight rating, the short-circuit is switched at full voltage (e.g. 480 V or 600 V). This means the protective devices used shall be approved at least for this.

Example

Approved devices for a 480 V power system are devices with the following designation:

- 480 V
- 600 V

Note

Devices with the designation 480Y/277V or 600Y/347V are not approved.

Other power supply system configurations

The "midpoint grounded delta" is found more rarely.

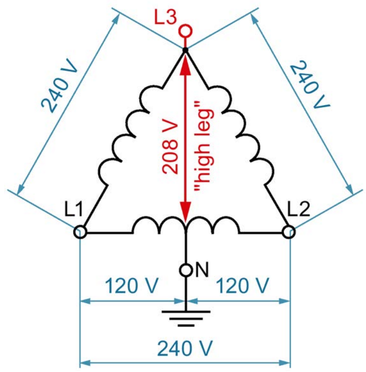


Figure 5-6 Midpoint grounded delta 240 V

With this system, grounding is carried out between the phases, with the result that the short-circuit is switched at "high leg voltage". This is 208 V in the case of a 240 V midpoint grounded delta. This means the protective devices used shall be able to disconnect the short-circuit at 208 V.

Example

Approved devices for a 240 V midpoint grounded delta system are devices with the following designation:

- 240 V
- 480Y/277V
- 480 V
- 600Y/347V
- 600 V

In summary, it should be said here that the power supply system configuration has a very considerable influence on the design of the installation and therefore also on the space requirements in the control panel and the costs. Devices approved for a straight rating are usually larger and more expensive than devices that are only approved for a slash rating.

Fuses in accordance with UL 248-4…12, -15 are approved equally for straight and slash ratings. The corresponding approved rating must be observed for industrial control equipment.

5.3 Incoming supply circuit and disconnecting means

5.3.1 Incoming supply circuit conductor and power terminals

The relevant standards (UL 508A, NFPA 79, and NEC) describe the connections between the system's incoming supply source(s) and power terminals in very different ways. UL 508A and the NEC do not offer much information at all on this matter, but NFPA 79 deals with it more comprehensively.

UL 508A just stipulates that a disconnecting means shall be provided for each incoming supply source. The specific use (Part 2) section, Chapter 66.6.1, also includes the restriction that no components other than terminals shall be located on the incoming supply side of the disconnecting means.

On the other hand, NFPA 79 covers the subject in great detail in Chapter 5.1 and Chapter 5.2.

Requirements of NFPA 79

- Where practicable, the electrical equipment of a machine shall be connected to a single power supply circuit.
- Where it is necessary to use another supply circuit for certain parts of the equipment (e.g., electronic circuits, electromagnetic clutches), that supply circuit shall, as far as practicable, be derived from devices (e.g., transformers, converters) forming part of the electrical equipment of the machine.
- The incoming supply circuit conductors shall be terminated at the supply circuit disconnecting means, where practicable. Connections to terminals ahead of the disconnecting means shall be permitted only for excepted circuits (lighting, maintenance, etc.) or for other incoming supply circuit conductors.

Note

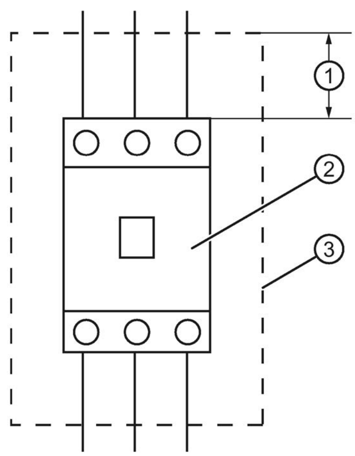
The required through air and over surface spacings shall be observed, since a feeder circuit is present.

- Terminals suitable for more than one conductor shall be so identified.
- Grounded conductors shall be marked and connected to a separate terminal.
- Terminals for each incoming supply circuit shall be clearly marked and correspond with markings in the technical documentation.
- The wire-bending space provided between the terminals of the supply circuit and the wall of the enclosure shall be observed in accordance with Table 430.10 (B), NEC.

Table 5- 6 Wire-bending space

Size of wire (AWG or kcmil)	Wires per terminal			
	1		2	
	mm	inches	mm	inches
14 … 10	Not specified		–	–
8 … 6	38	1 1/2	–	–
4 … 3	50	2	–	–
2	65	2 1/2	–	–
1	75	3	–	–

Extract from the NEC, Table 430.10 (B) "Minimum Wire-Bending Space at the Terminals of Enclosed Motor Controllers"



① Wire-bending space according to NEC, Table 430.10 (B)
② Main disconnecting means
③ Industrial control panel enclosure

Figure 5-7 Wire-bending space

- Each set of incoming supply circuit conductors on the line side of the disconnecting means shall be separated from all other internal conductors, including conductors of other supply circuits.

  To achieve this, one of the following two measures shall be applied:

  – Mounting the main disconnecting means as near as practicable to the top of the enclosure.

  – Separating by the use of barriers.

- All live parts on the line side of the main disconnecting means shall be protected from unintentional direct contact (that is, they must be safe to touch) when the disconnecting means is in the "Off" position and the enclosure door is open.
- A grounding terminal shall be provided for each incoming supply circuit.

Example photo for connecting the incoming supply circuit conductor to the disconnecting means:

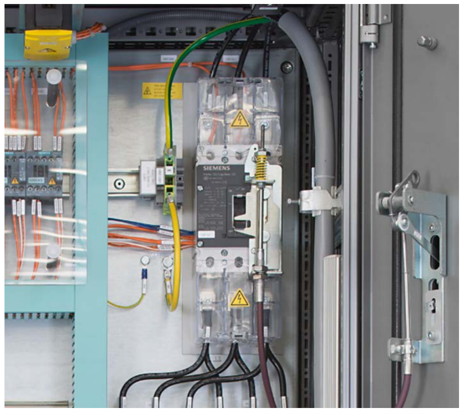


Figure 5-8 Connection of the supply conductor to the disconnecting means

5.3.2 Disconnecting means

According to NFPA 79, Chapter 5.3, and UL 508A, Chapter 30.3, each incoming supply circuit shall be provided with its own disconnecting means.

The disconnecting means shall switch off all electric circuits, including the control circuits. Circuits that are excepted from this are described in Chapter "Excepted circuits (Page 78)".

Conditions

The disconnecting means for the incoming supply circuit(s) shall be fitted with an external handle and meet the following conditions:

- When operated vertically, the "up" position of the handle shall be the "on" position. (UL 508A, Chapter 30.4.1)
- The "on" and "off" positions shall be clearly marked. (UL 508A, Chapter 30.4.2 and NFPA 79, Chapter 5.3.3.1 (7))
- Where two or more main disconnecting means are provided, they shall be grouped in one location where practicable. (UL 508A, Chapter 30.3.5 and NFPA 79, Chapter 5.3.1.5)
- The operating handle shall be capable of being locked in the "off" position. (UL 508A, Chapter 30.4.3 and NFPA 79, Chapter 5.3.3.1 (3))
- An operating mechanism (handle) shall be readily accessible (and operable) with the door in the open or closed position. (UL 508A, Chapter 66.6.3 (a) and NFPA 79, Chapter 5.3.4.2 (1))
- The disconnecting means shall be operable and lockable independent of the door position. (UL 508A, Chapter 66.6.3 (c), (d), NFPA 79, Chapter 5.3.3.1 (3), and 5.3.4.2 (3))

Exception

The disconnecting means does not have to be provided with an external operating handle if actuation of the disconnecting means is guaranteed by another function, such as a motorized operating mechanism for circuit breakers.

Installation conditions

To an equal extent, UL 508A, Chapter 60.1 allows the disconnecting means to be installed in the industrial control panel, or for the panel to be marked to indicate that a disconnecting means shall be provided by the installer.

NFPA 79, Chapter 5.3.1.3 states that the incoming supply circuit disconnecting means shall be mounted either in the panel or immediately adjacent to it. This does not include attachment plugs and receptacles. If the total output of the machine does not exceed 2 hp (horsepower) the main disconnecting means may also be mounted up to 6 m (20 ft) away. The main disconnecting means shall be located in sight of the operator and be easy to access.

The installation height is specified in UL 508A at a max. 79 inch (201 cm) and in NFPA 79 at a max. 6 feet 7 inch (200 cm).

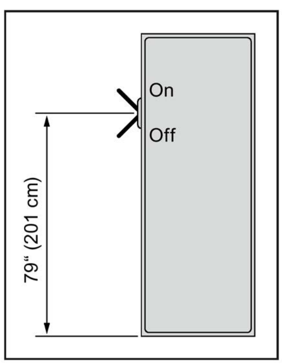


Figure 5-9 Installation height of main disconnecting means

5.3.2.1 Devices

In UL 508A, Chapter 30.1 and NFPA 79, Chapter 5.3.2, the following devices are permitted for use as the supply circuit disconnecting means:

- Molded case circuit breakers to UL 489
- Molded case switches according to UL 489

  (without overload trip unit)
- Manual motor controllers to UL 508 (Type E)

  (only when no more than 1 motor is operated)
- Disconnect switches to UL 98
- Disconnect switches to UL 977
- Power circuit breakers to UL 1066

UL 508A also acknowledges "Pull out switches" in accordance with UL 1429; these are not yet commonly used in Europe.

NFPA 79 also permits plug connections for supply cords with the suitable approval and disconnection properties.

5.3.2.2 Sizing

Although NFPA 79 in Chapter 5.3.3.1 does not make the sizing rules dependent on the type of disconnecting means, UL 508A in Chapter 30.2.2 makes a distinction between the types.

Sizing according to NFPA 79

In accordance with NFPA 79, the disconnecting means shall be sized in accordance with the following rules:

1. At least 115% of the total rated currents for all loads that can be operated simultaneously.
2. If rated values in hp are available for the disconnecting means:
   – At least the sum of the "locked rotor current" values according to NFPA 70 (NEC), Table 430.251 (B), for all motors that can be started simultaneously.
   – Plus the rated currents for the remaining motors and non-motor-operated loads that can be operated at the same time.
3. The rated voltage shall at least correspond to the supply voltage.

Sizing according to UL 508A

The **UL 508A** regulations depend on the type of main disconnecting means being used.

a) Inverse time circuit breakers to UL 489

Sizing

Standard circuit breakers should only be loaded with 80 % of their rated current. Thus a 125 A circuit breaker, for example, is only permitted to be rated at max. 100 A.

Exception

Circuit breakers approved for 100 % continuous rated current. However, this shall be marked on the circuit breaker itself, and specified in the UL certificate of the breaker.

b) Molded case switches according to UL 489

Sizing

I) One or more non-motor loads
- 100 % for switches with no integrated fuse
- 80 % for switches with an integrated fuse

II) A single motor load
- hp-rating not less than that of the motor
- Not less than 115 % of the motor full-load current rating in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Not less than the input current rating of a variable speed drive

III) For one or more motors or for one motor and any other loads (motor-operated and non-motor-operated)
- Not less than 115 % of the full-load current ratings of all motors in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Input current rating of a variable speed drive plus the rated currents of all other non-motor loads
- The permissible LRC (locked rotor current) of the switch shall not be less than the sum of the locked rotor currents of all motors, plus the rated currents of all other loads.
  - For single-phase motors: LRC = 6 x full-load current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
  - For three-phase motors, the LRC applies according to UL 508A, Table 50.3

c) Type E manual motor controllers

Manual self-protected combination motor controllers may be used in accordance with UL 508A as the main disconnecting means if only one motor is being operated via the associated control panel (including associated control circuits).

Sizing

A Type E motor controller may be dimensioned at 100 % of the motor full-load current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98).

d) Disconnect switches according to UL 98

(disconnect switch or switch unit)

Sizing

I) One or more non-motor loads
- 100 % for switches with no integrated fuse
- 80 % for switches with an integrated fuse

II) A single motor load
- hp-rating not less than that of the motor
- Not less than 115 % of the motor full-load current rating in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Not less than the input current rating of a variable speed drive

III) For one or more motors or for one motor and any other loads (motor-operated and non-motor-operated)
- Not less than 115 % of the full-load current ratings of all motors in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Input current rating of a variable speed drive plus the rated currents of all other non-motor loads
- The permissible LRC (locked rotor current) of the switch shall not be less than the sum of the locked rotor currents of all motors, plus the rated currents of all other loads.
  - For single-phase motors: LRC = 6 x full-load current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
  - For three-phase motors, the LRC applies according to UL 508A, Table 50.3

e) Disconnect switches according to UL 977

For currents above 600 A

Sizing

I) One or more non-motor loads
   - 100 % for switches with no integrated fuse
   - 80 % for switches with an integrated fuse

II) A single motor load
   - hp-rating not less than that of the motor
   - Not less than 115 % of the motor full-load current rating in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
   - Not less than the input current rating of a variable speed drive

III) For one or more motors or for one motor and any other loads (motor-operated and non-motor-operated)
   - Not less than 115 % of the full-load current ratings of all motors in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
   - Input current rating of a variable speed drive plus the rated currents of all other non-motor loads
   - The permissible LRC (locked rotor current) of the switch shall not be less than the sum of the locked rotor currents of all motors, plus the rated currents of all other loads.
     – For single-phase motors: LRC = 6 x full-load current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
     – For three-phase motors, the LRC applies according to UL 508A, Table 50.3

f) Power circuit breakers according to UL 1066

Sizing

I) One or more non-motor loads
- 100 % for switches with no integrated fuse
- 80 % for switches with an integrated fuse

II) A single motor load
- hp-rating not less than that of the motor
- Not less than 115 % of the motor full-load current rating in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Not less than the input current rating of a variable speed drive

III) For one or more motors or for one motor and any other loads (motor-operated and non-motor-operated)
- Not less than 115 % of the full-load current ratings of all motors in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
- Input current rating of a variable speed drive plus the rated currents of all other non-motor loads
- The permissible LRC (locked rotor current) of the switch shall not be less than the sum of the locked rotor currents of all motors, plus the rated currents of all other loads.
  - For single-phase motors: LRC = 6 x full-load current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)
  - For three-phase motors, the LRC applies according to UL 508A, Table 50.3

5.3.2.3 Excepted circuits

In the application area of industrial control panels and electrical equipment of machinery, it is sometimes a requirement that not all circuits are to be disconnected by the actual disconnecting means. With service and maintenance work in particular, or also with process-related procedures, it may be necessary to prevent shutdown of certain applications.

UL 508A and NFPA 79 meet this fact in very similar ways. The component requirements and the configuration are described separately below.

Excepted circuits according to NFPA 79

Circuits that are not required to be disconnected by the main supply circuit disconnecting means are listed in NFPA 79, Chapter 5.3.5 "Excepted circuits".

The following circuits are excepted:

- Lighting circuits for lighting needed during maintenance or repair
- Attachment plugs and receptacles (plugs and socket outlets) for the exclusive connection of repair and maintenance tools and equipment
- Undervoltage protection circuits that are only used for automatic tripping in the event of a supply circuit failure
- Circuits supplying equipment that are required to remain energized for satisfactory operation (e.g. temperature-control measuring devices, program storage devices, product (work in progress) heaters

Configuration

Excepted circuits shall be provided with the following:

- Dedicated disconnecting means, isolation transformer, overcurrent protection

  Integration into the door interlocking is not required for this disconnecting means.
- Installation of the components takes place either in a separate enclosure or in the actual control panel adjacent to the actual disconnecting means.
- Incoming supply circuit conductors shall be routed separately inside the enclosure. If the conductor length is ≥ 460 mm (18 in.), a cable duct shall (also) be used.

It shall be possible to disconnect the door interlocking circuit in the industrial control panel from which it is sourced.

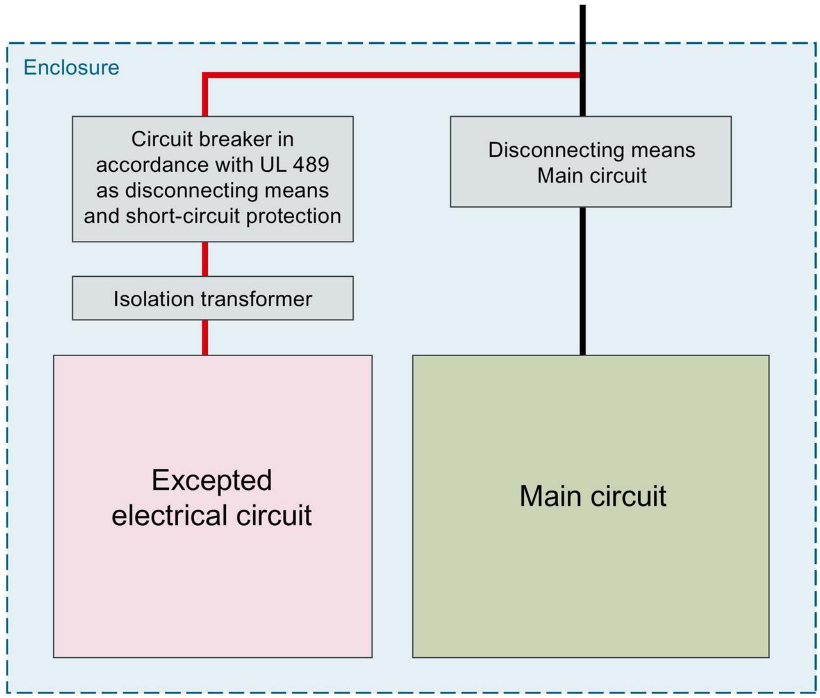


Figure 5-10 Example of the configuration of an excepted circuit

Conditions

The following conditions apply in the case of circuits that are not disconnected by the actual disconnecting means:

- Permanent safety sign, placed adjacent to the operating handle for the main disconnecting means, indicating that not all circuits are de-energized by the main disconnecting means.
- A statement about affected circuits shall be included in the machine documentation.
- Identification of the affected circuits inside the industrial control panel in the form of a safety sign or color coding (orange).

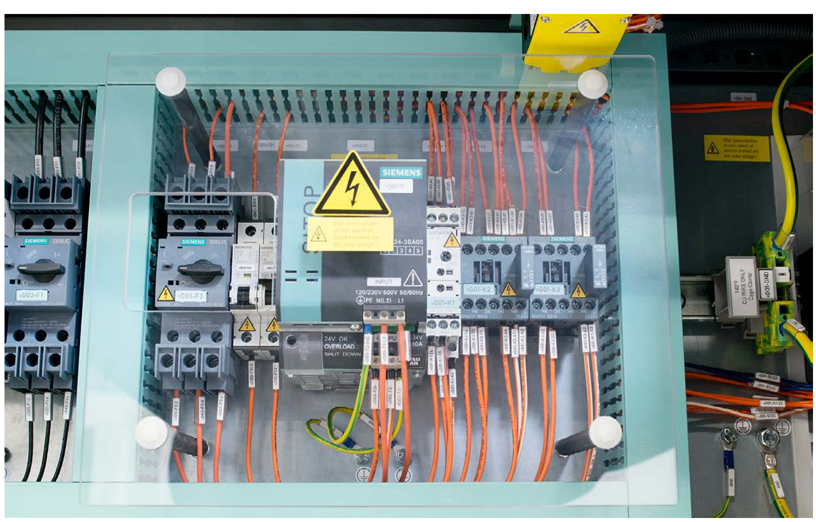


Figure 5-11 Example of the configuration of an excepted circuit

Definition according to UL 508A

UL 508A does not directly address "excepted circuits". The following circuits may be tapped upstream of the disconnecting means:

- Control circuits
- Lighting circuits for maintenance

Control circuits that are tapped upstream of the disconnecting means shall possess their own disconnecting means in accordance with UL 508A, Chapter 39.1.

Lighting circuits are to be configured as follows in accordance with Chapter 66.1.4:

- Max. voltage 150 V
- Branch Circuit protection max. 15 A
- When tapped upstream of the main disconnecting means, one of the following conditions should be met:
  – Supplied by the secondary side of an isolation transformer, tapped on the incoming supply circuit side of the main disconnecting means, used only to supply lighting circuits inside the industrial control panel.
  – Supplied by the secondary side of an isolation transformer, tapped on the incoming supply circuit side of the main disconnecting means where the transformer has a separate disconnect switch. The disconnect switch shall be installed near the main disconnecting means in the industrial control panel.

5.4 Protective measures

5.4.1 General information

An important and central issue in the application of standards for industrial equipment and machinery relates to accident prevention and, therefore, providing protection for people.

The relevant standards distinguish between "electrical safety" and "machine safety". The NEC, NFPA 79, and UL 508A primarily regulate topics regarding "electrical safety".

When it comes to "machine safety", they make reference to other standards. In the context of risk analysis, for example, Annex A of NFPA 79 refers to IEC 62061, ISO 13849-1 and 2, and also to ANSI, B11-TR3, and TR4.

Different hazards can arise when handling electrically operated equipment. To avoid these hazards or even to eliminate them completely, the appropriate measures must be taken.

The following chapter deals with the topic of "protection against electrical hazards" and addresses the requirements of the standards referred to above.

5.4.2 Protection against electrical hazards

"Electrical hazards" is taken to mean events of an electrical nature that pose a hazard to people. The essential ones to list here are electric shock and arcing faults.

In NFPA 79, 2012 edition, the title of Chapter 6 was changed from "Protection from Electric Shock" to "Protection from Electrical Hazards". Chapter 6 was also extended to cover the subject of "arc flash hazard".

NFPA 79, Chapter 6.1, requires electrical equipment to protect people from the following hazards:

- Electric shock due to direct or indirect contact
- Arc flashing

The options that the standards permit or prescribe, and the safety measures to be implemented, are described both in this chapter and in chapter Arc flash hazard (protection against arc flashing) (Page 94).

5.4.2.1 Protection against direct contact

The general rule for voltages that present a contact hazard (≥ 50 VAC or ≥ 60 VDC) is that protection against direct contact shall be ensured.

Protection against direct contact means that under normal operating conditions of the electrical equipment, no live parts that present a contact hazard can be touched.

UL 508A only deals with the industrial control panel and is therefore limited exclusively to its enclosure. An enclosure with a door shall be locked, as described in point 3 below, "Door locking protection".

According to Chapter 18.4, a **door is required** in the following circumstances:

- If the industrial control panel contains fuses.
- If there are circuit breakers located in the power circuit that cannot be reset from the outside.
- If the industrial control panel contains overload relays that cannot be reset from the outside.
- If the industrial control panel contains measuring devices that shall be reset or serviced.

Exception

A **door is not required** in the following instances:

- If access is only required to replace defective components (e.g. after a short circuit).
- If the industrial control panel only contains a control circuit fuse and the load for the control circuit can be found in the same enclosure.
- If all overload relays can be reset from the outside.
- If the cover is flanged and interlocked with the external operating handle of the main disconnecting means. This ensures that the power is removed before the cover can be removed in order to replace fuses or reset overload relays.

This means that when these exceptions apply, it is possible to install a cover instead of a door and thus do away with the need for door interlocking. According to UL 508A, Chapter 2.14, a cover shall not be hinged.

The logic behind this requirement is to allow the doors to be handled much more easily. As a general rule, a tool is required to remove a cover, whereas a door can be opened and closed with ease when the industrial control panel is de-energized. In the context of the requirements referred to above, a cover would not be practical during maintenance or regular component replacement work, for example. A cover would also make it less likely that users would lock the industrial control panel safely if maintenance and service work is being carried out on it frequently.

For smaller enclosures, a cover may be an entirely sensible solution. Generally speaking, however, it is not a practical option for larger enclosures (e.g. for reasons of weight and manageability).

Chapter 20 of UL 508A describes the minimum distances to live parts in the case of enclosure openings.

The table "Minimum distance from an opening to a part involving risk of electric electric shock or personal injury" below describes the following minimum distances:

- To uninsulated live parts > 30 V AC or 42.4 V DC
- To moving parts of components inside the enclosure, such as a fan blade

The shortest distance from the edge of the opening to the relevant part shall be measured.

Exception

This requirement does not apply to enclosures with the following properties:

1. Enclosure that is floor-mounted
2. The lower edge of the enclosure is at least 6 in. (152 mm) away from the floor (e.g. mounted on open base)
3. Exposed live parts in the enclosure are at least 6 in. (152 mm) above the highest portion of the lower edge of the enclosure

Table 5- 7 Minimum distance from an opening to a part involving risk of electric shock or personal injury

Minor dimension of opening [a]		Minimum distance from opening to uninsulated live part or moving part	
inches	**(mm)**	**inches**	**(mm)**
Less than 1/8	(Less than 3.18)	1/2	(12.7)
1/2	(12.7)	4	(101.6)
1[b]	(25.4)	6 … 1/2[b]	(165.0)
1 … 1/2[b]	(38.1)	8 … 3/8[b]	(212.7)
2[b]	(50.8)	11 … 5/8[b]	(295.3)
over 2 and not more than 3[b]	(over 50.8 and not more than 76.2)	30[b]	(762.0)

[a] The minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that is able to be inserted through the opening. The opening is evaluated without removable filters.

[b] Interpolation shall be used to determine intermediate distances between the table requirement and the previous entry specified in this table. Where: the intermediate distance = (distance for previous entry) + (difference between intermediate minor dimension and minor dimension of previous entry) x (difference between required distance and distance of previous entry) / (difference between required minor dimension and minor dimension of previous entry).

Example: To find required distance for 3/4 inch opening (minor dimension) between 1/2 inch (12.7 mm) and 1 inch (25.4 mm) table values

Required distance = 4 inch + (3/4 - 1/2) x (6-1/2 - 4) / (1 - 1/2) = 5.25 inches

Source: UL 508A, Table 20.1

NFPA 79, meanwhile, not only deals with the industrial control panel itself, but also encompasses all the electrical equipment for machines, including components such as cables and devices used in the field. Chapter 6.2 lists a number of possible measures for providing protection against direct contact:

1. Insulation of live parts
2. Protection by the enclosure
3. Protection by door interlocking
4. Restricting access to the enclosure

1. Insulation of live parts

If this measure for protection against direct contact is applied, live parts shall be completely covered by insulation material. Removing the insulation shall only be possible through destruction, and it must be resistant to mechanical, chemical, electrical and thermal influences.

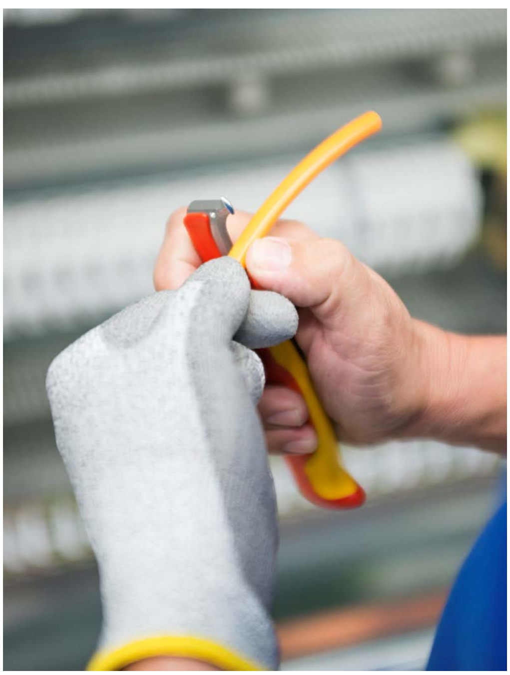


Figure 5-12 Insulated cables

Note

Paints, varnishes, lacquers, or similar products are not normally considered to provide protection against contact.

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2. Protection by the enclosure

Protection against direct contact from outside an enclosure

All electrically operated parts and devices are located within the enclosure. The aim is to make it impossible to touch live parts in the industrial control panel from the outside. To ensure this, the enclosure and enclosure openings shall comply with the one of the following standard requirements, and they shall be appropriately tested.

- ANSI / UL 508
- UL 508A
- ANSI / UL 50
- NEMA 250

Exception

Non-approved enclosures can be tested using a test finger: it can be applied in every opening of the enclosure after removal of all parts of the enclosure that are capable of being removed without the use of a tool. It should not be possible to touch the live parts with the test finger.

In practice, this means that empty panels shall be designed and configured in accordance with the rules of UL 508A Chapters 62 to 64, and then tested with a test finger to ensure at least protection against direct contact.

The figure below shows an example of such a test finger.

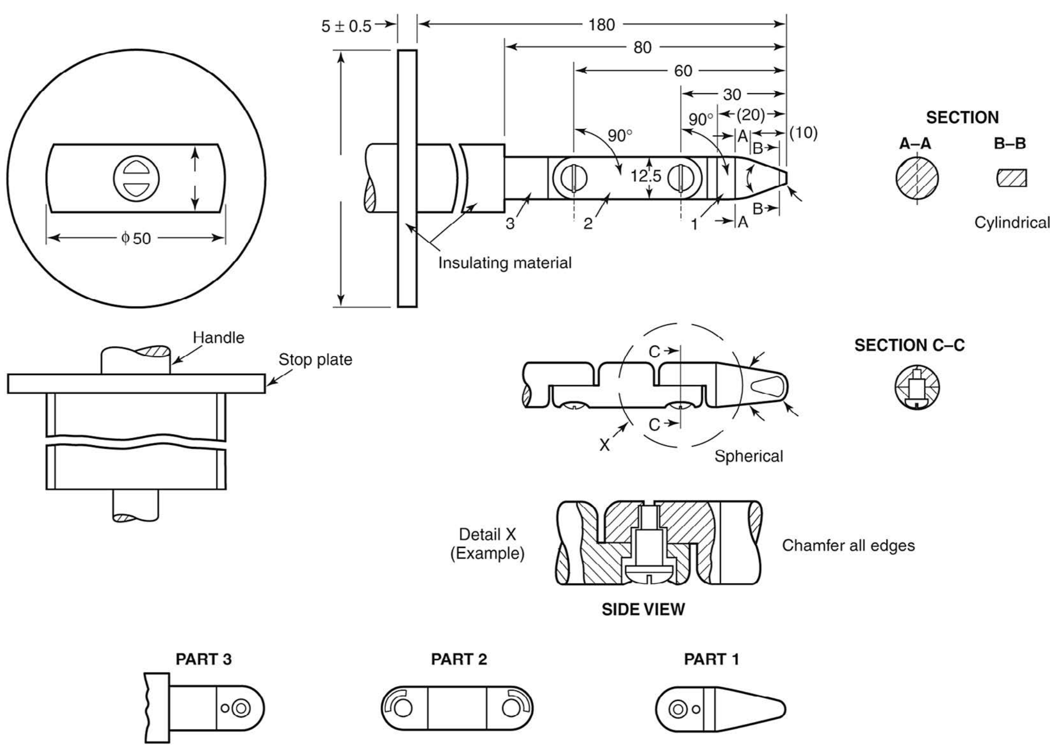

Figure 5-13 Test finger in accordance with NFPA 79, Fig. 6.2.2.1

Example: Sirius M200D motor starter with high enclosure type for field use, approved according to ANSI/UL 508

Figure 5-14 SIRIUS M200D distributed motor starter

Example: Industrial control panel enclosure, certified by UL according to ANSI/UL 50

Figure 5-15 Label for a UL-tested empty industrial control panel enclosure

3. Protection by door interlocking

For industrial control panels with an operating voltage of ≥ 50 VAC or ≥ 60 VDC, the isolating equipment (e.g. main disconnecting means) shall be interlocked with the industrial control panel door mechanically, electrically, or using a combination of the two.

The following disconnecting means do not have to be interlocked with the door:

- Disconnecting means for industrial control panel lighting
- Disconnecting means for memory elements to prevent loss of data

Conditions

According to UL 508A, Chapter 66.1.5.1, and NFPA 79, Chapter 6.2.3.2, the door interlocking shall meet the following requirements:

1. It shall be possible for qualified persons to defeat the interlocking so that the industrial control panel doors can also be opened for servicing and maintenance work when the main disconnecting means is in the "ON" position. A tool shall be required for this purpose (e.g. a small, flat screwdriver).

Figure 5-16 Example: Defeating with a screwdriver

2. The interlocking shall be automatically activated on closing the industrial control panel door without the need for any additional measures.
3. When the industrial control panel door is open, mechanical interlocking shall be used to prevent the disconnecting means from closing It shall be possible to defeat this interlocking without tools.

Figure 5-17 Example: Defeating without tools by actuating a lever on the reverse side of the door with the left hand.

A wiring diagram example of an electrical door interlocking can be found in the Annex (Page 325).

With voltages of ≥ 50 V, devices mounted on the inside of industrial control panel doors shall also be protected against unintentional contact according to NFPA 79, Chapter 6.2.3.3. This protection can be provided by the inherent design of the devices themselves, or by the application of barriers at a distance of 50 mm (2 in.) from the live parts.

This requirement is based on the IEC standards. The distance of 50 mm corresponds to the IEC test for back-of-hand safety with IP protection class IP1. Since the IP protection classes are not generally accepted in the USA, this has been described using distance specifications. The purpose of this requirement is to prevent unintentional contact with live parts while working on an open panel.

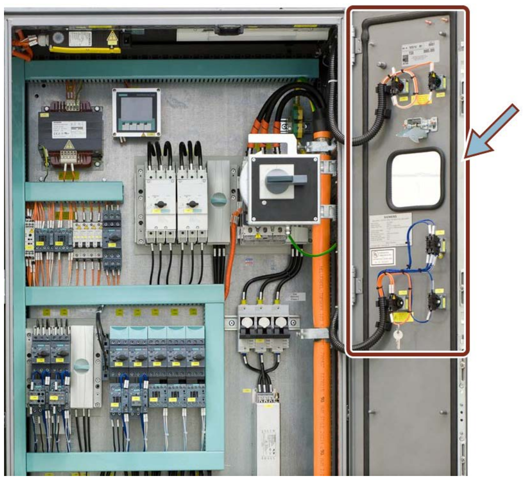

Figure 5-18 Equipment for door mounting

The logic behind the requirement for interlocking disconnection means and doors is the already mentioned protection against direct contact.

According to the US standards, contact with a voltage of 50 V AC or 60 V DC or higher results in impermissibly high bodily currents for people. For this reason, the aim of the regulations listed above is to ensure that lay persons do not have access to industrial control panels, and to prevent unintentional closing of the disconnecting means when the door is open. Qualified personnel may, however, defeat the interlock with a deliberate action so that they can still open the enclosure under voltage or energize with the door open. Qualified personnel possess the know-how, experience and training to carry this operation out properly and intentionally.

4. Restricting access to the enclosure

UL 508A describes the industrial control panel from the supply terminal to the outgoing terminals into the field (field wiring terminals). Areas outside the industrial control panel are no longer described in UL 508A.

On the other hand, NFPA 79 describes the entire machine. This includes possible subdistribution boards that may be supplied by a main panel with a disconnecting means.

Chapter 6.2.4 of NFPA 79 regulates this topic as follows:

If a qualified person opens an industrial control panel enclosure **that does not have its own disconnecting means** under voltage, one of the following conditions shall be met:

1. The use of a key or tool shall be required for opening the industrial control panel door.
2. An enclosure door shall be permitted to be opened without the use of a key or tool only when all live parts inside are separately enclosed or guarded such that there cannot be any direct contact with live parts.

As described in Chapter Incoming supply circuit conductor and power terminals (Page 69), every incoming supply circuit shall have a disconnecting means. Accordingly, every panel with a door and its own disconnecting means shall have a door interlocking facility, and the above listed rules are not applicable.

This rule can be applied, for example, to panels that are located in sight of the associated disconnecting means, and that do not have any additional disconnecting means of their own (e.g. modular panels or distributed panels). As a result, there may be no need to invest in expensive control systems for door interlocking mechanisms.

Note

Each operating means of the isolation devices (e.g. the handle for the main disconnecting means) shall have the following characteristics according to NFPA 79, Chapter 5.5.5.

- Accessible at all times
- Identified appropriately
- Lockable in the "OFF" position
- In sight of the part of the machine or system requiring disconnection

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5.4.2.2 Protection against indirect contact

As well as protection against direct contact, attention shall also be given to the hazardous situations that can result from faults, and suitable measures shall be taken. Indirect contact with live parts can only arise in the event of a fault. The most frequent fault condition is the insulation failure between live and exposed conductive parts. The resulting potentially hazardous contact voltage shall be prevented by means of suitable protective measures.

NFPA 79 describes two protective measures in Chapter 6.3.1:

1. **Protection by double insulation**

   Double or reinforced insulation is intended to prevent the occurrence of hazardous touch voltages on the accessible parts through a failure in the basic insulation.

   Equipment shall be listed accordingly or checked in a comparable way and distinctively marked.

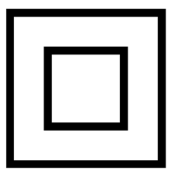
   

   Figure 5-19 "Double Insulation" symbol (protection class 2)

2. **Protection by automatic disconnection of supply**

   Exposed parts shall be grounded (see Chapter Grounding (Page 161)), and corresponding short-circuit protective devices that disconnect immediately and independently in the event of a fault shall be used. This ensures that the duration of potential contact with voltages that present a contact hazard is kept to a minimum. The disconnection time is generally in the millisecond range (see tripping characteristics for fuses, circuit breakers, etc.). Verification of this protective measure is described in Chapter Testing and verification (Page 305).

UL 508A describes protection against indirect contact through automatic disconnection of the supply in the relevant chapters ("Grounding and overcurrent protection"). It does not refer to protective measures explicitly, but these are covered by the structural requirements it sets out in any case.

5.4.2.3 Protection by the use of protective extra low voltage (PELV)

A PELV is described in **NFPA 79, Chapter 6.4**. A PELV is used to protect persons against electric shock from indirect contact and it also protects against limited area direct contact.

Conditions

A PELV circuit shall satisfy the following conditions:

1. The rated voltage shall not exceed the following values:

   a) 30 V AC (rms value) or 60 V DC (ripple-free) when the equipment is used in normally dry locations, and when large area contact of live parts with the human body is not expected.

   b) 6 V AC (rms value) or 15 V DC (ripple-free) in all other cases than described under a).
2. One side of the circuit or one point of the supply shall be grounded.
3. Live parts of PELV circuits shall be electrically separated from other live parts of circuits. The distance shall be ≥ the distance between the primary and secondary side of a safety transformer.
4. Conductors shall be physically separated from the conductors of any other circuits. Should this not be practicable, the electric strength of the conductors shall be dimensioned for the highest voltage occurring in the cable duct.

Devices used

The following devices may be used for supplying a PELV:

1. Safety transformer (isolation transformer!)
2. Current source providing a degree of safety equivalent to that of a safety transformer (e.g. motor generator with insulated windings).
3. Electrochemical sources (e.g. batteries) or another source independent of a higher-voltage circuit (e.g. diesel-driven generators).
4. Electronic power supply with fused outputs. An internal fault is not permitted to result in excess voltage in accordance with the PELV standard voltages.

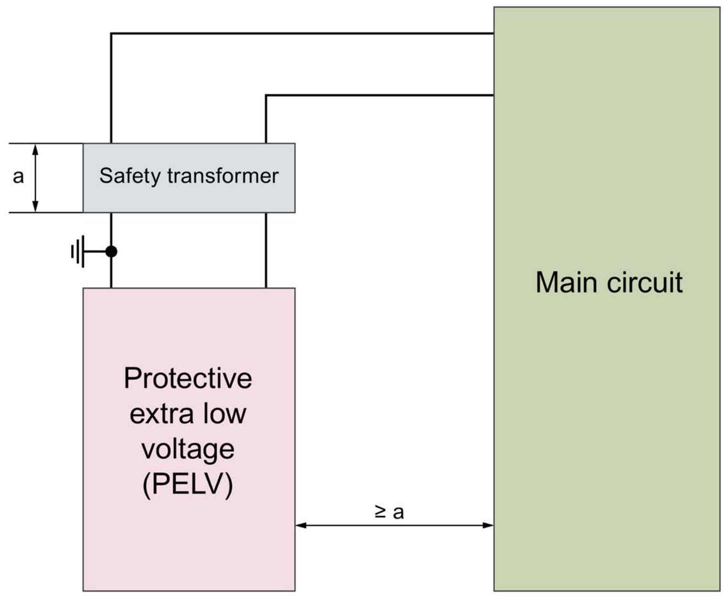


Figure 5-20 Example configuration of a protective extra low voltage (PELV) circuit

5.4.2.4 Protection against residual voltages

NFPA 79 regulates the handling of stored energy in Chapter 6.5.

1. Residual voltages > 60 V shall be reduced to ≤ 60 V within 5 seconds.

   Exceptions

   – Components with a stored charge of Q ≤ 60 µC

   – Where such a provision would interfere with the functioning of the equipment, if is permitted to attach a durable safety sign drawing attention to the hazard of electric shock and stating the delay required before entry to the enclosure is allowed. This sign shall be displayed at an easily visible location on or immediately adjacent to the enclosure containing the capacitance.

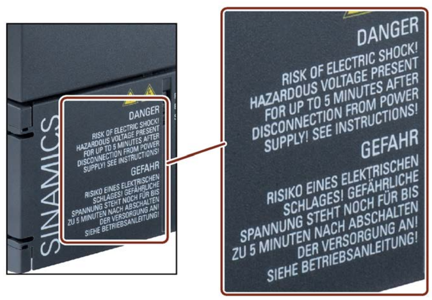


Figure 5-21 Sinamics variable speed drive with warning sign

2. The withdrawal of plugs which results in the exposure of conductors (e.g. pins) shall have a discharge time t ≤ 1 sec.

   Exceptions

   – Components with a stored charge of Q ≤ 60 µC

   – Conductors protected against direct contact

The following regulations on capacitors are described both in NEC, Chapter 460.6, and in NFPA 79, Chapter 6.5.3.

Capacitors shall:

1. Be capable of discharging stored energy.
2. Reduce the voltage to ≤ 50 V within one minute of the energy being disconnected.
3. The discharge circuit shall meet one of the following two requirements:
   – It must be permanently connected to the capacitor or the capacitor bank.
   – It must be automatically switched on when the voltage is switched off. Manual means of switch-on is not permitted.

5.4.3 Arc flash hazard (protection against arc flashing)

5.4.3.1 Background, objective, and purpose

The topic of "arc flash hazards" has an important role in the USA and is dealt with and promoted accordingly. Awareness of such hazards is significantly more pronounced than in Europe, for example. The relevant standards place emphasis on the subject of Arc Flash protection and its associated hazards, and specify requirements relating to it. This particularly applies to NEC (NFPA 70), NFPA 79 (for Industrial Machinery) and NFPA 70E (relating to electrical safety in the workplace).

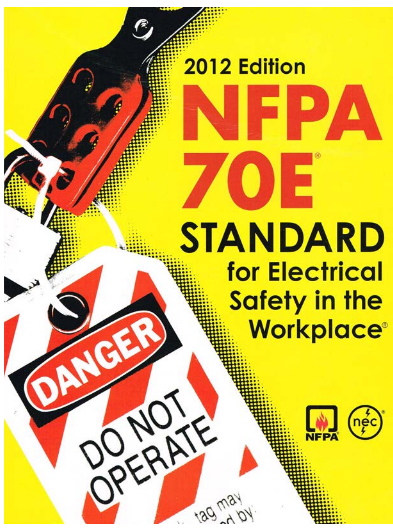


Figure 5-22 NFPA 70E Standard for Electrical Safety in the Workplace

NEC

The following requirement concerning Arc Flash Hazards can be found in the NEC, the US statutory Code for the electrical sector:

NEC 110.16, protection against arc flashes

Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked

to warn qualified persons of potential electric arc flashes. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

This means that industrial control panels built according to UL 508A, which are potentially also subject to the requirements of NFPA 79 for the electrical equipment of machines, offer the option of carrying out maintenance, adjustments, servicing, or checks while they are live. This is ensured by the requirements for the disconnecting means and the door interlocking (see ChapterProtection against direct contact (Page 82)).

NFPA 79

Along with its requirements for protection against electrical hazards, NFPA 79 also includes the following clear requirement:

NFPA 79 Section 6.6 and 16.2.3

A safety sign regarding Arc Flash Hazards shall be provided. The electrical equipment of machines (e.g. industrial control panels, enclosures with disconnecting devices) shall be marked to warn qualified persons of potential electric shock and arc flash hazards.

The marking shall be located so as to be clearly visible to qualified persons before they commence maintenance work, adjustments, servicing, or troubleshooting.

Omitting the safety signs is only permitted where the size of the enclosure precludes placement of the label on the enclosure (e.g. in the case of control stations, operator interfaces or position sensors).

The requirement in NFPA 79 has led to harmonization with the NEC in this regard.

NFPA 70E offers a proven method of determining the risk of potential hazards due to arc flashing. We recommend referring to the standard ANSI Z535.4 for information on the designs of safety labels on products.

5.4.3.2 Necessary data and identification by the manufacturer

Collection of necessary data

In this context, the process of collecting the necessary data to complete an Arc Flash study is the most time-consuming one.

IEEE 1584, 2002 edition, is a guide on how to evaluate Arc Flash Hazards. In this guide, the following 9 steps are recommended for completing the evaluation:

- Step 1: Collect all system and installation data
- Step 2: Determine the operating modes of the system
- Step 3: Determine the short-circuit current
- Step 4: Determine the arc flash currents
- Step 5: Determine the properties of the protective device and the duration of the arc flashes
- Step 6: Document the operating voltage and equipment classifications
- Step 7: Select the working distances
- Step 8: Determine the energy in the event of a fault
- Step 9: Define the protective boundaries for arc flashes for all the equipment

An in-depth level of technical knowledge is required to complete these 9 steps, particularly when it comes to collecting all the relevant system and installation data.

In most cases, manufacturers and suppliers of industrial control panels and mechanical equipment cannot provide much of this data.

Identification

Therefore, it is recommended that manufacturers and suppliers of equipment that shall be identified with an Arc Flash Hazard label according to the NEC and NFPA 79 provide a general safety mark for this equipment (see figure below).

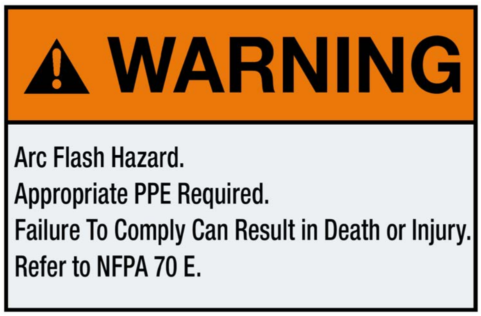


Figure 5-23 Label warning against arcing faults in accordance with NFPA 70E and ANSI Z535.4

Safety labeling with general information is usually adequate and meets the requirements of the NEC and thus also NFPA 79. However, it does not specify the existing conditions at the location of installation, the safety distances, or the protective clothing to be worn (Personal Protective Equipment (PPE)).

The safety information is intended for on-site operation. It is aimed at the operators and the service and maintenance personnel and it differs for this reason from the safety sign for construction and design carried out by the original manufacturer.

The safety label below, by contrast, specifies details of safety limits, arcing energy in the event of a fault, personal protective equipment, etc. These details are usually attached by the operator on-site after carrying out the arc-flash calculation and defining the necessary personal protective equipment.

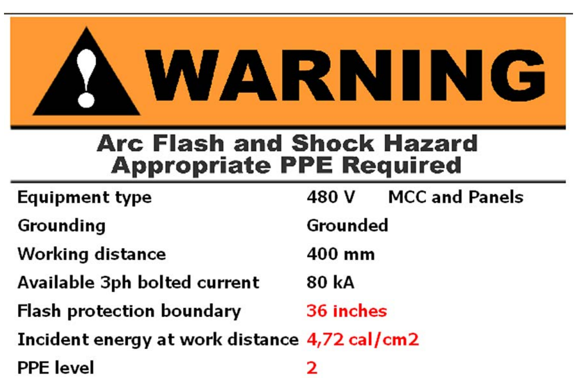


Figure 5-24 Warning sign relating to arch flash hazard that specifies the safety limits

5.4.3.3 Calculation example according to NFPA 70E

A detailed calculation example for determining the arc flash energy, limits, and the required personal protective equipment can be found in NFPA 70E 2009, Part 2, Annex A and Annex B.

Overcurrent protection and sizing of the power circuit 6

6.1 General information

In accordance with NEC, UL 508A and NFPA 79, industrial control panels and industrial machinery and plants shall be correspondingly sized and protected against overcurrent. The components and protective devices shall be approved for the respective use and the correct product category (see also Chapter Categorization using the Category Code Number (CCN) (Page 52)), and shall be selected and sized to match each other.

The coming chapters explain the relevant rules and the respective procedure.

6.2 Feeder Circuit

In accordance with NEC, NFPA 79 and UL 508A, all conductors and components upstream of the load branch circuit are designated as a Feeder Circuit (see Chapter Through air and over surface spacings (Page 56) for the definition).

To protect conductors and components in the Feeder Circuit correspondingly against short-circuit, the following devices shall be used in accordance with UL 508A, Chapter 32:

- Inverse-time circuit breakers in accordance with UL 489 **or**
- Fuses in accordance with UL 248-4 to 12 and -15

These devices meet the through air and over surface spacings in the Feeder Circuit without any other accessories (see also Chapter Through air and over surface spacings (Page 56)).

Overcurrent protection shall be provided in each ungrounded conductor, usually the phase(s).

Exception: Protective devices are provided outside the industrial control panel and are not part of the electrical equipment of the manufacturer. In this case, a clear label shall be attached specifying the type of protective device required and how it is to be rated. See Chapter Marking the control panel and the machine (Page 263).

Protective device

The sizing of the protective device shall not exceed any one of the following conditions:

1. The rated current of the largest branch circuit protective device in the circuit plus the rated currents in accordance with the following table "Full-load motor-running currents in amperes corresponding to various AC horsepower ratings" for AC motors, or the table "Full-load motor-running currents in amperes corresponding to various DC horsepower ratings" for DC motors, and the rated currents of other loads in the group. (See the figure "Example of sizing the protective device in the feeder circuit" below)
2. The ampacity of the conductors or bus bars on the load side of the protective device (see also Chapter Sizing (Page 222)).

Table 6- 1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings

Horse power	110 … 120 V		200 V		208 V		220 … 240 V[a]		380 … 415 V		440 … 480 V		550 … 600 V	
	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase
1/10	3.0	–	–	–	–	–	1.5	–	1.0	–	–	–	–	–
1/8	3.8	–	–	–	–	–	1.9	–	1.2	–	–	–	–	–
1/6	4.4	–	2.5	–	2.4	–	2.2	–	1.4	–	–	–	–	–
1/4	5.8	–	3.3	–	3.2	–	2.9	–	1.8	–	–	–	–	–
1/3	7.2	–	4.1	–	4.0	–	3.6	–	2.3	–	–	–	–	–
1/2	9.8	4.4	5.6	2.5	5.4	2.4	4.9	2.2	3.2	1.3	2.5	1.1	2.0	0.9
3/4	13.8	6.4	7.9	3.7	7.6	3.5	6.9	3.2	4.5	1.8	3.5	1.6	2.8	1.3
1	16.0	8.4	9.2	4.8	8.8	4.6	8.0	4.2	5.1	2.3	4.0	2.1	3.2	1.7
1-1/2	20.0	12.0	11.5	6.9	11.0	6.6	10.0	6.0	6.4	3.3	5.0	3.0	4.0	2.4
2	24.0	13.6	13.8	7.8	13.2	7.5	12.0	6.8	7.7	4.3	6.0	3.4	4.8	2.7
3	34.0	19.2	19.6	11.0	18.7	10.6	17.0	9.6	10.9	6.1	8.5	4.8	6.8	3.9
5	56.0	30.4	32.2	17.5	30.8	16.7	28.0	15.2	17.9	9.7	14.0	7.6	11.2	6.1
7-1/2	80.0	44.0	46.0	25.3	44.0	24.2	40.0	22.0	27.0	14.0	21.0	11.0	16.0	9.0
10	100.0	56.0	57.5	32.2	55.0	30.8	50.0	28.0	33.0	18.0	26.0	14.0	20.0	11.0
15	135.0	84.0	–	48.3	–	46.2	68.0	42.0	44.0	27.0	34.0	21.0	27.0	17.0
20	–	108.0	–	62.1	–	59.4	88.0	54.0	56.0	34.0	44.0	27.0	35.0	22.0
25	–	136.0	–	78.2	–	74.8	110.0	68.0	70.0	44.0	55.0	34.0	44.0	27.0
30	–	160.0	–	92	–	88	136.0	80.0	87.0	51.0	68.0	40.0	54.0	32.0
40	–	208.0	–	120	–	114	176.0	104.0	112.0	66.0	88.0	52.0	70.0	41.0
50	–	260.0	–	150	–	143	216.0	130.0	139.0	83.0	108.0	65.0	86.0	52.0
60	–	–	–	177	–	169	–	154.0	–	103.0	–	77.0	–	62.0
75	–	–	–	221	–	211	–	192.0	–	128.0	–	96.0	–	77.0
1000	–	–	–	285	–	273	–	248.0	–	165.0	–	124.0	–	99.0
125	–	–	–	359	–	343	–	312.0	–	208.0	–	156.0	–	125.0
150	–	–	–	414	–	396	–	360.0	–	240.0	–	180.0	–	144.0
200	–	–	–	552	–	528	–	480.0	–	320.0	–	240.0	–	192.0
250	–	–	–	–	–	–	–	604	–	403.0	–	302.0	–	242.0
300	–	–	–	–	–	–	–	722	–	482.0	–	361.0	–	289.0
350	–	–	–	–	–	–	–	828	–	560.0	–	414.0	–	336.0
400	–	–	–	–	–	–	–	954	–	636.0	–	477.0	–	382.0
450	–	–	–	–	–	–	–	1030	–	–	–	515.0	–	412
500	–	–	–	–	–	–	–	1180	–	786.0	–	590.0	–	472.0

[a] To obtain full-load currents for 265 and 270 volt motors, decrease corresponding 220 – 240 volt ratings by 13 and 17 percent respectively.

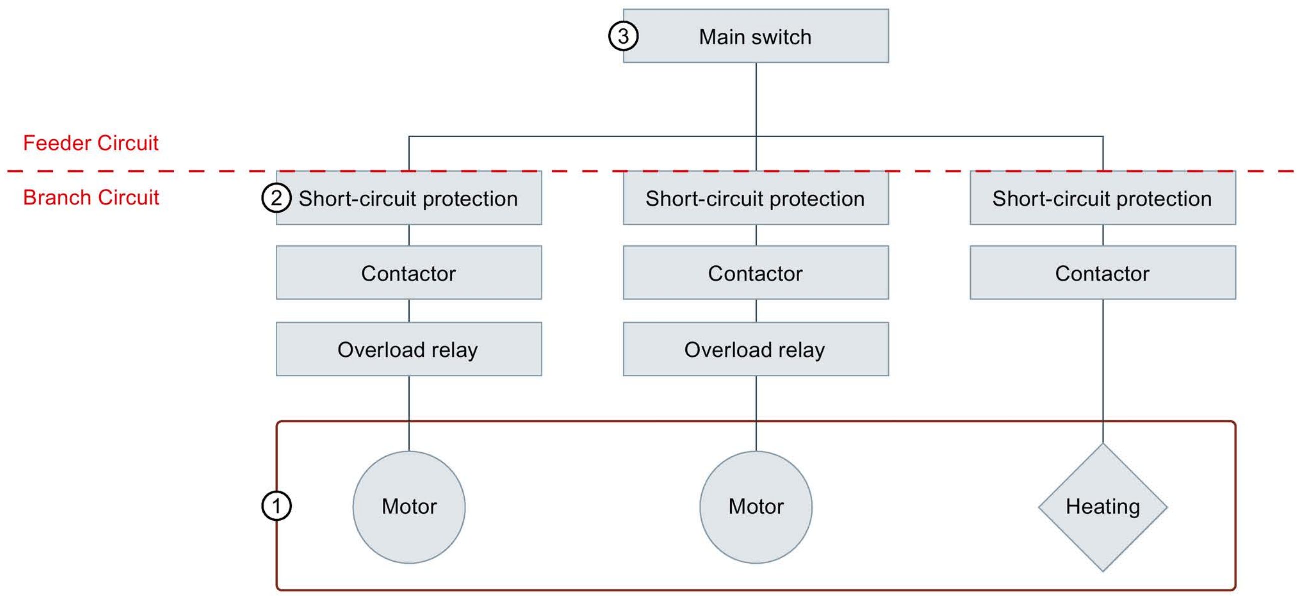
Source: UL 508A, Table 50.1

Table 6- 2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings

Horsepower	90 volts	110 … 120 volts	180 volts	220 … 240 volts	500 volts	550 … 600 volts
1/10	–	2.0	–	1.0	–	–
1/8	–	2.2	–	1.1	–	–
1/6	–	2.4	–	1.2	–	–
1/4[a]	4.0	3.1	2.0	1.6	–	–
1/3	5.2	4.1	2.6	2.0	–	–
1/2	6.8	5.4	3.4	2.7	–	–
3/4	9.6	7.6	4.8	3.8	–	1.6
1	12.2	9.5	6.1	4.7	–	2.0
1-1/2	–	13.2	8.3	6.6	–	2.7
2	–	17	10.8	8.5	–	3.6
3	–	25	16	12.2	–	5.2
5	–	40	27	20	–	8.3
7-1/2	–	58	–	29	13.6	12.2
10	–	76	–	38	18	16
15	–	110	–	55	27	24
20	–	148	–	72	34	31
25	–	184	–	89	43	38
30	–	220	–	106	51	46
40	–	292	–	140	67	61
50	–	360	–	173	83	75
60	–	–	–	206	99	90
75	–	–	–	255	123	111
100	–	–	–	341	164	148
125	–	–	–	425	205	185
150	–	–	–	506	246	222
200	–	–	–	675	330	294

[a] The full-load current for a motor with 1/4 HP and 32 V DC is 8.6 A.

Source: UL 508A, Table 50.2



① Determining the rated currents of the loads:

- Motor 10 HP in accordance with the table "Full-load motor-running currents in amperes corresponding to various AC horsepower ratings", 15 A at 480 V
- Motor 5 HP in accordance with the table "Full-load motor-running currents in amperes corresponding to various AC horsepower ratings", 7.6 A at 480 V
- Heater rated current in accordance with nameplate 10 A

② Determining the largest branch circuit protective device in accordance with Chapter 6.3.1.1. Inverse time circuit breaker max. 37.5 A permissible → selected 20 A

③ Protective device in the feeder circuit 20 A (②) + 7.6 A (rated current in accordance with the table "Full-load motor-running currents in amperes corresponding to various AC horsepower ratings") + 10 A = 37.6 A

→ **rating to be selected for protective device: 35 A**

Figure 6-1 Example of sizing the protective device in the feeder circuit

6.3 Branch Circuit

The outgoing load feeders from the branch circuit protective device and downstream components and conductors are designated as a Branch Circuit (see Chapter Through air and over surface spacings (Page 56) for the definition). See also Figure 6-1 Example of sizing the protective device in the feeder circuit (Page 100).

The correct protection and sizing of the Branch Circuits depends on the load involved. This topic is described in Chapter 31 of UL 508A, and it is explained in the coming chapters of this guide.

6.3.1 Motor loads

A motor feeder is designated in accordance with UL 508A as a Motor Branch.

In accordance with Chapter 2.10, a motor branch (combination motor controller) shall perform the following four basic functions:

- Disconnecting means
- Branch circuit protection
- Motor control
- Overload protection

These four functions can be implemented by means of different device combinations. Due to the different product categories, this results in a host of different Construction Types for a motor branch circuit.

For this reason, UL 508 (product standard for Industrial Control Equipment) defines six different Construction Types described as follows in Table 76.2:

Table 6- 3 Various constructions of Combination motor controllers

Construction type	Component[a]	Component standard	Component function			
			Disconnect	Branch circuit protection	Motor control	Motor overload
A	Manual disconnect	UL 98 or UL 489	•			
	Fuse	UL 248 series		•		
	Magnetic or solid state motor controller	UL 508			•	
	Overload relay	UL 508				•
B	Manual disconnect	UL 98 or UL 489	•			
	Motor short-circuit protection	UL 508		•		
	Magnetic or solid state motor controller	UL 508			•	
	Overload relay	UL 508				•
C	Inverse-time circuit breaker	UL 489	•	•		
	Magnetic or solid state motor controller	UL 508			•	
	Overload relay	UL 508				•
D	Instantaneous-trip circuit breaker	UL 489	•	•		
	Magnetic or solid state motor controller	UL 508			•	
	Overload relay	UL 508				•
E[b]	Self-protected control device	UL 508	•	•	•	•
F	Manual self-protected combination controller	UL 508	•	•		•
	Magnetic or solid state motor controller	UL 508			•	

[a] Tests are concluded on the individual components per the applicable requirements from the UL Standards in the table

Source: UL 508, Table 76.2

Examples

The combination of a motor circuit breaker and a contactor is a Combination Motor Controller Type F.

A thermal-magnetic circuit breaker combined with a contactor and overload relay is a Combination Motor Controller Type C.

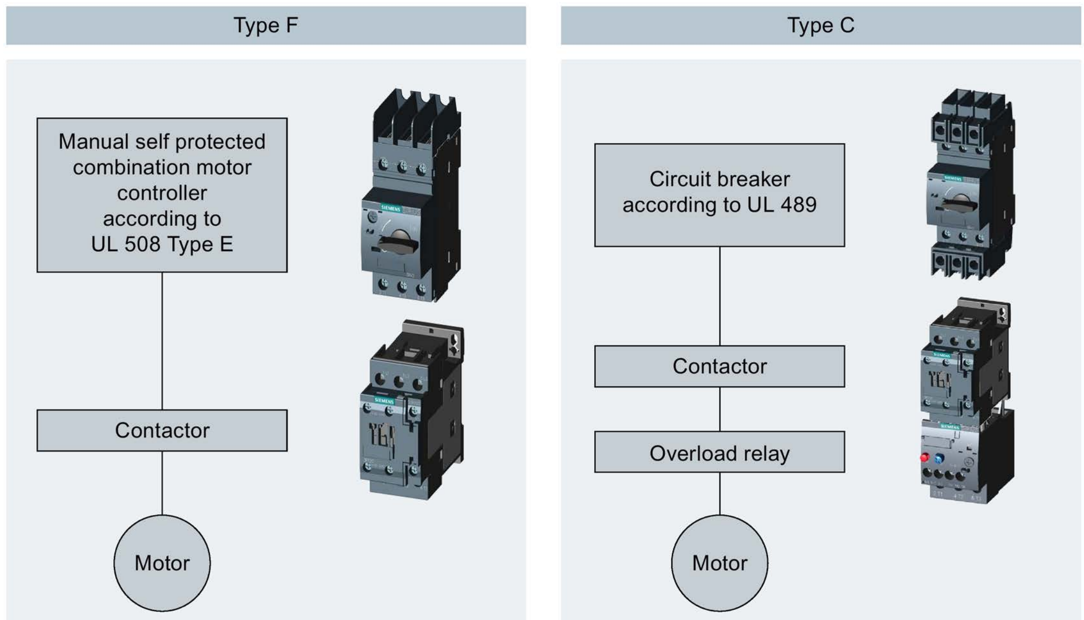


Figure 6-2 Examples of Type F and Type C

Construction types

UL 508A differentiates between single installation and group installation.

The logic behind these two construction types is explained in the coming Chapters Single Installation (Page 104) and Group Installation (Page 113).

6.3.1.1 Single Installation

"Single Installation" means each motor branch circuit is protected with its own short-circuit protective device.

This chapter is limited to only those rules in accordance with UL 508A that describe this topic in detail. NFPA 79 does not contradict UL 508A.

Selection of the device for motor control in accordance with UL 508A, Chapter 33

A motor controller (e.g. contactor or manual switch) shall meet the following requirements:

- Approved in compliance with product standard UL 508.
- Approved for at least the rated voltage of the circuit.
- Tested at least for the rated current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) (for AC motors) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99) (for DC motors). See Chapter Feeder Circuit (Page 97).
- Approved for the load type in accordance with the following table "Required controller ratings for various load types".

Table 6- 4 Required controller ratings for various load types

Controller rating		Usable load types
Type	Units	
AC heater or resistive	AC amperes	AC heater loads
DC heater or resistive	DC amperes	DC heater loads
AC amperes, general-purpose or general-use	AC amperes	AC non-motor-operated appliance or AC heater loads, AC power transformer for non-motor loads
DC amperes, general-purpose or general use	DC amperes	DC non-motor-operated appliances or DC heater loads
AC tungsten	AC amperes or watts	AC lighting load, AC heater load
DC tungsten	DC amperes or watts	DC lighting load, DC heater load
AC definite-purpose motor	FLA and LRA	AC hermetic refrigerant compressor motor, AC non-motor-operated appliance, or AC heater loads
DC definite-purpose motor	FLA and LRA	DC hermetic refrigerant compressor motor, DC non-motor-operated appliance, or DC heater loads
AC motor, design B, C or D	Horsepower	AC motor[a], ac motor-operated appliance, non-motor-operated appliance, AC heater loads, AC fluorescent ballast load, AC power transformer for motor loads
AC motor, design E	Horsepower	AC motor, AC motor-operated appliance, AC fluorescent ballast loads, AC power transformer for motor loads
DC motor	Horsepower	DC motor, DC motor-operated appliance, non-motor-operated appliance or DC heater loads

[a] Can be used for motor in version E, if rated in accordance with 33.2.4.

Source: UL 508A, Table 33.1

Selection and setting of overload protection in accordance with UL 508A, Chapter 34

An overload relay, including a thermal or solid-state relay as a stand-alone device, or also integrated into a Manual self-protected combination motor controller, shall be approved in accordance with UL 508.

If motors are already equipped with integral overload protection, the control panel shall be marked to indicate how this protective function is intended to be integrated into the motor control circuit. Furthermore, there shall be a provision for the overload protection to be connected to the ungrounded conductors of the motor control circuit.

If the motors are impedance-protected or temperature-protected (I.P. or T.P.) and they do not require a connection to a motor control circuit, this shall be marked on the control panel. An additional overload relay is no longer required in this.

In contrast to conductor sizing or the selection of a short-circuit protective device, the rated current on the nameplate of the motor shall be applied when setting the overload relay.

Since the overload trip unit is usually adjusted to 125 % of the rated current in the case of overload relays, the service factor of the motor plays a decisive role in the correct setting of the overload relay. The service factor states the maximum full-load motor current with which the motor can be loaded without incurring damage. Thus, a motor with SF 1.15, for example, can be loaded continuously with 115 % of its rated current. A motor with SF 1.00 can only be loaded with 100 %.

NEC, Chapter 430.32 states that motors shall be protected against overload as follows:

- Motors with service factor ≥ 1.15 ⇒ Overload protection 125 % of the rated current
- Motors with temperature rise ≤ 40 °C ⇒ Overload protection 125 % of the rated current
- All other motors ⇒ Overload protection 115 % of the rated current

This means:

- An overload relay that trips at 125 % of the rated current can be set to 1 x the rated current for a motor with SF 1.15.
- For a motor with SF <1.15, the overload relay shall be set to 0.92 x the rated current. ⇒ 0.92 x 125 % = 115 %.

For this reason, the motor overload protective device shall be selected in such a way that it is always possible to set it to 115 %.

Selection of short-circuit protection in accordance with UL 508A, Chapter 31

The rated current of a short-circuit protective device shall be selected according to the **lower value** of the conditions under Point 1 and 2.

1. In accordance with motor current and percentage values

a) Motor current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) (for AC motors) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99) (for DC motors). See Chapter Feeder Circuit (Page 97).

b) Determined according to the percentage specifications in accordance with the table "Maximum rating of motor branch circuit device percent of full load amperes" below, or lower (the values are maximum values)

c) The values from a) and b) shall be multiplied

Table 6- 5 Maximum rating of motor branch circuit device percent of full load amperes

Type of branch circuit protective device	Rated amperes	Nominal rating of motor branch circuit protective device, percent of full load amperes	Notes
Nontime delay fuse	0 … 600	300	See 31.3.7, 31.3.8, 31.3.9(a)
Nontime delay fuse	Over 600	300	See 31.3.7, 31.3.8, 31.3.9(b)
Dual element fuse (time delay) except Class CC	All	175	See 31.3.7, 31.3.8, 31.3.9(c)
Dual element fuse class CC (time delay)	0 … 30	300	See 31.3.7, 31.3.8, 31.3.9(a)
Inverse-time circuit breaker	0 … 100	250	See 31.3.7, 31.3.8, 31.3.9(d)
Inverse-time circuit breaker	Over 100	250	See 31.3.7, 31.3.8, 31.3.9(e)
Instantaneous-trip circuit breaker	All	800	See 31.3.4, 31.3.9(f)
Self-protected combination motor controller	All	100	See 31.3.3
Manual self-protected combination motor controller	All	100	See 31.3.3

Source: UL 508A, Table 31.1

2. In accordance with manufacturer specifications

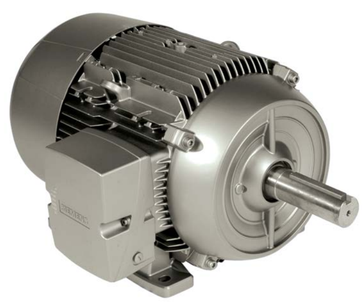
If the device manufacturer provides explicit specifications regarding protection, such as labels on the devices themselves, the temperature table of an overload relay, or manufacturer specifications supplied with the device (e.g. UL Certificate of Compliance), the short-circuit protection device shall be selected and sized to suit the components in the branch circuit.

a) Correspond to the rating specified by the manufacturer for the components to be protected.

b) Correspond to the type specified by the manufacturer for the components to be protected.

If the manufacturer information only contains the terms "fuse" and "circuit breaker", this refers to fuses in accordance with UL 248-4 to -12 or -15 and "Inverse-time circuit breaker" in accordance with UL 489

Examples of sizing rules



Power rating:	7.5 HP
Voltage:	460 V
Full-Load Amps FLA:	8.8 A
Service factor:	1.15

Figure 6-3 Siemens motor

Step 1 – Determining the motor current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)

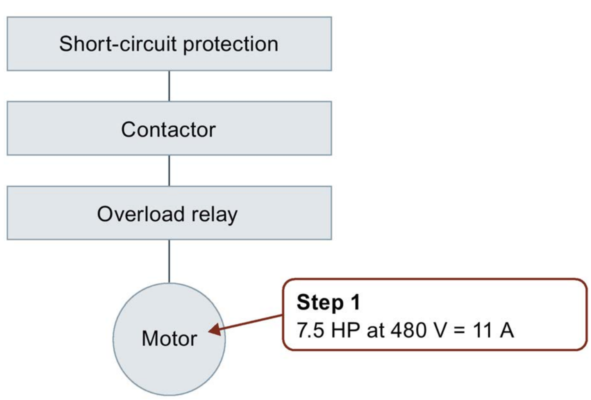


Figure 6-4 Determining the full-load amps

Step 2 – Selection of the motor controller

A contactor is intended to be used for motor control. Rated values shall be taken from the Certificate of Compliance.

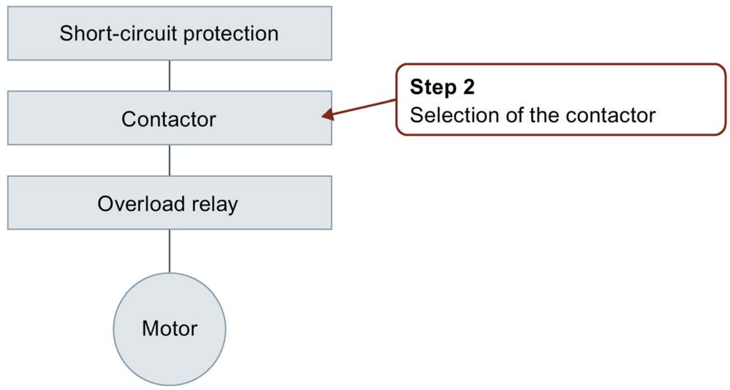


Figure 6-5 Selection of the motor controller

Table 6- 6 Extract from the UL Certificate of Compliance of the 3RT202… contactors from Siemens

Voltage	1-ph	3-ph	FLA / LRA
110 … 120 V	1-ph	-	16 /96
200	1	-	11.5 / 69
208	1½	-	13.2 / 79.2
220 / 240 V	2	-	12 / 72
200 V	2	3	11.0 / 73.6
208 V	-	3	10.6 / 71
220 / 240 V	-	3	9.6 / 64
380 … 415 V	-	5	9.7 / 61
440 / 480 V	-	7½	11 / 63.5
550 / 600 V	-	10	11 / 64.8

Step 3 – Selection of the overload protective device

A thermal overload relay is to be used as overload protection.

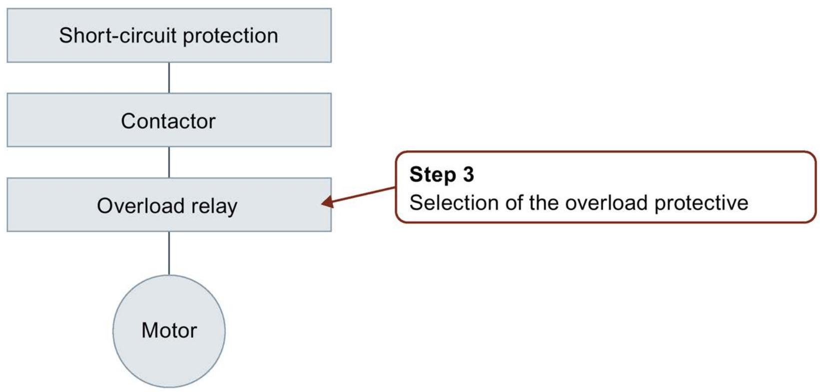


Figure 6-6 Selection of the overload protective device

Extract from the UL Certificate of Compliance of the 3RU2126 … thermal overload relays from Siemens

"These devices are open type 3-pole thermal overload relays. They are adjusted over a small range as indicated in the setting range table. They are provided with integral ambient compensated, non-replaceable thermal trip features and are suitable for providing overload protection. The trip current is 125 percent of the FLA shown on dial."

Trip current = 125 %, service factor of the motor = 1.15 ⇒ **setting value = 8.8 A**

→ Siemens Type 3RU2126-1J (current setting 7 to 10 A)

Step 4 – Sizing of the wiring

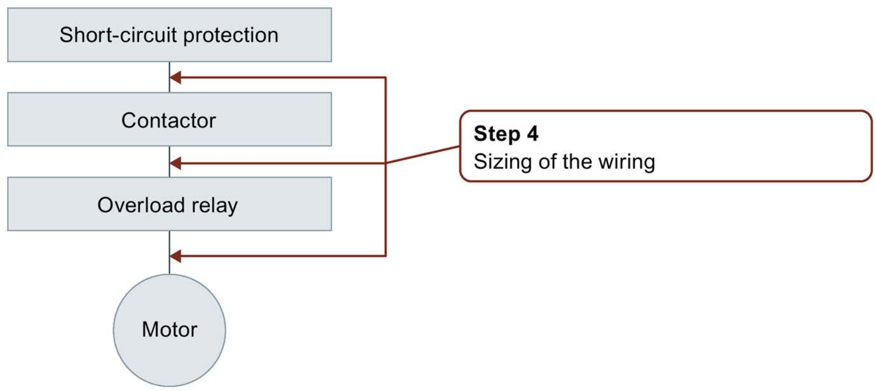


Figure 6-7 Sizing of the wiring

The procedure for sizing of the wiring is described in Chapter Sizing (Page 222).

⇒ 125 % of the motor current (see Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)) ⇒ 11 A x 1.25 = 13.75 A

In accordance with Table 11-5 Ampacities of insulated conductors (Page 223), the minimum cross-section in the power circuit is AWG 14. The conductor shall be protected with a short-circuit protective device ≤ 15 A.

Step 5 – Selection of the short-circuit protective device

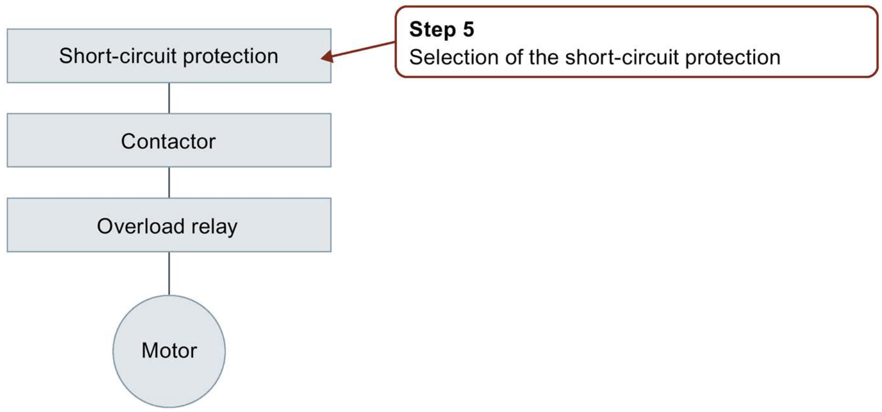


Figure 6-8 Selection of the short-circuit protective device

The short-circuit protective device shall be adapted to the devices and conductors of the motor branch circuit, and shall be sized in accordance with Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106) according to the motor current (Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)).

An inverse-time circuit breaker may be sized in accordance with Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106) with up to 250 % of the standard motor current (Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98)). ⇒ Maximum permissible rating: 11 A x 2.5 = 27.5 A

For the contactor and the overload relay, the respective protective device is described in the UL Certificate of Compliance.

Table 6- 7 Extract from the UL Certificate of Compliance of the 3RT202… contactors from Siemens

*Type No.	Fuse Class J	Comb. Mot. Ctlr. 3RV201 or 3RV202[1)]	Bkr TM 3RV1742	Bkr 3RV1721, 3RV1821	Bkr TM 3RV27, 3RV28	Bkr I	Short Circuit	Voltage
3RT2023		-				-	100 kA	600 V
	60 A			22 A	22 A	-	50 kA	480 V
		12.5 A			15 A	-	65 kA	480 V
				8 A	12.5 A	-	10 kA	600 V
			20 A			-	20 kA	600 V
		12.5 A				-	30 kA	600 V
3RT2024	60 A	-				-	100 kA	600 V
				22 A	22 A	-	50 kA	480 V
		12.5 A			**15 A**	-	65 kA	480 V
				12.5 A	12.5 A	-	10 kA	600 V
			20 A			-	20 kA	600 V
		12.5 A				-	30 kA	600 V

→ Circuit breaker 3RV27… maximum 15 A

Table 6- 8 Extract from the UL Certificate of Compliance of the 3RU2126 … thermal overload relays from Siemens

HIC Short Circuit Ratings for Overload Relays with CB Siemens type 3RV. 480V.

Overload Relay	Setting rating from (A) to (A)	Short Circuit Current	Voltage	Circuit Breaker type 3RV2711
3RU2126-1C	1.80 … 2.50	65 kA	480 V	15 A
3RU2126-1D	2.20 … 3.20	65 kA	480 V	15 A
3RU2126-1E	2.80 … 4.00	65 kA	480 V	15 A
3RU2126-1F	3.50 … 5.00	65 kA	480 V	15 A
3RU2126-1G	4.50 … 6.30	65 kA	480 V	15 A
3RU2126-1H	5.50 … 8.00	65 kA	480 V	15 A
3RU2126-1J	7.00 … 10.00	65 kA	480 V	15 A

→ Circuit breaker 3RV27… maximum 15 A

Since the protective device for the conductor is also not permitted to exceed 15 A, the following branch circuit results:

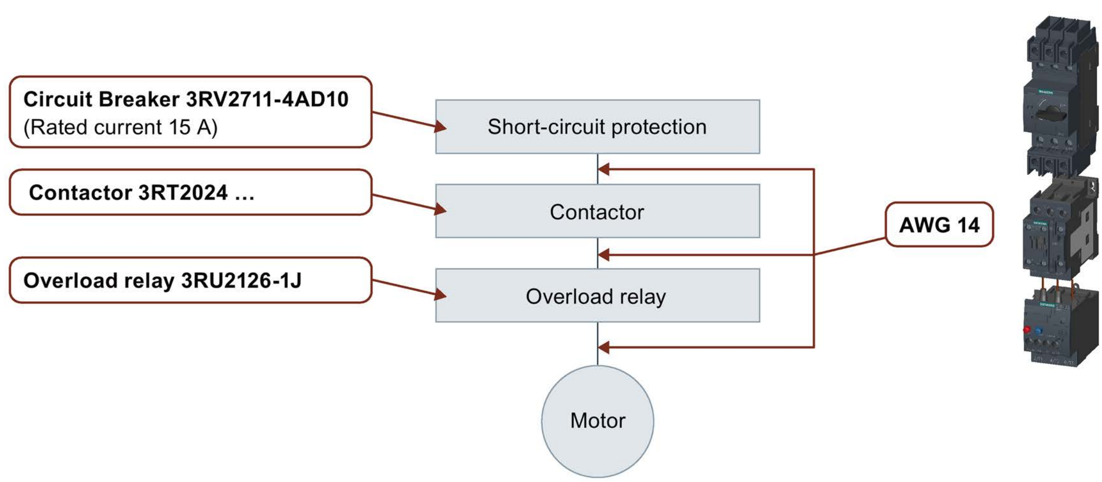


Figure 6-9 Fully dimensioned branch circuit

With a branch circuit Type F or Type E, the overload relay and the short-circuit protection are combined in one unit. In this case, the rated current shall be selected according to the overload relay.

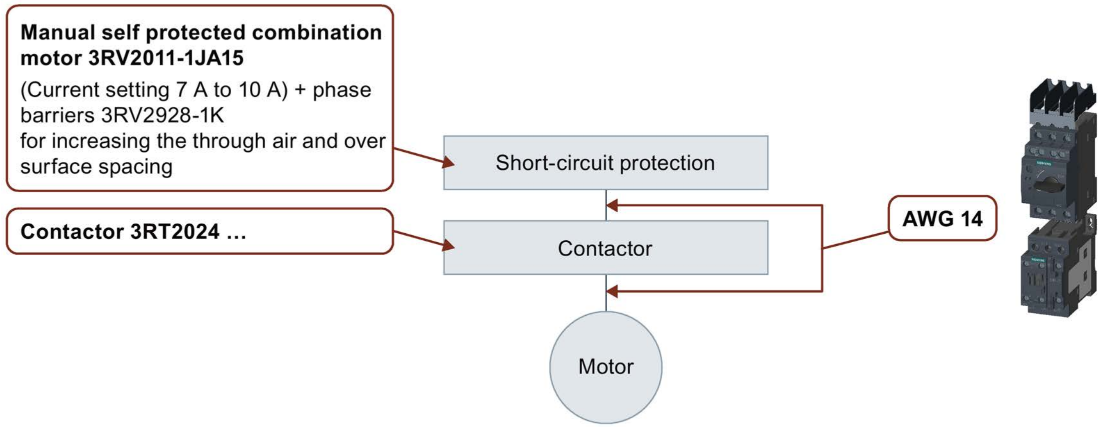


Figure 6-10 Motor branch circuit in accordance with Type F

You can find information on using industrial control equipment from Siemens in the UL Configuration Manual. You can download the UL Configuration Manual at:

- Industrial Control Panels for North America - Application consulting (http://www.siemens.com/applicationconsulting/ul)
- USA: UL Training - Automation Technology US (http://www.usa.siemens.com/controlpaneldesign)

6.3.1.2 Group Installation

Overview

"Group Installation" means several motors or one or more motors and other loads are protected with a shared short-circuit protective device.

The short-circuit protective device shall be a fuse in accordance with UL 248 – 4 … 12, 15 or an inverse-time circuit breaker in accordance with UL 489.

In relation to the four basic functions of a motor branch circuit, this means the following:

Table 6- 9 Basic functions of the motor branch circuit

Disconnecting means	→ Each motor individually or 1 x shared for the group
Short-circuit	→ 1 x shared for the group, sizing as described below
Motor control	→ Each motor individually, for sizing see Chapter Single Installation (Page 104)
Overload protection	→ Each motor individually, for sizing see Chapter Single Installation (Page 104)

The construction rules are described in detail in the NEC, UL 508A and also in NFPA 79. Since the rules are almost identical, the procedure in accordance with UL 508A is considered in more detail in this guide. Separate reference is made to differences to the NEC and NFPA 79.

UL 508A permits the following options in accordance with Chapter 31.4:

Method 1

- Short-circuit protective device does not exceed 20 A at ≤ 125 V or 15 A at ≤ 600 V
- No motor > 6 A
- Short-circuit protective device shall be selected in accordance with the manufacturer's specifications (nameplate or UL-Certificate of Compliance) for the components to be protected (e.g. contactor or overload relay)
- A group that contains non-motor loads shall be protected in each non-motor single branch circuit by an additional fuse in accordance with UL 248 – 4 … 12, 15 or an "Inverse-time circuit breaker" in accordance with UL 489, and it shall be sized in accordance with Chapter 6.3.2.1 to 6.3.2.4.

  Exception: If the group protection does not exceed the rating in accordance with Chapter 6.3.2.1 to 6.3.2.4, no additional short-circuit protection is required.

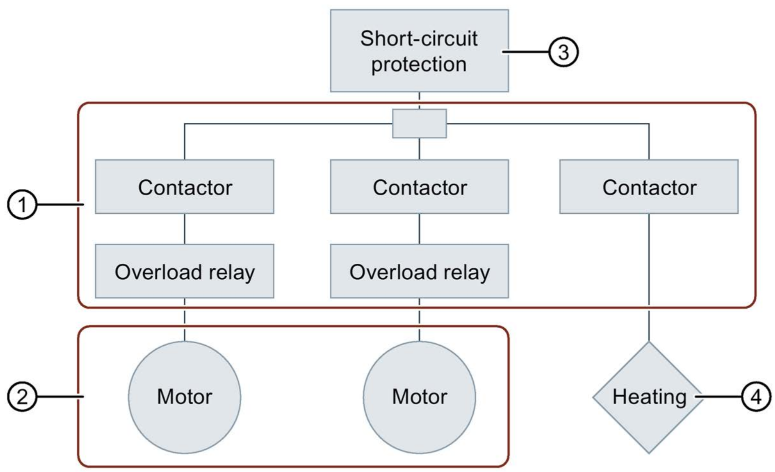


Figure 6-11 Group installation method 1

① **Step 1:** Check to see whether contactors and overload relays meet certain requirements for group installation. If they do, continue with method 3

→ **UL-Certificate of Compliance**

② **Step 2:** Motor current in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99), max. 6 A

③ **Step 3:** ≤ 20 A at max. 125 V or

≤ 15 A at max. 600 V

④ **Step 4:** Short-circuit protective device corresponds to the requirements in Chapter 6.3.2.2

→ **No additional short-circuit protection necessary in the individual branch circuit**

In the NEC, Chapter 430.53 and in NFPA 79, Chapter 7.2.10.2, the rule is described identically, with the addition that no motor > 1 HP may be connected.

Method 2

- The short-circuit protective device corresponds to the rules for Single Installation in Chapter Single Installation (Page 104) for each motor in the group.
- The ampacity of the tap conductors to individual loads shall not be less than $^1/_3$ of the ampacity of the branch circuit conductor for the load group.

  Exception: If a listed manual motor controller in accordance with UL 508 marked "Suitable for tap conductor protection" is provided in the individual branch circuits, the ampacity for each branch circuit may be sized to $^1/_{10}$ of the ampere rating of the branch circuit protection for the load group.

  The conductors on the load side of the manual motor controller shall have an ampacity of not less than 125 % in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99).

NOTICE
Non-motor loads
For non-motor loads, the cross-section is only permitted to be reduced to $^1/_3$.

- Non-motor loads: as described in method 1.

Without "Manual motor controller (MMC) suitable for tap conductor protection":

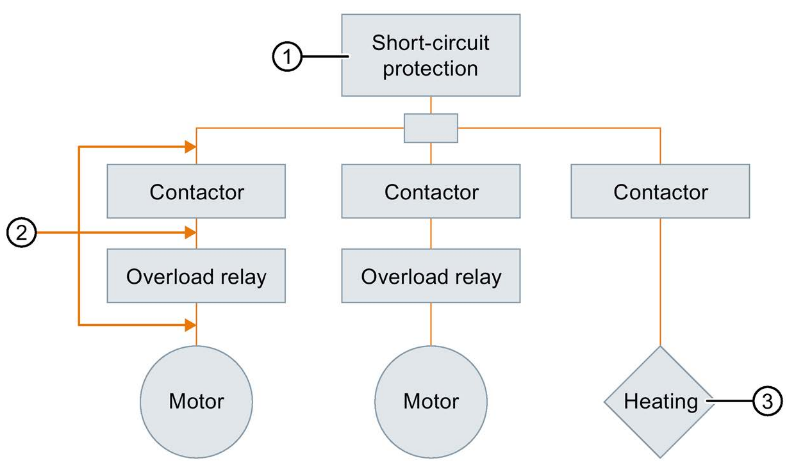


Figure 6-12 Group installation without tap conductor protection method 2

① **Step 1:** Short-circuit protection designed in accordance with rated motor current in compliance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98), sized acc. to Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106)

② **Step 2:** Ampacity of the conductor = $^1/_3$ of the branch circuit conductor to the load group

③ **Step 3:** Short-circuit protective device corresponds to the requirements in Chapter 6.3.2.2

→ **No additional short-circuit protection necessary in the individual branch circuit**

This rule too is similarly described in the NEC, Chapter 430.53, and in NFPA 79, Chapter 7.2.10.5.

However, the $^1/_3$ rule applies here only if the length of the cross-section-reduced conductor is ≤ 7.5 m (25 ft.) from the point where the ampacity of the branch circuit conductor is reduced up to the overload relay.

→ If the conductor length is > 7.5 m (25 ft.), it is not possible to reduce the cross-section in the individual branch circuits.

With Manual motor controller (MMC) suitable for tap conductor protection:

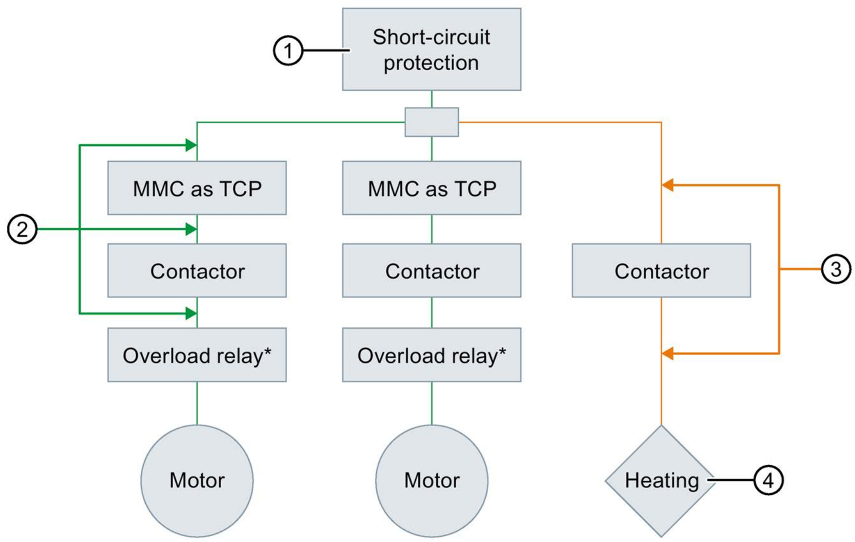


Figure 6-13 Group installation with tap conductor protection method 2

① **Step 1:** Short-circuit protection designed in accordance with rated motor current in compliance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98), sized acc. to Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106)

② **Step 2:** Ampacity of the conductor = $^1/_{10}$ of the rated current of the branch circuit protective device under Point 1

③ **Step 3:** Ampacity of the conductor = $^1/_3$ of the branch circuit conductor

④ **Step 4:** Short-circuit protection device corresponds to the requirements in Chapter Heater loads (Page 123)

→ **No additional short-circuit protection necessary in the individual branch circuit**

* Can also be integrated into the manual motor controller

Method 3

- All components on the load side of the short-circuit protective device are approved in accordance with the manufacturer's specifications for group installation. See the nameplate of the components, the UL-Certificate of compliance, or also the temperature rise table in the case of overload relays.
- The conductor is sized as in method 2.
- Non-motor loads as in method 1 and 2.
- The rating of the short-circuit protective device is not permitted to exceed the lower value of the following conditions:
  - Sizing according to the largest motor in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99)

    Maximum sizing in accordance with Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106) + of the standard currents of the other motors + the rated currents of all non-motor loads.
  - The smallest required short-circuit protective device of all components in the group installation (nameplate, UL-Certificate of compliance).

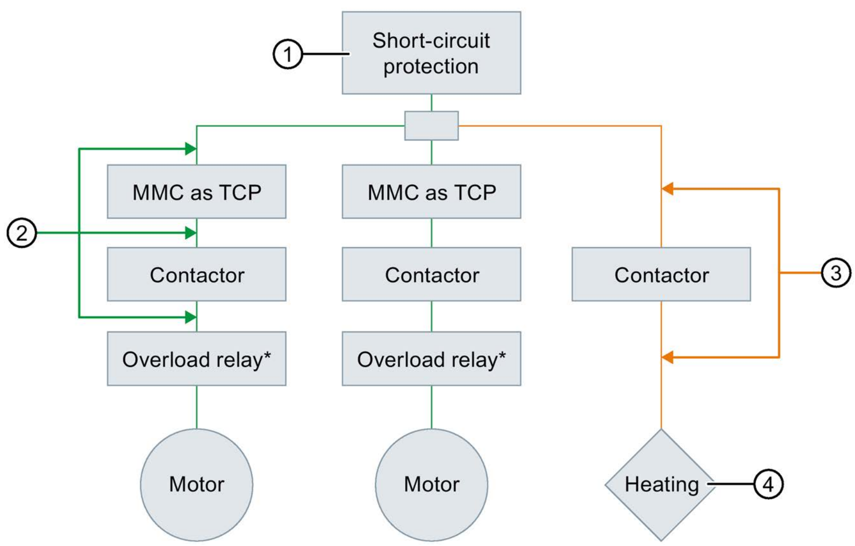


Figure 6-14 Group installation method 3

① **Step 1:** Short-circuit protection in accordance with the lower of the following:
- Largest motor x value from Table 6-5 Maximum rating of motor branch circuit device percent of full load amperes (Page 106) + sum of all other loads
- Lowest required short-circuit protection of all components in the group

② **Step 2:** Ampacity of the conductor = $^1/_{10}$ of the rated current of the branch circuit protective device under Point 1

③ **Step 3:** Ampacity of the conductor = $^1/_3$ of the branch circuit conductor

④ **Step 4:** Short-circuit protection device corresponds to the requirements in Chapter Heater loads (Page 123)

→ **No additional short-circuit protection necessary in the individual branch circuit**

* Can also be integrated into the manual motor controller

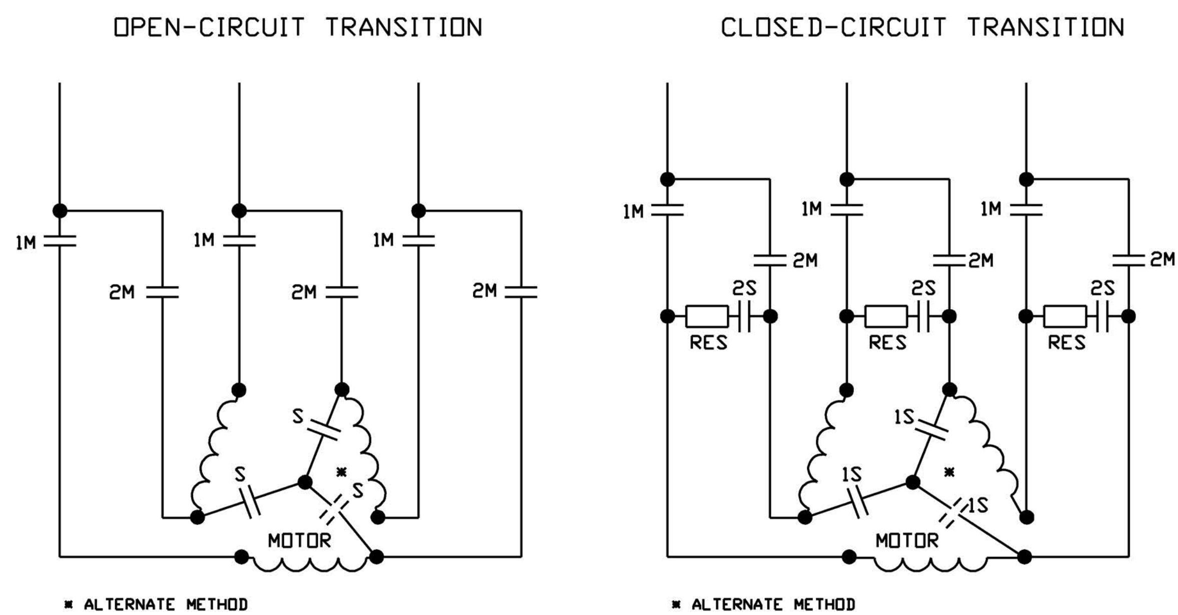
6.3.1.3 Contactor assemblies for wye-delta start

Wye-delta starting of motors is a very popular way of reducing the locked-rotor current.

UL 508A, Chapter 33.5, describes 2 arrangements, with and without current interrupts for switching from wye to delta: "open-circuit" and "closed-circuit transition".

Figure 33.1
Contactor sequencing

Figure 33.1 effective April 25, 2003



CONTACTOR SEQUENCE				
CON-TACTOR	START		TRAN-SITION	RUN
1M		X	X	X
2M				X
S	X			

CONTACTOR SEQUENCE						
CON-TACTOR	START		TRANSITION 1	TRANSITION 2	TRANSITION 3	RUN
1M		X	X	X	X	X
2M					X	X
1S	X		X			
2S			X	X	X	

SM1261

Figure 6-15 Wye-delta circuits in accordance with UL 508A (source: UL 508A, Figure 33.1)

With closed-circuit transition, the motor remains connected to the power system via an additional contactor-resistor assembly (not designed for full-load amps) during the switch from wye to delta.

The most common application is open-circuit transition. Closed-circuit transition is used when current peaks, which may arise with large motors when switching from wye to delta, are not permitted.

It is more economically effective today to use a soft starter instead of this assembly. Siemens too has many different soft starters in its portfolio.

Only open-circuit transition is described here.

Contactor sizing

The armature blocking current and the ampere rating of the contactor shall be sized at least according to the table below:

Table 6- 10 Contactor sizing for wye-delta controller

Contactor designation	Required contactor ampere rating	
	"make"current, LRA	"break" current, FLA
1M	0.3 multiplied by motor LRA	0.577 multiplied by motor FLA
2M	0.577 multiplied by motor LRA	0.577 multiplied by motor FLA
1S	No current	0.33 multiplied by motor LRA
2S	a	a
[a] Rating of contactor shall be determined on the basis of the impedance provided.		

Source: UL 508A, Table 33.2

The ampere rating of the contactor shall be selected to suit the motor rating in accordance with Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98). The contactor shall be approved for an armature blocking current corresponding to 6 times the full-load amps or the armature blocking current specified on the motor.

If contactors with standard sizes are used and the armature blocking current is not greater than 6 x the full-load amps the contactor size and resulting wye-delta rating can be taken from the table below.

Table 6- 11 Horsepower ratings of wye-delta controllers using standard size contactors

Size of controller	Size of contactor[a]		3-phase horsepower			
	M1 and M2	S	60 Hz	60 Hz	50 Hz	60 Hz
			200 volts	230 volts	380 volts	460 or 575 volts
1YD	1	1	10	10	15	15
2YD	2	2	20	25	40	40
3YD	3	3	40	50	75	75
4YD	4	4	60	75	150	150
5YD	5	5	150	150	250	300
6YD	6	6	300	350	500	700
7YD	7	6	500	500	800	1000
8YD	8	7	750	800	1000	1500
9YD	9	8	1500	1500	2000	3000

NOTE – For motors having locked-rotor currents greater than 6 times the full-load current, use Table 33.2

[a] See Table 33.4 for horsepower ratings corresponding to standard size contactors.

Source: UL 508A, Table 33.3

The table below shows the minimum horsepower ratings of standard size contactors:

Table 6- 12 Horsepower ratings of standard size full-voltage magnetic motor controllers

Size of controller	3-phase horsepower			
	60 Hz	60 Hz	50 Hz	60 Hz
	200 volts	230 volts	380 volts	460 or 575 volts
1	7-1/2	7-1/2	10	10
2	10	15	25	25
3	25	30	50	50
4	40	50	75	100
5	75	100	150	200
6	150	200	300	400
7	–	300	–	600
8	–	450	–	900
9	–	800	–	1600

NOTE – For motors having locked-rotor currents greater than 6 times the full-load current, use Table 33.2.

Source: UL 508A, Table 33.4

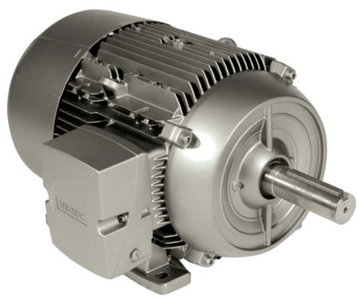
Overload protection

In accordance with UL 508A, Chapter 34.3.6, an overload relay shall be located on the load side of contactor 1M, and shall be sized with 0.577 multiplied by the Full-Load Amps.

The starting time of the motor shall be coordinated with an overload relay Class 20 (20 s).

Example

Sizing of a wye-delta contactor assembly for the same motor as in Chapter Single Installation (Page 104):



Power rating:	7.5 HP
Voltage:	460 V
Full-Load Amps FLA:	8.8 A
Service factor:	1.15

Figure 6-16 Siemens motor

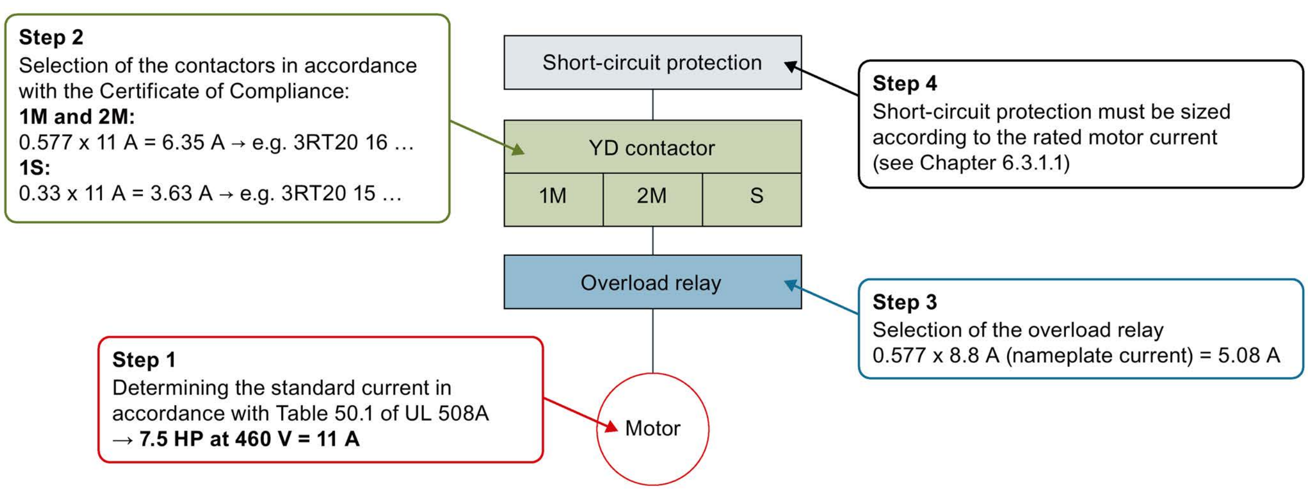


Figure 6-17 Sizing of a contactor assembly for wye-delta start

Note

The wye contactor is not relevant for the short-circuit current rating according to UL 508A, SB 4.2. This means that, in accordance with the Certificate of Compliance, the short-circuit protection device shall only be suitable for the line and delta contactor.

6.3.2 Non-motor loads

The type of protection for non-motor loads depends on the load involved. UL 508A regulates this in Chapters 31.5 to 31.8. NFPA 79 describes this in Chapter 7.

The rules to be complied with for the respective loads are described by this guide in the chapters below.

In general, only fuses to UL 248-4…12, -15 or circuit breakers to UL 489 are permissible for use as short-circuit protection for non-motor loads.

6.3.2.1 Receptacles

The requirements regarding receptacles are described in detail in Chapter Receptacle for accessories and maintenance (Page 251). This chapter is restricted to short-circuit protection for receptacles.

Requirements from UL 508A, Chapter 31.5

A single general-use receptacle shall not have a higher protection rating than the ampere rating of the receptacle.

A short-circuit protective device for a duplex receptacle or two or more receptacles shall not have a higher ampere rating than the receptacle(s).

Exception 1

A short-circuit protective device with a rating of 20 A is able to be used for a 15 A receptacle.

Exception 2

Short-circuit protective devices having a rating that is smaller than the rating of the receptacle(s) are able to be used for a receptacle intended for use with special loads and shall be marked with the rating and the intended load.

Figure 6-18 Marking of a receptacle

Requirements from NFPA 79, Chapter 7

Short-circuit protection shall be provided for circuits that supply receptacles for maintenance purposes.

Short-circuit protection ≤ 15 A shall be provided for all ungrounded conductors.

A fuse to UL 248-4…12, -15, or a circuit breaker to UL 489 shall be used as the short-circuit protective device.

6.3.2.2 Heater loads

Requirements from UL 508A, Chapter 31.6.1

Resistance heating elements (AC-1) shall be provided with branch circuit protection sized:

1. Not less than 125 % of the rated current of the heater
2. Not larger than 60 A or
3. Not larger than the ampacity of the wiring (see Table 6-11 Horsepower ratings of wye-delta controllers using standard size contactors (Page 120))

This means a heater shall carry no more than 48 A of rated current.

Exception 1

Resistance heating elements (AC-1) in a water heater or steam boiler having an ASME rating (professional association of mechanical engineers in the USA) shall comply with the following requirements:

- Short-circuit protection maximum 150 A
- The type of load shall be specified in addition to the load rating

  Examples: "Water heater with ASME vessel", "Steam boiler with ASME vessel", "Pipeline heater", "Industrial furnace" or comparable designations

Exception 2

For heaters used for industrial furnaces, pipelines and vessels/boilers, or outdoor de-icing systems or snow melting systems where the heater is not able to be subdivided into circuits ≤ 48 A, the short-circuit protective device shall be sized only in accordance with UL 508A, Chapter 31.6.1 (see Point 1 and Point 2 above).

Exception 3

Short-circuit protective devices > 60 A are able to be used in the industrial control panel if the field wiring diagram specifies additional short-circuit protective devices ≤ 60 A outside the control panel.

Requirements from NFPA 79, Chapter 7.2.11.2

Heater loads > 48 A shall be subdivided. The short-circuit protective devices of the subdivided loads shall not exceed 60 A.

Exception

A single sheath-type heating element requiring more than 48 A shall be protected at not more than 125 % of the rated current, where the element is integral with and enclosed within the machine housing.

The short-circuit protective devices of the subdivided loads shall fulfill all the following criteria:

1. Installed within or on the machinery, or provided as a separate assembly
2. They shall be accessible (but not readily accessible)
3. They shall be approved for short-circuit protection

A fuse to UL 248-4…12, -15, or a circuit breaker to UL 489 shall be used as the short-circuit protective device.

6.3.2.3 Overcurrent protection for appliance loads

For protecting a non-motor load not described under Chapter 6.3.2.1/2/4/5/6, the short-circuit protection shall be sized as follows in accordance with UL 508A, Chapter 31.7:

1. In accordance with the marking on the device or
2. Max. 20A for devices with less than 13.3A rated current (if 1. not available) or
3. Max. 150 % for devices with greater than 13.3A rated current (if 1. not available)

Exception 1

For appliances with a power supply cord and attachment plug, protection is provided via the receptacle (see Chapter Receptacles (Page 122))

Exception 2

If the short-circuit protective device calculated in accordance with Point 3 does not correspond to a standard size, the next larger size is able to be used.

NFPA 79 requires the following in Chapter 7.11.1:

If the branch circuit contains non-motor loads > 16.7 A, the short-circuit protection is not allowed to exceed 150 % of the rated current of the load.

6.3.2.4 Overcurrent protection for lighting loads

Lighting circuits are described in UL 508A, Chapter 31.8.

Short-circuit protective devices for standard-duty incandescent lampholders or fluorescent ballasts shall have a rating of ≤ 20 A, and shall not exceed the ampacity of the wiring.

Short-circuit protective devices for lampholders marked heavy duty for use with fluorescent or infrared lamps shall have a rating of ≤ 50 A, and shall not exceed the ampacity of the wiring.

In accordance with NFPA 79, Chapter 7.2.6, lighting circuits shall be protected with ≤ 15 A.

Further requirements for lighting are described in Chapter Control panel lighting and machine lighting (Page 255).

6.3.2.5 Variable-speed drives, servo motors and semiconductor devices

Variable-speed drives shall be approved in accordance with UL 508C and semiconductor devices in accordance with UL 508.

Requirements according to UL 508A

Branch circuit (short-circuit) protection

According to UL 508A, Chapter 31.3.2, branch circuit protection for variable-speed drives shall be of the type and size specified by the manufacturer of the drive (e.g. in the UL Certificate of Compliance).

Short Circuit Ratings are provided as follows:

Table A

Part No. / model	Volts	SCCR	Protective Device			
				current rating	class or model	voltage / SCCR
6SL3130-1TE24-0A..	480	65 kA	Fuse	100A	Class J	600Vac 200kA
	480	65 kA	C.B.		3VL2110-2KN30	480Vac 65kA
	480	65 kA	C.B.		3VL2110-3KN30	480Vac 100kA

C.B. = circuit breaker

Figure 6-19 Extract from a UL report of a Siemens Sinamics Basic Line Module

If the manufacturer does not specify a short-circuit protective device and rating, an Inverse-time circuit breaker to UL 489 or a Branch circuit fuse to UL 248-4…12, -15 shall be used.

In this case, the short-circuit protective device may be sized to no higher than the full-load output current of the variable-speed drive multiplied by the values of Table 6-6 Extract from the UL Certificate of Compliance of the 3RT202… contactors from Siemens (Page 108).

Exception 1

Additional short-circuit protection is not required if the Inverse-time circuit breaker, a Branch circuit fuse , or a semiconductor fuse is integrated into the variable-speed drive.

Exception 2

Unless specified in the manufacturer's instructions for a variable-speed drive, additional short-circuit protection is not necessary in the DC incoming supply circuit conductors for a common bus inverter.

Short-circuit protection of semiconductor contactors and soft starters shall be sized as described in the manufacturer's UL Certificate of Compliance.

Overload protection

Shall be specified in the UL report if integrated into the device.

```
-     This equipment is capable of providing internal motor overload
      protection according to UL508C. The marking shall indicate protection
      level in percent of full-load current & instructions for adjustment.
```

Figure 6-20 Extract from the UL report of the Siemens Sinamics G120D drive

Requirements of NFPA 79

Overload protection

- Overload protection shall be provided for every motor
- If the overload protection is integrated in the device, no additional protection is required
- Each motor in a motor group shall have its own overload protection

Protection against overtemperature

Servo drives shall be protected against overheating by means of one of the following measures:

- Integral thermistor protection
- Servo drive controllers with overload and overspeed protection with latching shutdown or cable loss through overheating
- Temperature relays with sensors in the motor
- Motors with cooling circuit

Note

In addition to conductor protection, protection against overheating shall also be used.

Systems for motor cooling (e.g. air or water cooling) shall have protective measures that exclude the possibility of failure of the cooling function.

Each motor in a motor group shall have its own protection against overheating.

Automatic restart is not permissible in the following cases:

- Not tested with the motor
- A hazard for persons can arise

Note

Shutdown in the event of a fault shall not result in an increased hazard. If it could result in an increased hazard, a higher-level alarm shall initiate a controlled shutdown.

6.3.2.6 Power transformers

Transformers in the power circuit shall be approved in accordance with UL 508A, Chapter 35.1 to UL 5085-1/2 or UL 1561.

Primary-side protection only

Chapter 35.2 of UL 508A stipulates only primary-side protection in the following cases:

- A two-wire single voltage on the secondary side
- A three-wire three-phase single voltage on the secondary side with both primary and secondary sides connected in a delta configuration

The protective device shall be a Branch circuit fuse to UL 248-4…12, -15 or an Inverse-time circuit breaker to UL 489, and shall be sized to UL 508A (see table below).

Table 6- 13 Sizing of primary winding only branch circuit protection

Power transformer primary current, amperes	Rating of branch circuit protection, maximum percentage of primary current
9 or more	125[a]
2 … 8.99	167
less than 2	300

[a] Where the calculated size of the branch circuit protection does not correspond to a standard size fuse or non-adjustable inverse-time circuit breaker, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection equipment.

Source: UL 508A, Table 35.1

The conductors on the secondary side of the transformer shall be sized in accordance with Table 11-7 Conductor ampacity based on copper conductors with 60 °C (140 °F), 75 °C (167 °F) and 90 °C (194 °F) insulation in an ambient temperature of 30 °C (86 °F) (Page 226), and in accordance with the primary-side protective device. The transformation ratio shall, of course, be observed here.

Primary-side and secondary-side protection

Primary-side and secondary-side protection is required if the transformer has multiple secondary-side windings / branches

The protective devices on the primary and secondary side shall be a Branch circuit fuse to UL 248-4…12, -15 or an Inverse-time circuit breaker to UL 489. The protective devices shall be sized according to UL 508A (see the table below), or according to UL 248-4…12, -15 if there are more than one Branch circuit fuse, and an Inverse-time circuit breaker shall be sized according to UL 489 if the total of the ampere ratings of the short-circuit protective devices do not exceed the values in the table below.

Table 6- 14 Sizing of primary and secondary branch circuit protection of a power transformer

Primary winding		Secondary winding	
Rated amperes	Branch circuit protection, percent of rated amperes	Rated amperes	Branch circuit protection, percent of rated amperes
9 or more	250	9 or more	125[a]
2 … 8.99	250	less than 9	167
less than 2	300	–	–

[a] Where the calculated size of the branch circuit protection does not correspond to a standard size fuse or non-adjustable inverse-time circuit breaker, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection equipment.

Source: UL 508A, Table 35.2

6.4 Short-circuit current rating (SCCR) and calculation

In accordance with NEC, Chapter 409.110, every Industrial control panel shall be labeled with a short-circuit rating (SCCR). The specified SCCR shall meet one of the following requirements:

- Corresponds to a listed and labeled device
- Has been calculated using an approved method

The logic behind this requirement is fire safety and personal safety. Connection of the industrial control panel to a current source in which a short-circuit current can arise that is potentially higher than the calculated value of the control panel should be prevented.

An approved method is, for example, the method according to UL 508A, Supplement SB.

The SCCR value that can arise depends on the supply transformer and shall be specified to the panel builder by the customer.

All components in the power circuit are included when considering the short-circuit current rating. The component with the smallest SCCR value defines the SCCR value of the overall control panel.

In Section SB4.2.1 and Table SB4.1, UL 508A lists the following components as parts of the power circuit:

- Disconnect switches
- Supplementary protectors
- Branch Circuit Protective Devices
- Bus bars
- Fuse holders
- Current meters
- Load controllers
- Current shunts
- Motor overload relays
- Industrial control equipment
- Receptacles
- Terminal blocks or distribution blocks

Exception 1

- Power transformers
- Reactors
- Current transformers
- Dry-type capacitors
- Resistors
- Varistors
- Voltmeters

Exception 2

The wye (S) contactor of a wye-delta motor controller

Exception 3

Enclosure air conditioners or multi-motor and combination load equipment that are cord-and-attachment-plug connected or supplied from a Branch Circuit that is protected at 60 A or less are not required to have a short circuit current rating.

In Section SB3.2.1, UL 508A stipulates that the primary short-circuit protective device for the control circuit shall also be included in the calculation of the SCCR value for the power circuit. For this reason, the SCCR value of overcurrent protective devices used on the primary side of a control transformer (exclusively Supplementary Protectors recognized according to UL 1077 or Supplemental fuses recognized according to UL 248-13) is included in the calculation of the SCCR of the control panel. Control circuit components downstream of these devices are not included when calculating the SCCR.

The SCCR of individual power circuit components can be determined using four possible methods:

1. On the basis of SCCR marked on the component or on data sheets provided with the components

Most control and protective devices for the power circuit are marked on the front or on the nameplate with a standard SCCR.

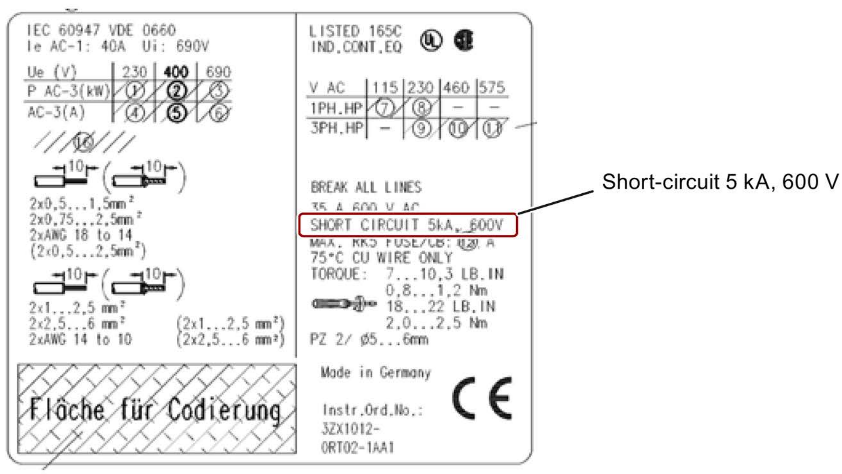


Figure 6-21 Example of 3RT contactor label

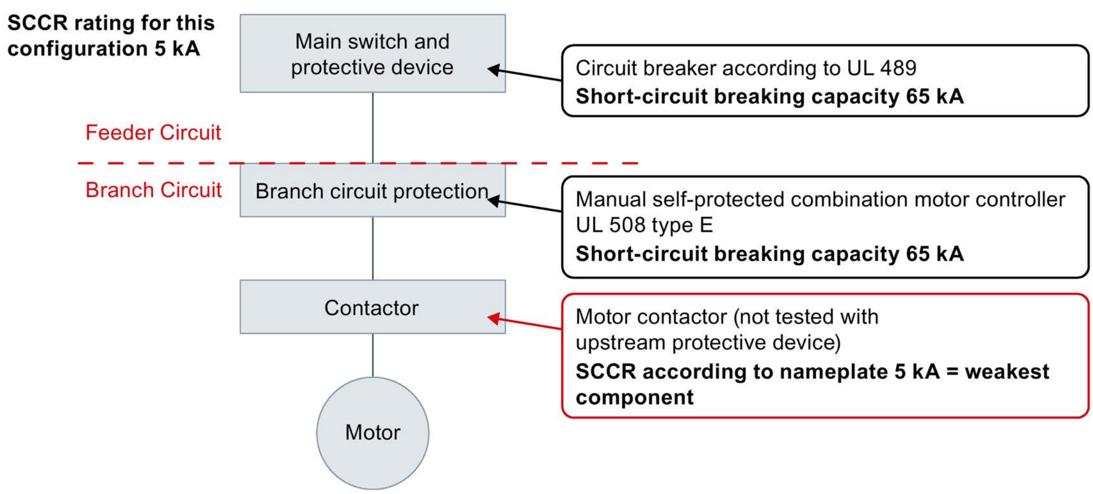


Figure 6-22 Example of "Determining the SCCR marked on the component"

2. On the basis of the assumed SCCR

For unmarked components, the assumed maximum SCCR can be used in accordance with the table below when determining the SCCR:

Table 6- 15 Assumed maximum short circuit current rating for unmarked components

Component	Short-circuit current rating, kA
Bus bars	10
Circuit breakers (including GFCI type)	5
Current meters	a
Current shunt	10
Fuse holder	10
Industrial control equipment	
a. Auxiliary devices (overload relays)	5
b. Switches (other than mercury tube type)	5
c. Mercury tube switches	
Rated over 60 A or 250 V	5
Rated 250 V or less, 60 A or less and over 2 kVA	3.5
Rated 250 V or less and 2 kVA or less	1
Motor controller, rated in horsepower (kW)	
a. 0 … 50 (0 … 37.3)	5[c]
b. 51 … 200 (38 … 149)	10[c]
c. 201 … 400 (150 … 298)	18[c]
d. 401 … 600 (299 … 447)	30[c]
e. 601 … 900 (448 … 671)	42[c]
f. 901 … 1500 (672 … 1193)	85[c]
Meter socket base	10
Miniature or miscellaneous fuse	10[b]
Receptacle (GFCI type)	2
Receptacle (other than GFCI type)	10
Supplementary protector	0.2
Switch unit	5
Terminal block or power distribution block	10

[a] A short-circuit current rating is not required when connected via a current transformer or current shunt. A directly connected current meter shall have a marked short circuit current rating.

[b] The use of a miniature fuse is limited to 125-V circuits.

[c] Standard fault current rating for motor controller rated within specified horsepower range.

Source: UL 508A, Table SB4.1

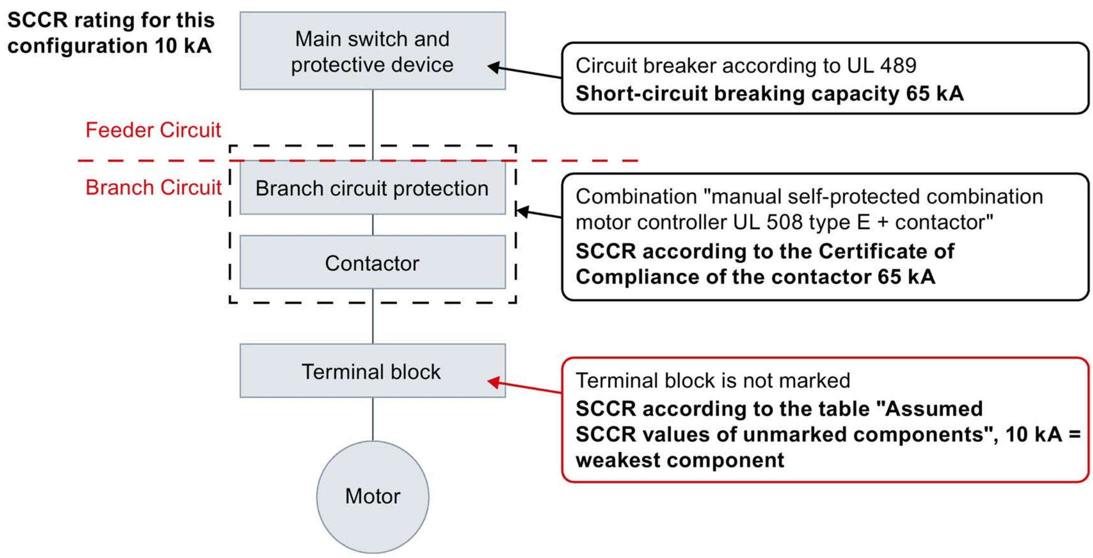


Figure 6-23 Example of "Determining the SCCR on the basis of the assumed SCCR"

3. On the basis of tested device combinations in accordance with UL 508

If the SCCR value of a component in the power circuit does not fulfill the desired SCCR value, measures shall be taken to increase it. To increase the SCCR value of a device, an appropriate protective device shall be connected upstream. The suitable protective device is to be taken from the respective UL Certificate of Compliance of the device for which the SCCR value is to be increased.

Example: A 3RT2015… contactor has a standard value of 5 kA according to the nameplate. The UL Certificate of Compliance specifies the protective devices with which the short-circuit rating can be increased. Thus a value of, for example, 65 kA at 480 V is achieved if the contactor is protected with a 3RV2.1 or 3RV2.2 combination motor controller max. 16 A.

High Capacity Short Circuit Ratings:

			Circuit Breaker					
Type No.	Fuse Class J	Comb. Mtr. Ctlr. 3RV2.1 or 3RV2.2	Bkr TM 3RV1742	Bkr TM 3RV1721, 3RV1821	Bkr TM 3RV2711, 3RV2811	Bkr I	Short Circuit	Voltage
3RT2015	25 A					-	100 kA	600 V
			10 A			-	42 kA	480 V
				22 A		-	50 kA	480 V
		16 A			15 A	-	65 kA	480 V
				8 A	3.2 A	-	10 kA	600 V
		12.5 A				-	30 kA	600 V

Figure 6-24 Extract from the Certificate of Compliance of the Siemens 3RT2015… contactor

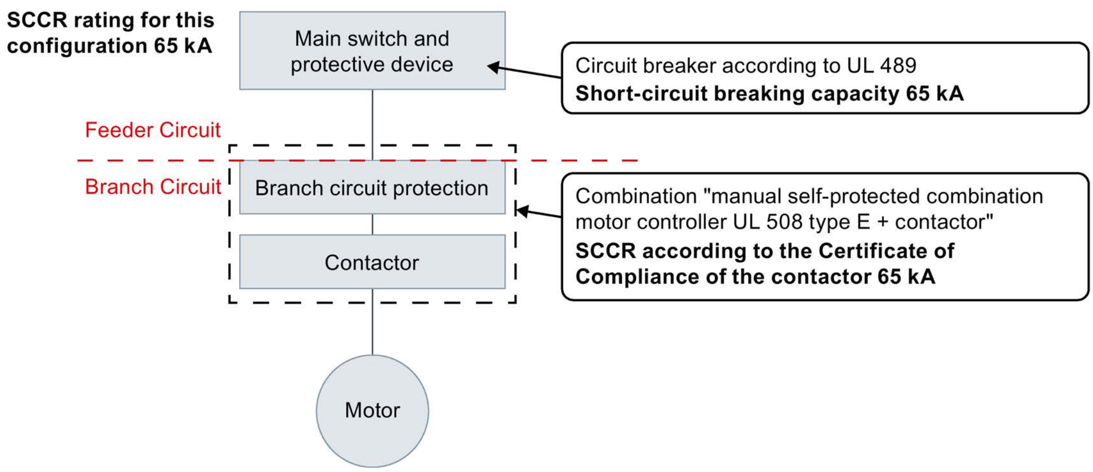


Figure 6-25 Example of "Determining the SCCR on the basis of tested device combinations"

4. Adaptation of the available short-circuit current on the basis of let-through values when using current-limiting devices in the feeder circuit

When using short-circuit-current-limiting components in the feeder circuit, all components in the branch circuit shall be sized for the let-through current of the short-circuit-current-limiting component in the feeder circuit.

Short-circuit-current-limiting components shall be located **fully in the Feeder Circuit**. The following components can be used to limit the short-circuit current:

- Transformers
- Fuses
- Circuit breakers according to UL 489 marked "current limiting"

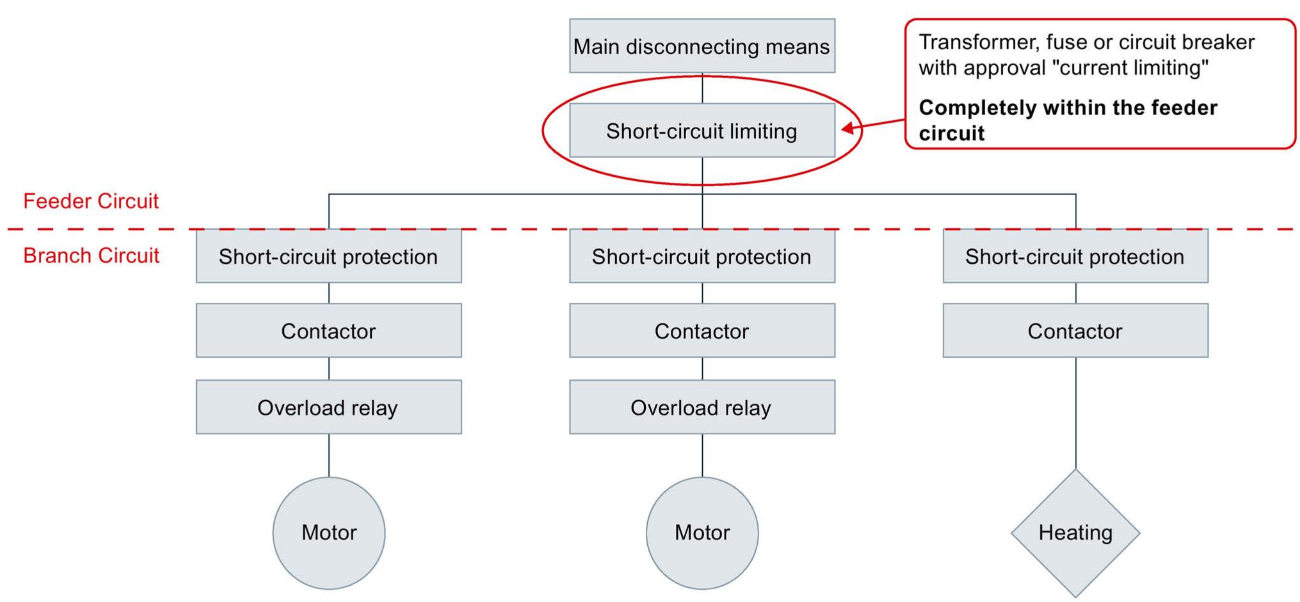


Figure 6-26 Diagram showing "short-circuit limiting in the feeder circuit"

a) Current-limiting transformers

Transformers with known relative short-circuit voltage (= Impedance Z in accordance with UL 508A)

The short-circuit current that can arise on the secondary side of the transformer is calculated as follows:

$$\text{Secondary rated current } (I_{FL}) \text{ [A]} = \frac{\text{Transformer rating (P) [VA]}}{\text{Secondary voltage } (U_{sec}) \text{ [V]} \times \sqrt{3}}$$

Note

With single-phase transformers, the factor √3 is omitted.

$$\text{Secondary short-circuit current } (I_{SC}) \text{ [A]} = \frac{\text{Secondary rated current } (I_{FL}) \text{ [A]}}{\text{Impedance (Z) [\%]}}$$

All branch circuits on the secondary side of the transformer shall be sized to be ≥ the calculated short-circuit current (I_{sc}).

→ SCCR of the branch circuits = short-circuit interrupting rating of the primary short-circuit protective device

Transformers with unknown relative short-circuit voltage (= Impedance Z in accordance with UL 508A) or impedance Z ≥ 2.1 %

The maximum secondary short-circuit current can be calculated either using the formulas above assuming Z = 2.1 % , or with the help of the two tables below "Secondary short-circuit current of single-phase transformers" (single-phase) or "Secondary short-circuit current of three-phase transformers" (three-phase) as follows:

1. The transformer power shall be ≤ column 1 **and**
2. The secondary voltage shall not be less than the values in column 2. If the secondary voltage is between the values, the column with the next lower voltage is to be selected.

Table 6- 16 Single phase transformer secondary available short circuit currents [a]

Column 1	Column 2							
Trans-former Max. kVA	Minimum transformer secondary voltage (V)							
	120	120/240[b]	208	240	277	347	480	600
1	400 A	300 A	230 A	200 A	180 A	140 A	100 A	80 A
3	1,200 A	900 A	690 A	600 A	520 A	420 A	300 A	240 A
5	1,990 A	1,490 A	1,150 A	1,000 A	860 A	690 A	500 A	400 A
10	3,970 A	2,980 A	2,290 A	1,990 A	1,720 A	1,380 A	1,000 A	800 A
15	5,960 A	4,470 A	3,440 A	2,980 A	2,580 A	2,060 A	1,490 A	1,200 A
25	9,930 A	7,450 A	5,730 A	4,970 A	4,300 A	3,440 A	2,490 A	1,990 A
37.5	14,890 A	11,170 A	8,590 A	7,450 A	6,450 A	5,150 A	3,730 A	2,980 A
50	19,850 A	14,890 A	11,450 A	9,930 A	8,600 A	6,870 A	4,970 A	3,970 A
75	29,770 A	22,330 A	17,180 A	14,890 A	12,900 A	10,300 A	7,450 A	5,960 A

[a] Requirement: Z assumed to be 2.1 %.

[b] Short-circuit current shown is line-to-neutral.

Source: UL 508A, Table SB4.3

Table 6- 17 Three-phase transformer secondary available short circuit currents [a]

Column 1	Column 2						
Trans-former Max. kVA	Minimum transformer secondary voltage (V)						
	208Y/120[b]	208	240	480Y/277[b]	480	600Y/347[b]	600
5	1,160 A	930 A	810 A	510 A	410 A	410 A	330 A
10	2,320 A	1,860 A	1,610 A	1,010 A	810 A	810 A	650 A
15	3,470 A	2,780 A	2,410 A	1,510 A	1,210 A	1,210 A	970 A
20	4,630 A	3,710 A	3,210 A	2,010 A	1,610 A	1,610 A	1,290 A
25	5,790 A	4,630 A	4,010 A	2,510 A	2,010 A	2,010 A	1,610 A
30	6,940 A	5,560 A	4,820 A	3,010 A	2,410 A	2,410 A	1,930 A
45	10,410 A	8,330 A	7,220 A	4,520 A	3,610 A	3,610 A	2,890 A
75	17,350 A	13,880 A	12,030 A	7,520 A	6,020 A	6,020 A	4,820 A
100	23,140 A	18,510 A	16,040 A	10,030 A	8,020 A	8,020 A	6,420 A

[a] Requirement: Z assumed to be 2.1 %.

[b] Short-circuit current shown is line-to-neutral.

Source: UL 508A, Table SB4.4

All branch circuits on the secondary side of the transformer shall be sized to be ≥ the calculated secondary short-circuit current (I_{sc}).

→ SCCR of the branch circuits = short-circuit interrupting rating of the primary short-circuit protective device

b) Current-limiting circuit breakers (in accordance with UL 489)

To be able to use a circuit breaker in accordance with UL 489 as a current-limiting component in the feeder circuit, it shall be marked with the information "current limiting".

In this case, the let-through values of the circuit breaker shall be taken into account.

The let-through value is taken from the characteristic of the circuit breaker.

The **SCCR value** of the branch circuits **corresponds to the interrupting rating of the circuit breaker** in the feeder circuit under the following conditions:

- The SCCR value of all individual components in the branch circuit is not less than the peak let-through current of the circuit breaker in the feeder circuit.
- The interrupting rating of all branch circuit protective devices or the SCCR value of all Combination Motor Controllers is not less than the interrupting rating of the circuit breaker in the feeder circuit.

→ The SCCR value of the branch circuits corresponds to the smallest interrupting rating of a branch circuit protective device or Combination Motor Controllers connected downstream of the circuit breaker in the feeder circuit if this is less than the interrupting rating of the circuit breaker in the feeder circuit.

→ The SCCR value of the configuration corresponds to the smallest SCCR value of any branch circuit connected downstream of the circuit breaker if the above-named conditions are not met.

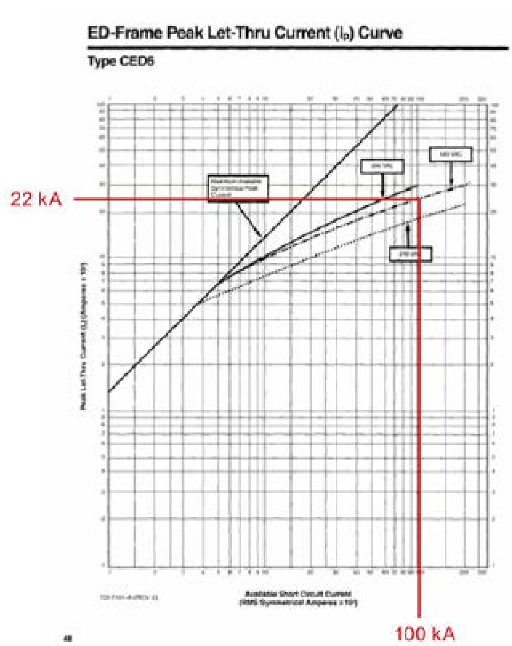


Figure 6-27 Let-through characteristic of a circuit breaker marked as "current limiting"

The selected circuit breaker lets 22 kA through at a short-circuit current of 100 kA.

⇒ In other words, all components in the branch circuit shall be sized for at least 22 kA.

The industrial control panel is suitable for a maximum let-through value of 100 kA.

c) Current-limiting fuses

Only fuses from the table "Peak let-through currents and I^2t values for fuses" below may be used as current-limiting fuses. This table contains the corresponding let-through values (see the column $I_p \times 10^3$).

Table 6- 18 Peak let-through currents and I^2t values for fuses

Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
Class CC	15	2	3	2	3	3	4
	20	2	3	3	4	3	5
	30	7	6	7	7.5	7	12
Class G	15	–	–	3.8	4	–	–
	20	–	–	5	5	–	–
	30	–	–	7	7	–	–
	60	–	–	25	10.5	–	–

Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
300 V, Class T[b]	1	–	–	0.4	0.8	–	–
	3	–	–	0.6	1.3	–	–
	6	–	–	1	2	–	–
	10	–	–	1.5	3	–	–
	15	–	–	2	4	–	–
	20	–	–	2.5	4.5	–	–
	25	–	–	2.7	5.5	–	–
	30	3.5	5	3.5	7	3.5	9
	35	–	–	6	7	–	–
	40	–	–	8.5	7.2	–	–
	45	–	–	9	7.6	–	–
	50	–	–	11	8	–	–
	60	15	7	15	9	15	12
	70	–	–	25	10	–	–
	80	–	–	30	10.7	–	–
	90	–	–	38	11.6	–	–
	100	40	9	40	12	40	12
	110	–	–	50	12	–	–
	125	–	–	75	13	–	–
	150	–	–	88	14	–	–
	175	–	–	115	15	–	–
	200	150	30	150	16	150	20
	225	–	–	175	21	–	–
	250	–	–	225	22	–	–
	300	–	–	300	24	–	–
	350	–	–	400	27	–	–
	400	500	22	550	28	550	35
	450	–	–	600	32	–	–
	500	–	–	800	37	–	–
	600	1000	29	1000	37	1000	46
	700	–	–	1250	45	–	–
	800	1500	37	1500	50	1500	65
	1000	–	–	3500	65	–	–
	1200	3000	50	3500	65	4000	80

Fuse types	Fuse rating amperes	Between threshold and 50 kA		100 kA		200 kA	
		$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
Class CF (up to 100 A), Class J and 600 V Class T[b]	1	–	–	0.8	1	–	–
	3	–	–	1.2	1.5	–	–
	6	–	–	2	2.3	–	–
	10	–	–	3	3.3	–	–
	15	–	–	4	4	–	–
	20	–	–	5	5	–	–
	25	–	–	5.5	6	–	–
	30	7	6	7	7.5	7	12
	35	–	–	12	7.5	–	–
	40	–	–	17	8	–	–
	45	–	–	18	8.5	–	–
	50	–	–	22	9	–	–
	60	30	8	30	10	30	16
	70	–	–	50	11.5	–	–
	80	–	–	60	12.5	–	–
	90	–	–	75	13.5	–	–
	100	60	12	80	14	80	20
	110	–	–	100	14.5	–	–
	125	–	–	150	15.5	–	–
	150	–	–	175	17	–	–
	175	–	–	225	18.5	–	–
	200	200	16	300	20	300	30
	225	–	–	350	22.5	–	–
	250	–	–	450	24	–	–
	300	–	–	600	26	–	–
	350	–	–	800	29	–	–
	400	1000	25	1100	30	1100	45
	450	–	–	1500	36	–	–
	500	–	–	2000	42	–	–
	600	2500	35	2500	45	2500	70
	700	–	–	1200	45	–	–
	800*	4000	50	4000	55	4000	75

Fuse types	Fuse rating amperes	Between threshold and 50 kA				100 kA				200 kA			
		$1^2t \times 10^3$		$I^p \times 10^3$		$1^2t \times 10^3$		$I^p \times 10^3$		$1^2t \times 10^3$		$I^p \times 10^3$	
Class L	800	10000		80		10000		80		10000		80	
	1200	12000		80		12000		80		15000		120	
	1600	22000		100		22000		100		30000		150	
	2000	35000		110		35000		120		40000		165	
	2500	–		–		75000		165		75000		180	
	3000	–		–		100000		175		100000		200	
	4000	–		–		150000		220		150000		250	
	5000	–		–		350000		–		350000		300	
	6000	–		–		350000		–		500000		350	
Class R		**RK1**	**RK5**	**RK1**	**RK5**	**RK1**	**RK5**	**RK1**	**RK5**	**RK1**	**RK5**	**RK1**	**RK5**
	30	10	50	6	11	10	50	10	11	11	50	12	14
	60	200	200	10	20	40	200	12	21	50	200	16	26
	100	500	500	14	22	100	500	16	25	100	500	20	32
	200	1600	1600	18	32	400	1600	22	40	400	2000	30	50
	400	5000	5000	33	50	1200	5000	35	60	1600	6000	50	75
	600	10000	10000	43	65	3000	10000	50	80	4000	12000	70	100

* Value applies to Class T fuses.

[b] When values at 50 kA and 200 kA are needed, the standard case size shall be used.

Source: UL 508A, Table SB4.2

The **SCCR value** of the branch circuits corresponds to the **interrupting rating of the fuse** in the feeder circuit under the following conditions:

- The SCCR value of all individual components in the branch circuit is not less than the peak let-through current of the fuse in the feeder circuit.
- The interrupting rating of all branch circuit protective devices or the SCCR value of all Combination Motor Controllers is not less than the interrupting rating of the fuse in the feeder circuit.

→ The SCCR value of the branch circuits corresponds to the smallest interrupting rating of a branch circuit protective device or Combination Motor Controllers connected downstream of the fuse in the feeder circuit if this is less than the interrupting rating of the fuse in the feeder circuit.

→ The SCCR value of the branch circuits corresponds to the smallest SCCR value of each branch circuit connected downstream of the fuse if the above-named conditions are not met.

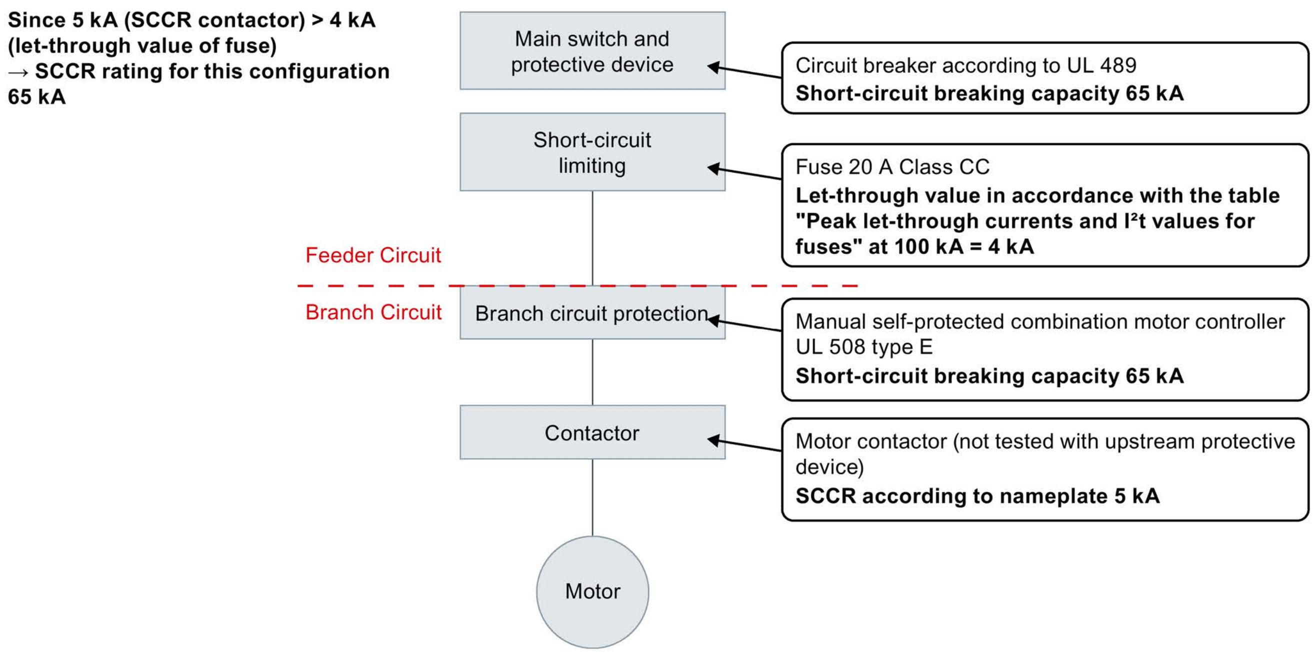


Figure 6-28 Example of "Determining the SCCR on the basis of a short-circuit-current-limiting fuse"

The Appendix Flowcharts for calculating the SCCR value of a component (Page 331) will help in calculating the short circuit current rating of an industrial control panel.

Overcurrent protection and sizing of the control circuit 7

7.1 General information

The next chapter describes control circuits in accordance with NEC, UL 508A and NFPA 79.

According to UL 508A, Chapter 2.11, NEC, Chapter 409.2 and NFPA 79, Chapter 3.3.21, a control circuit is a circuit that carries the signals for the function and the controller. It does not carry the electrical power for the connected loads.

UL 508A usually limits the control circuit to 15 A. This is a recommendation. A mandatory maximum value is not specified.

The following control circuits are defined in UL 508A:

1. Class 1 control circuit
2. Class 2 control circuit
3. Low-voltage limited energy circuit

The NEC and NFPA 79 define only Class 1 and Class 2 circuits. This means if a low-voltage limited energy circuit in accordance with UL 508A exits the industrial control panel, it is treated outside the control panel as a Class 1 circuit. Output terminals of a low-voltage limited energy circuit are to be marked "Class 1 circuit" (see also Chapter Other markings for terminals in control circuits (Page 272)).

NEC also defines a Class 3 circuit. However, since neither UL 508A nor NFPA 79 have anything to say about this control circuit, it is not dealt with in this guide.

The coming chapters deal with the properties, sizing rules and protection of the control circuits.

7.2 Classification

7.2.1 Class 1 control circuit

Definition in accordance with UL 508A, Chapter 2.6

A Class 1 control circuit is a control circuit with the following properties:

- On the load side of a short-circuit protective device
- On the load side of a transformer or power supply
- With max. 600 V control voltage (regardless of whether AC or DC)

In Chapter 9.1.2.1 and 9.1.2.2, NFPA 79 limits the voltage to 120 V AC or 250 V DC.

7.2.2 Class 2 control circuit

A Class 2 control circuit shall always be established when components are approved only for a Class 2 control circuit. Such components are marked "For use in class 2 circuits only" or similarly.

Definition in accordance with UL 508A, Chapter 2.8

A Class 2 control circuit is a control circuit with the following properties:

- Supplied from a source with a limited voltage of 30 V_{rms} or less
- Supplied by a Class 2 power supply or transformer

NFPA 79 contains the Class 2 control circuit but does not describe it in more detail since it is defined as follows in the NEC, Chapter 725:

- Circuit on the load side of a listed Class 2 power supply
- Offers fire safety and protection against electric shock due to the limited energy

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Note

Components and wiring located completely within a Class 2 control circuit do not have to be accepted by the inspector.

→ Unlisted components and wiring can be used.

However, despite this exception, use of UL approved components and wiring is recommended if this is possible. This exception is primarily intended to nevertheless enable the use of components available on the market that do not have UL approval. In special purpose machine manufacturing, for example, components without UL approval can be mandatory (e.g. proprietary control PCBs).

7.2.3 Low-voltage limited energy circuit

The low-voltage limited energy circuit is described **only in UL 508A**. In Chapter 2.33, this is defined as follows:

- Voltage ≤ 42.4 V peak (= 30 V_{rms} at AC voltage) or DC voltage
- Supplied by a battery or an isolated secondary circuit
- Current limiting through

  a) An overcurrent protective device (e.g. a listed fuse in accordance with UL 248-4…12, -15 or a circuit breaker in accordance with UL 489) *or*

  b) The inherent capacity of an isolation transformer or power supply, *or*

  c) The combination of a secondary winding and an impedance
- Tap from the line voltage using a voltage divider is not permitted

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Note

The short-circuit protective device shall be selected in accordance with the table "Overcurrent protection for a low-voltage limited energy circuit" below.

The low-voltage limited energy circuit is limited to:

- Max. power of 100 VA
- Output current of 5 A at a voltage of ≤ 20 V
- 42.4 V peak (= 30 V_{rms} at AC voltage) or DC voltage

Conversions in accordance with the table below are permitted provided the maximum values are not exceeded.

Table 7- 1 Overcurrent protection for a low-voltage limited energy circuit

Open-circuit secondary voltage, volts (peak)	Maximum overcurrent device, amperes
0 … 20	5
20.1 … 42.4	100/V[a]

[a] Where "V" is equal to the peak or DC open-circuit secondary voltage.

Source: UL 508A, Table 43.1

Exception 1

A secondary circuit that complies with the limited voltage/current circuit requirements for secondary circuits in accordance with UL 508 (Industrial Control Equipment) is not required to be protected in accordance with the table "Overcurrent protection for a low-voltage limited energy circuit".

Exception 2

A current transformer is not required to be protected in accordance with the table "Overcurrent protection for a low-voltage limited energy circuit".

Note

Analogously to the Class 2 control circuit, components and wiring located completely within a low-voltage limited energy circuit do not have to be accepted by the inspector.

→ Unlisted components and wiring can be used.

However, despite this exception, use of UL approved components and wiring is recommended here too if this is possible. This exception is primarily intended to nevertheless enable the use of components available on the market that do not have UL approval. In special purpose machine manufacturing, for example, components without UL approval can be mandatory (e.g. proprietary control PCBs).

7.3 Power supply and short-circuit protection

7.3.1 Tapping and power supply

Control circuits can be supplied with power in different ways in accordance with UL 508A.

In accordance with Chapter 39, control circuits can be supplied from a separate source. In this case, the control circuits shall be provided with a separate disconnecting means.

A separate incoming supply circuit can be implemented using a separate incoming supply circuit conductor or by tapping upstream of the main disconnecting means.

Separate incoming supply circuit conductor

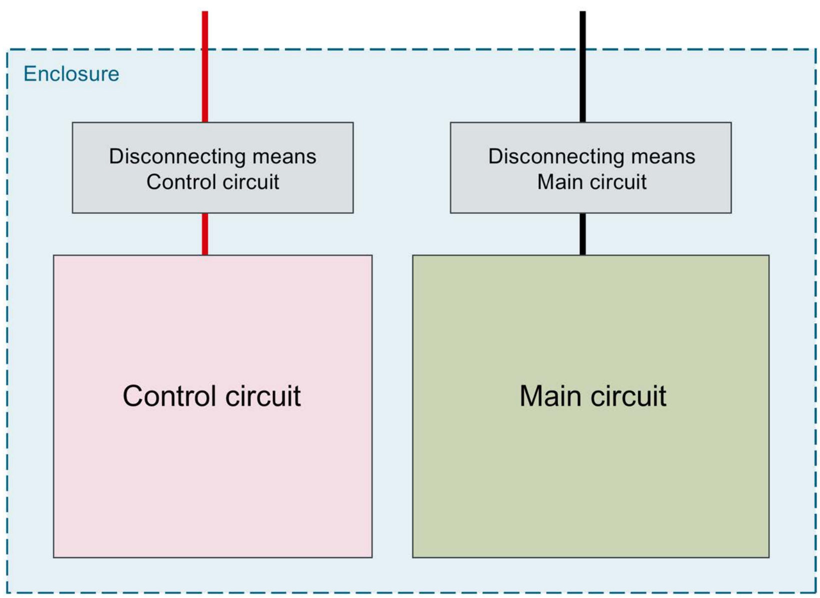


Figure 7-1 Control circuit with separate incoming supply circuit conductor

Tapped upstream of the main disconnecting means

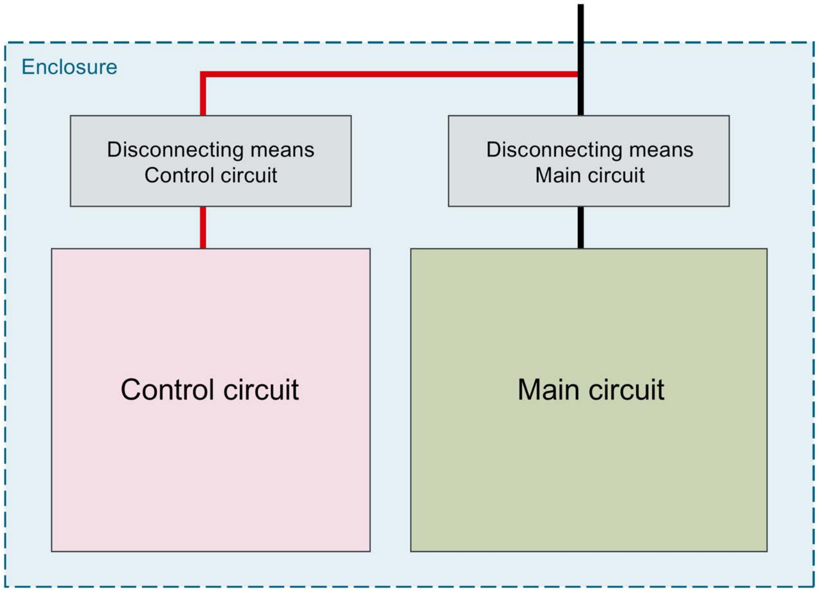


Figure 7-2 Control circuit tapped upstream of the main disconnecting means

Tapped downstream of the main disconnecting means

In most cases, the control circuit is tapped downstream of the main disconnecting means and upstream of the load branch circuits.

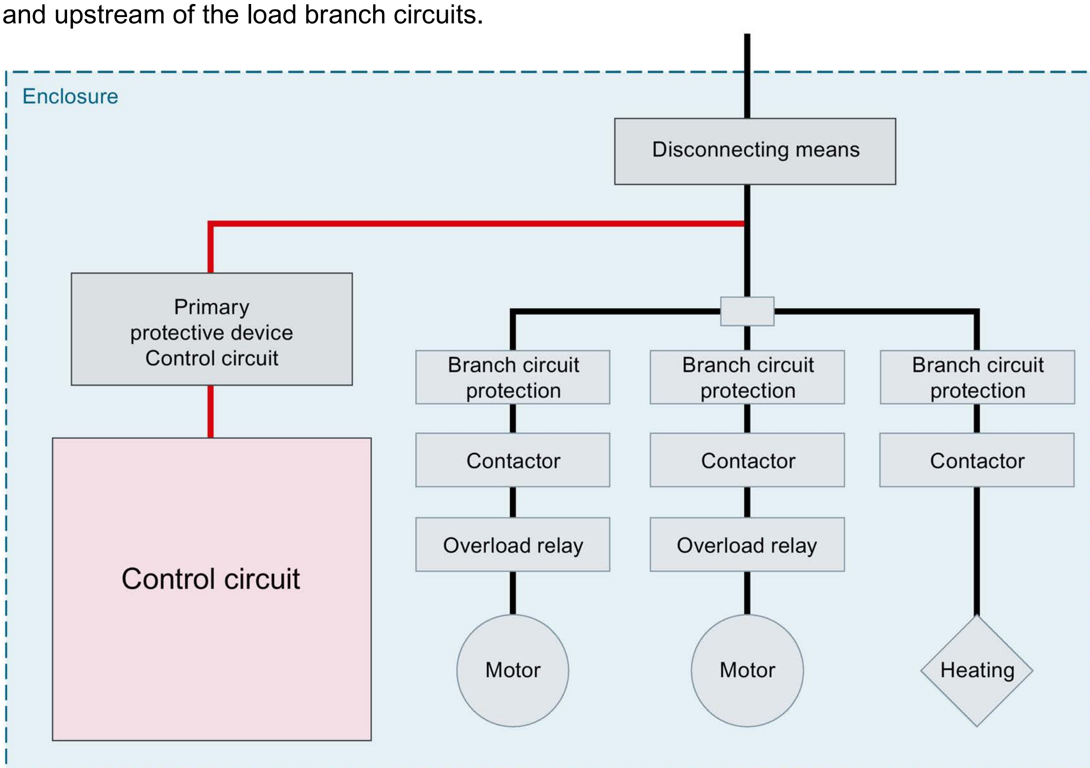


Figure 7-3 Control circuit tapped downstream of the main disconnecting means and upstream of the load branch circuits

In the relevant standards it is also not unusual to tap the control circuit downstream of the branch circuit protective device. In this case, supplementary protectors in accordance with UL 1077 or supplemental fuses in accordance with UL 248-14 may be used as the primary protective device. For more information, see Chapter Overcurrent protection of control circuits (Page 150).

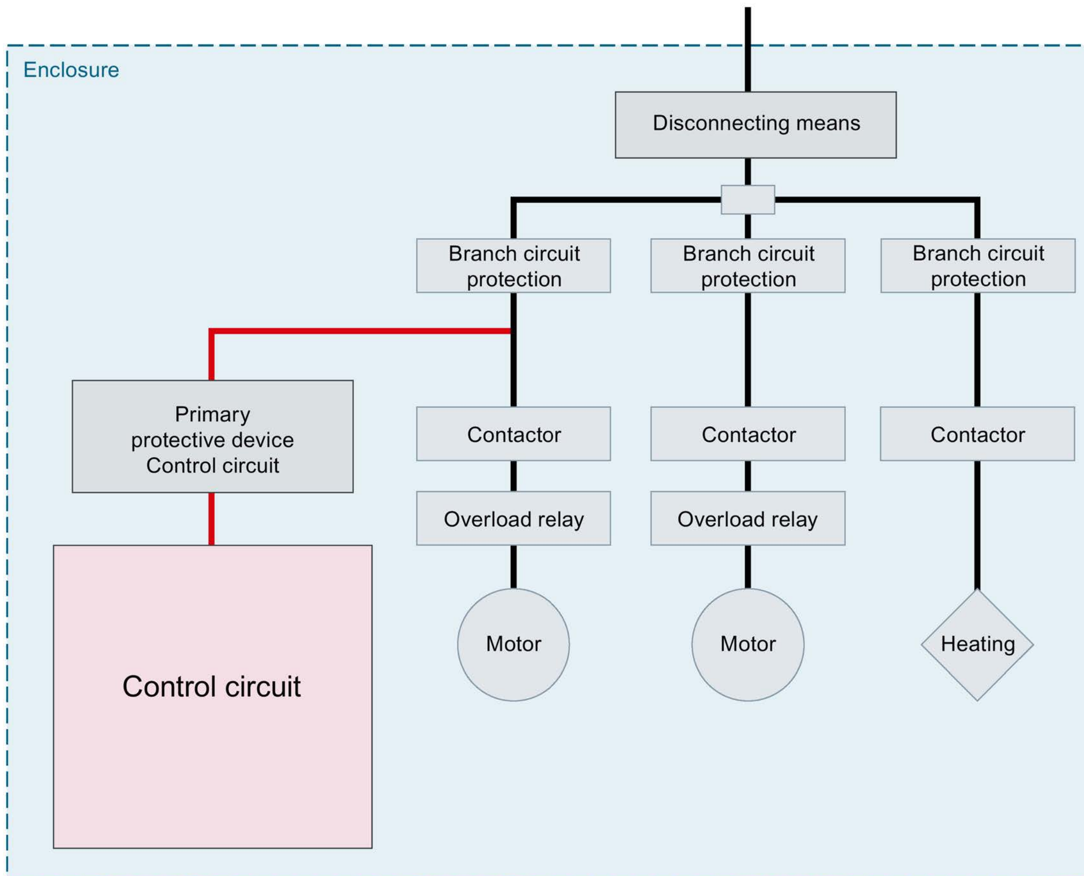


Figure 7-4 Control circuit tapped downstream of the branch circuit protective device

Power supply units

Power supply units for Class 1 control circuits in accordance with UL 508A, Chapter 42.1:

- Transformers in accordance with UL 5085-1/-2 or UL 1561
- Power supplies (with galvanic isolation) in accordance with UL 1012, UL 60950 and UL 1950
- Control devices with isolated secondary circuits approved in accordance with UL 508 or UL 508C

Power supply units for Class 2 control circuits in accordance with UL 508A, Chapter 44.1:

- Transformers in accordance with UL 5085 -1/-3
- Power supplies in accordance with UL 1310
- Devices for supplying a circuit for information technology equipment shall be approved in accordance with UL 60950

Power supply units for low-voltage limited energy circuits in accordance with UL 508A, Chapter 43.1:

- Power supplies for Class 1 control circuits
- Sealed batteries according to UL 1989
- Lithium batteries according to UL 1682
- Current transformers according to UL 5085-1/-2
- Current transformers with max. secondary current of 5 A

7.3.2 Overcurrent protection of control circuits

The overcurrent protection of control circuits is described in UL 508A, Chapter 40.

The following devices are approved without restrictions for protecting a control circuit:

- Branch circuit fuse according to UL 248-4…12, -15
- Inverse time circuit breaker according to UL 489

Devices approved with restrictions:

- Supplemental fuses according to UL 248-14
- Supplementary protectors according to UL 1077

Fuse holders shall comply with UL 4248-1 and to the part of UL 4248 applicable for the fuse used

If the above-named protective devices are used in control circuits with a DC voltage **above** 32 V, they shall be approved in accordance with the appropriate product standard to have a voltage rating **equal to or greater** than the rated voltage.

Note

Supplemental fuses and supplementary protectors are only "recognized", but are often similar in appearance to the "listed" fuses or circuit breakers. Pay attention, therefore, to the approval to avoid any danger of mix-up.

Circuit breaker according to UL 489 | Supplementary protector according to UL 1077

Figure 7-5 Comparison of supplementary protectors and circuit breakers in the design of miniature circuit breakers

Supplemental fuses in accordance with UL 248-14 and supplementary protectors in accordance with UL 1077 are only approved as primary protection if the control circuit has been tapped downstream of a branch circuit protective device (see Figure 7-4 Control circuit tapped downstream of the branch circuit protective device (Page 149)).

There are also restrictions when using these devices as secondary protection, downstream of the transformer or power supply. These protective devices are not listed, but they are recognized. That means Conditions of Acceptability shall be observed here.

Example: Recognized devices do not always have a Field Wiring approval. If the devices are only approved for Factory Wiring, wiring that exits the control panel shall not be connected direct, but instead shall be routed to the outside via a component approved for Field Wiring (e.g. a terminal block).

Every ungrounded conductor (phase) shall be protected.

Protection of a separate supply source (not an isolated secondary circuit)

(see Figure 7-1 Control circuit with separate incoming supply circuit conductor (Page 147)):

- Protection with max. 20 A or
- less in accordance with the ampacity of the wiring
- or in accordance with the max. permissible current consumption of the devices

Protection of an isolated secondary circuit in accordance with UL 508A, Chapter 42

(see Figure 7-2 Control circuit tapped upstream of the main disconnecting means (Page 148) and Figure 7-3 Control circuit tapped downstream of the main disconnecting means and upstream of the load branch circuits (Page 148)):

a) Only one protective device required on the primary side

Only one protective device is required on the primary side if the rated current of the load on the secondary side is **equal to or less than** the rated current of the primary protective device. **Note here the transformation ratio in the case of transformers.**

Example: Primary protective device 3 A / 480 V → Secondary current ≤ 12 A / 120 V

In this case, the protective device shall be sized in accordance with the table "Sizing of primary winding only overcurrent protection of a control transformer" below.

Table 7- 2 Sizing of primary winding only overcurrent protection of a control transformer

Control transformer primary current, amperes	Rating of overcurrent protection, maximum percentage of primary current
9 or more	125[a]
2 … 8.99	167
less than 2	500

[a] Where the calculated size of the overcurrent protection, branch circuit or supplementary type, does not correspond to a standard size protective device, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection equipment.

Source: UL 508A, Table 42.1

b) Every secondary circuit shall be protected separately

In the following cases, every secondary circuit shall be protected separately:

- The rated current of the load on the secondary side is **greater than** the rated current of the primary protective device. **Note here the transformation ratio in the case of transformers.**
- The summation current of all loads is greater than the output current of the power supply.
- The secondary circuit exits the industrial control panel.
- The transformer/power supply has several secondary-side taps/windings.

Table 7- 3 Sizing of primary and secondary overcurrent protective devices

Primary winding		Secondary winding	
Rated amperes	Overcurrent protection percent of rated amperes	Rated amperes	Overcurrent protection percent of rated amperes
9 or more	250	9 or more	125[a]
2 … 8.99	250	less than 9	167
less than 2	500	-	-

[a] Where the calculated size of the overcurrent protection, branch circuit or supplementary type, does not correspond to a standard size protective device, the next larger size is able to be used. See 31.3.8 for standard sizes of branch circuit protection equipment.

Source: UL 508A, Table 42.2

Protection of a control circuit that is tapped downstream of the branch circuit protective device

(see Figure 7-4 Control circuit tapped downstream of the branch circuit protective device (Page 149))

Wiring of a control circuit that is tapped downstream of a branch circuit protective device shall be sized in accordance with Table 11-4 Ampacity and protection for power circuits with AWG 16 and AWG 18 conductors (Page 222) and Table 11-5 Ampacities of insulated conductors (Page 223), and shall be protected accordingly.

Exception 1

If the control circuit meets all the following conditions:

- Tapped from the load side of a motor branch circuit protective device
- The control wires **do not leave the industrial control panel** (such as when a start-stop button is provided on the industrial control panel enclosure)
- The rating of the motor branch circuit protective device does not exceed the maximum values in the table "Motor branch circuit protection of common control circuit without remote control devices"

If these conditions are fulfilled, the motor branch circuit protective device also ensures the required short-circuit protection for the control circuit. That means an additional overcurrent protective device on the primary side of the control circuit is not required.

Table 7- 4 Motor branch circuit protection of common control circuit without remote control devices

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm^2)	
22	(0.32)	12
20	(0.52)	20
18	(0.82)	25
16	(1.3)	40
14	(2.1)	100
12	(3.3)	120

Source: UL 508A, Table 41.1

Exception 2

If the control circuit meets all the following conditions:

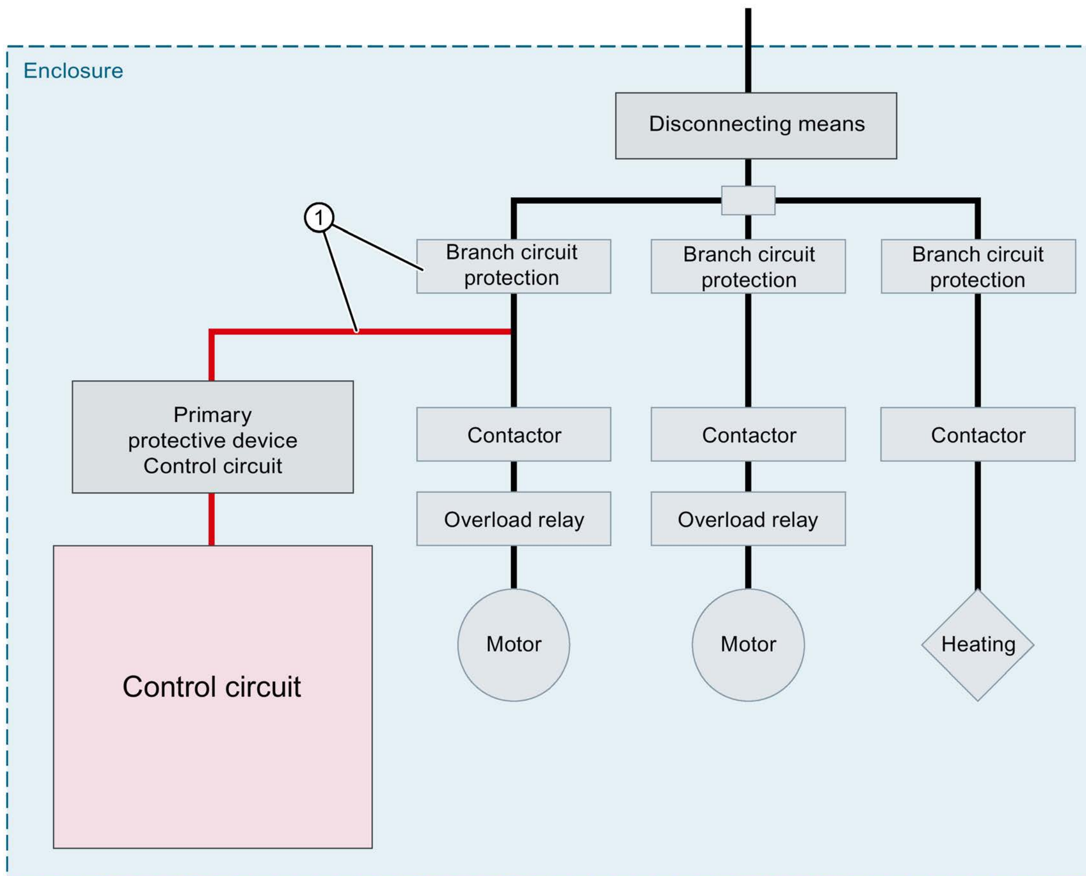
- Tapped from the load side of a motor branch circuit protective device
- The control wires **leave the industrial control panel** (such as when a start-stop button is provided outside the industrial control panel in the field)
- The rating of the motor branch circuit protective device does not exceed the maximum values in the table "Motor branch circuit protection of common control circuit with remote control devices"

If these conditions are fulfilled, the motor branch circuit protective device also ensures the required short-circuit protection for the control circuit. That means an additional overcurrent protective device on the primary side of the control circuit is not required.

Table 7- 5 Motor branch circuit protection of common control circuit with remote control devices

Control circuit wire size		Maximum protective device rating, amperes
AWG	(mm²)	
22	(0.32)	3
20	(0.52)	5
18	(0.82)	7
16	(1.3)	10
14	(2.1)	45
12	(3.3)	60

Source: UL 508A, Table 41.2



① 1. Tapped on the load side of the protective device of a motor branch circuit
2. Cable cross-section of the control circuit in accordance with the values of the table "Motor branch circuit protection of common control circuit without remote control devices" or the table "Motor branch circuit protective device of common control circuit with remote control devices"

⇒ **An additional protective device for the control circuit is not required.**

Figure 7-6 Tapped downstream of the main disconnecting means and downstream of the branch circuit protection of a motor

7.4 Unlisted components

As described in Chapter General information for manufacturers of machinery and their associated electrical equipment (Page 27), components used shall be approved in accordance with the relevant US standards for the respective application.

However, Appendix B of UL 508A describes some cases where components that are neither "listed" nor "recognized" are approved, and the requirements under which this is possible.

Conditions of use

The exceptions described in this chapter are not applicable to the following components:

- Components that function to cause the opening of a circuit in the case of short circuit, overload, running motor overload, or ground fault
- Where additional safety concerns are present

  Examples: A risk of an implosion of a cathode ray tube, use of components with flammable gas (e.g. oxygen) and liquids, or high pressures (300 psi = 2.08 MPa)
- Components that have been previously evaluated and are now being used for a purpose or at electrical ratings other than those for it has been evaluated, or if this product standard is not approved in UL 508A
- Components with a direct electrical connection to power circuits
- Components that are located entirely within a circuit that is isolated from the control circuit voltage in which the ground fault circuit interrupter is installed

  → Components without approval are only allowed to be installed in a control circuit

Possible devices and components are:

- Switches
- Relays
- Measuring devices
- Recording devices
- Similar components that control loads or other devices within the control circuit and do not include connections to external devices

Components that do not fall within the conditions listed above shall be approved in accordance with UL 508 Industrial Control Equipment or another applicable standard. With UL-certified panel builders, the components shall also be included in the UL file of the industrial control panel builder.

The component shall be completely enclosed and located within the industrial control panel.

Exception 1

The component used is able to extend through an opening in the industrial control panel enclosure when the enclosure of the component has one of the following properties:

1. The component is made of polymeric plastic and the exposed area is not larger than 30 square inches (194 cm^2)
2. The component is made of metal or glass and the exposed area is not larger than 100 square inches (654 cm^2)

Exception 2

Components in an open-type industrial control panel have one of the following two properties:

1. Installed in a completely enclosed enclosure.
2. Protected by barriers. The barriers shall comply with the conditions for "Barriers used with ventilation openings".

With ventilation openings, the unlisted component is to be treated as an arcing part.

All signal inputs and signal outputs to the unlisted component shall only be connected to control system components that are approved in compliance with UL.

Marking

The industrial control panel shall have the following markings:

a) "*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.*"

This marking shall be followed by a table showing the components referred to.

Table 7- 6 Example - Devices to be protected by a ground fault circuit interrupter

Component	Identification
Relay, K1	Acme, p/n 508

Source: UL 508A, Appendix B

b) Note that the ground fault circuit interrupter should be checked periodically for proper operation.

Power supply

- Transformer with isolated secondary winding and a secondary voltage of 115 to 120 V or 230 to 240 V

Note

Since NFPA 79 limits the control circuit to a voltage of 120 V AC, a maximum of 120 V applies for an industrial machine.

- One side of the secondary winding shall be grounded.
- The secondary side shall be protected by a ground fault circuit interrupter in accordance with UL 943 (Class A, 6 mA or receptacle type)
- When using a receptacle type, the following requirements apply:
  - The component shall be connected directly to the terminals and not plugged into the receptacle.

    Note

    If a component has a power supply cord that includes an attachment plug, this plug shall be removed.

  - A marking immediately adjacent to the receptacle shall indicate the receptacle is not to be used for devices external to the industrial control panel.
  - The receptacle shall be mounted so that it is not accessible from outside the enclosure.

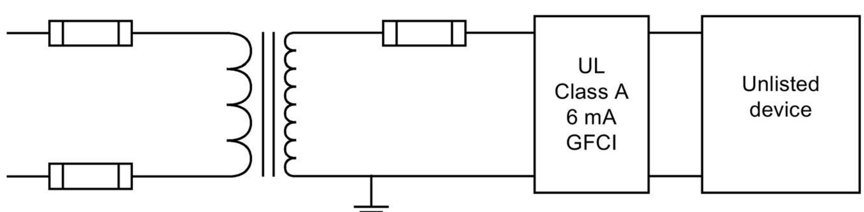


Figure 7-7 Design of a control circuit for an unlisted component

Inputs and outputs

U > 30 V rms (42.4 peak or DC)

- The signals shall be routed via a UL-approved device (e.g. a relay)
- This device shall be installed in the industrial control panel.
- The voltage shall be supplied from the load side of a ground fault circuit interrupter.

U ≤ 30 V rms (42.4 peak or DC)

Signal input via any of the following devices:

- Low-voltage limited energy circuit
- Class 2 power supply/transformer

Note

In these two cases, no additional protection by means of a ground fault circuit interrupter is required

---

Signal inputs from outside the industrial control panel shall be protected by a 0.5 A fuse for each ungrounded conductor. The fuse shall be located within the industrial control panel. A marking shall be provided near the fuse with the following information:

- **"CAUTION"**
- **"To reduce the risk of fire, replace only with same type and rating of fuse"** (or equivalent wording)

The following marking shall be placed next to the field wiring terminals:

- **"CAUTION"**
- **"To reduce the risk of electric shock, connections to these terminals shall not involve a potential of greater than 30 Vrms or 42.4 V peak between live parts of opposite polarity and between a live part and ground."**

Signal inputs from measuring devices that are isolated from the supply voltage (such as current transformers, tachometers, thermocouples, or similar feedback devices), and that are located inside or outside the industrial control panel, do not require any additional protection.

Responsibility of the manufacturer

The manufacturer is obliged to test the ground fault circuit interrupter as follows:

- Control circuit energized
- Connection of a resistance between the live parts of the unlisted component and ground.

Note

The resistance value shall be such that the current flowing through it is greater than 6 mA and less than the rating of the secondary short-circuit protective device.

→ The ground fault circuit interrupter shall open the circuit.

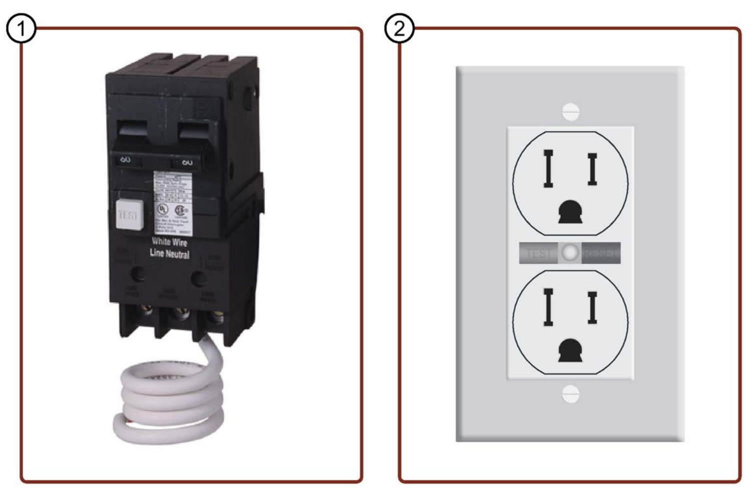
Records shall be made of the tests of the evaluated devices. The records shall be maintained at all times for viewing by UL inspectors.

The records shall be retained for at least 6 months.

Table 7- 7 Example "Logging form"

Component designation	Component manufacturer's name	Catalog designation	Number used	Panel identification	Ground fault date of testing
…	…	…	…	…	…

Source: UL 508A, Appendix B



① Class A - GFCI
② Receptacle type - GFCI

Figure 7-8 Ground fault circuit interrupter

Grounding 8

8.1 General requirements

The requirements for grounding and protective conductors are described in detail in this chapter. An in-depth distinction is made between the requirements for the industrial control panel according to UL 508A, Chapters 14 to 16, and the requirements for electrical equipment according to NFPA 79, Chapter 8.

The requirements of both standards differ on some points. For this reason, it is recommended that manufacturers of industrial control panels observe the requirements of UL 508A. The requirements of NFPA 79 on the subject of grounding (which provide additional information and are more extensive in some respects) are recommended for industrial control panel builders and machine builders.

In the case of discrepancies between the requirements, clarification between the manufacturer and operator should take place in advance.

a) General information

The purpose of grounding is to establish a continuous electrical connection between conductive parts so that they can reach the same electrical potential.

b) Combination of equipment grounding (protective) conductor and grounded conductor

Combining the protective conductor and grounded conductor is not permitted according to current US standards (NEC, UL 508A, and NFPA 79).

Exception

For "Separately derived systems"* according to NEC, combination is permitted under specific conditions.

*Separately derived systems are systems with one or more separate supplies beyond the usual incoming supply (e.g. via batteries, generators, photovoltaic systems, etc.), provided there is **no** direct electrical connection to another supply.

c) Marking

Terminals can be marked in the following three ways:

- The following **abbreviations** are recommended: "G", "GND", "GRD", "Ground" or "Grounding"

  "PE" (protective earth) can also be used as marking according to NFPA 79. However, this is a typical abbreviation taken from the IEC standards and does not correspond to the standard abbreviation that is currently used in North America.
- **Color:** green or green/yellow
- **Grounding symbol** according to IEC ⏚

8.2 Requirements of UL 508A for grounding the industrial control panel

All conductive parts that may be touched by persons under normal operating conditions or while adjusting parts of the industrial control panel shall be connected to the equipment grounding (protective) conductor and grounded. In the event of a fault (e.g. an insulation fault), this is intended to prevent a hazardous contact voltage occurring with loose electrical connections and the supply being automatically disconnected.

Suitable terminals (Field Wiring Terminals) shall be available for connecting external grounding wires.

These terminals shall also meet the following two requirements:

- Requirements for external interfaces to the industrial control panel (see feeder circuits in Chapter Through air and over surface spacings (Page 56))
- Requirements of the standard UL 467 "Standard for Grounding and Bonding Equipment" or correspondingly tested

The connection between the terminals and the conductive parts shall be established using metallic contact surfaces or connecting wires with a minimum cross section. The minimum cross section shall correspond to one of the following two specifications:

- **UL 508A, Table 15.1**

  For cross sections of grounding conductors and equipment grounding terminals, see the table below, "Size of equipment grounding conductor terminal".
- Same cross section as the external supply conductors for the industrial control panel

The smaller cross section of these two options should be used in this case.

These requirements apply to permanently installed industrial control panels that are operated in a particular location.

Note

A flexible supply cord shall be provided for industrial control panels that are to be operated with different supplies and, therefore, in different locations.

Table 8- 1 Size of equipment grounding conductor terminal

Maximum ampere rating of overcurrent protection for field wiring conductors supplying the panel	Size of equipment grounding or bonding conductor, minimum			
	Copper		Aluminum	
	AWG or kcmil	[mm^2]	AWG or kcmil	[mm^2]
15	14	2.1	12	3.3
20	12	3.3	10	5.3
30	10	5.3	8	8.4
40	10	5.3	8	8.4
50	10	5.3	8	8.4
100	8	8.4	6	13.3
200	6	13.3	4	21.2
300	4	21.2	2	33.6
400	3	26.7	1	42.4
500	2	33.6	1/0	53.5
600	1	42.4	2/0	67.4
800	1/0	53.5	3/0	85.0
1000	2/0	67.4	4/0	107.2
1200	3/0	85.0	250 kcmil	127
1500	4/0	107.2	350	177
2000	250 kcmil	127	400	203
2500	350	177	600	04
3000	400	203	600	304
4000	500	253	800	405
5000	700	255	1200	608
6000	800	506	1200	608

Source: UL 508A, Table 15.1

Requirements for grounding transformers and power supplies (UL 508A, Chapter 16)

A secondary circuit that contains field wiring terminals and is supplied from a power transformer, control transformer or power supply shall have the secondary grounded under any of the following conditions:

a) **Voltage ≤ 50 V**

1. Primary voltage is ≥ 150 V line – ground, or
2. Primary side is ungrounded, regardless of the operating voltage

b) **Voltage ≥ 50 V**, and it is possible to limit the secondary voltage to ≤ 150 V line – ground by means of grounding

c) **When the secondary is a 3-phase or 4-wire,** (wye connection) in which the midpoint of the wye is used as a circuit conductor.

d) **When the secondary is a 3-phase, 4-wire** (delta connection) in which the midpoint of one phase winding is used as a circuit conductor.

This is particularly relevant to devices on the secondary side that are marked by a "Slash Rating" (e.g. 120/240 V, 480 Y/277 V, or 600 Y/347 V). In this case, it is essential that the control circuit complies with condition b) or c). For a 3-phase wye network with only 3 implemented phases, the midpoint of the wye shall be grounded.

Note

Detailed information on the power supply system configurations listed in c) and d) can be found in Chapter Power supply system configurations (Page 65)

Grounding shall be carried out on site in the industrial control panel. It shall be ensured that there is a connection between the enclosure and the grounding terminal. Corresponding marking is also required for the size of the terminal and the external equipment grounding (protective) conductor. The following two exceptions shall be observed:

- The grounding terminal is not required for control circuit transformers with a rating of S ≤ 1,000 VA. The ground connection shall be made of copper and have a minimum cross section of 14 AWG (2.1 mm^2)
- For multiple incoming supply circuits which use other supplies (e.g. generators) for the same industrial control panel, besides the usual supply line, a grounding terminal with a minimum cross section of 3/0 AWG shall be provided.

Ungrounded circuits

For a power circuits or control circuit supplied from a secondary circuit voltage that is not required to be grounded and is rated ≥ 100 V, one of the following conditions shall be met:

- The secondary circuit shall be provided with ground fault monitoring devices which issue an audible or visual indication when a ground fault occurs in any ungrounded conductor (e.g. an indicator light or display).
- It shall be provided with a monitoring device that interrupts the circuit automatically in the event of a ground fault (e.g. a ground fault circuit interrupter).

If the monitoring device only issues a visual or audible indication for a ground fault but does not interrupt the circuit, a ground fault shall not result in the bypassing of safety shutdown devices.

Exception: Control circuits with a secondary voltage of more than 100 V and with no provision for connection to external circuits (Field Wiring) do not require ground fault monitoring or an automatic disconnection device in the event of a ground fault.

Single-phase loads of "straight rated" transformers in the industrial control panel

If external, single-phase loads between a phase and the neutral are supplied via a transformer in the industrial control panel, which has a delta connection on the secondary side and is a midpoint-grounded power supply, an additional orange label is required for the internal conductor at the connection points for the "high-leg" voltage.

* The higher voltage between line – ground (see Chapter Power supply system configurations (Page 65))

Note

More details on labels, colors, etc., are described in Chapter Identification and color (Page 234).

8.3 Requirements of NFPA 79 for grounding machinery

General information

The primary objective of the requirements is to ensure that the impedance in the equipment grounding (protective bonding) circuit is as low as possible. The purpose of this, in turn, is to ensure that the overcurrent protection will cause automatic disconnection of the overcurrent protective devices in the event of a fault. The occurrence of a hazardous contact voltage shall also be prevented. All conductive parts that are not live shall be connected to this equipment grounding (protective bonding) circuit. The requirements of **NFPA 79** on the subject of grounding also cover the requirements for the grounded conductor.

The **NFPA 79** requirements are based on **NEC, Art. 250.4**.

Equipment grounding (protective bonding) circuit

Components

Only the following parts may be used for the equipment grounding (protective bonding) circuit:

- Equipment grounding (protective) conductor terminals
- Equipment grounding (protective) conductors and equipment bonding jumpers

This requirement has changed significantly in comparison with NFPA 79, 2007 edition. Structural machine components or other supporting parts of the electrical equipment may no longer be used to establish continuity in the equipment grounding (protective bonding) circuit; only electrical conductors may be used for this.

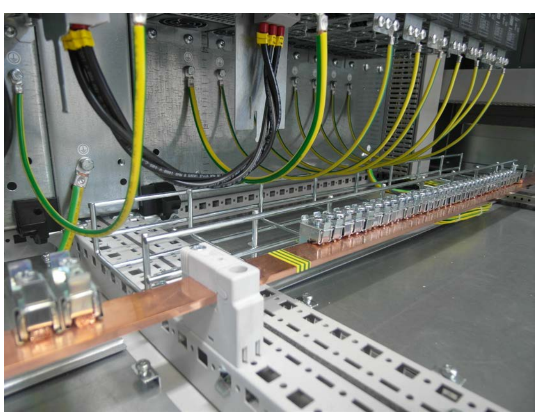


Figure 8-1 Grounding concept of an industrial control panel

All parts of the equipment grounding (protective bonding) circuit (terminals and conductors) shall be capable of withstanding the associated mechanical and thermal stress without incurring unacceptable damage, particularly in the event of a short circuit.

NFPA 79 does not provide any further specifications on how this can be achieved, however. The logic behind this is that the short-circuit current flows back via the equipment grounding (protective) conductor to the source in the event of single-pole short circuits. Equipment grounding (protective) conductors are often designed with a smaller cross section than the associated phase conductor. In addition, the smaller cross section of the equipment grounding (protective) conductor does not feature separate overcurrent protection that is appropriate for its smaller size; instead, it shall be protected indirectly via the overcurrent protection device in the ungrounded conductors (phases).

On the other hand, it is also assumed that the ground fault loop impedance for the single-pole short circuit is significantly higher than it is in the case of the two or three-pole phase short circuit. This means that the usual level of the single-pole short circuit in machines and industrial control panels is lower than that of the three-pole short circuit and, therefore, in the case of thermal and mechanical stress.

If the equipment grounding (protective) conductors are designed with these minimum cross sections according to Table 8.2.2.3 in NFPA 79 (see Table 8-1 Size of equipment grounding conductor terminal (Page 163)), this is usually sufficient for thermal and mechanical stress in the event of a short circuit.

If there is any uncertainty (for example, if the prospective short circuit current specified by the system operator is very high), additional measures shall be stipulated in order to provide the equipment grounding (protective bonding) circuit with adequate protection.

Examples of additional measures:

- Installing an additional parallel protective equipment grounding (protective) conductor
- Increasing the cross section of the equipment grounding (protective) conductor

Terminals in the equipment grounding (protective bonding) circuit are also tested for a max. SCCR with the relevant overcurrent protection device during the certification process (e.g. UL approval).

The exceptions for conductive parts that are not required to be connected to the equipment grounding (protective bonding) circuit are small parts for which the occurrence of voltages that present a contact hazard is not expected.

Examples:

- Screws
- Rivets
- Nameplates

Industrial control panel enclosures or enclosures for subdistribution boards made from non-conductive material (e.g. plastic) may contain devices that are installed on metallic mounting panels. In this case, the mounting panels shall be bonded to the grounding equipment (protective bonding) circuit.

Note

In their installation instructions, some manufacturers of components and subassemblies require these to be grounded using special means to ensure that they function efficiently. If this is explicitly required, bonding to the equipment grounding (protective bonding) circuit shall be established.

Equipment grounding terminal

Each incoming supply circuit conductor shall have its own grounding terminal. This shall be located in the vicinity of the associated phase conductors.

All equipment grounding (protective bonding) circuits and, where applicable, assemblies and components shall be connected to the system grounding terminal.
Example:

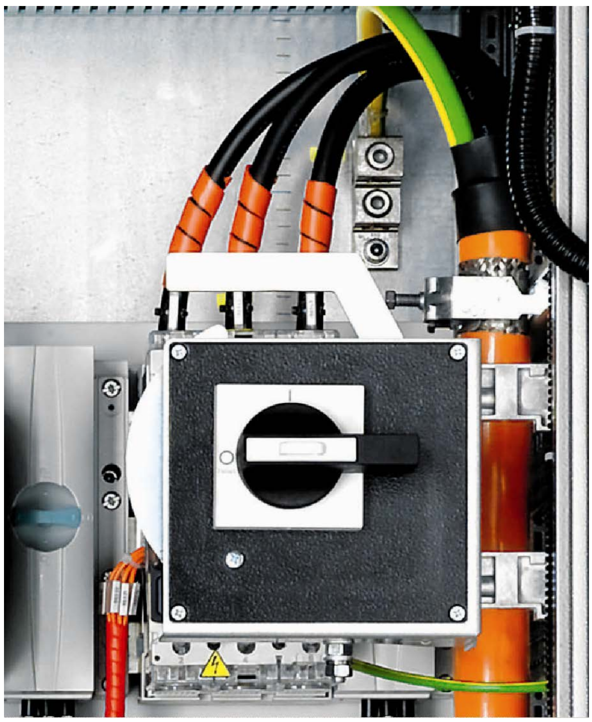


Figure 8-2 Equipment grounding terminals for the incoming supply circuit conductor

The terminal shall be sized so that a minimum cross section can be connected (as specified in the table below, "Minimum size of equipment grounding conductors and bonding jumpers").

If a ground electrode is provided for auxiliary circuits, the equipment grounding terminal shall be able to include these additional grounding conductors.

Table 8- 2 Minimum size of equipment grounding conductors and bonding jumpers

Rating or setting of automatic overcurrent device in circuit ahead of the equipment (not exceeding amperes)	Copper conductor size (AWG or kcmil)
10	16
15	14
20	12
30	10
40	10
60	10
100	8
200	6
300	4
400	3
500	2
600	1
800	1/0
1000	2/0
1200	3/0
1600	4/0
2000	250
2500	350
3000	400
4000	500
5000	700
6000	800

Source: NFPA 79, Table 8.2.2.3

Equipment grounding (protective) conductors and bonding jumpers

Note

According to NFPA 79, equipment grounding (protective) conductors and bonding jumpers shall be made of copper. Aluminum is not permitted.

When installed, grounding conductors and their associated bonding jumpers may be insulated, covered, or bare (non-insulated). Sufficient protection against mechanical damage shall be provided.

The cross sections of grounding conductors and bonding jumpers shall not be smaller than the required minimum cross section according to Table 8-2 Minimum size of equipment grounding conductors and bonding jumpers (Page 169). However, a cross section that is larger than the cross section of the circuit conductors supplying the equipment shall not be required.

Equipment grounding (protective) conductors and bonding jumpers shall be identified as described in Chapter General requirements (Page 161) and Chapter Identification and color (Page 234).

Continuity of the equipment grounding (protective bonding) circuit

The continuity of the equipment grounding (protective bonding) circuit shall only be ensured by effective connections through conductors. Structural, supporting, and conductive parts of the machine shall no longer be used for the purposes of maintaining continuity. The same applies to raceways, wireways, and cable trays.

If devices have to be removed from the system (for routine maintenance, for example), this should not result in an interruption of the continuity of the equipment grounding (protective bonding) circuit as far as the remaining parts and subassemblies are concerned. This also applies if there is a junction at this point. If an equipment grounding (protective) conductor is disconnected, this shall not result in an interruption to the junction.

Bonding of equipment with bolts or other identified means shall be permitted if paint and dirt are removed from the joint surfaces or the bonded members are effectively penetrated.

In the event that grounding terminals for parts and subassemblies are not provided, it should be ensured that the electrical contact point is established independently of the plate or metal fastening mechanisms.

NOTICE
Damage to property
The use of different metals at the contact point can lead to electro-chemical corrosion.

Note

Doors and covers

Where electrical devices (indicator lights, pushbuttons, displays, etc.) are mounted on doors or covers, bonding shall be established between these doors and covers to the equipment grounding (protective bonding) circuit. This can either be a connection to the enclosure or to an equipment grounding terminal.

Portable, pendant, and resilient-mounted equipment shall be bonded by separate conductors. Where multiconductor cable is used, the bonding conductor shall be included as one conductor of the cable.

Exclusion of switching and overcurrent protection devices

The equipment grounding (protective bonding) circuit shall not be interrupted under any circumstances. For this reason, the equipment grounding (protective bonding) circuit shall not contain any switching devices or overcurrent protective devices (e.g. fuses).

Separable connections (such as those provided in draw-out equipment, separable by means of an attachment plug) shall ensure that the equipment grounding (protective) conductor is the first point of contact made when making, and the last to be broken when disconnecting ("First make – last break")

Connecting points for equipment grounding (protective) conductors

All equipment grounding (protective) conductors shall have their own connecting point. This ensures that the connection to other system parts and assemblies is not interrupted unintentionally when an equipment grounding (protective) conductor is removed.

The connecting points are identified as described in Chapter General requirements (Page 161).

Control circuits

Control circuits shall be permitted to be **grounded** or **ungrounded**.

Grounded control circuits

Where the control circuit is grounded, that side of the circuit that is directly connected to the solenoids shall be grounded as follows:

- AC – the secondary side of the control transformer
- DC – the secondary side of the power supply

Exceptions:

- Exposed PELV control circuits shall always be grounded. See Chapter Protection by the use of protective extra low voltage (PELV) (Page 91).
- Overload relay contacts shall be permitted to be connected between solenoids and grounded conductors where the conductors between electromagnetic devices (e.g. solenoids for magnetic motor controllers or relays) do not extend beyond the industrial control panel enclosure.

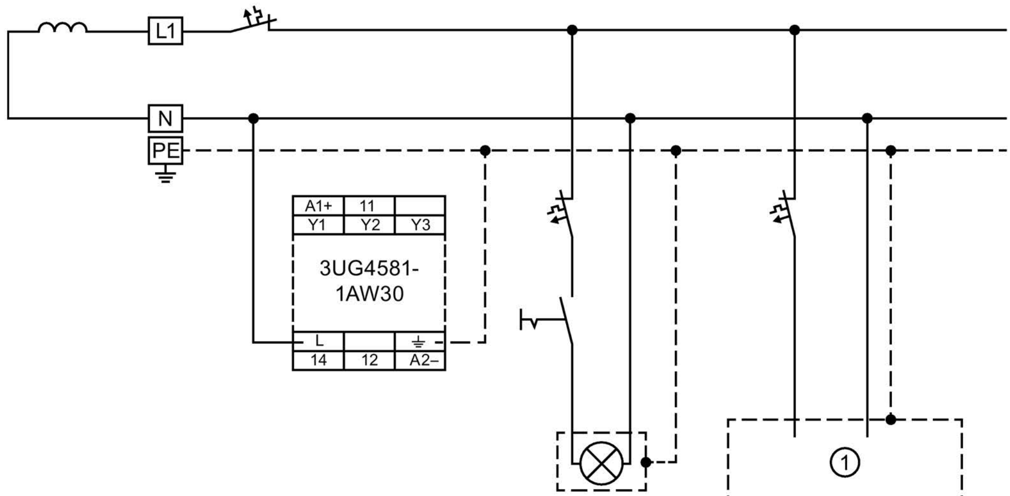
Ungrounded control circuits

Ungrounded control circuits shall be provided with an insulation monitoring device that meets the following requirements:

- A ground fault is indicated (visually, acoustically). The fault shall be rectified within a reasonable period of time.
- The circuit is interrupted automatically.

In the event of a double ground fault, this is intended to prevent important actuators (such as EMERGENCY OFF switches) from being bypassed unnoticed during normal operation.

See the figure below.



① Loads

Figure 8-3 Ungrounded control circuits

Also compare the UL 508A requirements in Chapter Requirements of UL 508A for grounding the industrial control panel (Page 162), Section "Ungrounded circuits".

Lighting circuits

Lighting circuits for machine lighting or maintenance shall be grounded. Identification shall be carried out as described in Chapter Identification and color (Page 234).

Where the lighting circuit is supplied by a separate isolation transformer, the secondary side shall be connected directly to the equipment grounding (protective bonding) circuit.

Grounded conductors, where run to a screw-shell lampholder, shall be connected to the screw-shell. See the figure below.

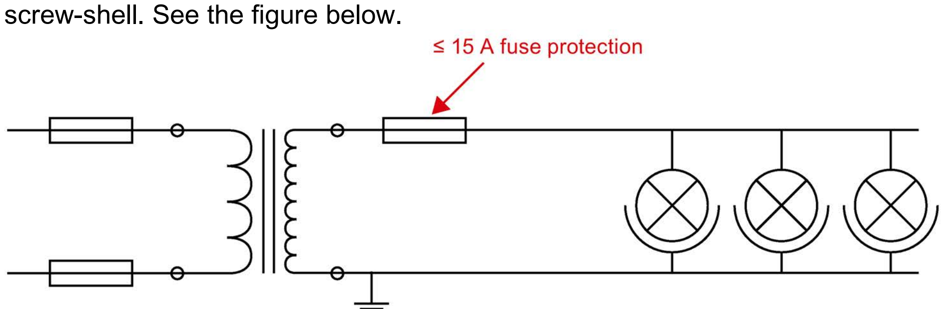


Figure 8-4 Lighting circuits

9 Control circuit functions

9.1 Start and stop functions

Start functions

Start functions shall operate by energizing the relevant circuit. This means that a device (such as a converter/drive, magnetic motor controller or circuit breaker) is activated by the generation of a signal. Interrupting a signal in order to activate a start function is not permitted.

Stop functions

Stop functions shall operate by de-energizing that relevant circuit, and shall override related start functions. The reset of the stop functions shall not initiate any hazardous conditions.

NFPA 79 defines three different categories for controlling electrical actuators with the aim of stopping them.

These categories do not make a distinction between an emergency measure (EMERGENCY STOP) and an operational measure (e.g. service and maintenance). In addition, the 0, 1, and 2 classifications do not denote any particular priority or rank. As a result, the stopping process shall always be carried out for the entire actuator, not just the electrical part of the equipment.

Table 9- 1 Stop categories

Category	Aspects		
	Energy supply	**Delay**	**Stopping**
Category 0 stop	Immediate interruption	Uncontrolled	No control
Category 1 stop	Interruption once the specified position is reached	Controlled delay via the control system	No control
Category 2 stop	No interruption	Controlled delay via the control system	Ensured by the actuator control system

9.2 Operating modes

Each machine shall be permitted to have one or more operating modes.

The operating modes for a machine are defined according to the following criteria:

- Type of machine
- Area of application (automatic and manual operation, service and maintenance, setup mode, etc.)

No hazardous conditions shall be created and no machine operation shall be initiated as a result of the mode selection. Machine functions shall be initiated separately after selecting the operating mode.

If necessary, inadvertent mode selection shall be prevented by the use of a key-operated switch or an access code.

Indication of the selected and set operating mode shall be provided (e.g. position of the mode selector switch, visual display indication, indicating light).

9.3 Overriding safety functions and protective devices

Where it is necessary to temporarily override one or more safeguards.

A mode selection device or means capable of being secured (e.g. locked) in the desired mode shall be provided to prevent automation operation. In addition one or more of the following measures shall be provided:

- Initiation of motion only by a Hold-to-run device (which automatically reverts to its original position upon release) or other control device
- A portable control station (e.g. pendant) with an EMERGENCY STOP device shall be provided. The control station shall come with an enabling function. Where a portable station is used, motion shall only initiated from that station.
- Limiting the range of motion
- Limiting the speed or power of motion

9.4 Operation

General information

All necessary safety functions and protective measures (e.g. interlocks) required for safe operation shall be provided.

The safety functions and protective measures are generally derived from the risk assessment carried out beforehand.

Safety functions according to ISO 12100

Function of a machine whose failure may lead to a direct increase of the risk(s).

These safety functions are active precautions designed to ensure that a machine is working in its intended environment and that its safety-related functions are only executed within permissible limits.

Protective measures according to ISO 12100

Technical measures using protective equipment to protect personnel against hazards or risks. Protective measures are required in the following cases:

- Hazards that cannot be adequately removed by means of inherently safe design.
- When risks cannot be sufficiently reduced.

Protective measures are passive precautions and their primary function is not to operate the machine. They are actually additional measures that are intended to protect individuals.

Further measures shall also be taken to prevent unintentional or unexpected machine movements.

Examples:

- Cancelation of a locked-off condition
- Fault in the power supply
- Battery replacement
- Loss of control signals with cableless control systems

9.4.1 Start

It shall only be possible to start an operation once all safety functions and safeguards are in place. If the conditions for cancelation are met (see Chapter Overriding safety functions and protective devices (Page 174)), however, then this constitutes an exception.

Depending on the structure, function, and area of operation, it may not be possible to apply protective measures adequately. If this is the case, it shall only be possible to perform operation via a manual hold-to-run switch and, where applicable, the controls shall be enabled beforehand.

Interlocks shall be provided to ensure correct sequential starting, e.g. sequential process steps.

Machines with multiple control stations

On machines requiring the use of more than one control station to initiate a start, the following criteria shall be met:

- Each control station shall have a separate manually actuated start control device.
- All required conditions for operating the machine shall be met.
- All start control devices shall be in the "OFF" position (released position/normally-open function) before a start can be initiated.
- All start control devices shall be actuated at the same time, but not necessarily synchronously. This means that the switch-on commands shall overlap at a particular point in time.

9.4.2 Stop

The term "Stop" is used to refer to all stop commands, regardless of whether these are initiated manually or automated by the control system.

The three stop categories are described in Chapter "Start and stop functions (Page 173)". The stop category to be applied shall be defined by the risk assessment and the functional requirements of the machine.

Note

The stop category to be applied shall be defined by the risk assessment and the functional requirements of the machine.

Recommendations for the use of stop categories

Category 0 stop is used particularly in cases where faults are present in the power supply or control system. The logic behind this is that Categories 1 or 2 may no longer be functional in such cases.

Category 1 stop is recommended in the following cases:

- When external influences are present.
- If the machine needs to be stopped for operational reasons, but the equipment (e.g. motors) need to be stopped with care because the brakes are not available, for example.

Category 2 stop can be used in cases where the process requires a specific position to be maintained after stopping. This position requires, for example, a holding torque that shall be applied by the motor.

NFPA 79 requires the following in Chapter 9.2.5.3.1:

- Each machine shall be equipped with a Category 0 stop.
- Categories 0 and 1 stops shall be operational regardless of the operating mode.
- Category 0 shall always take priority.

9.4.3 Operations in the event of an emergency (EMERGENCY STOP, EMERGENCY OFF)

General information

This section specifies more details on the two operations used in the event of an emergency, EMERGENCY STOP and EMERGENCY OFF.

The requirement for this is always:

- A conscious, human action and decision. The process shall only require a single human action.

  If the same process is performed by a machine control system, this is not considered to be an EMERGENCY STOP or EMERGENCY OFF as it does not involve conscious, human action.
- The command issued shall be stored until the process is reset by a conscious, human action.
- The system shall be reset to the state it was in before the action was initiated. This also applies in cases where multiple EMERGENCY STOP or EMERGENCY OFF buttons are actuated at different points on the machine.

In addition to the requirements for stop, the emergency stop shall have the following requirements:

- It shall override all other functions and operations in all modes.
- Power to the machine actuators, which causes a hazardous condition, shall be removed as quickly as possible without creating other hazards.
- Resetting a stop command in the event of an emergency should only permit restarting, it should not be possible to restart the machinery.

Note

EMERGENCY OFF and EMERGENCY STOP serve exclusively as additional, supplementary protective measures and not as primary, risk-minimizing measures. It is not possible to assume that people who are able to assess the risks concerned will always be at the site when a risk arises.

As a result, **NFPA 79** recommends the following:

- **ISO 12100:** Risk assessment and risk reduction
- **ISO 13850:** for the principles of design for EMERGENCY STOP and functional aspects for machines

Selecting a stop category in the event of an emergency

EMERGENCY STOP

An EMERGENCY STOP shall function as either a Category 0 or Category 1. The choice of the category of the emergency stop shall be determined by the risk assessment of the machine.

Final removal of power to the machine actuators shall be ensured. Therefore, Category 2 is not permitted. This interruption shall be ensured by means of electromechanical components, although these do not necessarily require the properties of a disconnector.
If electromechanical switching devices (such as magnetic motor controllers and relays) are used to meet the requirements of Category 0, for example, these shall be non-retentive relays.

Exception

Power electronics devices (such as drives or solid-state contactors) shall only be allowed to interrupt the power supply if they have been tested in accordance with the relevant standards.

Note

IEC 61508 and **IEC 61800-5-2** are standards for drives used in the context of safety-related functions.

EMERGENCY OFF

The EMERGENCY OFF function can be used in all cases where electrical voltage presents an immediate hazard. Above all, it is used if protection against direct contact has been achieved only by placing out of reach or by obstacles. Examples of this include collector wires/bars, control gear in electrical operating areas, and slip-ring assemblies.
Only Category 0 is available for selection in the case of EMERGENCY OFF, as the incoming supply circuit conductor is required to be disconnected in this case. EMERGENCY OFF primarily involves eliminating hazards that are caused directly by electricity.
This may even be required under load, which means that power electronics devices are not allowed to be used. Only electromechanical industrial control equipment with appropriate load-switching behavior is allowed to be used. This does not necessarily require the properties of a disconnecting device, however, which means that even magnetic motor controllers, for example, are allowed to be used for this purpose.

Where the machine cannot tolerate the Category 0 stop for EMERGENCY OFF due to safety reasons, it shall be necessary to provide other measures so that the EMERGENCY OFF function is no longer necessary. These include appropriate and adequate protective measures that prevent direct contact with live parts.

Note

EMERGENCY OFF and its functional aspects are described in **IEC 60364-5-53, Chapter 536.4**.

Control equipment 10

10.1 Enclosure type ratings

The protection of control equipment in enclosures shall be adequate, taking into account the external influences under which the machine is intended to operate. This includes the location and physical environmental conditions, including dust, coolants, and swarf. The primary concern in this case is providing protection against the ingress of foreign objects and liquids.

Enclosure type ratings are designed to protect equipment not only against external environmental influences, but also against direct contact. See Chapter Protection against direct contact (Page 82). For this reason, enclosures containing electrical equipment shall provide a minimum protection of NEMA type 1 (similar to UL Enclosure Type 1).

Exception

The minimum degree of enclosure protection, NEMA Type 1, is not required for removable collectors on collector wire or collector bar systems; in these cases, NEMA Type 1 is not practicable or achievable. Instead, adequate covers should be attached to ensure protection against direct contact.

The following information refers essentially to the requirements of UL 508A, Chapter 19 and NFPA 79, Chapter 11.

UL enclosure types (UL 508A, Chapter 26)

Requirement

Enclosure accessories, such as ventilators (fans), air conditioners, heaters, and so on, shall be UL-approved.
Most manufacturers of UL-listed enclosures have also approved all necessary accessories and tested these accordingly.

Peculiarities

The enclosure type ratings are specified both in the NEC and by UL with type numbers (e.g. Type 12). In most manufacturers' catalogs, however, the enclosure type rating is indicated with the NEMA designation (e.g. NEMA Type 12 (NEMA ICS-6)).

Note

- Comparison of UL and NEMA: An enclosure built in accordance with NEMA (standard ICS-6) is not automatically UL-listed. It shall be examined by UL for the enclosure type rating (UL type 1) and tested (UL type 3R, 12, 4, etc.).
- For UL/NEMA type 1: If there are uninsulated, live conductors in the industrial control panel, the panel shall have a roof to protect against falling dirt. (UL 508A, Art. 21.2.1)
- If a water-cooled drive is installed in an industrial control panel, mechanisms shall be put into place (preferably installed in a separate panel) to ensure that water does not touch any of the live parts should a water pipe burst.
- UL 508A – swing-out panels (only for "Industrial Control Panels for use in Industrial Machinery"). It shall be possible for these panels to swing out by more than 110 degrees. (UL 508A, Art. 66.1.1)
- In UL 508A – 3RX, 3SX, and 3X are type 3 with extra corrosion protection requirements.

"Enclosure ratings" for "Non-Hazardous" locations

Table 10- 1 List of all currently applicable "Enclosure ratings" for "Non-Hazardous" locations

Table 1
Comparison of specific applications of enclosures for indoor and outdoor non-hazardous locations

Provides a degree of protection against the following environmental conditions	**Type of enclosure**												
	1[a]	**2[a]**	**3**	**3R[a]**	**3S**	**4**	**4X**	**5**	**6**	**6P**	**12**	**12K**	**13**
Incidental contact with the enclosed equipment	●	●	●	●	●	●	●	●	●	●	●	●	●
Falling dirt	●	●	●	●	●	●	●	●	●	●	●	●	●
Dripping and light splashing of non-corrosive liquids	-	●	●	●	●	●	●	●	●	●	●	●	●
Rain, snow and sleet[b]	-	-	●	●	●	●	●	-	●	●	-	-	-
Sleet[c]	-	-	-	-	●	-	-	-	-	-	-	-	-
Circulating dust, lint, fibers, and flyings[d]	-	-	●	-	●	●	●	-	●	●	●	●	●
Settling airborne dust, lint, fibers, and flyings[d]	-	-	●	-	●	●	●	●	●	●	●	●	●
Wind-blown dust	-	-	●	-	●	●	●	-	●	●	-	-	-
Hosedown and splashing water	-	-	-	-	-	●	●	-	●	●	-	-	-
Oil and coolant seepage	-	-	-	-	-	-	-	-	-	-	●	●	●
Oil or coolant spraying and splashing	-	-	-	-	-	-	-	-	-	-	-	-	●
Corrosive agents	-	-	-	-	-	-	●	-	-	●	-	-	-
Occasional prolonged submersion	-	-	-	-	-	-	-	-	-	●	-	-	-

[a] These enclosures may be ventilated.

[b] External operating mechanisms are not required to be operable when the enclosure is ice-covered.

[b] External operating mechanisms are operable when the enclosure is ice-covered.

[d] These fibers and flyings are nonhazardous materials and are not considered Class III type ignitable fibers or combustible flyings.

Source: UL 50E

Fitting devices in industrial control panel openings

Devices which are fitted in industrial control panel openings shall be of the same Enclosure Type rating or higher (e.g. operating handles, ammeters and voltmeters, pushbuttons, indicator lights, fans, filters, and fasteners for openings, etc.). The definitions of device enclosure types and the permissible enclosure type ratings of devices for installation in enclosure openings are specified in UL 508A, Table 19.1 and 19.2.

Table 10- 2 Openings for conduit connections in enclosures with environmental rating other than Type 1

Enclosure type (Column 1)	Required construction (Column 2)
2, 3R, 3RX	a) All holes for conduit shall be below all uninsulated live parts; or b) Conduit openings below the lowest uninsulated live parts shall be provided with conduit fittings having an environmental rating that complies with Table 19.2; or c) The enclosure shall be marked as in 53.2 with instructions for the installer to apply fittings complying with (a) or (b).
3, 3S, 3SX, 3X, 4, 4X, 5, 12, 12K	d) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2 or as specified by the enclosure manufacturer; or e) The enclosure shall be marked as in 53.3 with instructions for the installer to apply fittings complying with (d).
6, 6P	f) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2.
13	g) All holes for conduit shall be provided with conduit fittings having an environmental rating that complies with Table 19.2; or h) No conduit openings shall be provided.

Source: UL 508A, Table 19.1

Table 10- 3 Openings for components in enclosures with environmental rating other than Type 1

Enclosure type	Openings are able to be closed by equipment marked
2[a]	2, 3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, "Wet Location" or "Raintight"
3	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3R[b]	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 6, 6P, "Wet Location" or "Raintight"
3RX	3RX, 3SX, 3X, 4X
3S[c]	3, 3S, 3SX, 3X, 4, 4X, 6, 6P
3SX[c]	3SX, 3X, 4X
3X	3SX, 3X, 4X
4	4, 4X, 6, 6P
4X	4X
5	3, 3R, 3RX, 3S, 3SX, 3X, 4, 4X, 5, 6, 6P, 12, 12K, 13, "Wet Location" or "Raintight"
6	6, 6P
6P	6P
12, 12K	12, 12K, 13
13	13

[a] 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.

[b] Components marked "Weatherproof" or "Rainproof" are able to be installed below all other live parts within the enclosure.
[c] 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.

Source: UL 508A, Table 19.2

Fitting devices with different ratings in one enclosure

If devices with other ratings are installed in one enclosure, and if these combinations are not covered in UL 508A, Table 19.1 and 19.2 (alternative applications), the resulting rating of the overall enclosure is given in the table below.

Table 10- 4 Alternative enclosure ratings

Enclosure type (including components and fittings that comply with Tables 19.1/19.2) (Column 1)	Component/fitting ratings that do not comply with Tables 19.1/19.2) (Column 2)	Resulting enclosure rating (Column 3)
3, 3RX, 3S, 3SX, 3X,4, 4X, 6, 6P	3R, "Wet Location", "Raintight", "Weatherproof"[c], "Rainproof"[c]	3R[a,b,c]
4X	3RX, 3SX, 3X, 4X	3RX[a, b]
4, 4X, 6, 6P	3, 3S	3[b]
4X	3X, 3SX	3X[b]
6, 6P	4, 4X	4
6P	6	6
13	12, 12K	12
12, 12K, 13	3, 3S, 4, 4X, 5, 6, 6P, "Wet Location", "Raintight"	5[b]

[a] When a drain is added.

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

[c] 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 UL 508A, Table 19.1 for Type 3R enclosures.

Source: UL 508A, Table 19.3

If the combination of ratings (enclosure and installed equipment) also does not correspond to the table above, the enclosure shall be marked with the rating "Enclosure Type 1".

Comparison of IP code and NEMA Enclosure Types

A comparison between IP codes and enclosure ratings is nothing more than a rough estimation because the tests and the pass and fail criteria are different. The table below gives you an overview of the different enclosure types. The correlation was published by NEMA.

The two tables below are intended to help users in orientation and when comparing the two rating concepts. Conversion between the enclosure types without further tests of the respective standard is not possible.

According to UL, enclosures with IP data alone are automatically awarded Enclosure Type rating 1 only, whatever the level of their IP protection.

Table 10- 5 Examples of enclosure ratings; comparison between Enclosure Type Rating and IP (Ingress Protection) rating

NEMA		**Place of installation (typical application)**	**Protection against**	**Comparable IP rating**
Type				
1	General use	Indoors	Accidental contact with live parts and ingress of falling dirt	IP 20
2	Protection against dripping water	Indoors	Ingress of dripping water and falling dirt	IP 22
3R	Rain, hail, ice	Outdoors (starter for pump)	Ingress of dust and rain blown by the wind, and protection from icing over	IP 54
4	Dustproof, waterproof	Indoor/outdoor (food industry)	Ingress of falling rain, splash water, and jet water, no damage should ice form	IP 65
4X	Dustproof, waterproof, resistant to corrosion	Indoor/outdoor (water treatment plants, manure production)	Ingress of falling rain, splash water, and jet-water, no damage should ice form, anti-corrosion protection	Not available
12	Protection against dripping water, dustproof, oil and cooling water-proof	Indoors (machine tools)	Ingress of dripping water, dust, oil, and cooling liquid	IP 54 (IP 55)
13	Protection against dripping water, dustproof, oil and cooling water-proof	Indoors (command devices on machine tools)	Ingress of dripping water, dust, spraying oil, and cooling liquid	IP 54+

The only common features between enclosure type ratings and IP ratings are:

- Personal protection against devices and components inside the enclosure that are dangerous to touch.
- Protection for devices inside the enclosure against the ingress of foreign bodies, including dust.
- Protection for devices inside the enclosure against the ingress of water.

Enclosures with only one IP code do not correspond with the additional requirements of NEMA 250 and its Enclosure Type ratings. NEMA 250 specifies further exclusive requirements for enclosures that are only identified with one IP code, meaning that Enclosure Type ratings cannot be used.

As there are fewer IP code requirements, allowing them to be considered as covered by the Enclosure Type ratings according to NEMA 250, a conservative IP Rating can be added alongside an Enclosure Type rating. The NFPA 79 Assignment of IP-Ratings to Type-Rated Enclosures table can be used to help determine this. The optional letters in the IP code are not taken into consideration in such cases.

In many practical applications, the enclosures are generally provided with an IP code and an Enclosure Type rating, and have thus been tested for the requirements of both.

Table 10- 6 NFPA 79 Table F.5.5 "Assignment of IP-ratings to type-rated enclosures"

A	NEMA enclosure type													B
IP first character	1	2	3	3R	3S	4	4X	5	6	6P	12	12K	13	IP second character
IP0_	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_0
IP1_	A	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_1
IP2_		B	AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_2
IP3_			AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_3
IP4_			AB	B	AB	AB	AB	AB	AB	AB	AB	AB	AB	IP_4
IP5_			AB		AB	AB	AB	A	AB	AB	A	A	A	IP_5
IP6_			A		A	AB	AB		AB	AB				IP_6
									B	B				IP_7
										B				IP_8

A: The first IP character designation is the protection against access to hazardous parts and solid foreign objects. The respective NEMA enclosure type meets the requirements for the IEC 60529 IP first character designation.

B: The IP second character designation is the protection against ingress of water. The respective NEMA enclosure type meets the requirements for the IEC 60529 IP second character designation.

Notes:

(1) Type-rated enclosures for hazardous locations and potentially explosive areas have been excluded from the table. The additional and supplementary letters for IP-ratings have also been excluded from the table. (See NEMA 250, ANSI/UL 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 assists in specifying enclosure ratings and should not be used as a definitive guide. For example, if the conditions of installation require an IP55, this table indicates that Type 3, 3S, 4, 4X, 6 or 6P enclosure can be utilized. However, if the conditions of installation require a NEMA Type 4, 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, the IEC does not currently accept these type-ratings without further IEC testing.

Source: NFPA 79, Table F.5.5

10.2 Working space

Chapter 11.5 of NFPA 79 specifies set minimum clearances and requirements regarding access and working spaces for industrial control panels and compartments that have a maximum voltage of 600 V and are likely to require maintenance, examination, adjustment, or servicing while energized.

Essentially, it shall be ensured that sufficient access and working space shall be provided to enable the doors or hinged panels on industrial control panels and compartments to be opened by at least 90°.

Working space depth

The working space depth in the direction of access to live parts shall be not less than indicated in the following table: "Working space depth". Distances shall be measured from the control cabinet or compartment front or opening to live parts.

Table 10- 7 Working space depth

Nominal voltage line – ground	Typical supply voltages line – line	Minimum clear distance		
		Condition 1	Condition 2	Condition 3
0 … 150	1203, 120 / 2403, 208 Y; 240Δ 3.) Single phase	914 mm (3 ft)	914 mm (3 ft)	914 mm (3 ft)
151 … 600	480 (Δ or Y) 600 (Δ or Y)	914 mm (3 ft)	1.07 m (3½ ft)	1.22 m (4 ft)

Condition 1: Exposed, live parts on one side and no live or grounded parts on the other side of the working space Or exposed, live parts on both sides effectively guarded by insulating materials. Insulated wire or insulated bus bars operating at not over 300 V to ground shall not be considered live parts.

Condition 2: Exposed, live parts on one side and a grounded surface on the other side. Concrete, brick, or tile walls shall be considered as grounded.

Condition 3: Exposed, live parts on both sides of the working space (not guarded as provided in **"Condition 1"**) with the operator between.

Exceptions to the minimum working space

- On the sides or back of industrial control panels or compartments, if:
  - no renewable or adjustable parts are installed
  - all connections are accessible from locations other than the back or sides.

  Where rear access is required to work on de-energized parts on the back of enclosed industrial control panels, a minimum working space of 762 mm (2.5 ft) horizontally shall be provided.
- If exposed parts are operated with a maximum voltage of 50 VAC or 60 VDC, a working space depth of 762 mm (2.5 ft) or less is permitted.
- The minimum working spaces under condition 2 are permitted for:
  - Industrial control panels and compartments located across the aisle from each other
  - Industrial control panels and compartments arranged across from non-machinery-associated switchgear, panelboards, or motor control centers.
    The maintenance and supervision conditions ensure that written procedures have been adopted to prohibit the affected equipment doors on both sides of the aisle from being open at the same time. In addition, qualified persons who are authorized will service the installation.
- The minimum working spaces under "Condition 1" are permitted for industrial control panels and compartments that are arranged across the aisle from each other or across from a grounded surface, and all associated control cabinet or compartment devices and equipment operating at > 50 VAC or 60 VDC are separately enclosed, guarded, or constructed so that openings to live parts of the devices and equipment are not greater than 12.5 mm (0.5 in.) diameter.
- A minimum working space of 762 mm (2.5 ft) is permitted if the following five conditions are met:
  - The operating voltage does not exceed 150 V line – line or line – ground.
  - The conditions of maintenance and supervision ensure that only qualified persons will service the installation.
  - Industrial control panels and compartments require a tool to open.
  - Where only diagnostic troubleshooting and testing on live parts are involved.
  - The doors for the industrial control panels or compartments can be opened by at least 90° or are removable.

Working space width

The width of the working space in front of industrial control panels and compartments shall be the greater of the following two minimum widths:

- The width of the industrial control panel enclosure or compartment
- Minimum 750 mm (2.5 ft)

Working space height

The minimum height of the working space is 2.0 m (6.5 ft). Other equipment associated with the machine which is installed within this minimum height, is only permitted to extend into the working space by a maximum of 150 mm (6 in.).

Doors for access to the electrical equipment shall be at least 0.7 m (2 ft/4 in.) wide and 2.0 m (6.5 ft) high. It shall be possible to open them outwards from the interior without using a key or tool. (Direction of flight in hazardous situations). This also applies, for example, to containers that house the electrical equipment for the machine.

10.3 Access and maintenance

According to NFPA 79, Chapter 11.2, all items of electrical equipment shall be installed in such a way that they can be identified without having to remove them or move the wiring. The same applies to equipment items that require regular maintenance or adjustment without the need to remove machine parts (with the exception of doors or covers) in advance. Identification refers to the conformance of equipment including its associated function with the documentation. This is generally established by means of a label whose information is the same on the equipment as it is in the documentation.

Access to terminals and their connected conductors shall be completely unobstructed.

Clearances

Exposed, live parts in industrial control panels with an operating voltage of more than 50 VAC or 60 VDC shall maintain the following clearances:

- At least 13 mm (0.5 in.) to uninsulated enclosure parts, including conduit fittings
- At least 25 mm (1 in.) to uninsulated doors

Maintenance

All devices shall be installed in a way that facilitates their maintenance and operation. Where a special tool is necessary to remove a device, the tool shall be supplied with the machine.

Specifically, the following is recommended:

- An installation height for devices involving normal maintenance and adjustment between 0.4 m (15.75 in.) and 2.0 m (6.5 ft) above the normal floor space
- An installation height for terminals of at least 0.2 m (7.88 in.). The terminals shall be arranged in a way that allows the conductors to be connected easily.

Connections and screws

To attach the components to the subplate, threaded fasteners with machine threads shall be used.

In this case, the following minimum thicknesses shall be ensured for the subplates:

- Steel subplates: At least 2 full threads
- Aluminum subplates: At least 3 full threads

Assuming the requirements specifying 2 or 3 threads for steel and aluminum subplates have been met, thread-forming or thread-cutting screws shall be permitted.

Rivets, sheet metal screws, welds, solders, or bonding materials shall not be used to mount components to a subplate.
Exception: Smooth, flat rivets shall be permitted to be used for attaching mounting rails and wiring channels.

Swing-out enclosure panels

Industrial control panels are becoming increasingly compact. In cases where this requires devices to be arranged in two vertical tiers, one on top of the other, it shall be possible to swing out the front tier. It shall also be possible to swing out the frame and enclosure panels by at least 110°. As a result, it shall be easy to access items of equipment situated behind swing frames.

10.4 Separation and grouping

10.4.1 Separation

Chapter 11.2.2 of NFPA 79 advocates strict separation between electrical equipment parts and coolant/oil reservoirs in enclosures and compartments. Compartments that open downward (open to the floor) are not permitted, whether to the foundation upon which the machine rests, or to other compartments that are not clean and dry. The same applies to pipelines, tubing, or devices for handling air, gases, or liquids.

Exception:

- Devices for cooling the electronic devices
- Pipelines, tubings and devices that are an integral part of checked and listed (e.g. UL-listed) equipment and are also separated by suitable barriers

Experience has shown that using a mixture of electrical and non-electrical items of equipment can have a significant effect on operational safety.

This requirement is based on two key **principles**:

1. Maintenance and adjustments on non-electrical equipment may, where necessary, be carried out by people who are laypersons in terms of their knowledge of electrotechnical equipment. If electrical and non-electrical equipment is arranged together in the same compartment, this may, under certain circumstances, expose these electrotechnical laypersons to increased risk.
2. If defects should arise in non-electrical equipment (e.g. pipelines, pipes, or valves that carry gases or liquids), this may have a considerable impact on the electrical equipment and its functions. In addition, it may become increasingly difficult to eliminate any other potential hazards that could arise from these defects (e.g. Arc Flash, see Chapter Arc flash hazard (protection against arc flashing) (Page 94)).

For the purpose of separating electrical and non-electrical equipment, there are various Enclosure Type ratings that relate to the principles listed above and may be applied between the equipment parts:

- Separation with an Enclosure Type rating of at least type 1 to ensure protection against accidental contact during maintenance work. (See principle 1.)
- If liquids and/or gases are present in the vicinity of non-electrical equipment, which in some cases may also still be under pressure, a high enclosure type (e.g. Enclosure Type 12 or 13) is recommended for separation purposes.

For "mixed" (electrical and non-electrical) parts in a subassembly (e.g. in the case of valves), there are additional aspects to consider. It is recommended that electrical valves for controlling liquids are situated in the non-electrical section, for example. Electrical valves that only control compressed air could be placed in the electrical section, as the consequences in the event of a defect are less significant than in the case of liquids.

10.4.2 Grouping

According to NFPA 79, Chapter 11.2.2, control devices shall be grouped separately depending on the supply voltage. Devices that are connected to the supply voltage (and which may also be connected to the control voltage) shall be arranged in groups and separated from devices that are only connected to the control voltage.

A similar principle applies to terminals and terminal strips: Separation shall be established for terminals for power circuits and associated control circuits, as well as control circuits supplied by other external sources (e.g. interlocking control circuits).
Terminals may be arranged adjacently, provided that each group is readily identified (e.g., by markings, by use of different sizes, by use of barriers, by colors). (For example, see the figure below "Grouping and separating terminals for the connection of external conductors")

These requirements are designed to ensure a neat, isolated wiring system, particularly in respect of the insulation resistance and the requirements relating to this (see Chapter Wiring practice (Page 235)), and to make it easier to identify components. This is particularly important for circuits that are capable of remaining live even when the main disconnecting means is switched off (see Chapter Identification and color (Page 234) and Chapter Excepted circuits (Page 78)).

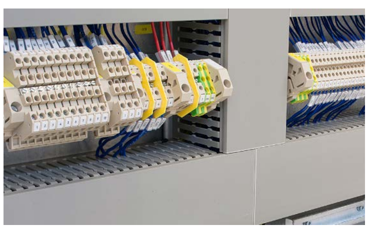


Figure 10-1 Grouping and separating terminals for the connection of external conductors

Where components are grouped, however, it is also essential to consider the interaction between the resulting power losses of the electrical equipment parts. On a general level, the NFPA 79 standard only requires that the permissible ambient temperature shall remain within the limits specified by the device manufacturer.

10.5 Enclosures, doors, and openings

Chapter 11.4 of NFPA 79 requires that the enclosure shall withstand the mechanical, electrical and thermal stresses encountered during operation. It is therefore crucial for the design and materials to be suitable for this. This applies not only to industrial control panel enclosures, but also to field devices, motor enclosures, and even electrical equipment that is housed in a container.

Equivalent requirements also apply to observation windows, and it is recommended that either reinforced glass or polycarbonate panes with a minimum thickness of 3 mm (⅛ in.) are used for these.

Corrosion protection is covered by the standard enclosure types. If additional corrosion protection is required, however, this is permitted for non-metallic enclosures that meet the criteria of the standard UL 508 "Industrial Control Equipment". In the most basic of cases, checking the relevant product certificate (issued by UL, for example) will suffice.

For subplates with a surface area greater than 1.5484 m^2 (2400 $in.^2$), additional supports shall be installed in addition to the standard mounting means. This provides aid when installing the subplate.

Fasteners of the captive type shall be used to secure doors. The fasteners shall comply with one of the following standards:

- ANSI / UL 50 Enclosures for Electrical Equipment, Environmental Considerations
- ANSI / UL 508 Industrial Control Equipment
- UL 508A Industrial Control Panels
- NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

If necessary, a simple check of the manufacturer's certificate from the testing institute (e.g. UL-Certificate) is also recommended.

NFPA 79 has an entire range of general requirements, relating to aspects such as fastening holes or openings for cable entries. One of the purposes of these is to ensure the relevant enclosure type is maintained consistently throughout the equipment.

It is a general requirement that these openings shall not result in structural changes that diminish the required enclosure type rating. The formation of condensation shall be prevented; and if this is not possible, an adequate drainage system shall be provided. Seals, doors, and covers shall be able to withstand the effects of emerging gases, vapors, or liquids and shall not diminish the enclosure type rating.

Accessories for securing the doors and covers shall not have a negative impact on the enclosure type, even when these are removed for maintenance. The accessories shall be securely connected to the door, cover, or enclosure.

In addition, strict separation shall be established between electrical equipment and parts which contain coolants, lubricants, and hydraulic fluids. See also Chapter Separation (Page 194).

NFPA 79 also has a general requirement for equipment which, during normal or abnormal operation, is capable of attaining surface temperatures sufficient to cause a fire hazard or have a harmful effect on the enclosure material.

The following requirements apply in this case:

- Installation in an enclosure that can withstand such temperatures without fire hazards or harmful effects.
- Installation and location at a sufficient distance from adjacent equipment so as to allow dissipation of heat without creating a hazard. See also Chapter Grouping (Page 195).

  Alternatively, screened by a material that can withstand the heat emitted by the equipment without the risk of fire or harmful effects.

However, there are no specific temperatures given in this context. In this case, an example of an abnormal ambient temperature would be one that is over 40 °C; this exceeds the standard area of application for UL 508A and NFPA 79.

10.6 Operator interfaces and control devices

10.6.1 General information

This chapter contains the requirements for control equipment in conjunction with the electrical equipment of machinery. The functions, types, colors and arrangement of such equipment are described throughout.

Many items of control equipment and operator interfaces are arranged completely outside or partially outside the industrial control panel. Control devices (e.g. pushbuttons, selector switches, indicator lights) shall always be readily accessible. However, control devices shall also be arranged in such a way as to prevent inadvertent or undesired operation.

Since machines are used in many different environments, the NFPA 79 standard encompasses rules on the following topics:

- Selection and use of control devices and operator interfaces
- Location and mounting of control devices and operator interfaces
- Color
- Ambient conditions

NFPA 79 also recommends the two IEC standards for other requirements beyond the scope of the standard with regard to selection, mounting, color, and marking of user interfaces and control devices:

- **IEC 61310-1**

  "Safety of machinery - Indication, marking and actuation - Part 1: Requirements for visual, acoustic and tactile signals"
- **IEC 61310-3**

  "Safety of machinery - Indication, marking and actuation - Part 3: Requirements for the location and operation of actuators"

10.6.2 Location and mounting

10.6.2.1 Control devices

As far as is practicable, control devices shall always be arranged as ergonomically as possible and shall be readily accessible to facilitate reading, operation, service and maintenance. The normal operating conditions and machine operations shall also be taken into account since the possibility of damage to the control equipment by machine movements (e.g. material handling) shall be minimized.

If the control devices are hand-operated control devices, they shall be installed not less than 2 ft (0.6 m) above the normal standing level of operating personnel. The hand-operated control devices shall be installed in such a way that the operator is not placed in a hazardous situation when operating them, and the danger of accidental, inadvertent operation is minimized.

Figure 10-2 Machine environment

10.6.2.2 Control equipment outside the industrial control panel in the machinery field

Control devices (e.g. limit switches, brakes, solenoids, position sensors) shall be mounted rigidly and arranged in such a way as to exclude accidental operation by the operator, or as a result of machine movements.

The environment shall be as clean and dry as possible in case the devices have not been tested for the respective ambient conditions. In addition, there shall be sufficient protection against mechanical damage. Position sensors such as limit switches and proximity switches shall be installed such that accidental overtravel by the machine will not damage them by, for example, arranging the sensor in parallel with the direction of movement. See the figure "Proximity switch" below.

Suitable cable ducts or conduits are often used for the mechanical protection of incoming supply cables to these external devices installed in the field.

Exception

Prewired devices such as limit switches or proximity switches provided with an identified cable need not be equipped with provisions for termination of conduits. See the figure "Proximity switch" below.

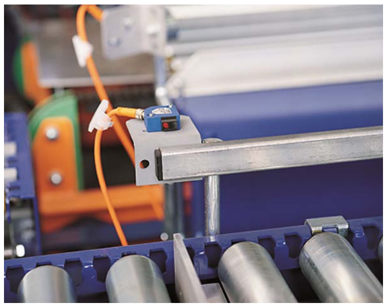


Figure 10-3 Proximity switch

10.6.2.3 Protection

All control devices, operator interfaces, sensors and actuators arranged partially outside the industrial control panel or mounted in the vicinity of the machine shall have a suitable enclosure type rating, and they shall withstand the stresses of expected use created by the respective environmental conditions.

Care shall be taken to select a correspondingly tested protection rating (e.g. Enclosure Type rating). The UL/NEMA Enclosure Types normal in North America are described in the standards ANSI / UL 50, ANSI / UL 508 or NEMA 250.

The IP enclosure types common in IEC standards are found in the IEC 60529 standard. For more detailed information on enclosure type ratings, see Chapter Enclosure type ratings (Page 181).

10.6.3 Special features of the individual devices

10.6.3.1 Arrangement of pushbuttons for START

Pushbuttons for STARTING a machine operation shall be positioned either above or to the left of the associated STOP pushbuttons.

Exception

- EMERGENCY STOP pushbuttons mounted in the floor of suspended stations with a spring rod or rod lever for actuation.
- Series-switched START pushbuttons (e.g. for presses)

10.6.3.2 Foot-operated switches

Foot-operated switches shall be protected against accidental operation, e.g. by falling objects, to avoid the creation of a hazardous situation.

However, if the foot-operated switch is used for the EMERGENCY STOP function, the actuation element shall not be covered.

Figure 10-4 Siemens 3SE2 foot-operated switch with cover

10.6.3.3 Operator controls on pushbuttons and color displays

Design requirements

Pushbuttons are frequently used for initiating a STOP function. In this case, the operator control can be one of the following design versions:

- Mushroom-head type

  Example:

Figure 10-5 Siemens 3SB3 mushroom-head type pushbutton

- Extended operator control type that projects beyond the protective ring

  Example:

Figure 10-6 Siemens 3SB3 extended operator control type pushbutton

Color

The color for operator controls of pushbuttons and icons for displays shall be selected according to a specific color scheme. In the table "Colors for the operator controls of pushbuttons" below, the respective meanings of the required colors is shown.

Table 10- 8 Colors for the operator controls of pushbuttons

Identification of pushbuttons	Color
Start / "On"	Green or black / white / gray
Stop / "Off"	Red or black / white / gray **Exception:** Position switches with spring rod or rod lever
EMERGENCY STOP	Red
Pushbuttons with double-assignment (Start and Stop; On and Off)	Black / white / gray
Unusual operating states	Yellow
Hold-to-run switches	Black or white / gray / blue
Reset	Blue / black / white / gray **Exception:** with simultaneous Off / Stop function: Red

Function identification

All operator interfaces shall be provided with a permanent and legible function identification. See Chapter Function identification (Page 287) for further details.

EMERGENCY STOP devices that already meet the requirements of the color scheme (red/yellow) do not absolutely require this additional function identification. More detailed information on this can be found in Chapter Devices and requirements for STOP and EMERGENCY STOP (Page 205).

Colors for indicator lights and icons in color displays

In the table "Colors for indicator lights and icons in color displays" below shows the colors for indicator lights and icons in color displays depending on the machine operation.

Alternative uses are permitted to display other machine or process states. This is often implemented on signal columns. The recommendation here is to maintain the following order of colors (from top to bottom).

Figure 10-7 Example of Siemens 8WD4 signal column

This is designed to display the meaning by means of the position of the light for service personnel with color blindness problems. Similarly to traffic lights, operating personnel often use not only the color but also the position of the lighting for orientation. In that case, the importance of the information diminishes from top to bottom.

Table 10- 9 Colors for indicator lights and icons in color displays

Color	Purposes		
	Safety of persons or environment	Condition of process	State of machine
Red	Danger	Emergency	Faulty
Yellow (amber)	Warning / caution	Abnormal	Abnormal
Green	Safe	Normal	Normal
Blue	Mandatory action		
Clear White Gray Black	Neutral		

Note

With emergency stop devices, the indicator color shall be red regardless of the lighting source.

10.6.3.4 Flashing lights

The use of flashing lights shall be permitted to be used for any of the following purposes:

1. To attract attention
2. To request immediate action
3. To indicate a discrepancy between the command and actual states
4. To indicate a change in process (flashing during transition)

For further, detailed information with regard to flashing frequencies and pulse and pause rates, IEC 61310-1 "Safety of machinery - Indication, marking and actuation" is recommended.

10.6.3.5 Illuminated pushbuttons

If pushbuttons with integral lighting are used, the same colors shall be maintained as for pushbuttons, indicators and warning lights.

The required color specifications can be found in Table 10-9 Colors for indicator lights and icons in color displays (Page 204).

Note

The warning color red for EMERGENCY STOP devices shall not be dependent on the illumination source. This means that even if the light source fails, EMERGENCY STOP devices are still clearly recognizable.

10.6.3.6 Rotary control devices

When installed in operator consoles or control panel doors, for example, devices having a rotational member, such as potentiometers and selector switches, shall be secured not only by means of the created friction. With diminishing friction, safe fixing would be lost.

10.6.4 Devices and requirements for STOP and EMERGENCY STOP

10.6.4.1 General information

It shall be possible to operate and access STOP and EMERGENCY STOP devices at all times. STOP and EMERGENCY STOP devices shall always be located at every operator control station.

EMERGENCY STOP devices shall be installed at other locations where required. An EMERGENCY STOP is required on every machine and is always required at the operator control station. See the figure "Example of operator control station with EMERGENCY STOP" below.
The requirements regarding the positions at which an additional EMERGENCY STOP shall be installed can vary widely for different machines. This is usually derived from the result of the risk analysis based on a standard such as ANSI B11 TR3 and TR4 "Standards for machine tools" or IEC 62061 "Safety of machinery" or ISO 13849-1 /-2 "Safety of machinery"

Figure 10-8 Example of operator station with EMERGENCY STOP

NFPA 79 has no detailed definition for the term "operator control station". Rather, this is a general term for the equipment of a machine that is used by the operator to control the different functions of the machine.

Furthermore, EMERGENCY STOP shall not be used as a replacement for a protective measure or another safety function. The EMERGENCY STOP is rather a supplementary protective measure but not a suitable measure for minimizing a risk. The reason for this is that it cannot necessarily be assumed that a person is always in the immediate vicinity to detect the hazard and actuate the EMERGENCY STOP.

10.6.4.2 Types of EMERGENCY STOP devices

The following device types are always approved for EMERGENCY STOP, but are not limited to this:

- Pushbuttons, palm or mushroom-shaped
- Pull-cord-operated switches
- Foot-operated switches without protective covers
- Push-bar-operated switches
- Rod-operated switches

On EMERGENCY STOP devices, the contacts of pushbuttons shall latch mechanically and have positive opening.

Note

Switches with flat actuation or graphical symbols in software applications are not permitted for EMERGENCY STOP.

10.6.4.3 EMERGENCY STOP actuators

The color combination is a primary recognition feature for the actuators on EMERGENCY STOP devices. The following are mandatory and reserved exclusively for this function:

- Actuator with palm or mushroom shape: Red
- Background: Yellow

Note

- The background can be a yellow enclosure of the HMI device. Optionally also a yellow ring stuck, for example, onto the enclosure behind the actuator.
- Labeling can be dispensed with on EMERGENCY STOP devices if it is not possible for space reasons, for example.
- With pull-cord operated switches, a yellow background is usually not available.
  ISO 13850 recommends suitable identification with marking flags here. See the figure "Symbol for EMERGENCY STOP" below (ISO 13850 Safety of machinery – Emergency stop – Principles for design).

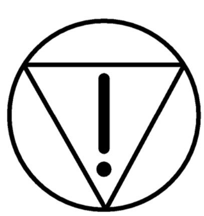


Figure 10-9 Symbol for EMERGENCY STOP

10.6.4.4 Local operation of the disconnecting means to effect EMERGENCY STOP

In addition to the devices listed in Chapter Types of EMERGENCY STOP devices (Page 206), the disconnecting means is also permitted to be used for EMERGENCY STOP if all the following conditions are met:

- Corresponding color scheme (actuator red, background yellow)
- Readily accessible
- "ON" and "OFF" positions are available
- Lockable in the "OFF" position
- External actuator capable of being operated regardless of the door position (see Chapter Protection against direct contact (Page 82), Section "3. Protection by door interlock")

There are no specific requirements regarding the shape of the actuator. A toggle lever or rotary lever actuator is usually used here. See the figure "Door coupling rotary operating mechanism for EMERGENCY STOP" below.

Figure 10-10 Door coupling rotary operating mechanism for EMERGENCY STOP

Note

- The requirement for ease of access often means this can only be implemented on smaller machines.
- Use of the disconnecting means as EMERGENCY STOP leads functionally to uncontrolled stopping! (Category 0 stop, see Chapter Start and stop functions (Page 173)). An assessment is therefore required to decide if this is permissible in the respective application in conjunction with an EMERGENCY STOP.

10.6.5 Devices and requirements for the EMERGENCY OFF

10.6.5.1 General requirements and position of the EMERGENCY OFF

EMERGENCY OFF devices are necessary in the case of electrical hazard. Such an electrical hazard includes, for example, the risk of electric shock or other hazards that can be caused by electricity, e.g. fire.

Note

Since this involves disconnection of the electrical supply and thus Category 0 stop (uncontrolled stopping) is applied, it is also necessary here to consider the situation in advance to avoid other resulting hazards.

Position of the EMERGENCY OFF

The EMERGENCY OFF for preventing electrical hazards shall be located wherever required in the respective application. This can vary from case to case and is frequently within the environment of the respective machine (e.g. production hall).

A clear differentiation between EMERGENCY OFF and EMERGENCY STOP is not initially provided for an operator. However, if conditions dictate that an EMERGENCY OFF has to be arranged in the immediate vicinity of an EMERGENCY STOP, additional measures can be taken to avoid priority operation of the EMERGENCY OFF. On pushbuttons, this can be implemented with a folded-edge disk behind which the EMERGENCY OFF is attached.

10.6.5.2 Types of EMERGENCY OFF devices

The following device types are always approved for EMERGENCY OFF but are not limited to this:

- Pushbuttons (palm or mushroom-shaped)
- Pull-cord-operated switches

Note

- Switches with flat actuation or graphical symbols in software applications are not permitted for EMERGENCY OFF.
- After actuating the EMERGENCY OFF; the electrical power may only be restored by manually resetting the EMERGENCY OFF switch.

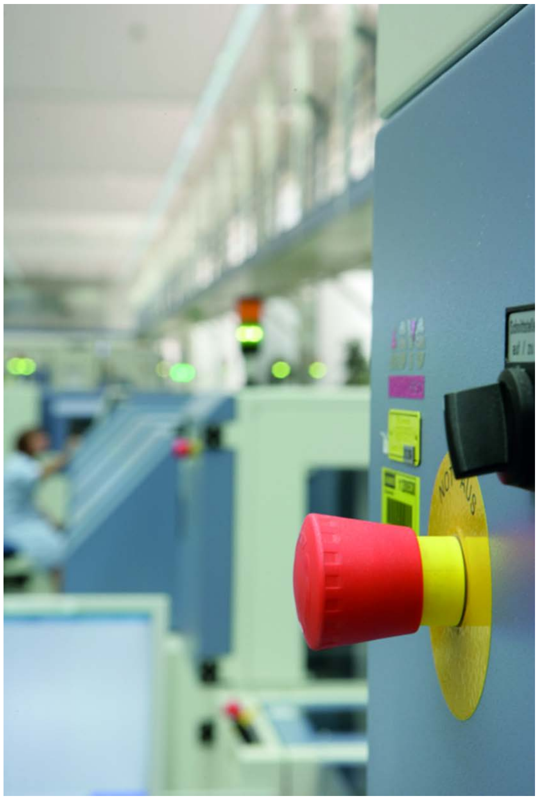


Figure 10-11 Example of an EMERGENCY OFF pushbutton in the application

10.6.5.3 Actuators

The color scheme shall be maintained as follows:

- Actuator: Red
- Background: *may* be yellow

Note

The optional color yellow for the background results from the possibility of confusion with EMERGENCY STOP devices. Placing EMERGENCY OFF and EMERGENCY STOP devices with the same type of construction (e.g. pushbuttons) next to each other shall be avoided. However, if this cannot be avoided, the risk of confusion can be reduced with the help of the following identification methods:

- Color differences
- Suitable labeling

10.6.5.4 Local operation of the disconnecting means to effect EMERGENCY OFF

If the disconnecting means is used for the EMERGENCY OFF function, the disconnecting means shall be readily accessible at all times, and shall meet the same requirements regarding color scheme as described in Chapter Actuators (Page 209).

Cables and conductors 11

11.1 General information

This chapter focuses on:

- Certifications
- Sizing
- Marking and colors
- Cables

These topics are described comprehensively in the relevant standards, and explained in more detail in the coming chapters.

11.2 Certifications

According to NFPA 79, Chapter 12, and UL 508A, Chapters 29, 66.5 and 38, cables and conductors shall be approved for the relevant purpose and be selected in accordance with the relevant area of application.

Within the industrial control panel, this guide refers primarily to the rules of UL 508A, and outside the control panel it refers mainly to the rules of NFPA 79.

11.2.1 Inside the industrial control panel

11.2.1.1 Power circuit

- All conductors or bus bars shall be made of copper.
- The insulation shall be designed for the relevant voltage.

Exception

The voltage rating of conductors connected to a DC circuit shall be the peak equivalence of the rms voltage marked on the conductor ($U_{rms} \times \sqrt{2}$). Example: A DC bus or DC motor circuits supplied from power conversion equipment.

All internal wiring shall be approved for at least 90 °C (194 °F).

Approved cables/conductors

The following cables/conductors are permitted:

Designation	Standard	CCN
Machine tool wire ("flexing" or "class K") installed in accordance with UL 508A, Chapter 29.3.11	UL 1063	ZKHZ
Thermoset insulated wire	UL 44	ZKST
Appliance wiring material	UL 758	AVLV2
Welding cable installed in accordance with UL 508A, Chapter 29.3.11	UL 63	ZMAY
Flexible supply cords for heavy-duty and medium-duty use	UL 62	ZJCZ

Exception

Cables that are a permanent component part of a plug connector do not have to comply with the above requirements if used with UL 498 approved receptacles.

See also

Wiring practice (Page 235)

11.2.1.2 Control circuit

The same cable approvals and requirements apply in the control circuit as in the power circuit. One of the following conditions shall also be met:

- Internal conductors 90 °C (194 °F).

  This does not include conductors that are ≤ AWG 16. These shall be approved for at least 60 °C (140 °F)
- Power limited cable according to UL 13 (CCN: QPTZ) and Communication cable according to UL 444 (CCN: DUZX) are approved for use in class 2 or Low voltage limited energy circuits and shall be routed separately to internal conductors of other circuits if the conductor has a lower insulation resistance than the maximum occurring voltage of any circuit (see also Chapter Inside the industrial control panel (Page 236)).

NFPA 79 does not make a distinction between the inside and outside of the industrial control panel in terms of the requirements for cables/conductors. For this reason, the following regulations listed under Outside the industrial control panel (Page 214) apply equally to the industrial control panel according to NFPA 79.

Unlike NFPA 79, UL 508A refers more to the relevant approvals in more specific terms and, in some respects, stipulates somewhat stricter requirements (e.g. in relation to the permissible insulation temperature (90 °C)).

On the whole, however, the regulations listed above can be said to cover both standards.

11.2.2 Outside the industrial control panel

11.2.2.1 Fundamental requirements of cables and conductors

Only NFPA 79 covers the area **outside the industrial control panel** (field wiring) for industrial machinery. The subject of "Conductors, Cables, and Flexible Cords" is described in Chapter 12.

Note

a) Conductors shall be insulated.

Exceptions

- Bus bars
- Exposed supply cords for capacitors, resistors, jumpers between terminals, for example
- Grounding conductors and bonding jumpers shall be permitted to be covered or exposed.

b) Conductors shall be of copper

Exception

- Bus bars inside the industrial control panel; these may be made of aluminum if this means they are suitable and approved for the relevant application.

NOTICE
UL 508A permits only copper bus bars.

In conjunction with conductors, NFPA 79 usually only describes properties but does not refer to specific testing standards in the way that UL 508A does, for example.

The following table is designed to provide a guide for users. The table shows a selection of "listed" conductors that are suitable for industrial machines. In the case of UL-listed conductors, the Category Control Number (CCN) is specified in a separate column.

Type	Designation	CCN	Approval	Temp. [°C]	
				Dry	Wet
MI cable	Mineral-insulated metal-sheathed cable	PPKV	LISTED	85	85
MTW	Machine tool wire	ZKHZ	LISTED	90	60
THHN	Thermoplastic-insulated wire	ZLGR	LISTED	90	--
THW	Thermoplastic-insulated wire	ZLGR	LISTED	75	75
THWN	Thermoplastic-insulated wire	ZLGR	LISTED	75	75
RHH	Thermoset-insulated wire	ZKST	LISTED	90	--
RHW	Thermoset-insulated wire	ZKST	LISTED	75	75
RHW-2	Thermoset-insulated wire	ZKST	LISTED	90	90
XHHW	Thermoset-insulated wire	ZKST	LISTED	90	75
XHHW-2	Thermoset-insulated wire	ZKST	LISTED	90	90

Figure 11-1 Selection of "UL-listed" conductors suitable for industrial machines

11.2.2.2 Conductors and cables for flexible applications

Conductors and cables that are subject to permanent movement and high bending stresses shall be suitable for the respective application area.

The table below describes the different classes of flexible conductors. Conductors shall be selected according to this table.

Table 11- 1 Single conductor characteristics

Wire size (AWG or kcmil)	Cross-sectional area, nominal (cm / mm^2)	DC resistance at 25 °C (77 °F) (ohms / 1000 ft)	Nonflexing (ASTM class)	Flexing (ASTM class)	Constant flex (ASTM class/AWG size)
22 AWG	640/0.324	17.2	7(‘)	7(‘)	19(M/34)
20	1020/0.519	10.7	10(K)	10(K)	26(M/34)
18	1620/0.823	6.77	16(K)	16(K)	41(M/34)
16	2580/1.31	4.26	19(C)	26(K)	65(M/34)
14	4110/2.08	2.68	19(C)	41(K)	41(K/30)
12	6530/3.31	1.68	19(C)	65(K)	65(K/30)
10	10380/5.261	1.060	19(C)	104(K)	104(K/30)
8	16510/8.367	0.6663	19(C)	(\)	(–)
6	26240/13.30	0.4192	19(C)	(\)	(–)
4	41740/21.15	0.2636	19(C)	(\)	(–)
3	52620/26.67	0.2091	19(C)	(\)	(–)
2	66360/33.62	0.1659	19(C)	(\)	(–)
1	83690/42.41	0.1315	19(B)	(\)	(–)
1/0	105600/53.49	0.1042	19(B)	(\)	(–)
2/0	133100/67.43	0.08267	19(B)	(\)	(–)
3/0	167800/85.01	0.06658	19(B)	(\)	(–)
4/0	211600/107.2	0.05200	19(B)	(\)	(–)
250 kcmil	– /127	0.04401	37(B)	(\)	(–)
300	– /152	0.03667	37(B)	(\)	(–)
350	– /177	0.03144	37(B)	(\)	(–)
400	– /203	0.02751	37(B)	(\)	(–)
450	– /228	0.02445	37(B)	(\)	(–)
500	– /253	0.02200	37(B)	(\)	(–)
550	– /279	0.02000	61(B)	(\)	(–)
600	– /304	0.01834	61(B)	(\)	(–)
650	– /329	0.01692	61(B)	(\)	(–)
700	– /355	0.01572	61(B)	(\)	(–)
750	– /380	0.01467	61(B)	(\)	(–)
800	– /405	0.01375	61(B)	(\)	(–)

Wire size (AWG or kcmil)	Cross-sectional area, nominal (cm / mm²)	DC resistance at 25 °C (77 °F) (ohms / 1000 ft)	Nonflexing (ASTM class)	Flexing (ASTM class)	Constant flex (ASTM class/AWG size)
900	– /456	0.01222	61(B)	(\)	(–)
1000	– /507	0.01101	61(B)	(\)	(–)

Notes:

(B), (C), (K): ASTM class designation B and C per ASTM B 8; class designation K per ASTM B 174.

(‘): A class designation has not been assigned to this conductor but it is designated as 22-7 AWG in ASTM B286 and is composed of strands 10 mils in diameter (30 AWG).

(\): Nonflexing construction shall be permitted for flexing service per ASTM class designation B 174, Table 3.

(–): Constant flexing cables are not constructed in these sizes.

Source: NFPA 79, Table 12.2.2

ASTM classifications are also specified in the table. These are usually specified by cable manufacturers in the technical data.

Cables subjected to severe duties shall be protected against the following influences:

- Abrasion due to sharp edges
- Kinking due to operation without guides
- Stress due to guide rollers, forced guiding, and being wound and rewound on cable drums

The cables shall be handled in such a way that the tensile load is kept to a minimum during operation. The manufacturer's specifications shall be observed.

Conductors and cables for such conditions are described in the respective national standards. Most countries now follow the international IEC standards. In the USA, however, they continue to use their national standards.

The service life of cables and conductors is influenced crucially by unfavorable operating conditions such as high tension, small bending radii, unfavorable horizontal/vertical routing in combination with high movement stresses.

11.2.2.3 Cable drums

Cable drums shall be selected with cables that do not exceed the maximum permissible operating temperature when wound up.

Derating factors according to NFPA 79, Table 12.7.3:

Table 11- 2 Derating factors for cables wound on drums

Drum type	Number of layers of cable				
	Any number	1	2	3	4
Cylindrical venti-lated	-	0.85	0.65	0.45	0.35
Radial ventilated	0.85	-	-	-	-
Radial nonventilat-ed	0.75	-	-	-	-

Notes:

(1) A radial-type drum is one where spiral layers of cable are accommodated between closely spaced flanges. If fitted with solid flanges, the drum is described as nonventilated; if the flanges have suit-able apertures, as ventilated.

(2) A ventilated cylinder drum is one where the layers of cable are accommodated between widely spaced flanges and the drum and end flanges have suitable ventilating apertures.

(3) It is recommended that the use of derating factors be discussed with the cable and the cable drum manufacturers. This can result in other factors being used.

Source: NFPA 79, Table 12.7.3

11.2.2.4 Cords

Cords

Cords shall have the following properties:

- Suitable for the relevant application
- Listed in the table

Cords from Table 400.4 of the NEC are permitted if they form part of a tested and listed assembly and are suitable for the intended use.

Exception

Other cord types shall be permitted if they form part of a listed assembly or are otherwise suitable for the intended application.

11.2.2.5 Special cables and conductors

General information

Particularly with machines for special applications, it is often the case that the required cables and conductors are not covered by the conductor types specified in the standard. When using such special conductors, additional factors shall be taken into account to ensure intended use. The following factors shall be taken into account especially: Chemical influences, flexibility, flammability, shielding, cable routing/arrangement. Conductors/cables tested in accordance with ANSI / UL 758 usually have, in addition to the AWM labels, markings referring to their insulation (see Chapter Fundamental requirements of cables and conductors (Page 214)) and their suitability as cords (see Chapter Cords (Page 218)).

Special conductors and cables shall be suitable for the relevant type of use and approved as specified in NFPA 79, Chapter 12.9.

Appliance Wiring Material (AWM)

Cables marked Appliance Wiring Material (AWM) may be used if one of the following requirements has been met:

- Part of a tested application

  This means the AWM cable has been identified for use with approved equipment and shall be used in accordance with the equipment manufacturer's instructions as per UL certification.

Figure 11-2 Example of AS-Interface cable as a component of a tested application

- Required for a tested application according to the manufacturer's instructions (UL certification)

Insulated Conductor	40 AWG min., Labeled or complying with Manufacturer's AWM Procedure.
Assembly	Consists of two or more conductors, twisted pairs or groups of twisted conductors twisted together. The conductors or groups of conductors may be laid parallel forming a flat, oval or round cable. The lay of the conductors is not specified. A barrier layer and/or fillers are optional. Manufacturer shall maintain a complete description of each assembly. May use same or mixed AWG size.
Use	External interconnection or internal wiring of electronic equipment.

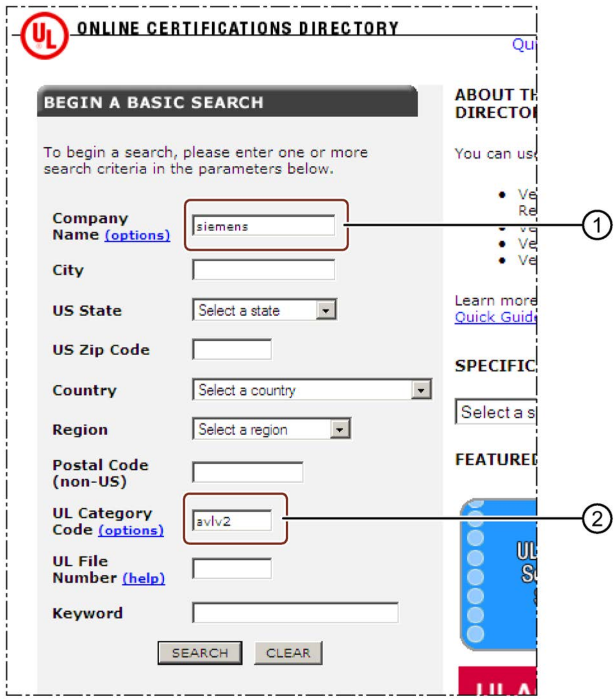
Figure 11-3 Example of a motor cable on the load side of a variable-speed drive with associated extract from the Guide Info (UL database) of the manufacturer

- If the sizing of the AWM cable corresponds to the requirements of NFPA 79, Chapter 12.9.2 (3) (e.g. insulation properties)

AWM cables are approved in accordance with UL 758 recognized. This means that the "Conditions of Acceptability" shall be adhered to. The approved area of application can be found in the "Table of recognized styles" under UL – Online Certifications Directory (http://www.ul.com/database).

Example

❶



① Enter manufacturer

② Enter Category Control Number "AVLV2"

❷

You may choose to **Refine Your Search.**

Company Name	Category Name	Link to File
SIEMENS AG	Appliance Wiring Material - Component	AVLV2.E223748
SIEMENS AG	Appliance Wiring Material - Component	AVLV2.E172119

③ Select the required file

❸

Table of Recognized Styles

Single-conductor, thermoplastic insulation.

1003	1060	1160	1296	1371	1507	1632	10152
1007	1061	1161	1297	1375	1508	1642	10239
1011	1062	1162	1298	1379	1511	1645	10258
1013	1063	1176	1299	1380	1516	1647	10263
1015	1064	1177	1300	1381	1517	1649	10269
1017	1065	1184	1301	1382	1518	1650	10271
1019	1066	1185	1302	1385	1519	1662	10324
1020	1071	1186	1303	1386	1520	1672	10390
1021	1095	1195	1304	1420	1521	1680	10449

④ Select the required style number

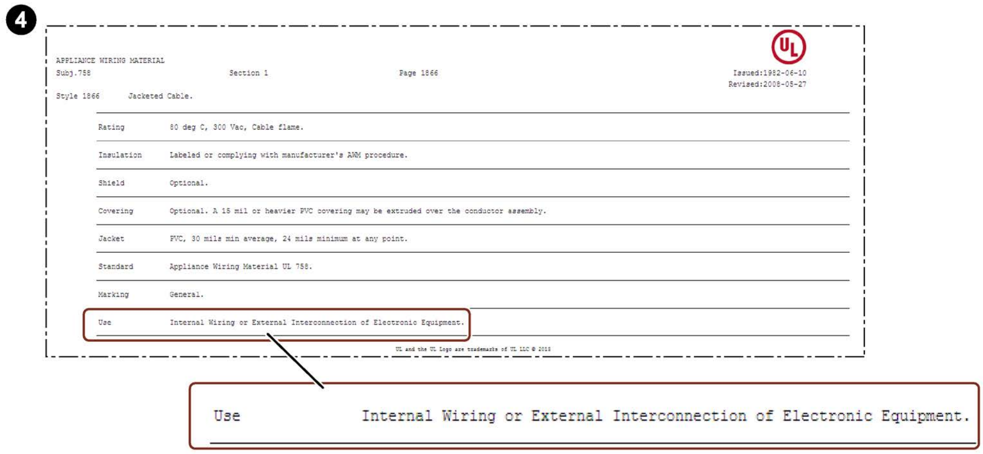


Figure 11-4 Extract from the guide information for style number 1866

Table 11- 3 AWM style number system (4 or 5-digit number)

1xxxx	Single conductors with thermoplastic insulation
2xxxx	Multiple conductors with thermoplastic insulation
3xxxx	Single conductors with thermoset (cross-linked) insulation
4xxxx	Multiple conductors with thermoset (cross-linked) insulation
5xxxx	All others that do not fall between 1xxxx and 4xxxx (e.g. mineral-insulated conductors).

11.3 Sizing

The following chapter of this guide describes the regulations according to UL 508A and NFPA 79 that govern the conductor/cable sizing inside and outside the industrial control panel.

11.3.1 Inside the industrial control panel

11.3.1.1 Power circuit

Conductor sizing in the power circuit is described in UL 508A, Chapter 29.6.

Conductors in the power circuit shall not be smaller than AWG 14 (2.1 mm²). See also Chapter 66.5.4.

Exception for Industrial Machinery

For power circuits that correspond to the requirements of the table below, AWG 16 or AWG 18 cables may be used.

Table 11- 4 Ampacity and protection for power circuits with AWG 16 and AWG 18 conductors

Conductor		Load type	Max. ampere rating for branch circuit protection	Motor overload trip class
Size	**Ampacity**			
16 AWG	8	Non-motor	10[a]	-
	8	Motor	Per "UL 508A, Table 31.1 "Maximum rating of motor branch circuit device percent of full load amperes", Chapter Single Installation (Page 104) [a]	Class 10
	5.5	Motor	Per "UL 508A, Table 31.1 "Maximum rating of motor branch circuit device percent of full load amperes", Chapter Single Installation (Page 104) [a]	Class 20
18 AWG	5.6	Non-motor	7[b]	-
	5	Motor	Per "UL 508A, Table 31.1 "Maximum rating of motor branch circuit device percent of full load amperes", Chapter Single Installation (Page 104) [b]	Class 10
	3.5	Motor	Per "UL 508A, Table 31.1 "Maximum rating of motor branch circuit device percent of full load amperes", Chapter Single Installation (Page 104) [b]	Class 20

[a] Inverse time circuit breaker marked for use with 16 AWG or 18 AWG conductors, Class CC, J or T fuse.

[b] Inverse time circuit breaker marked for use with 18 AWG conductors, Class CC, J or T fuse.

Source: UL 508A, Table 66.2

The full-load amps shall be determined by adding the nameplate currents for all external loads that are supplied by this conductor. The full-load amps for motors with power specified in terms of horsepower shall be determined according to Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) (AC motors) or Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99) (DC motors).

Background

As motors can have different levels of efficiency, sizing should be performed using the values in Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98) and Table 6-2 Full-load motor-running currents in amperes corresponding to various DC horsepower ratings (Page 99). These values represent the worst-case scenario and are generally overestimated. However, this ensures that the conductors are not underdimensioned if a motor has to be replaced (e.g. in the event of damage), even if the replacement motor has a lower level of efficiency and carries a higher rated current at the same level of power.

The conductor appropriate to the calculated rated current shall be selected in accordance with the following table "Ampacities of insulated conductors". The table below shows the ampacity of insulated conductors with different cross-sections.

Table 11- 5 Ampacities of insulated conductors

Wire size		60 °C (140 °F)		75 °C (167 °F)	
AWG	(mm²)	Copper	Aluminum	Copper	Aluminum
14	(2.1)	15	-	15	-
12	(3.3)	20	15	20	15
10	(5.3)	30	25	30	25
8	(8.4)	40	30	50	40
6	(13.3)	55	40	65	50
4	(21.2)	70	55	85	65
3	(26.7)	85	65	100	75
2	(33.6)	95	75	115	90
1	(42.4)	110	85	130	100
1/0	(53.5)	-	-	150	120
2/0	(67.4)	-	-	175	130
3/0	(85.0)	-	-	200	155
4/0	(107.2)	-	-	230	180
250 kcmil	(127)	-	-	255	205
300	(152)	-	-	285	230
350	(177)	-	-	310	250
400	(203)	-	-	335	270
500	(253)	-	-	380	310
600	(304)	-	-	420	340
700	(355)	-	-	460	375
750	(380)	-	-	475	385
800	(405)	-	-	490	395

Wire size		60 °C (140 °F)		75 °C (167 °F)	
AWG	(mm²)	Copper	Aluminum	Copper	Aluminum
900	(456)	-	-	520	425
1000	(506)	-	-	545	445
1250	(633)	-	-	590	485
1500	(760)	-	-	625	520
1750	(887)	-	-	650	545
2000	(1013)	-	-	665	560

NOTES –

1 For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in this table for that conductor multiplied by the number of conductors that the terminal is able to accommodate.

2 These values of ampacity apply only when not more than three conductors are intended to be field-installed in the conduit.
When four or more conductors, other than a neutral that carries the unbalanced current, are intended to be installed in a conduit (occurring because of the number of conduit hubs provided in outdoor equipment, the number of wires necessary in certain polyphase systems, or other reasons), the ampacity of each of the conductors is: 80 percent of these values if 4 – 6 conductors are involved, 70 percent of these values if 7 – 24 conductors, 60 percent of these values if 25 – 42 conductors, and 50 percent of these values if 43 or more conductors.

Source: UL 508A, Table 28.1

The first column contains the cross sections (wire sizes) of the conductors. Columns 60 °C and 75 °C represent the temperature at the terminal. The maximum permissible protective device shall be sized according to the terminal temperature. For example, an AWG 8 conductor shall be protected with a maximum of 40 A according to the 60 °C column, and a maximum of 50 A according to the 75 °C column.

The maximum permissible terminal temperature is required through the devices. Thus, for example, a maximum permissible terminal temperature of 75 °C is specified for motor starter protectors of the Siemens 3RV2 series. This means that the 75 °C column is to be used for sizing the conductors in this case.

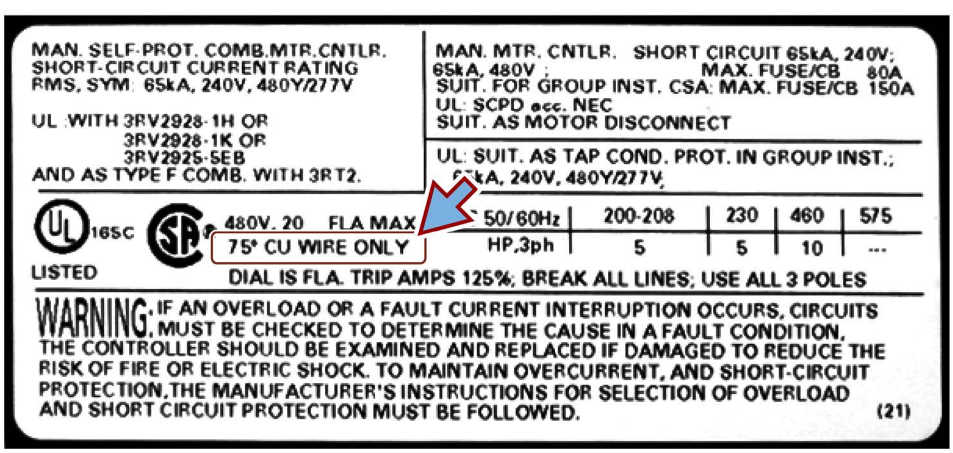


Figure 11-5 Example of a nameplate

Industrial control panels for industrial machines

According to UL 508A, Chapter 66.5.5 and 66.5.6, the following applies to industrial control panels for industrial machines:

1. Power circuit conductors that carry current for a motor or heater load shall be sized for an ampacity not less than 125 % of the calculated rated current.
2. Power circuit conductors that carry current for one or more motors or heaters shall be sized for an ampacity at least as follows:
   – 125 % of the rated current of all heater loads
   – 125 % of the rated current of the largest motor
   – Sum of the rated currents of the remaining motors and other loads

11.3.1.2 Control circuit

According to UL 508A, Chapter 38.2, conductors in the control circuit shall be sized as follows:

- According to the overcurrent protection device for a control circuit or the ampere rating on the secondary of a control transformer or power supply.
- According to Table 11-5 Ampacities of insulated conductors (Page 223) (>10 A) or the following table "Ampacities of control circuit conductors" (≤10 A).

Table 11- 6 Ampacities of control circuit conductors

Ampacity, amperes	Conductor size	
	AWG	(mm^2)
10	16	(1.3)
7	18	(0.82)
5	20[b]	(0.52)
3	22[b]	(0.32)
2	24[b]	(0.20)
1	26[b]	(0.13)
0.8	28[a, b]	(0.08)
0.5	30[a, b]	(0.05)

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

[b] These sizes of conductors are only for connection of control circuits for electronic programmable input/output and static control (having no moving parts).

Source: UL 508A, Table 38.1

According to UL 508A, Chapter 66.9.2 regarding industrial control panels for industrial machinery, the conductors in a control circuit shall have a cross-section of at least AWG 18 (0.82 mm^2).

Exception

Control circuit conductors for programmable input/output devices and devices that contain no moving parts may have a cross-section of AWG 18 to 30 (0.82 to 0.05 mm²).

The logic behind this is that with electronic devices, e.g. a PLC, no vibration occurs during operation, but the operational switching of contactors causes vibration due to the moving contacts, and this can result in excessive stress on the control circuit conductors.

If the panel builder or machine manufacturer and the operator of the industrial control panel or machine agree that NFPA 79 should also be applied to the industrial control panel, then the following regulations in accordance with Chapter Outside the industrial control panel (Page 226) shall also apply inside the panel.

11.3.2 Outside the industrial control panel

Outside the industrial control panel, the regulations according to NFPA 79, Chapter 12.5/6 apply.

11.3.2.1 Power circuit

The table below shows the permissible ampacity of conductors for the different maximum temperatures and connecting terminals.

Table 11- 7 Conductor ampacity based on copper conductors with 60 °C (140 °F), 75 °C (167 °F) and 90 °C (194 °F) insulation in an ambient temperature of 30 °C (86 °F)

Conductor size (AWG)	Ampacity		
	60 °C (140 °F)	75 °C (167 °F)	90 °C (194 °F)
30	-	0.5	0.5
28	-	0.8	0.8
26	-	1	1
24	2	2	2
22	3	3	3
20	5	5	5
18	7	7	14
16	10	10	18
14	20	20	25
12	25	25	30
10	30	35	40
8	40	50	55
6	55	65	75
4	70	85	95
3	85	100	110
2	95	115	130
1	110	130	150

Source: NFPA 79, Table 12.5.1

Power circuit conductors to individual motors shall be sized with at least 125% of the rated current of the motor.

The ampacity of supply conductors to combined loads shall be calculated at least as follows:

- 125 % of the rated current of all heater loads
- 125 % of the rated current of the largest motor
- The sum of the rated currents of the remaining motors and other loads that can be in operation simultaneously

If the ambient temperature ≠ 30 °C (86 °F) and/or more than three live conductors are routed in a raceway or cable, the correction factors from the following two tables shall be observed.

Table 11- 8 Ambient temperature correction factors

Ambient temperature (°C)	Correction factor 75 °C	Ambient temperature (°F)
21 … 25	1.05	70 … 77
26 … 30	1.00	78 … 86
31 … 35	0.94	87 … 95
36 … 40	0.88	96 … 104
41 … 45	0.82	105 … 113
46 … 50	0.75	114 … 122
51 … 55	0.67	123 … 131
56 … 60	0.58	132 … 140
61 … 70	0.33	141 … 158

Source: NFPA 79, Table 12.5.5(a)

Table 11- 9 Adjustment factors for more than three current-carrying conductors in a raceway or cable

Number of current-carrying conductors	Percent of values in table 12.5.5(a) as adjusted for ambient temperature if necessary
4 … 6	80
7 … 9	70
10 … 20	50
21 …30	45
31 … 40	40
41 and higher	35

Source: NFPA 79, Table 12.5.5(b)

The logic behind the correction table for bundling is to reduce heat buildup in the cable raceway. For this reason, only conductors that carry current simultaneously are to be considered. See also the NEC, Table 310.15 (B)(3)(a).

Insulated conductors for higher temperatures may also be used (e.g. 90 °C), if the maximum permissible ampacity at the connection point is not exceeded after application of all correction factors.

Cross section

The conductors in a power circuit shall not be smaller than AWG 14 according to Chapter 12.6.1.

Exceptions according to Chapter 12.6.1.1/2/3:

AWG 16 (~ 1.5 mm²)

AWG 16 (~ 1.5 mm²) conductors may be used if they meet one of the following requirements:

- a. Part of a jacketed conductor, cord, or individual conductors inside the industrial control panel or enclosure

  b. Non-motor loads with max. 8 A
  - Fused against overcurrent with max. 10 A
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489
- Motor loads with max. 8 A rated current
  - Fused against overcurrent
  - Class 10 motor overload protection
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489
- Motor loads with max. 5.5 A rated current
  - Fused against overcurrent
  - Class 20 motor overload protection
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489

AWG 18 (~ 1.0 mm²)

AWG 18 (~ 1.0 mm²) conductors may be used if they meet one of the following requirements:

- a. Part of a jacketed conductor, cord, or individual conductors inside the industrial control panel or enclosure

  b. Non-motor loads with max. 5.6 A
  - Fused against overcurrent with max. 7 A
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489
- Motor loads with max. 5 A rated current
  - Fused against overcurrent
  - Class 10 motor overload protection
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489
- Motor loads with max. 3.5 A rated current
  - Fused against overcurrent
  - Class 20 motor overload protection
  - BCPD (branch circuit protection device), Fuse UL 248-4 up to 12 or Circuit Breaker UL 489

AWG 16 (~ 1.5 mm²) and AWG 18 (~ 1 mm²)

AWG 16 (~ 1.5 mm²) and AWG 18 (~ 1 mm²) conductors may be used for motor and non-motor circuits if they meet the following requirements:

- Component of a listed power cable kit (e.g. pre-assembled cable with connector)
- Approved for the respective application
- Protected appropriately (see Table 12.5.1)

Supply cables for servo drives

Supply cables for servo drives shall be sized in accordance with NFPA 79 for at least 115 % of the drive input current.

Note

In accordance with NEC, Chapter 430.122 (A), supply cables for variable-speed drives and servo drives shall be sized with at least 125 % of the input current.

Cords

The continuous current by cords shall not exceed the values given in Table 12.8.2 of NFPA 79.

Table 11- 10 Ampacity for cords at an ambient temperature of 30 °C (86 °F)

Size (AWG)	Thermoset types: S, SJ, SLO, SJOW, SJOO, SJOOW, SO, SOW, SOO, SOOW	
	Thermoplastic versions: SE, SEW, SEO, SEOW, SEOOW, SJE, SJEW, SJEO, SJEOW, SJEOOW, SJT, SJTW, SJTO, SJTOW, SJTOO, SJTOOW, STO, STW, STOW, STOO, STOOW	
	A[1]	B[2]
18	7	10
17	-	12
16	10	13
14	15	18
12	20	25
10	25	30
8	35	40
6	45	55
4	60	70
2	80	95

[1] The allowable currents apply to 3-conductor cords and other multi-conductor cords connected to utilization equipment so that only 3 conductors are current carrying.

[2] The allowable currents apply to 2-conductor cords and other multi-conductor cords connected to utilization equipment so that only 2 conductors are current carrying.

Source: NFPA 79, Table 12.8.2

Derating factors for bundling shall be taken from Table 12.5.5(b).

The type designations for supply cords, their properties and usage in accordance with the NEC are described in Chapter Further information and support (Page 380).

11.3.2.2 Lighting circuit

Cross section

NFPA 79, Chapter 12.6.2

- ≥ AWG 16: if routed in a raceway
- ≥ AWG 18: if part of a jacketed cable assembly

11.3.2.3 Control circuit

Cross section

NFPA 79, Chapter 12.6.2 and 3:

- ≥ AWG 16 if routed in a raceway
- ≥ AWG 18 if part of a jacketed multiconductor cable assembly in enclosures or operating stations

Conductors for control circuits in electronic input/output and control devices

According to NFPA 79, Chapter 12.6.4, conductors for control circuits in electronic input/output and control devices shall be sized as follows:

- Conductors routed in raceways: ≥ AWG 24

  Exception: AWG 30, if part of a jacketed, multiconductor cable assembly or cord
- Conductors routed in raceways: ≥ AWG 26

  Exception: AWG 30 for jumpers and special applications
- ≥ AWG 30 for conductors as part of a jacketed, multiconductor cable assembly that are identified as suitable for the application and routed according to NFPA 79, Chapter 13 (see Chapter Wiring practice (Page 235))

Shielded conductors in subassemblies

Shielded conductors in subassemblies shall be flexible, made from annealed copper, and ≥ AWG 25. For all other applications, they shall be ≥ AWG 22.

Sizing rules

Both standards are based on the NEC so that the sizing rules of UL 508A and those of NFPA 79 are very similar. UL 508A provides for a maximum ambient temperature of 40 °C, and in contrast to NFPA 79 it has no correction factors for the ambient temperature. In many cases, the same cross-sections would be calculated using the rules of the two standards (see the following Sizing examples (Page 233)).

However, it is always to be recommended that the standards to be used are agreed between the customer and the machine manufacturer. If this is not clearly agreed, the recommendation is to carry out the sizing in accordance with both standards, and to select the larger conductor cross-sections if the results differ.

11.3.3 Sizing examples

Example

- 1 motor with 2 horsepower
- 3 motors with 1 horsepower each
- 3 heater loads at 10 A each
- 2 transformers with an input current of 5 A each
- Voltage 480 Y/277 V
- Ambient temperature 35 ℃

Sizing according to UL 508A (inside the industrial control panel)

1. Determine the full-load amps of the motors according to Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98).

   ⇒ 2 horsepower = 3.4 A

   ⇒ 1 horsepower = 2.1 A
2. Determine the relevant full-load amps for the conductor according to Chapter Inside the industrial control panel (Page 222)

   ⇒ 3.4 A x 1.25 + 3 x 2.1 A + 3 x 10 A x 1.25 + 2 x 5 A = **58.05 A**
3. Determine the required cross section of the conductor according to Table 11-5 Ampacities of insulated conductors (Page 223).
   58.05 A is not a standard value, which means the next-highest value shall be selected. According to the 75 °C column, this would be 65 A ⇒ **The required cross section of the conductor is at least AWG 6.**

Sizing according to NFPA 79 (inside and outside the industrial control panel)

1. Determine the rated currents of the motors according to the NEC, Table 430.250 (values analogous to Table 6-1 Full-load motor-running currents in amperes corresponding to various AC horsepower ratings (Page 98))

   ⇒ 2 horsepower = 3.4 A

   ⇒ 1 horsepower = 2.1 A
2. Determine the relevant full-load amps for the conductor in accordance with Chapter Outside the industrial control panel (Page 226)
   ⇒ 3 x 10 A x 1.25 + 3.4 A x 1.25 + 3 x 2.1 A + 2 x 5 A = **58.05 A**
3. Determine the required cross section of the conductor according to Table 11-7 Conductor ampacity based on copper conductors with 60 °C (140 °F), 75 °C (167 °F) and 90 °C (194 °F) insulation in an ambient temperature of 30 °C (86 °F) (Page 226) and take into account the derating factors from Table 11-8 Ambient temperature correction factors (Page 227).

   58.05 A is not a standard value, which means the next-highest value shall be selected. According to the 75 °C column, this would be 65 A, which would result in a conductor cross section of AWG 6.

   However, as the ambient temperature is 35 °C, a derating factor of 0.94 shall also be applied. 65 A x 0.94 = 61.1 A ⇒ **The required cross section of the conductor remains at least AWG 6.**

11.4 Identification and color

Conductor colors

According to UL 508A, Chapter 17.3, 66.5 and 66.9.1, and NFPA 79, Chapter 13.2, conductors shall have the following colors:

Table 11- 11 Conductor colors

Identification of conductors	Color	
Grounding (protective) conductor		Green or green/yellow
Ungrounded line voltage circuits (power & control)		Black
Ungrounded AC control current (operating voltage < line voltage)		Red
Ungrounded DC control current (operating voltage < line voltage)		Blue
Ungrounded conductor "excepted circuits"		Orange (or yellow)
Grounded conductor of an AC line voltage circuit		White, gray or three white continuous stripes
Grounded conductor of a DC control circuit		White with blue stripes
Grounded conductor of an "excepted" circuit		White with orange or yellow stripes

Identification of conductor and connection point

Each conductor shall also be identified (termination identification) corresponding with the wiring diagrams. Identification can consist of digits, letters or a combination of both.

UL 508A is restricted in this requirement to the power circuit in accordance with Chapter 66.5.2. NFPA 79, Chapter 13.2.1.1 does not distinguish between the power circuit and the control circuit.

Aim

The aim is a unique assignment between the conductor and the connection point.

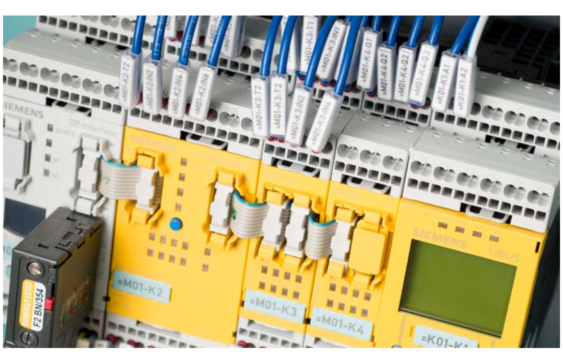


Figure 11-6 Example of conductor identification

11.5 Wiring practice

The wiring practice in industrial control panels and machines is described in great detail in UL 508A and NFPA 79.

While UL 508A is restricted to the control panel only, NFPA 79 describes routing inside and outside the control panel.

The aim of both standards is to protect cables against damage and damaging influences, and thus to contribute towards safe operation of the machine.

a) General requirements (NFPA 79, Chapter 13.5)

NFPA 79, Chapter 13.5 describes general requirements on the topic of "Raceways (ducts) / supports and connection boxes.

- Raceways (ducts), elbows, couplings, and associated fittings shall be listed → UL approval or Plastic Recognition Yellow Card (see Chapter Plastic materials (Page 59))

  Exception: Raceways (ducts) fabricated as part of the machine.
- Sharp corners, edges, etc., shall be avoided to protect the conductors. Depending on the operating conditions, flame-retardant and oil-resistant insulating material (Plastic Recognition Yellow Card!) shall be used.
- Drain holes in raceways (ducts), junction boxes, etc., shall not substantially compromise the required enclosure type rating.
- Drain holes ≤ 6.4 mm are permissible for wiring in raceways and connection boxes that are subject to accumulations of oil or moisture.
- Raceways (ducts) shall be securely fastened in place and supported.

  Exception: Flexible raceways

b) Percentage fills of raceways (ducts)

To be able to ensure adequate heat dissipation and reasonable handling in the case of changes, the combined cross-sectional area of all conductors shall be ≤ 50 % of the interior cross-sectional area of the raceway (duct).

c) Machine enclosures and supports or pillars

Machine enclosures and supports or pillars for machines may be used as raceways (ducts) in the following cases:

- Separate from cooling liquids and oil containers; completely enclosed
- Secured and protected against damage

→ An identification as electrical enclosure is recommended.

Figure 11-7 Example identification of an electrical enclosure

11.5.1 Inside the industrial control panel

11.5.1.1 UL 508A

UL 508A, Chapter 29.3, 29.4 and 29.5 describes how conductors in the power circuit are to be connected and routed. For control circuit conductors, UL 508A refers in Chapter 38.3 to Chapters 29.3, 29.4 and 29.5.

→ In accordance with UL 508A, the same rules for connecting and routing conductors apply for the power circuit and the control circuit.

Connection

Connection of a conductor to a component shall be carried out using one of the following measures:

- Direct connection to the terminal of a component
- Quick-connect terminal of a component in which the mating part is equipped with, e.g., a spring-type connection or similar such that the connection does not rely solely upon friction between the conductor and the connecting terminal
- Crimped-on supply cord or closed eyelet
- Soldered joints in accordance with UL 508A, Chapter 29.3.2
- Terminal screws in accordance with UL 508A, Chapter 29.3.3
- Open-type eyelet in accordance with UL 508A, Chapter 29.3.5

Wiring ferrules

The topic of "wiring ferrules" frequently arises in this context. In the current version of UL 508A, wiring ferrules are not yet mentioned, however, there is a bulletin from UL permitting the use of wiring ferrules.

According to this, wiring ferrules, insulated or not, may be used if they are suitable according to the manufacturer, and if the following requirements are met:

- Inside the industrial control panel, in the main and control circuit
- Crimped using a tool recommended by the manufacturer of the wiring ferrules
- Sized in diameter for the number of cores, the conductor type (solid / stranded), and the conductor cross-section as per the manufacturer's specifications
- The wiring ferrules shall be secured in such a way that the uninsulated part of the conductor is fully surrounded and no individual cores protrude.

Figure 11-8 Manual crimping operation

Note

The UL Bulletin does not necessarily demand the use of UL-tested and certified wiring ferrules, but it recommends the use of UL 486-tested and certified wiring ferrules (CCN: ZMVV2).

Routing of wiring

Wire routing is regulated in Chapters 29.4 and 29.5 of UL 508A.

- Cable entries into the enclosure shall be through a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces to avoid damage to the insulation.

  Figure 11-9 Cable entry example

- Wires shall be routed properly, and away from sharp edges, screw threads, burrs, moving parts or drawers that are able to abrade the wire insulation. Wires shall also be routed away from heat-producing components, such as heat sinks of power circuit components, power supplies, transformers, cabinet heaters, and resistors.

- Cable clamps, spiral wraps, wire ties, and wiring troughs for stationary internal wiring, either metallic or nonmetallic, shall have smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion of the insulation is not able to occur.

Figure 11-10 Cable clamp example

- Wiring that is subject to movement, flexing, or other influences during use, or during mechanical maintenance, shall meet the following requirements:
  - Insulation of at least 1/32 inch (0.8 mm) at every point at which the wire is flexed.
  - Stranded-type conductor
  - Routing such that the wire is not damaged when opening and closing the door or cover.

  It shall correspond to these requirements:
  - Flexible conductors and supply cords
  - Welded cables
  - MTW conductors (Machine Tool Wire) with the following cross-sections:

    - Cross-section AWG 8 (8.4 mm²) and larger

    - Cross-section AWG 18 to AWG 10 (0.8 to 5.3 mm²), labeled as "flexing" or "class K"

The same shall be observed when modifying electrical equipment , e.g. wiring from a permanently installed system component to a movable component (e.g. a door or cover).

Separation of circuits

A conductor in the industrial control panel shall be routed separately to other circuits in the following cases:

- If the conductor has a lower insulation resistance than the maximum occurring voltage of any circuit.
- In the case of non-insulated components of other circuits.

Separation can be achieved in accordance with the following specifications:

- **UL 1441:** Electrical sleeving
- **UL 224:** Insulating tubing
- **UL 510:** wrapping consisting of at least two layers of insulating tape
- Clips, guides, or similar measures

Separation of conductors shall be ensured using separate fixings (e.g. cable clamps), separate routing or similar measures, e.g. barriers in the cable duct.

A conductor shall be provided with strain relief if stresses can result in failure to maintain separate routing as described above.

11.5.1.2 NFPA 79

NFPA 79 deals with the topic of "Wiring Inside Enclosures" in Chapter 13.3.

The following rules are described there:

- Nonmetalic ducts are only permitted when they are made with a flame-retardant insulating material.

  → Verification of plastic materials through a "Yellow Card", for example. See Chapter Plastic materials (Page 59), or further information on flame-retardant materials in IEC 60332-1 (tests on cables, insulated conductors and glass-fiber cables in the event of fire)
- Electrical equipment shall be mounted in such a way as to permit easy access to the wiring.

- Cables used to connect devices mounted on doors shall be of sufficient length, and shall permit full movement of the door. The conductors shall be anchored to the enclosure and to the door to avoid mechanically hampering the electrical connection on the device when the door moves.

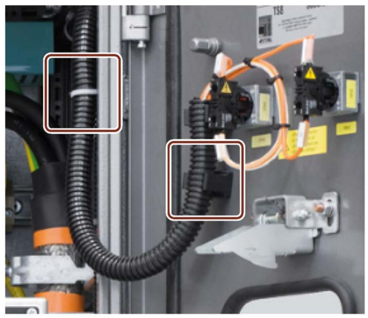


Figure 11-11 Example of cable fixing

- Cables shall be supported if no cable ducts, etc., are used. Supporting can be carried out appropriately using cable ties or cable clamps, for example.

Figure 11-12 Example of supporting using cable clamps

- Industrial control panels with multiple devices shall be equipped with attachment plugs or terminal blocks for all outgoing conductors.

  Exception: Wiring for input or output modules of programmable controllers (e.g. PLCs) may be connected directly.

- Direct connection of power cables and cables of measuring circuits to the terminals of the devices for which the connections were intended shall be permitted. An example of this is the disconnecting means where the incoming supply circuit conductor is connected directly for preference.

11.5.2 Outside the industrial control panel

This topic is described in great detail in NFPA 79, Chapter 13.4. The following topics are dealt with in the standard under the heading "Wiring Outside Enclosures":

- External raceways (ducts)
- Connection to moving elements of the machine
- Cable handling systems
- Interconnection of devices on the machine
- Attachment plug and receptacle (plug/socket) combinations
- Dismantling for shipment
- Rigid, flexible and liquidtight conduits
- Raceways (ducts) and cable trunking systems
- Requirements for the proper routing of cables

Due to the wide scope involved, this guide is restricted to the most important topics. You can find more detailed information in NFPA 79.

A general requirement is that the enclosure type shall not be impaired through the connection of cable ducts and the means of introduction of cables with their individual glands, bushings and so forth into the control panel.

This means cable entries in accordance with UL 514B shall be permitted and shall have the same or a higher Enclosure type Rating than the industrial control panel enclosure. See Chapter Enclosure type ratings (Page 181) for the combination options of enclosure types.

Figure 11-13 Cable entry through a connection receptacle (socket) in accordance with UL 514B

11.5.2.1 External raceways (ducts)

- The conductors of an AC circuit to an item of equipment shall be routed in the same cable raceway.
- The conductors external to the control panel shall be routed in raceways as described in NFPA 79, Chapter 13.5. See Chapter Wiring practice (Page 235).

Figure 11-14 Conductors routed in raceways

Note

Cables and cable connectors are the exception here and do not have to be enclosed in raceways if suitable measures have been taken in accordance with NFPA 79, Chapter 13.1.6 (see subpoint i).

- Connection pieces and fittings for raceways and multiconductor cables shall be suitable for the physical environment, and shall be correspondingly identified The enclosure type rating in particular shall be assigned greater significance here.
- Movable control devices shall be wired with flexible conductors. The conductors shall not be used as mechanical support unless they are approved for that purpose. An appropriate strain relief shall be provided.
- Flexible conductors shall also be used for infrequent and small machine movements. They shall also be permitted to complete the connection to stationary motors, position switches, or externally mounted devices.

Figure 11-15 Cable routing to moving elements of the machine

11.5.2.2 Connection to moving elements of the machine

- Connections to moving elements of the machine shall be made using conductors in accordance with Chapter Conductors and cables for flexible applications (Page 215).
- Flexible cables and conduits shall have vertical connections for preference. The connection pieces in particular shall be protected against excessive movement and straining.
- Horizontal connections shall be permitted where the cables or conduits are adequately supported.
- Flexible cables and conduits shall be installed in such a way as to avoid excessive movement and straining, particularly at the fittings.
- Flexible conductors subject to machine movements shall be supported in such a way that there is neither mechanical strain on the connection points nor any sharp flexing. If this is ensured by generous cable routing providing scope for bending, the radius of the bend shall be at least 10 times the cable diameter.
- Cables with flexible properties shall be installed and protected in such a way as to avoid damage during use or potential abuse. Examples include the following
  - Being run over by the machine itself
  - Being run over by vehicles or other machines
  - Coming into contact with the machine structure during movements
  - Imprecise running in and out of cable baskets or on or off cable drums
  - Excessive rubbing on cable guide systems
  - Exposure to excessive radiated heat sources

Figure 11-16 Drum cable example

- The cable sheath shall be resistant to movement and ambient conditions (e.g. oil, water, coolants, dust).

- Protection of cables to moving parts by means of:
  – Barriers or cable tracks
  – The minimum space shall be 1 inch (25.4 mm).

    If this distance is not practicable, fixed barriers or cable tracks shall be provided for protection against moving parts.
- Flexible cables and cable tracks shall be protected against damage from moving machine parts.
- Flexible conduits shall not be used for rapid movements unless they are approved for this purpose.

See also

Chapter Certifications (Page 211)

11.5.2.3 Cable handling systems

See NFPA 79, Chapter 13.4.3.2.

11.5.2.4 Interconnection of devices on the machine

NFPA 79 provides only general information designed to facilitate commissioning, ongoing maintenance, and possible troubleshooting. For this reason, terminals and measuring points shall be used that are readily accessible but still appropriately protected against the operating and ambient conditions. Terminals and measuring points shall correspond to the associated documentation.

11.5.2.5 Attachment plug and receptacle (plug/socket) combinations

- On removable equipment it is permitted to use polarized attachment plugs that ensure protection against electric shock and have been tested and listed for the respective application.
- Plugs for 20 A or higher shall be locked against inadvertent disconnection.
- With a voltage of phase to phase or phase to ground of 300 V or more, plug pins shall be skirted so that open arc flashes remain in the enclosure when a connection is made or broken.
- Plugs shall be designed in such a way that the equipment grounding circuit connection is made before current-carrying connections are made and is not disconnected until all current-carrying connections are disconnected.

  → "first make / last break"

  Exception: Attachment plug and receptacle (plug/socket) combinations used in PELV circuits and for assembling and disassembling (not during operation!).
- Attachment plug and receptacle (plug/socket) combinations used for carrying motor loads need to be able to be disconnected under load (load-break-rating) if the circuit is likely to be opened under load.

- If several attachment plug and receptacle (plug/socket) combinations are used, incorrect insertion shall be prevented by means of mechanical coding or clear identification.

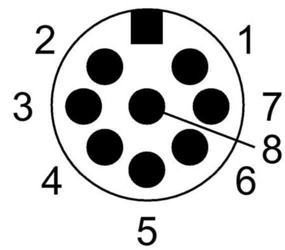


Figure 11-17 Coded receptacle example

- Externally mounted receptacles (machine or control panel enclosure) shall be covered when the plugs are removed.

11.5.2.6 Dismantling for shipment

- Receptacles and terminals shall be used for preference and appropriately covered and protected.
- Enclosure openings shall be closed.
- Connectors shall be designed in such a way as to prevent the danger of electric shock.

11.5.2.7 Rigid, flexible and liquidtight cable conduits

This topic is described in great detail in NFPA 79, Chapter 13.5.3, 13.5.4 and 13.5.5. Due to the wide scope involved, this guide is restricted to just a few important topics. Please refer to NFPA 79 for additional information.

NFPA 79 permits fixed, non-flexible metal conduits such as "Rigid Metal conduit (RMC)", "Intermediate Metal Conduit (IMC)" and "electrical metallic tubing (EMT)".

Nonmetalic conduits are also permitted (PVC Sch. 80).

Flexible metal conduits such as Flexible Metal Conduit (FMC) and liquidtight flexible metal conduit (LFMC) are of help when fixed conduits are not suitable or when vibration occurs.

Note

Cable conduits shall be approved for the respective use and environment.

→ UL 1242 – Standard for Electrical Intermediate Metal Conduit – Steel or UL 651 - Standard for Schedule 40 and 80 Rigid PVC Conduit

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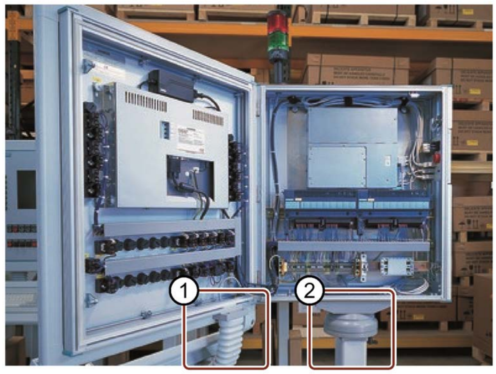


① Plastic
② Metal

Figure 11-18 Examples of cable conduits

Fixed conduits

The minimum metric size shall be 16 (1/2 in.).

The maximum metric size shall be 155 (6 in.).

Table 11- 12 Metric designators/trade sizes

Metric designator	Trade size
12	$^{3}/_{8}$
16	$^{1}/_{2}$
21	$^{3}/_{4}$
27	1
35	$1^{1}/_{4}$
41	$1^{1}/_{2}$
53	2
63	$2^{1}/_{2}$
78	3
91	$3^{1}/_{2}$
103	4
129	5
155	6

Note: The metric designators and trade sizes are for identification purposes only and are not actual dimensions.

Source: NFPA 79, Table A.13.5.3.1.2

For problem-free insertion of cables into conduits there shall be no more than four 90° bends between the start and end of the conduit, or the combination of bends shall not exceed 360°.

"NFPA 79, Table 13.5.3.1.4 Minimum Radii of Conduit Bends" shows the minimum bending radii of cable conduits.

Table 11- 13 Minimum Radii of Conduit Bends

Conduit size		One-shot and full-shoe benders		Other bends	
Metric designator	**Trade size**	**mm**	**Inches**	**mm**	**Inches**
16	$^{1}/_{2}$	101.6	4	101.6	4
21	$^{3}/_{4}$	114.3	$4^{1}/_{2}$	127	5
27	1	146.05	$5^{3}/_{4}$	152.4	6
35	$1^{1}/_{4}$	184.15	$7^{1}/_{4}$	203.2	8
41	$1^{1}/_{2}$	209.55	$8^{1}/_{4}$	254	10
53	2	241.3	$9^{1}/_{2}$	304.8	12
63	$2^{1}/_{2}$	266.7	$10^{1}/_{2}$	381	15
78	3	330.2	13	457.2	18
91	$3^{1}/_{2}$	381	15	533.4	21
103	4	406.4	16	609.6	24
129	5	609.6	24	762	30
155	6	762	30	914.4	36

Source: NFPA 79, Table 13.5.3.1.4

Conduits shall be securely positioned and fastened in accordance with NFPA 79, Table 13.5.3.3.2 Support of Rigid Nonmetallic Conduit (RNC)". In addition, a conduit with a maximum length of 900 mm (3 ft) shall be securely fastened and connected between the two connection points.

Table 11- 14 Support of Rigid Nonmetallic Conduit (RNC)

Conduit size		Maximum spacing between supports	
Metric designator	**Trade size**	**mm or m**	**ft**
16 … 27	$^{1}/_{2}$ … 1	900 mm	3
35 … 53	$1^{1}/_{4}$ … 2	1.5 m	5
63 … 78	$2^{1}/_{2}$ …3	1.8 m	6
91 … 129	$3^{1}/_{2}$ … 5	2.1 m	7
155	6	2.5 m	8

Source: NFPA 79, Table 13.5.3.3.2

Flexible and liquidtight conduits

- Flexible metal conduit (FMC) and liquidtight flexible metal conduit (LMFC) shall correspond to the minimum size 12 (trade size 3/8).

  Exception: Flexible conduit for cable routing to thermocouples and other sensors
- The maximum size corresponds to metric size 103 (trade size 4)

11.5.2.8 Raceways (ducts) and cable trunking systems

Cable raceways (ducts) may be used as well as conduits. Cable raceways (ducts) provide protection against damaging external influences. The metallic strength and design of raceways shall be in accordance with ANSI / UL 870 Wireways, Auxiliary Gutters and associated fittings .

11.5.2.9 Requirements for the proper routing of cables

The following measures are described in Chapter 13.1.6:

- Exposed cables are permitted if they are installed along the structure of the machine or the chases of the machinery. Exposed cables shall be installed to closely follow the structural members of the machinery.

Figure 11-19 Example of exposed cables

- Cables shall be supported as follows:
  - In such a manner that the cable will not be damaged by normal equipment use.
  - Every 305 mm (12 in.) in a nonvertical run.

    Exception: The supporting distance may be increased up to 914 mm (36 in.) if the structure of the machine or system makes support impractical every 305 mm (12 in.).
  - Every 914 mm (36 in.) in a nonvertical run.

    Exception: The supporting distance may be increased up to 2.44 m (96 in.) if the structure of the machine or system makes support impractical every 914 mm (36 in.).
  - When suspended in air spanning a distance of 457 mm (18 in.).

    Exception: The span distance may be increased up to 914 mm (36 in.) if the structure of the machine or system makes support impractical every 457 mm (18 in.).

- Cables shall not be supported by machinery guards that have to be removed for maintenance access.

  Exception: Wiring for components that are an integral part of the guard and designed to remain on the guard when the guard is removed for maintenance access.

- Multiple cables may be fastened together in a bundle provided the method of fastening is sufficient to support the mechanical weight and strain of the bundle.
- Cable shall be fastened to the cable runs.

  Exceptions:

  – Where horizontal runs are inherently supported by the machine or system structure, or by floors or decks, fastening is not required.

  – Where run at ≤ 45° from the horizontal, fastening is not required.

- The ends of cable ties shall be cut flush. Reusable cable ties that can be opened again shall not be used as permanent fastenings.
- Cables subjected to physical damage shall be protected by means of the following measures:

  – Alternative routing

  – With additional guarding or railings

  – When laid on the floor, additional protective measures are required with walk-over or drive-over cable protective devices.

  – By installation in a wireway

  – By installation in a floor or trapezoidal walk-over raceway specifically designed for cable protection.

- Bends in cables shall not result in undue stress. The radius of the curve on the inside edge of the bend shall be ≥ 5 x the cable diameter.
- If a cable is used in a length longer than required, the excess cable shall be coiled in loops. The coil shall be fastened to itself and to the machinery structure.

  Exception: When excess cables are associated with a horizontal cable run that is inherently and fully supported, the solenoids do not have to be fastened to the machine structure.

12 Accessories and lighting

12.1 Receptacle for accessories and maintenance

12.1.1 Requirements from UL508A, Chapter 28.6

The requirements listed below apply equally for receptacles in the power circuit and the control circuit.

However, receptacles in the control circuit may only be used for the operation of programming and diagnostics devices, and they shall therefore be correspondingly marked. See Chapter Receptacles (Page 285).

Exception: Receptacles in the control circuit for Class 2 or in Low voltage limited energy circuits.

12.1.1.1 UL tests and certifications

Receptacles for general purposes shall be approved in accordance with the UL 498 "Standard for Plugs and Receptacles".

The following additional requirements apply for receptacles mounted through the enclosure of the industrial control panel and therefore accessible from outside:

- The receptacle shall be provided with a metal enclosure or comply with UL 508 Standard for Industrial Control Equipment for enclosures with polymeric materials.
- The receptacle shall have no exposed pins (receptacle is a female type)
- The receptacle shall be appropriately marked. See Chapter Device marking on the industrial control panel acc. to UL 508A (Page 283).

Receptacles for which the mating part is connected to a flexible cord may only be used for portable loads or for equipment parts that are frequently changed.

For receptacles provided for the permanent connection of a specific load, there shall be equipment available that permits the connection of conduit if required.

In the following cases, the connection shall be protected by means of mechanical measures:

- Rated current of the receptacle of more than 20 A for general purposes
- Use of multi-pin connectors

A bracket lock is often found here, for example. Furthermore, a marking shall be provided permitting disconnection only in the no-load state. Disconnection under load is not permissible. You can find the specifications for the marking and an example in Chapter Device marking on the industrial control panel acc. to UL 508A (Page 283).

12.1.1.2 Ground fault circuit interrupters on receptacles

Receptacles with a rated current of 15 amperes or 20 amperes and up to 120 V shall be equipped with a ground fault circuit interrupter if they are located in the industrial control panel and the enclosure of the control panel has "enclosure type 3" or "enclosure type 3RX", and is designed for outdoor operation (e.g. enclosure types 4, 4X, 6, 6P).

The ground fault circuit interrupter shall be a Class A – Ground Fault Circuit Interrupter (GFCI) approved in accordance with UL 943.

These trip at a residual current of 4 to 6 mA and thus also meet the requirements for operator protection.

Note

There are many ground fault circuit interrupters available that are not approved for operator protection. Thus, UL-listed ground fault circuit interrupters according to UL 1053, for example, are suitable for plant and fire protection, but not for operator protection. IEC-certified ground fault circuit interrupters used in Europe for protecting receptacles sometimes also have UL approval. However, since the tripping current on these devices is 30 mA, they are approved in the USA according to UL 1053 for plant protection but not for operator protection. European panel builders frequently mix this up.

12.1.2 Requirements of NFPA 79

12.1.2.1 Receptacles for associated equipment parts of the machine

Machines and their associated equipment parts (e.g. control panels) are frequently provided with receptacles to enable the operation of additional equipment when required. Examples include measuring devices, electric tools, and test equipment. (See the figure below "Siemens 5TE6 800 receptacle in accordance with UL 498, with cover")

In this case, the receptacles shall be protected using a residual-current circuit breaker for operator protection.

Such devices for operator protection are called Ground Fault Circuit Interrupter (GFCI) and are UL 943-listed. (See Figure 12-2 Siemens GFCI, class A according to UL 943, 2-pole, IΔN = 5 mA (Page 254) in this respect)

The supply voltage is limited to max. 120 V in receptacle circuits. The receptacle itself shall fulfill the following requirements:

- Rated voltage of 125 V
- Rated current of 15 or 20 A
- Tested and listed for the intended voltage. Receptacles listed in accordance with UL 498 are usual here.

In cases where the circuit for supplying the receptacle is connected upstream of the disconnecting means, and can thus still carry power despite the disconnecting means being switched off, the receptacle circuit shall be treated and marked as an "excepted circuit". See Chapter Excepted circuits (Page 78).

A suitable enclosure type rating shall be provided for receptacles installed in the machinery field or outside the industrial control panel, and that are thus exposed to shavings, dust, oil or other contaminants. After removing the plug, a cover shall be attached. (See the figure below "Siemens 5TE6 800 receptacle in accordance with UL 498, with cover")

Figure 12-1 Siemens 5TE6 800 receptacle in accordance with UL 498, with cover

12.1.2.2 Receptacles for maintenance purposes

Machines and associated plant parts are frequently equipped with receptacles to enable the operation of further equipment while performing maintenance work.

These receptacles shall **always** be protected with a ground fault circuit interrupter (GFCI in accordance with UL 943), regardless of whether this is installed inside or outside the industrial control panel.

Figure 12-2 Siemens GFCI, class A according to UL 943, 2-pole, IΔN = 5 mA

12.2 Control panel lighting and machine lighting

12.2.1 General information

The requirements described in UL 508A and NFPA 79 refer only to the electrical supply for lighting circuits in the control panel and the machine environment. As well as the supply for control panel lighting, other lighting circuits are included here too (e.g. workplace lighting). Lighting requirements are not included here. The grounding of lighting circuits is described in Chapter Requirements of NFPA 79 for grounding machinery (Page 166).

12.2.2 Requirements for the industrial control panel in accordance with UL 508A, Chapter 27

12.2.2.1 Components in the lighting circuit and their certification

- Lampholders for incandescent lamps shall be certified in accordance with UL 496
- Fluorescent lighting shall be certified in accordance with UL 1598
- When using such lighting as accessories for control panels, approval in accordance with UL 508 is required.

12.2.2.2 Configuration and overcurrent protection in accordance with UL 508A

- Lampholders shall be connected to the grounded conductor.
- Max. supply voltage of ≤ 150
- Protection against overcurrent takes place according to the requirements for power circuits. See Chapter Non-motor loads (Page 122).

Exception

Lighting circuits with a supply voltage ≤ 120 V can be supplied by an isolation transformer for control circuits. Protection is carried out here in accordance with the relevant rules for control circuits and control transformers. See Chapter Overcurrent protection of control circuits (Page 150).

12.2.3 Requirements for machines and equipment parts in accordance with NFPA 79

12.2.3.1 General information

Grounding

The grounding of lighting circuits for machines and their equipment parts is described in Chapter Requirements of NFPA 79 for grounding machinery (Page 166).

Enclosure types

When selecting lighting, the enclosure type rating for protection against external influences shall be taken into account.
Lighting for machines and in the environment of machinery can be exposed to harsh conditions (e.g. condensing mist, spraying liquids). Lighting that is equipped with switches and receptacles shall not be used here unless a correspondingly suitable enclosure type rating is available. For information about enclosure types, see Chapter Enclosure type ratings (Page 181).

Note

When using lighting in humid ambient conditions, ground fault protection shall be provided. Ground fault protection shall meet the requirements for operator protection here. (GFCI – Ground Fault Circuit Interrupter according to UL 943)

Cables

A ≥ 18 AWG (≈ 1 mm²)
Minimum cross-section for supply cables to stationary, permanently installed lighting

The following flexible supply cords or cable types are approved for the supply:
SO, STO, STOW, SJO, SJOW or SJTO
UL Category Code Number (CCN): ZJCZ; ELBZ

You can find additional information on cable types in Chapter Certifications (Page 211).

Note

In-line ON/OFF switches shall not be incorporated.

Stroboscopic effects

Stroboscopic effects refer primarily to the illusion of motion that does not correspond to the actual movement. This illusion can result, for example, in an incorrect response from operating personnel.
This effect is caused especially in the case of rotary movements at high frequency while simultaneously using fluorescent lamps for lighting. The remedy is often simply another type of lighting.

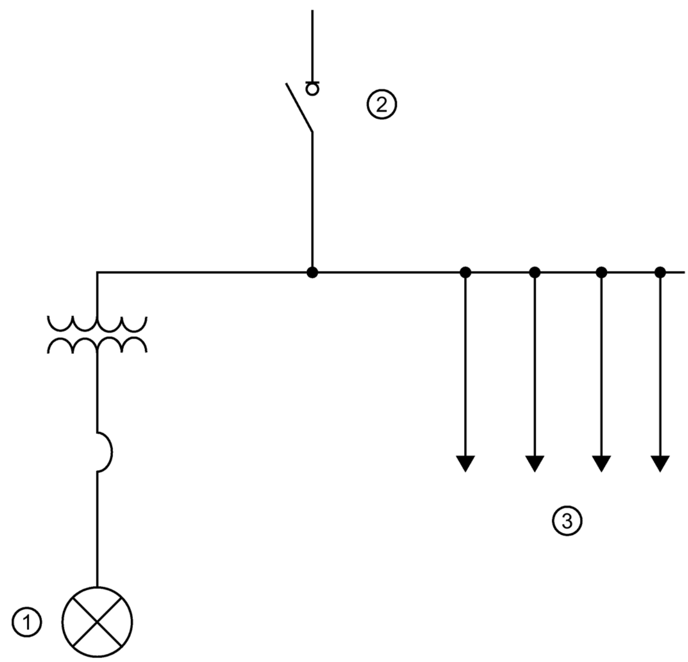
12.2.3.2 Supply

The following maximum values apply for lighting circuits:

- **Max. supply voltage: U ≤ 150 V**
- **Max. protection: I ≤ 15 A**

The lighting circuits shall be supplied from one of the following sources:

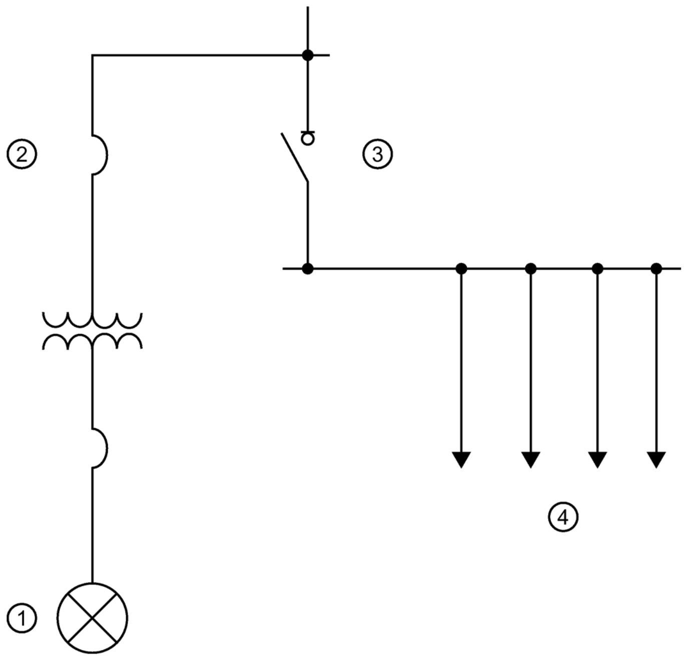
1. On the secondary side is a separate isolation transformer with overcurrent protection. The transformer is connected to the load side of the supply disconnecting means.



① Lighting
② Supply disconnecting means
③ Machine circuits

Figure 12-3 Design of machine lighting option 1

2. A separate isolation transformer is connected to the line side of the supply disconnecting means. Overcurrent protection is provided on the secondary side of the transformer. Although primary-side overcurrent protection is not required by the standard, it is nevertheless recommended.



① Control panel lighting
② Optional primary-side overcurrent protection
③ Supply disconnecting means
④ Machine circuits

Figure 12-4 Design of machine lighting option 2

Note

Use is only permitted for control panel lighting.

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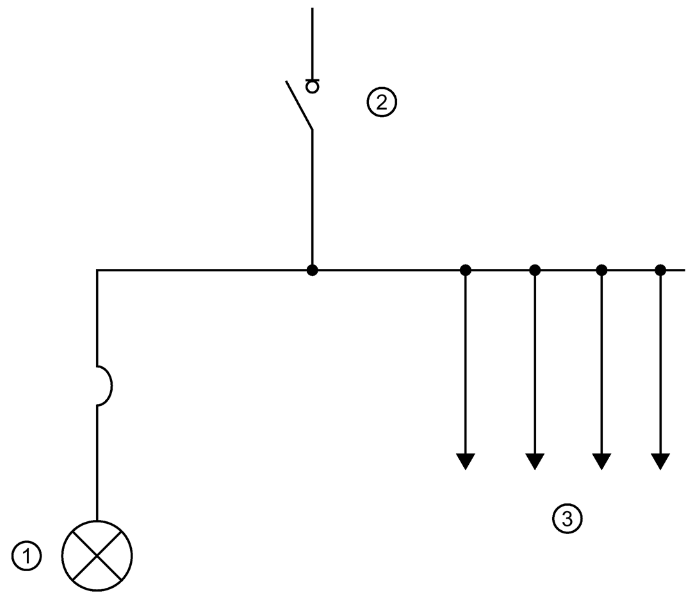
3. A grounded circuit of the actual machine supply shall be permitted. The following conditions shall be fulfilled for this purpose:
   - U ≤ 150 V
   - Separate overcurrent protection



① Lighting
② Supply disconnecting means
③ Machine circuits

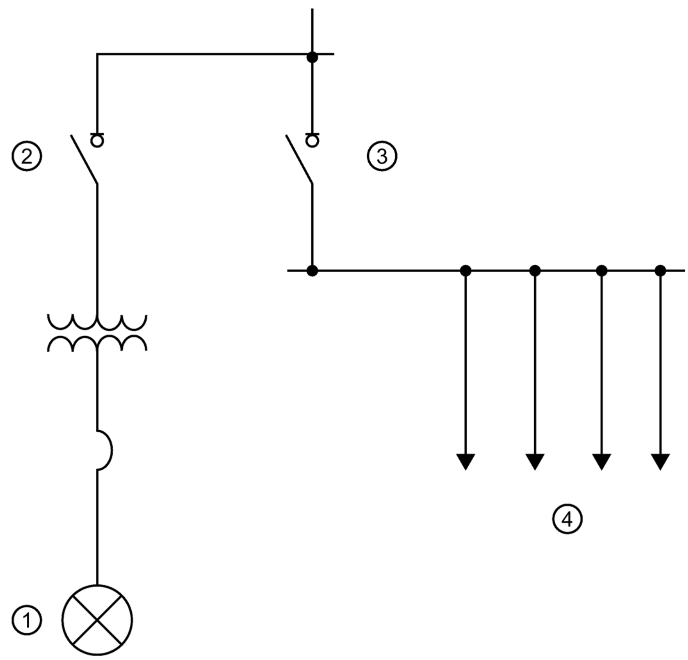
Figure 12-5 Design of machine lighting option 3

4. A separate isolation transformer is connected to the line side of the supply disconnecting means, where a separate disconnecting means shall be provided for the circuit on the primary side.

   and where overcurrent protection shall be provided on the secondary side. The overcurrent protection shall meet one of the following conditions:

   – Inside the control panel enclosure adjacent to the supply disconnecting means

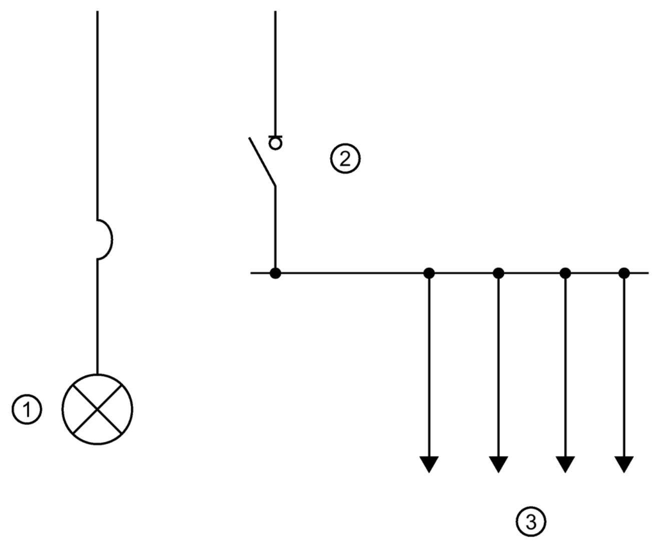
   – Outside the control panel, but immediately adjacent to control panel enclosure



① Lighting
② Disconnecting means for lighting
③ Supply disconnecting means
④ Machine circuits

Figure 12-6 Design of machine lighting option 4

5. An externally supplied control circuit (e.g. via the factory lighting supply). This shall be permitted both for the control panel enclosure and for the machine lights.
   The permissible power rating is restricted to P ≤ 3 kW. This minimizes the risk if there is a failure, or if someone other than the machine operating personnel switches off, or it ensures that the personnel still have a clear overview of the machine since the machine lighting cannot be relied on alone due to its limited lighting power.



① Lighting P ≤ 3 kW
② Supply disconnecting means
③ Machine circuits

Figure 12-7 Design of machine lighting option 5

13 Marking the control panel and the machine

13.1 General requirements

When attaching labels and warning plates, the expected ambient conditions shall always be taken into account. The ambient conditions can affect the material and the method of fixing.

The attachment of labels and markings is used to provide adequate information for the connection and commissioning of the machine and its associated equipment parts. On the other hand, markings can provide adequate information for the operation, for the operator, and for the service personnel.

The markings shall be provided before any possible testing and commissioning, and before adjustments and maintenance work.

It is also important for machine operators that function markings are provided on operator controls, visual indicators and displays. Some of the requirements for marking in the standards NFPA 79, Chapter 16 and UL 508A, Chapter 52 ff go beyond the minimum requirements of the NEC.

13.2 Nameplate

Industrial control panel enclosures and the electrical equipment of machinery shall be provided with a readable nameplate. The nameplate shall be permanently attached and shall remain visible following installation and commissioning.

13.2.1 Requirements of NFPA 79

The nameplate shall be attached either to the enclosure or to the machine immediately adjacent to the enclosure. On smaller machines, this data can also be included in the nameplate for the machine.

The following information is required on the nameplate:

- Manufacturer's name or trademark
- Serial number / production number
- Rated voltage, number of phases, and frequency (if AC voltage), and full-load current for each supply
- Ampere rating of the largest motor or load
- Maximum ampere rating of the short-circuit and ground fault protective device (if provided in the electrical equipment)
- SCCR of the control panel
- Number for the electrical documentation

Information regarding the machine nameplate data

- **Rated voltage**

  If overcurrent protective devices with a slash rating are used (e.g. 120 / 240 V, 480 Y / 277 V, 600 Y / 347 V), either the lower voltage or the complete slash rating shall be specified on the nameplate.

- **Full-load current**

  Specification of the full-load current does not have to include the total of all rated currents of all installed loads or circuits. A capacity factor (e.g. for oversized motors) or a simultaneity factor (max. possible operation) may be used.

- **Incoming supply**

  Where more than one incoming supply circuit is to be provided, there shall be a marking on the nameplate for each incoming supply circuit

- On small machines where only a single motor or motor controller is used, the motor nameplate shall be permitted to serve as the electrical equipment nameplate where it is plainly visible.

- **Overcurrent protection in the incoming supply circuit**

  If overcurrent protection is furnished in the incoming supply circuit conductor, this shall be marked. A separate nameplate shall be permitted to be used for this.

  Requirement of NFPA 79:

Supply conductor and machine overcurrent protection provided at machine supply terminals

  Figure 13-1 Marking of the incoming supply circuit conductor with overcurrent protection

13.2.2 Requirements according to UL 508A

The nameplate for control panels can be attached either inside the enclosure or externally on the enclosure.

Screws, rivets or adhesive can be used to fasten the nameplate. The information on the nameplate shall be applied either by means of die-stamping, silkscreening, or etching in metal or plastic. Optionally, indelible ink on adhesive-backed labels is also permissible.

The requirements for nameplate information are very similar to the specifications in NFPA 79 as described in the previous section "Requirements of NFPA 79".

The nameplate shall also provide the following information:

- Enclosure Type Rating – against external influences
- Place of manufacture (for those cases where industrial control panels of one manufacturer are assembled at different sites)
- Greatest connected heater load in amperes

Additional information shall be added to the nameplate if the control panel is part of the equipment of a machine and thus NFPA 79 can be required.

"Industrial control panel for Industrial Machinery"

13.2.3 Example

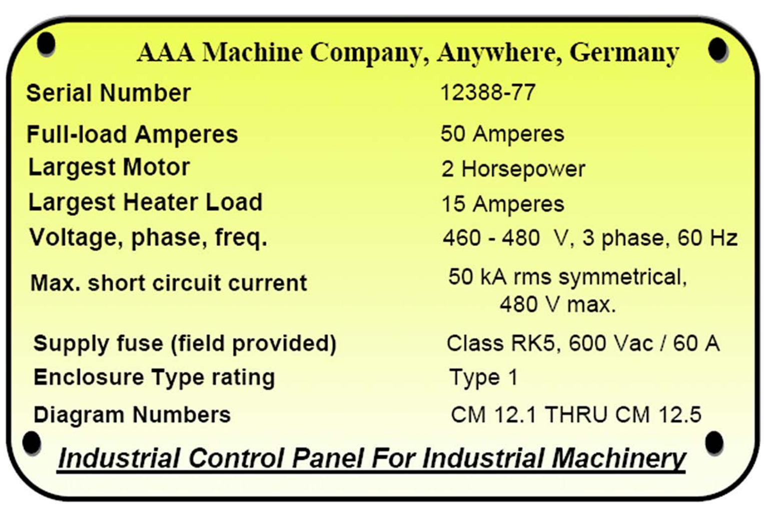


Figure 13-2 Example of a nameplate

13.3 Marking of the enclosure type rating on enclosures

As well as the marking of the enclosure type rating on the enclosure (see Chapter Requirements according to UL 508A (Page 265)), UL 508A stipulates further requirements with regard to openings and cable entries in enclosures.

Openings for the following components shall be correspondingly marked:

- Conduits
- External connections
- Pushbuttons
- Cable entries
- Cable distributors

This information is for the electrical installation engineer on-site and shall ensure that the desired enclosure type rating is observed even after completion of the wiring work.

You can find detailed information about this in UL 508A §53 "Enclosure Markings"

Furthermore, suitable markings are required on each section of several industrial control panels that are assembled and connected on-site.

Example:

Section ___ of ___, see diagram No. ___ for interconnections

Figure 13-3 Marking of industrial control panel sections

13.4 Terminal markings for connecting external circuits (Field Wiring)

13.4.1 General information

All terminals in the industrial control panel provided for the connection of field wiring shall be appropriately marked.
Information about the following shall be provided:

- Connection of the incoming supply circuit conductor
- Loads
- Control circuits

A terminal marking consisting of an alphanumeric code used shall correspond to markings on the field wiring diagram.

13.4.2 Markings for all field wiring terminals

All terminals in the industrial control panel used for field wiring shall be provided with the following information:

- Type of conductor material
- **"Use Copper Conductors only"**
- **"Use Aluminum Conductors Only"**
- Suitable for copper or aluminum conductors
  - **"Use Copper or Aluminum Conductors"** or
  - **"Use Copper, Copper-Clad Aluminum or Aluminum Conductors"**
- Suitable for copper or copper-clad aluminum conductors

  "Use Copper or Copper-clad Aluminum conductors"
- Permissible temperature range (**applies only to terminals in the power circuit!**)
  - **60 °C (140°F)** for terminals with a rated current less than 100 A
  - **75 °C (167°F)** for terminals with a rated current less than 100 A and approval for the 75 °C temperature range
  - **75 °C (167°F)** for terminals with a rated current greater than 100 A

  Exception: Specification of the temperature is not required for non-motor loads with a rated current less than 15 A.

- Tightening torque for terminals with screw-type terminals
  - Marking in accordance with the manufacturer's specifications, the installation instructions, or the markings on the product.

    Example:

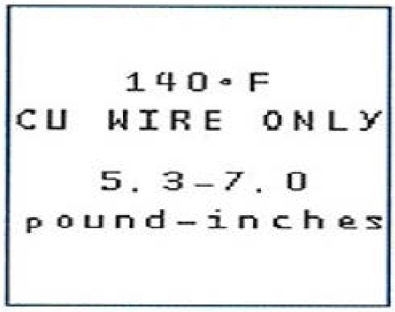


Figure 13-4 Example of terminal marking

  - *Or* in accordance with the table values of the **UL 508A standard.** In the tables below, the values are specified depending on the screw type:

    Table 13-1 Tightening torque for screws (Page 269)

    Table 13-2 Tightening torque for slotted head screws smaller than No. 10 intended for use with 8 AWG (8.4 mm²) or smaller conductors (Page 270)

    Table 13-3 Tightening torque for socket head screws (Page 270)

Components that are already visibly marked with the required torque (e.g. on the nameplate of motor protection devices, contactors, or fuse holders) do not require any further separate marking.

If spring-loaded connections (Cage Clamp) are used, there is no need for marking the required tightening torque. A "Cage Clamp" indication can be attached instead.

Example:

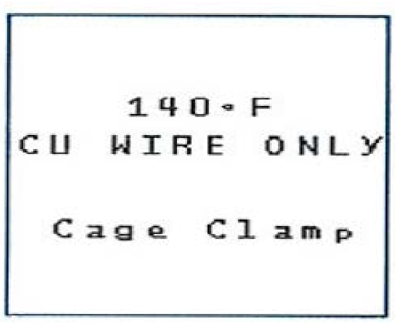


Figure 13-5 Example of terminal marking with spring-loaded terminals

Exceptions to marking with the tightening torque:

- Terminal screws for wire connections
- Terminals for control circuits with a rated tightening torque of 7 inch-lb (0.8 Nm)

Table 13- 1 Tightening torque for screws

Test wire size installed in connector		Tightening torque, pound-inches (Nm)							
		Slotted head No. 10 and larger				Hexagonal head-external drive socket wrench			
AWG or kcmil	(mm²)	Slot width – 0.047 inch (1.2 mm) or less and slot length 1/4 inch (6.4 mm) or less		Slot width – over 0.047 inch (1.2 mm) or less and slot length 1/4 inch (6.4 mm)		Split-bolt connectors		Other connectors	
18 … 10	(0.82 … 5.3)	20	(2.3)	35	(4.0)	80	(9.0)	75	(8.5)
8	(8.4)	25	(2.8)	40	(4.5)	80	(9.0)	75	(8.5)
6 … 4	(13.3 … 21.2)	35	(4.0)	45	(5.1)	165	(18.6)	110	(12.4)
3	(26.7)	35	(4.0)	50	(5.6)	275	(31.1)	150	(16.9)
2	(33.6)	40	(4.5)	50	(5.6)	275	(31.1)	150	(16.9)
1	(42.4)	–	–	50	(5.6)	275	(31.1)	150	(16.9)
1/0 … 2/0	(53.5 … 67.4)	–	–	50	(5.6)	385	(43.5)	180	(20.3)
3/0 … 4/0	(85.0 … 107.2)	–	–	50	(5.6)	500	(56.5)	250	(28.2)
250 … 350	(127 … 177)	–	–	50	(5.6)	650	(73.4)	325	(36.7)
400	(203)	–	–	50	(5.6)	825	(93.2)	375	(36.7)
500	(253)	–	–	50	(5.6)	825	(93.2)	375	(36.7)
600 … 750	(304 … 380)	–	–	50	(5.6)	1000	(113.0)	375	(36.7)
800 … 1000	(406 … 508)	–	–	50	(5.6)	1100	(124.3)	500	(56.5)
1250 … 2000	(635 … 1010)	–	–	–	–	1100	(124.3)	600	(67.8)
NOTE – For values of slot width or length not corresponding to those specified, the largest torque value associated with the conductor size shall be marked. Slot width is the nominal design value. Slot length shall be measured at the bottom of the slot.									

Source: UL 508A, Table 54.1

Table 13- 2 Tightening torque for slotted head screws smaller than No. 10 intended for use with 8 AWG (8.4 mm²) or smaller conductors

Slot length of screw[a]		Tightening torque, pound-inches (Nm)			
		Slot width of screw[b], in (mm)			
Inches	**(mm)**	**Smaller than 0.047 (1.2)**		**0.047 (1.2) and larger**	
Less than 5/32	(4)	7	(0.79)	9	(1.0)
5/32	(4)	7	(0.79)	12	(1.4)
3/16	(4.,)	7	(0.79)	12	(1.4)
7/32	(5.6)	7	(0.79)	12	(1.4)
1/4	(6.4)	9	(1.0)	12	(1.4)
9/32	(7.1)	–	–	15	(1.7)
Above 9/32	(7.1)	–	–	20	(2.3)

[a] For slot lengths of intermediate values, torques pertaining to the next shorter slot length shall be utilized. For screws with multiple tightening means, the largest torque value associated with the conductor size shall be marked. Slot length shall be measured at the bottom of the slot.

[b] Slot width is the nominal design value.

Source: UL 508A, Table 54.2

Table 13- 3 Tightening torque for socket head screws

Socket size across flats		Tightening torque	
Inches	**(mm)**	**Pound-inches**	**(Nm)**
1/8	(3.2)	45	(5.1)
5/32	(4.0)	100	(11.3)
3/16	(4.8)	120	(13.6)
7/32	(5.6)	150	(16.9)
1/4	(6.4)	200	(22.6)
5/16	(7.9)	275	(31.1)
3/8	(9.5)	375	(42.4)
1/2	(12.7)	500	(56.5)
9/16	(14.3)	600	(67.8)

[a] For screws with multiple tightening means, the largest torque value associated with the conductor size shall be marked. Slot length shall be measured at the bottom of the slot.

Source: UL 508A, Table 54.3

Marking of grounding terminals for the connection of field-installed equipment grounding (protective) conductors

Terminals for connecting field-installed equipment grounding (protective) conductors shall be additionally marked with the following information:

1. Green hexagonal screw that cannot be readily removed from the terminal.
2. Green hexagonal nut that cannot be readily removed from the terminal.
3. With the words "Ground" or "Grounding"
4. With the letters "G", "GR", "GRD", "GND" or "GRND"
5. With the symbol from IEC 60417 ⏚
6. If the terminal is within an enclosure (e.g. terminal block), identification is made either with designations/abbreviations (see Point 3 or 4) or with the symbol in accordance with Point 5.

   The color combination green/yellow can also be optionally used.

   Example: Green/yellow marked grounding terminals together with other through-type terminals

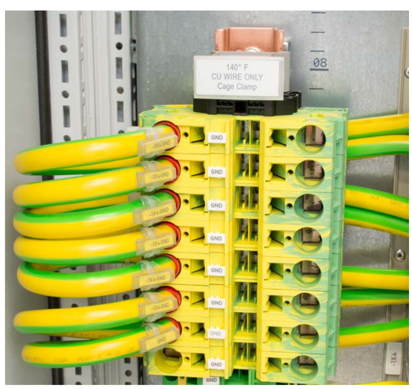


Figure 13-6 Siemens 8WH grounding terminals

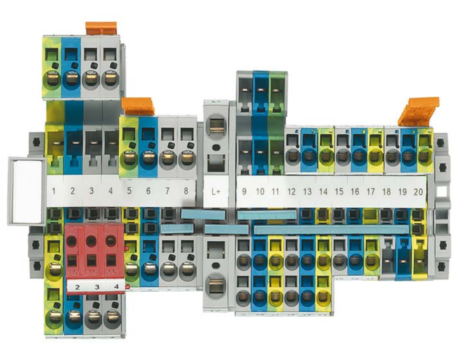


Figure 13-7 Siemens 8WH terminal arrangement

13.4.3 Other markings for terminals in control circuits

In accordance with UL 508A, the following terminals in control circuits shall be appropriately marked for the connection of field conductors.

1. Terminals in "Low-voltage limited energy circuits" or control circuits with a voltage ≤ 30 Vrms shall be marked with one of the following:
   - **"Class 1 control circuit"**
   - **"Use Class 1 conductors"**
   - **"For connection to a Class 1 remote Control Circuit"**

   Background: Since neither the NEC nor NFPA 79 describe a Low-voltage limited energy circuit, this is regarded as a Class 1 control circuit when it leaves the control panel.
2. Terminals in Class 2 control circuits shall be marked with one of the following:
   - **"Class 2 control circuit"**
   - **"Use Class 2 conductors"**
   - **"For connection to a Class 2 remote control circuit"**
3. Industrial control panels that contain Class 2 control circuits as well as Class 1 control circuits and/or power circuits" shall be provided with instructions on how to ensure the minimum distance of 2 inches to other terminals if the isolation of the terminals is not ensured by means of barriers. (UL 508A, Chapter 28.4.2)
4. When using conductor cross-sections less than 14 AWG (2.1 mm²), marking shall be carried out dependent on the connectable cross-section in accordance with the table "Ampacity of field wiring conductors smaller than 14 AWG (2.1 mm²)" below.

Table 13- 4 Ampacity of field wiring conductors smaller than 14 AWG (2.1 mm²)

Maximum control circuit terminal ampacity, amperes	Minimum terminal wire range		Marking required
	AWG	(mm²)	
10	16	(1.3)	Yes
10	16 … 14	(1.3 … 2.1)	No
7	18	(0.82)	Yes
7	18 … 14	(0.82 … 2.1)	No
5	20 … 18	(0.52 … 0.82)	Yes
5	20 … 14	(0.52 … 2.1)	No
3	22 … 18	(0.32 … 0.82)	Yes
3	22 … 14	(0.32 … 2.1)	No
2	24 … 18	(0.20 … 0.82)	Yes
2	24 … 14	(0.20 … 2.1)	No
1	26 … 18	(0.13 … 0.82)	Yes
1	26 … 14	(0.13 … 2.1)	No
0.8	28 … 18	(0.08 … 0.82)	Yes
0.8	28 … 14	(0.08 … 2.1)	No
0.5	30 … 18	(0.05 … 0.82)	Yes
0.5	28 … 14	(0.05 … 2.1)	No

Source: UL 508A Table 37.1

13.5 Warning and safety instructions

The standards UL 508A for Industrial Control Panels and NFPA 79 for Industrial Machinery contain a host of requirements regarding warning and safety information.

The UL 508A requirements are dealt with first below, and then the requirements of NFPA 79 separately.

13.5.1 Warning information in accordance with UL 508A

13.5.1.1 General information

Warning information is used on one hand to provide the operator with information on safe operation and operator control. On the other hand, it is used to inform service and maintenance personnel of the electrical hazards involved with the machines and plants. For this reason, the information shall be easy to read in the respective application, easily visible, and permanently attached without impairing the user of the machinery and associated equipment. For the operator, the information shall be easy to read under normal operating conditions, and it shall be attached at appropriate positions where service and maintenance work is carried out.

Warning information shall always start with the preface **"Caution"** or **"Warning"**, depending on the potential hazard. The minimum size of the letters shall be 1/8 inch (3.2 mm).

The letters for the remaining text of the warning notice shall have a minimum height of 1/16 inch (1.6 mm).

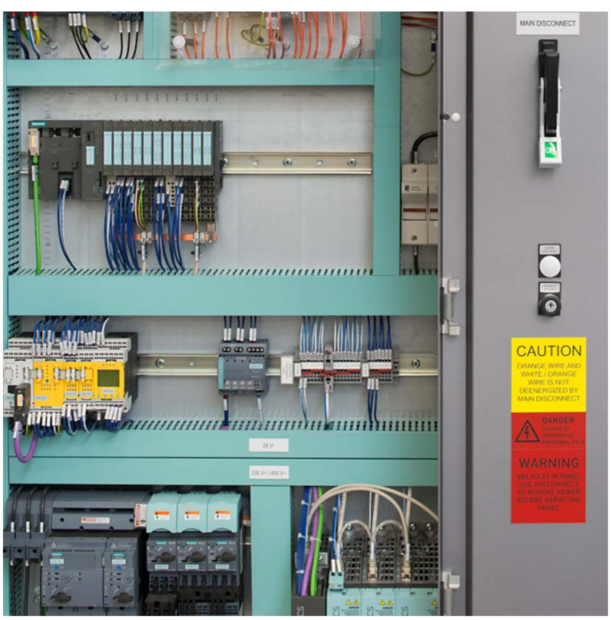


Figure 13-8 Example of warning information on the industrial control panel enclosure

ANSI Z535

The ANSI Z535 series of standards offers comprehensive information for marking safety labels.

ANSI Z535 offers support in deciding on which signal is to be used.

Each signal word represents initially a specific hazard potential and the consequences of the hazard.

DANGER indicates a hazardous situation that will result in death or severe injury if the hazard situation is not prevented.

WARNING indicates a hazardous situation that can result in death or severe injury if the hazard situation is not prevented.

CAUTION indicates a hazardous situation that can result in minor or moderate injury if the hazard situation is not prevented.

NOTICE is used for practical information outside the context of possible personal injury.

Safety instructions or similar terms indicate specific safety-related instructions or processes.

Table 13- 5 Selection guide for signal word when death or injury can occur

		Probability of an accident if the hazardous situation is not prevented	
		Will occur	Could occur
Probability of death or severe personal injury in the event of an accident	Will occur	⚠ DANGER	⚠ WARNING
	Could occur	⚠ WARNING	⚠ WARNING

Source: ANSI Z535 Ed. 2011

Table 13- 6 Selection guide for signal word in the case of minor or moderate injury

For all occurrences	⚠ CAUTION

Source: ANSI Z535 Ed. 2011

Table 13- 7 Selection guide for signal word if there is no risk of injury

For all occurrences	NOTICE

Source: ANSI Z535 Ed. 2011

Flowchart for the process of selecting signal words

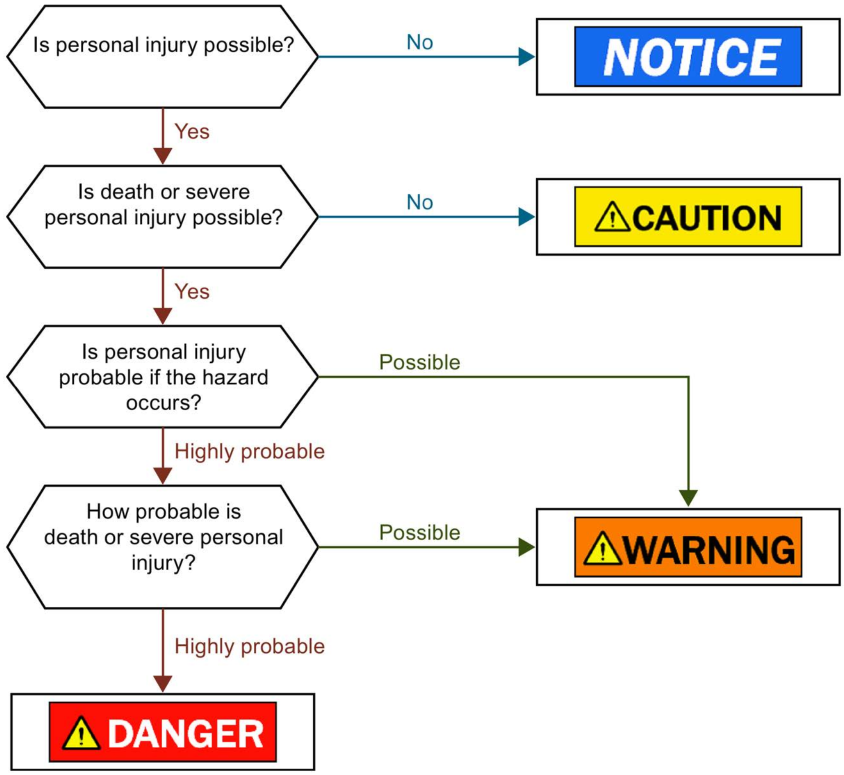
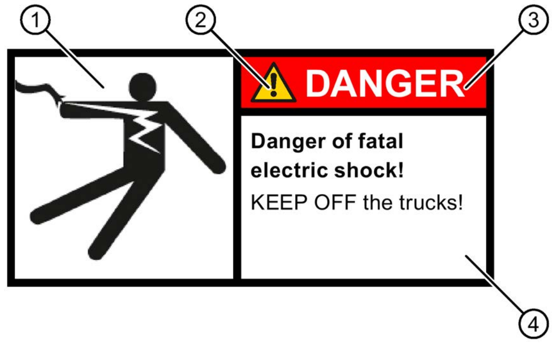


Figure 13-9 Flowchart for selecting signal words

According to ANSI Z535, safety information has several features.

The figure below describes the features of safety information:



① **Pictogram(s)**
(optional)
Consequences, measures or prohibitions

② **Hazard symbol**
Indicates danger of injury

③ **Signal word**
Classifies the hazard

④ **Information text**

- Type and source of the danger
- Possible consequences
- Measures / prohibitions

Figure 13-10 Elements of a safety sign

13.5.1.2 Multiple incoming supply circuits

If multiple incoming supply circuits are available for an industrial control panel and multiple disconnecting means have been provided for them, this shall be indicated.

Exception: This requirement does not apply for galvanically isolated, separately supplied control circuits. An example of this would be an "excepted control circuit". See Chapter Excepted circuits (Page 78).

Example of marking:

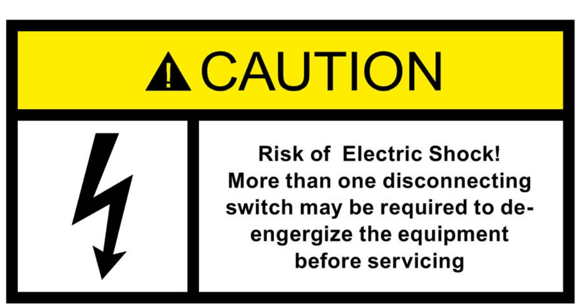


Figure 13-11 Example marking for multiple incoming supply circuit conductors

13.5.1.3 Separate markings for circuit breakers and motor circuit breakers

Instantaneous trip circuit breakers without overload protection

If instantaneous trip circuit breakers are used for branch circuit protection in combination with motor controllers and motor overload protective devices (e.g. contactor-overload assembly), the following information shall be attached adjacent to the circuit breaker.

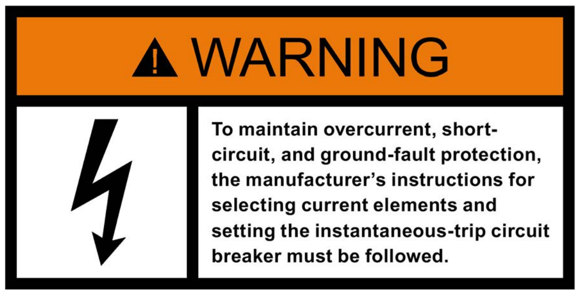


Figure 13-12 Example of warning notice for instantaneous trip circuit breakers

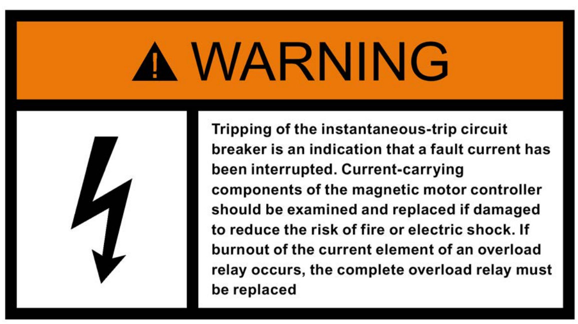


Figure 13-13 Example of warning notice for instantaneous trip circuit breakers

Motor circuit breakers tested as "Self-protected combination motor controller"

Motor circuit breakers tested as "self-protected combination motor controllers" shall be marked with the following information in the control panel. The marking shall be attached adjacent to the motor circuit breaker.

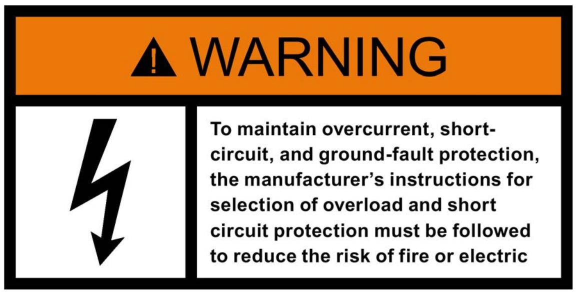


Figure 13-14 Example of warning notice for motor circuit breakers

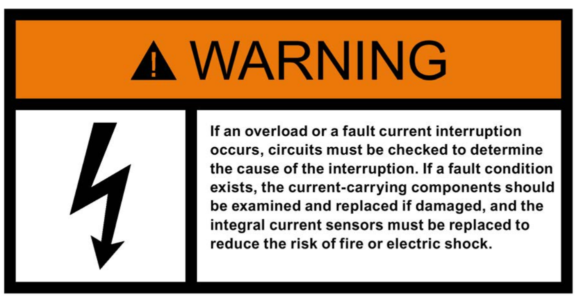


Figure 13-15 Example of warning notice for motor circuit breakers

13.5.2 Safety signs in accordance with NFPA 79 for enclosures with electrical components

13.5.2.1 General information

Safety signs shall always be clearly recognizable and permanently attached. Ambient conditions such as possible contamination, liquids or UV radiation shall also be included.

Machines and associated equipment parts can contain a host of electrical components. In some cases this is not clearly recognizable. For this reason, such enclosures shall be provided with appropriate safety signs. This information shall be attached to the door or the cover. The IEC symbol is an example of an appropriate marking.

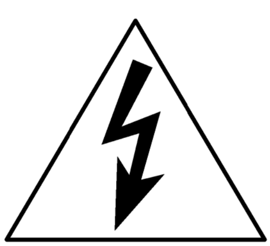


Figure 13-16 IEC symbol for the use of electrical components in enclosures

13.5.2.2 Hazard warning for electric shock and arc flashes

Furthermore, on electrical equipment such as industrial control panels and enclosures containing a main disconnecting means, the hazard of electric shock and the potential hazard of arc flashes (see Chapter Arc flash hazard (protection against arc flashing) (Page 94)) shall be correspondingly marked. Here too, care shall be taken that the marking is clearly and easily visible. The aim is to alert qualified persons to potential hazards before starting service and maintenance work and to provide them with suitable information. It shall be permitted to omit safety signs where the size of the enclosure precludes placement of the label on the enclosure. Examples in this case are control stations, human-machine interface touch panels (HMI panels), position sensors, etc.

13.5.2.3 Safety sign for disconnecting means

It is not the case that all circuits are always de-energized by the disconnecting means, see Chapter Excepted circuits (Page 78). If disconnect switches or circuit breakers are used in this case as the disconnecting means for the incoming supply circuit conductor, and if they are interlocked with the enclosure, safety signs shall be provided adjacent to the operating handle for the disconnecting means. This sign indicates that not all live parts are de-energized when the disconnecting means is in the open (off) position.

Example sign:

Figure 13-17 Example of safety sign for disconnecting means

When an attachment plug is used as the disconnecting means (see Chapter Devices (Page 73)), a safety sign shall be attached to the control panel enclosure. This shall indicate that the incoming supply circuit conductor shall be disconnected before the enclosure is opened.

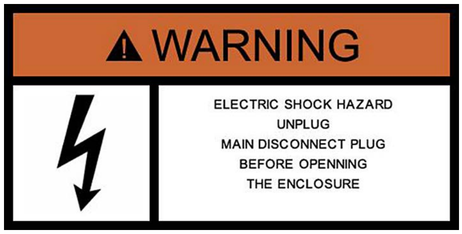


Figure 13-18 Example of safety sign when using attachment plugs as the disconnecting means

The disconnecting means does not necessarily have to be in the same enclosure as the associated electrical equipment. In some cases, this is located in its own enclosure adjacent to the industrial control panel. In such cases, there shall be a sign on the control panel providing the following information:

- The power shall be disconnected from the equipment before the enclosure is opened.
- The enclosure door shall be closed or the cover attached before the power is restored.

13.5.2.4 Arc flash hazards

In addition to the above-mentioned warning notices, the enclosure shall be provided with a sign indicating potential arc flash hazards. This shall be located on the enclosure adjacent to the operating handle for the disconnecting means.

You can find more detailed information and an example of a marking in Chapter Arc flash hazard (protection against arc flashing) (Page 94).

13.6 Device marking on the industrial control panel acc. to UL 508A

13.6.1 Fuse holders

Fuse holders used in the power circuit for branch circuit protection shall be marked.

If the fuse holder is also designed for larger fuses than the rated current of the circuit, the marking shall include details of the following:

- **Fuse type**
- **Voltage**
- **Current rating**

Fuse holders for overcurrent protection of control circuits shall always be marked with the replacement fuse.

The marking shall be provided either immediately adjacent to the respective fuse holder, or as information on the door, or visibly inside the control panel.

Example of marking for fuse holders:

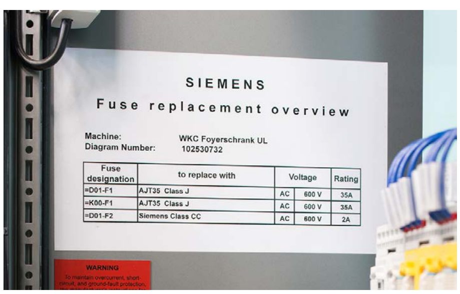


Figure 13-19 Example of marking for fuse holders

13.6.2 Switches

The "ON" and "OFF" positions on the operating handle of each disconnecting means shall be marked. This is usually provided for in the manufacturer's accessories.

Examples of marking the disconnecting means:

Figure 13-20 Toggle lever for main disconnecting means

Figure 13-21 Front rotary operating mechanism for main disconnecting means

A manual switch not intended to be operated under load shall be provided with an appropriate marking in the vicinity of the switch.

Example of marking:

Do not operate under load

Figure 13-22 Example of the marking indicating that switching under load is prohibited

In some cases, it may be necessary to back-feed the disconnecting means. This may be the case where space is restricted in the control panel, for example, to meet the minimum requirements for wire bending space (see Chapter Incoming supply circuit conductor and power terminals (Page 69)).

Back-feeding of the disconnecting means is permissible when:

- The switch is *not* provided with the marking "line" and "load"
- A marking is provided with unambiguous information concerning the location of the disconnect switch. The marking shall be visible on the outside of the control panel without the need to open the door.

13.6.3 Receptacles

Receptacles for general use **in the power circuit** provided with overcurrent protection rated less than the rating of the receptacle shall be clearly marked to this effect immediately adjacent to the receptacle.

Receptacles supplied via a control circuit shall also be marked with the following information:

- Rating of the overcurrent protective device
- The intended use for the devices/receptacles

Figure 13-23 Example of the marking of receptacles for control circuit devices

Multiple pin type receptacles or receptacles for general use rated more than 20 A shall be provided with a marking that they are only permitted to be used for disconnecting and not for current rupturing.

For disconnecting use only,
not for current rupturing

Figure 13-24 Example of text for the marking

13.6.4 Field-installed devices

It is often the case that devices such as disconnecting means, overcurrent protective devices for branch circuits, or also motor overload protective devices are not installed components of the industrial control panel, or the panel builder requires that they are to be provided on-site by the installer.

Another example for this is the use of disconnect switches as the supply disconnecting means without any overcurrent protection or terminals for connecting the incoming supply circuit conductor. These require separate overcurrent protection usually approved by the manufacturer or stated on the UL certificate. The installer or operator of the electrical equipment is thus responsible for installing these field provided devices.

In this case, a suitable marking shall be provided containing sufficient information about the required device and sizing.

The marking shall be included in the relevant documentation (see the documentation reference on the nameplate, in Chapter Marking of the enclosure type rating on enclosures (Page 266)). These are usually the installation diagrams and the assembly instructions used for connecting to the system supply, and for commissioning the equipment.

13.6.5 Separately supplied control circuits

Control circuits in the industrial control panel that are not supplied within the control panel but via a separate incoming supply circuit conductor, and that are not provided with their own overcurrent protection and/or disconnecting means in the control panel, shall be provided with a marking. The marking shall indicate the devices to be provided by the installer. The marking is also provided in the installation diagrams or assembly instructions.

13.6.6 Marking in circuit diagrams / wiring diagrams

All circuit diagrams and wiring diagrams shall always be provided for the respective industrial control panel. These diagrams shall also include information on all devices that may have to be provided on-site by the installer.

The documentation can either be provided separately, in its own document storage area in the industrial control panel, or within the respective control panel.

Optional circuits and components in the circuit and wiring diagrams shall be marked as being not included in the actual scope of supply.

This marking shall be provided separately for each individual component and circuit.

13.7 Function identification

Electrical equipment of control panels and machinery often contain a host of visual indicators, control devices, displays, and operator interfaces.

Each individual device shall be provided with a function identification. The function identification can be provided either directly on the device or immediately adjacent to the device. Many devices (e.g. twin pushbuttons, see the figure below) already have a function identification. On other devices (e.g. pendant pushbuttons, see the figure below), marking is provided directly on the enclosure adjacent to the actuating element.

Figure 13-25 Siemens twin pushbutton with 3SB31 00 indicator light function identification on the actuator

Figure 13-26 Siemens 3SB3 38 pendant pushbutton with customized components, function identification adjacent to the actuator

NFPA 79 recommends that manufacturers and customers agree on the symbols for function identification. The following standards are recommended for information on possible symbols:

- IEC 60417-2 Graphical Symbols for Use on Equipment
- ISO 7000 Graphical Symbols for Use on Equipment

Special attention shall be paid here to pushbuttons and the associated IEC symbols.

13.8 Marking of equipment in accordance with NFPA 79

General information

All electrical equipment and machinery components shall comply with the relevant documentation and be marked accordingly.

The marking shall be durable and easy to read in the installed state.

The markings shall not be removed, even after installation and commissioning of the electrical equipment.

All devices and components in the control panel and in the machinery field shall be plainly marked. The type designation used shall be the same as that used in the circuit diagrams and the relevant documentation. The identification shall be attached immediately adjacent to the equipment, not on the device or component itself.

Exceptions

1. A group identification can also be used in place of an individual identification. This can be necessary where an individual identification is not practicable due to the size or location of the devices.
2. Detailed identification can be omitted on small machines. The scope of the components and devices is restricted in this case to a single motor and controller, and the associated pushbuttons and work lights.

Technical documentation 14

14.1 General requirements and information

Introduction

The two standards considered in this guide differ widely with regard to the documentation; both with reference to the type and scope of the documentation.

The number of requirements for industrial control panels is considerably lower in UL 508A. The requirements for control panels are dealt with in Chapter Documentation according to UL 508A for machine control panels (Page 291).

The requirements and background principles of NFPA 79 are explained in Chapter Documentation according to NFPA 79 for the electrical equipment of machines and systems (Page 292).

General information on electronic documentation for industrial control panels and machines

Since electrical equipment for machines and their associated industrial control panels is often of a unique nature and varies in terms of its complexity, sufficient documentation shall be provided to cover all the eventualities presented by this.

The purpose of the documentation is to provide the necessary information for:

- **Installation**
- **Operation**
- **Maintenance**

This information may differ considerably due to the varying complexity of the machines and their associated electrical equipment. For relatively basic electrical equipment parts or machines, it shall be permitted to even contain the information in a single document. This document shall still show all the electrical equipment, however, and enough information shall be provided to ensure that the equipment can be connected without difficulty.

The NFPA 79 therefore has a minimum requirement that the technical documentation shall contain information on the following:

- Normal operating conditions
- Electrical supply
- Required ambient conditions
- Handling, transport, and storage
- Inappropriate operation and use of the equipment

Information to be provided

The documentation shall be provided in the form of drawings, diagrams, tables, graphics, and appropriate instructions. The machine manufacturer shall ensure that the machine is supplied together with this documentation. The standards do not specify whether the documentation shall be in hard copy or on a data storage medium. The type and medium of the information provided shall be agreed between the manufacturer and the equipment user, particularly in the case of export trade.

Language

The agreed language for clients and operators in North America is predominantly English. However, simply assuming this will be adequate is not advisable. A second language (such as Spanish or French) is often desirable. This is not restricted to the documentation itself, but may also apply to the markings (such as warning notices).

In addition, many "American English" expressions are used in the standards and these are often completely different to the relevant IEC standards, which strongly favor "British English". If the information is being translated, this aspect shall be taken into account in order to avoid misunderstandings.

General note

Both the UL 508A and the NFPA 79 standards refer to the electrical equipment of machines. If a machine manufacturer obtains the electronic equipment (e.g. the industrial control panel) from a third-party panel builder, the documentation format and level of detail should be agreed in advance. This is particularly important in the case of overlapping documents (e.g. mechanical overview diagrams) that contain electrical components. When exporting to North America in particular, it is crucial to ensure that both partners are aware of the necessary standards and requirements.

14.2 Documentation according to UL 508A for machine control panels

Requirement according to UL 508A, Chapter 61

General information

The following documentation requirements refer exclusively to the electrical components and functions of the respective industrial control panel.
The following complete set of documents shall be provided for the industrial control panel:

- Circuit diagram
- Installation diagram
- Wiring diagram

The components used by the manufacturer shall be clearly shown.

Components external to the industrial control panel

If the diagrams referred to above include field components that are connected to the industrial control panel, these shall be identified clearly and visibly, and they shall correspond to the marking of the terminals (see also Chapter Identification and color (Page 234)). Based on this identification, it should be clear that the components shall be provided and installed by the installer.

Standardized industrial control panel diagrams

Some manufacturers use standardized industrial control panel diagrams to achieve the best possible coverage for the various types of panel available.

If these standardized industrial control panel diagrams contain components and circuits that are **optional** and **usually provided by the manufacturer/panel builder,** the diagrams shall be adapted accordingly. They shall be limited to those components and circuits that are actually provided by the manufacturer or panel builder.

The modifications shall be made for each individual device and/or circuit.

14.3 Documentation according to NFPA 79 for the electrical equipment of machines and systems

Information and documents to be provided

The following table summarizes the required information that shall be provided with the electrical equipment according to NFPA 79, Chapter 17.2.

Some requirements are optional and identified as such in the "Comments" column.

Table 14- 1 Summary of the required information and specifications

Information/Documents	Comments
Clear and comprehensive description of the equipment. Including installation, mounting, and connecting to the electrical supply (or supplies)	-
Requirements for the electrical supply	-
Overview diagrams, block diagrams	If appropriate and applicable
Information on: • Programming • Sequence of operation • Frequency of inspections • Frequency and methods of function tests • Adjustments, maintenance, and repair • Interconnection diagrams • Industrial control panel layout • Manual with instructions and servicing information • Required ambient conditions (e.g. lighting, vibration, noise levels, atmospheric contaminants)	Where appropriate and applicable
Description of the safety monitoring features, interacting functions, and function interlocking	-
Description of the safety monitoring measures if the primary safety functions are overridden (e.g. manual programming, program verification)	-
Information for safety lockout procedure	-
Explanation of unique conditions/terms	-
Parts list and list of recommended spare parts	-
Maintenance instructions and adjustment procedure	-
Reference information for: • Lubrication diagrams • Pneumatic diagrams • Hydraulic diagrams • Diagrams for miscellaneous equipment (coolant, refrigerator, etc.)	If relevant and applicable

Requirements applicable to all documentation

The information required in the table "Summary of the required information and data" shall be provided in a set format. For referencing of the different documents, NFPA 79 offers some leeway and offers the following two selection options:

- Every document shall carry as cross-reference the document numbers of all other documents belonging to the electrical equipment of the machine. This method is limited to a maximum of 4 documents.
- All documents shall be listed with a document number and title in a drawing or document list.

A table of contents with references to the main sections of the electronic documents (e.g. terminal diagram, parts list, control system, circuit diagram, assembly drawing, etc.) shall appear on the first page where helpful.

Recommendation

Where appropriate, the documents shall also contain information regarding current ratings, peak starting currents, and the maximum permissible voltage drop. Preferably, this data shall be provided in the wiring diagram or layout diagrams.

14.3.1 Installation diagrams according to NFPA 79, Chapter 17.5

To enable the electrical equipment to be assembled on site, sufficient information shall be provided. This is ensured by providing installation and set-up diagrams. In more complicated cases, it is recommended that the assembly drawings are referred to for further details.

The installation site and position of the incoming power supply shall be clearly identified. The operator shall normally provide overcurrent protection for the incoming power supply circuit and supply conductor(s) to the machine. The overcurrent protection shall be adapted in line with the electrical equipment for the machine.

Clear specifications shall be provided regarding the required overcurrent protection for the incoming supply circuit conductor, in the form of the following:

- Nature and type of the protective device (e.g. fuse, circuit breaker)
- Characteristics (selectivity behavior, time delay, overload behavior)
- Rated currents of the protective device

Where necessary, a requirement for raceways and ducts shall be detailed; to be provided as follows:

- In the foundations, provided by the user
- Outside the machine, between the machine and the associated equipment parts, or in the factory, by the user

This generally forms part of the agreement between the manufacturer and the user; it is essential that this is agreed on. The inquiry form Checklists (Page 328) in the Annex provides some assistance here.

If necessary, data relating to space required for removal or servicing of electrical equipment and components shall be provided. Pay particular attention to Chapter Working space (Page 189).

If necessary, data relating to all external connections shall be provided. In addition to the supply-side connection, other connections may be required (e.g. for interlocking with other machines, emergency power supplies).

Where the machine is intended to be operated from more than one source of electrical supply, this shall be noted in the interconnection diagram. This information shall indicate all the modifications for every possible supply and specify the required modifications.

14.3.2 Layout diagrams, block diagrams, and function diagrams

Layout diagrams and block diagrams for the interaction of functions are particularly useful for gaining a quick introduction to machines and an understanding of the principles of operation.

Block diagrams

Block diagrams shall only represent the functional interrelationships as symbols and do not necessarily need to show all interconnections.

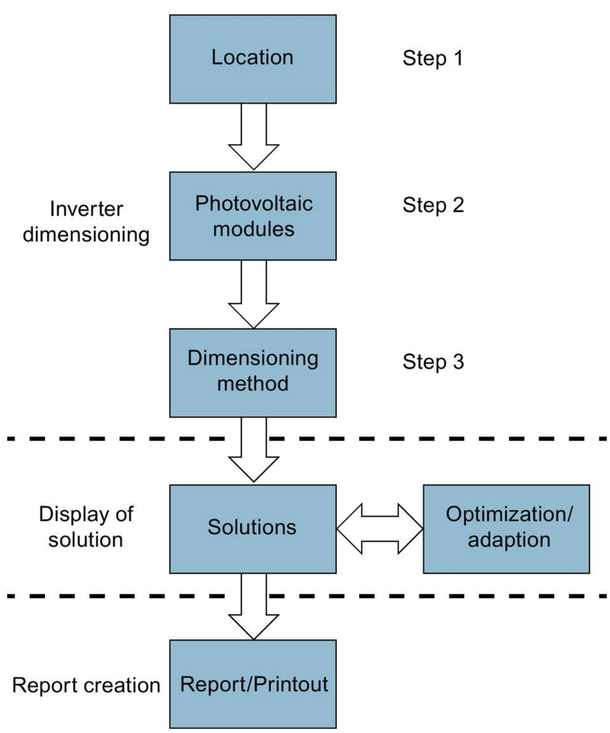


Figure 14-1 Example of a block diagram

Function diagrams

Function diagrams are particularly appropriate for showing logical interconnections. These diagrams are often very useful when it comes to commissioning and troubleshooting; for this reason, they shall not just be used for complex functional interrelationships.

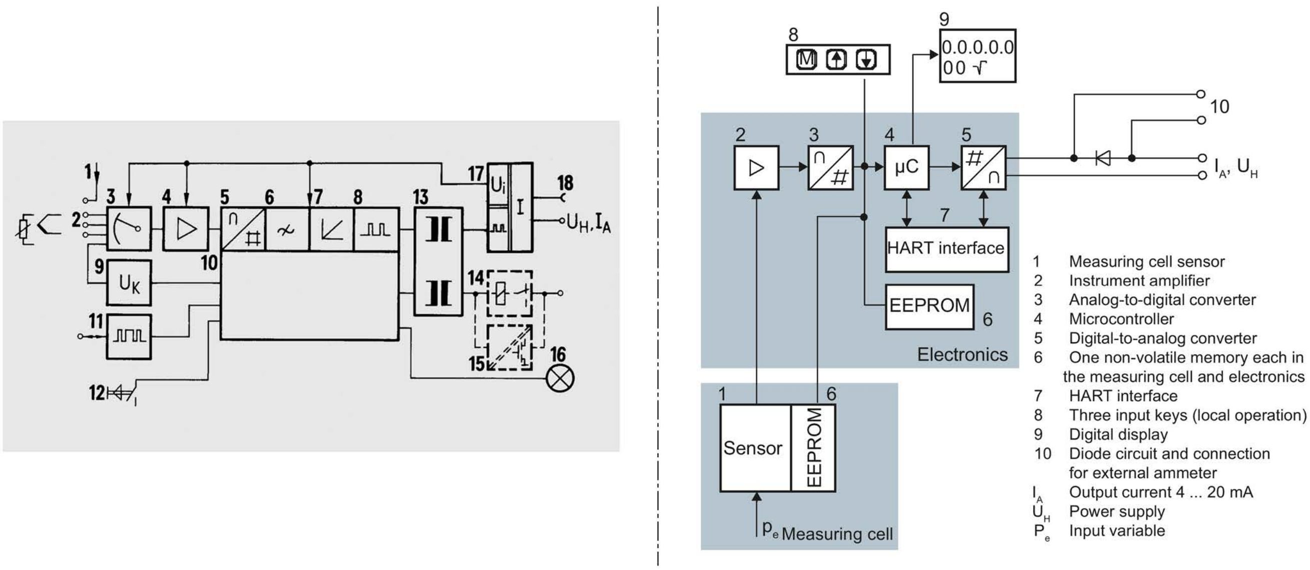


Figure 14-2 Examples of function diagrams

Circuit diagrams

Circuit diagrams are the most important documents for qualified persons working with electrical equipment for machines. NFPA 79 accordingly contains comprehensive requirements for the layout of these diagrams.
Circuit diagrams shall show the electrical circuits of the machine itself and of the associated equipment.

Exception

Commercially available products or field replaceable components do not require circuit diagrams that have been specially prepared for the documentation.

Symbols

All electrical symbols that are included shall be listed in accordance with the IEEE 315/315A standard "Graphic Symbols for Electrical and Electronics Diagrams".
If symbols that are not included in IEEE 315 are used, these shall be described separately in the circuit diagrams. The symbols used shall be applied consistently throughout. Switching between symbols that have the same meaning but different representations is not permitted.

A comprehensive list of the IEEE 315 symbols can be found in the Annex under Graphical symbols and abbreviations in accordance with IEC and UL / NFPA (Page 340).

Relevant information, such as the motor horsepower, frame size or speed, shall be listed adjacent to its symbols.

Where appropriate, a diagram showing the terminals for the connection interfaces shall be provided. Circuit symbols shall be shown in electromechanical diagrams with all supplies turned "off".
Examples of these include the electrical power supply, pneumatic and hydraulic components, and lubricating devices.
For the sake of simplicity, terminal diagrams are permitted to be provided in conjunction with the circuit diagrams if document references are made to the detailed circuit diagram.

Starting condition

Specifications for the machine and the associated electrical equipment shall be provided in the circuit diagrams in normal starting condition at an ambient temperature of 20 °C (68 °F). Settings shall be indicated in the circuit diagram.

Marking of conductors

Conductors shall be marked in a logical, comprehensible order.

The standard recommends identifying them according to one or a combination of the following methods:

- Numbers
- Letters
- Colors

For more detailed information, refer to Chapter Identification and color (Page 234).

Circuit characteristics

Circuits are intended to display functions and facilitate understanding. They are also particularly helpful for troubleshooting as well as service and maintenance work.
For this reason, they should be created with the relevant users in mind and in a useful format.

A cross-referencing scheme shall be used in conjunction with relays, output devices, limit switches, and pressure switches. This allows any contact associated with the device to be found easily on the circuit diagram.

Note

Classification and function identification

As referred to in the section on "Symbols", the symbols in the circuit diagram are based on IEEE 315. However, the classifications and function identification methods from IEEE 315 are not intended to be used for marking the devices or components.
Examples of equipment designations according to NFPA 79 are shown in the figure "Examples of equipment designations".
NFPA 79, Annex E, offers an overview of device and component designations. Below is an extract. You can find the complete overview in the Annex under Graphical symbols and abbreviations in accordance with IEC and UL / NFPA (Page 340).

Table 14- 2 Examples of equipment designations

Designation	Device
ABE	Alarm or Annunciator Bell
ABU	Alarm or Annunciator Buzzer
AH	Alarm or Annunciator Horn
AM	Ammeter
AT	Autotransformer
CAP	Capacitor
CB	Circuit Breaker
CI	Circuit Interrupter
CNC	Computerized Numerical Controller
CON	Contactor
COs	Cable-Operated (Emergency) Switch
CPU	Central Processing Unit

Source: NFPA 79, Table E.1 "Device and Component Designations"

Control circuits

Control circuits shall be displayed between two vertical lines. These represent the AC or DC supply for the control circuit.

The left line (from the perspective of the reader) represents the DC positive supply (phase L+), while the right line represents the DC negative (N, ground).

The control circuit devices shall be shown on horizontal lines (rungs) between the two vertical lines.

Parallel control circuits shall be shown on separate horizontal lines, either above or below the control circuits that supply them.

The following figure, "Example of control circuit diagram", shows example of a control circuit to facilitate understanding.

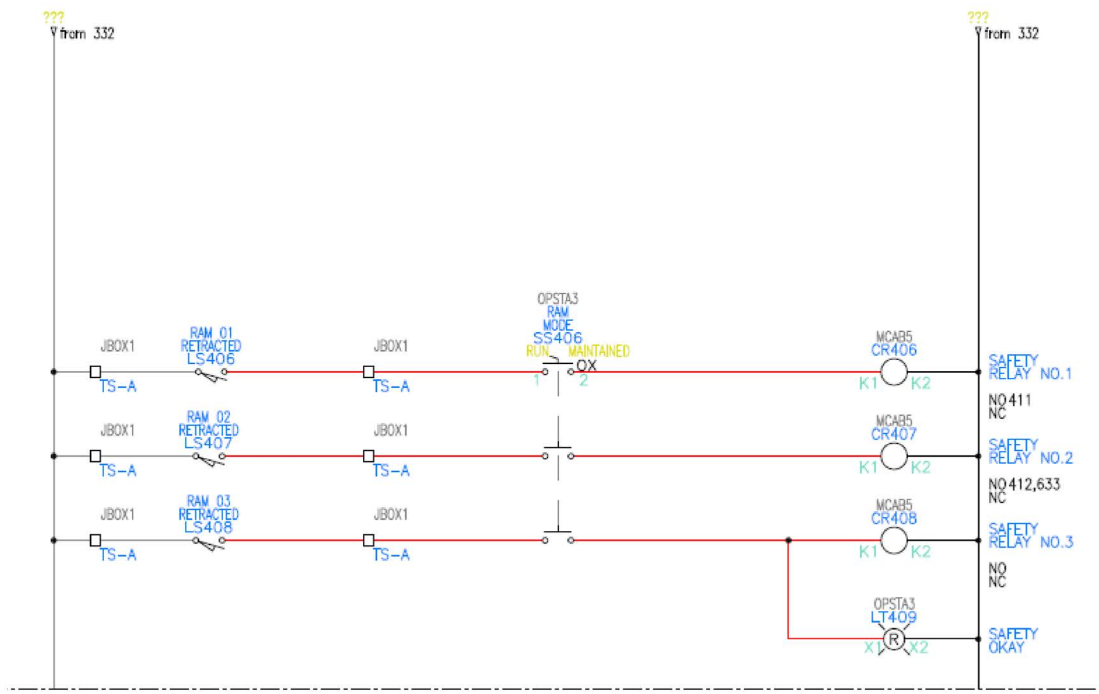


Figure 14-3 Example of control circuit diagram

Exception

Alternative conventions for circuit diagrams may be used, provided this has been agreed between the manufacturer and the user.

Diagrams according to IEC standards

Diagrams that comply with IEC standards are a very common alternative. Example: IEC 60617 "Graphical Symbols for Diagrams", for the symbols in electrical circuit diagrams.
See also the examples in the figure "Power circuit according to IEC representation", and the figure "Control circuit according to IEC representation".

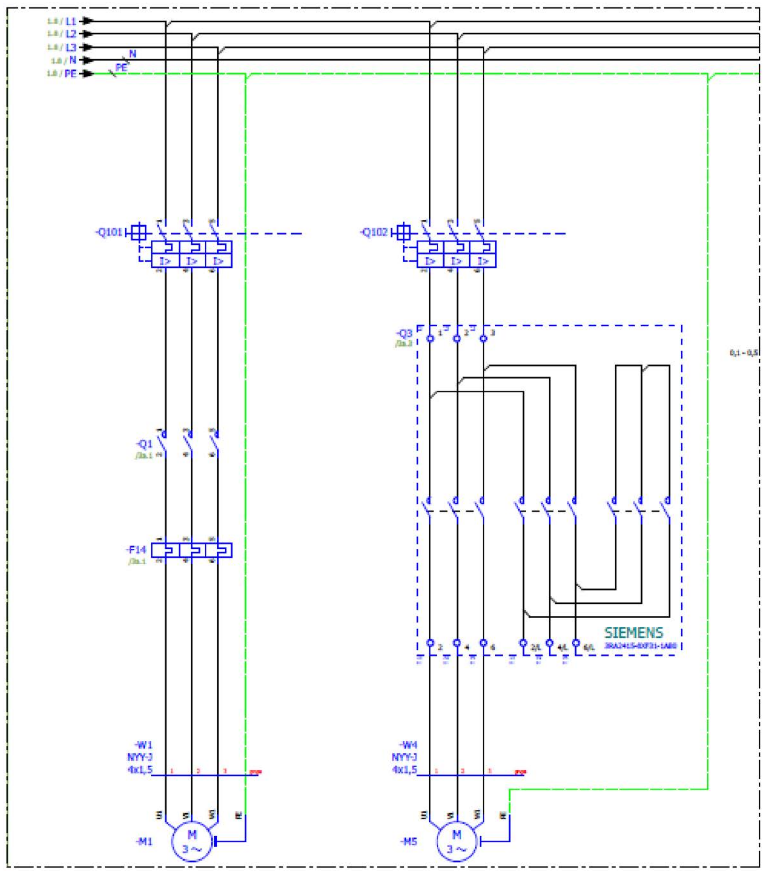


Figure 14-4 Power circuit according to IEC representation

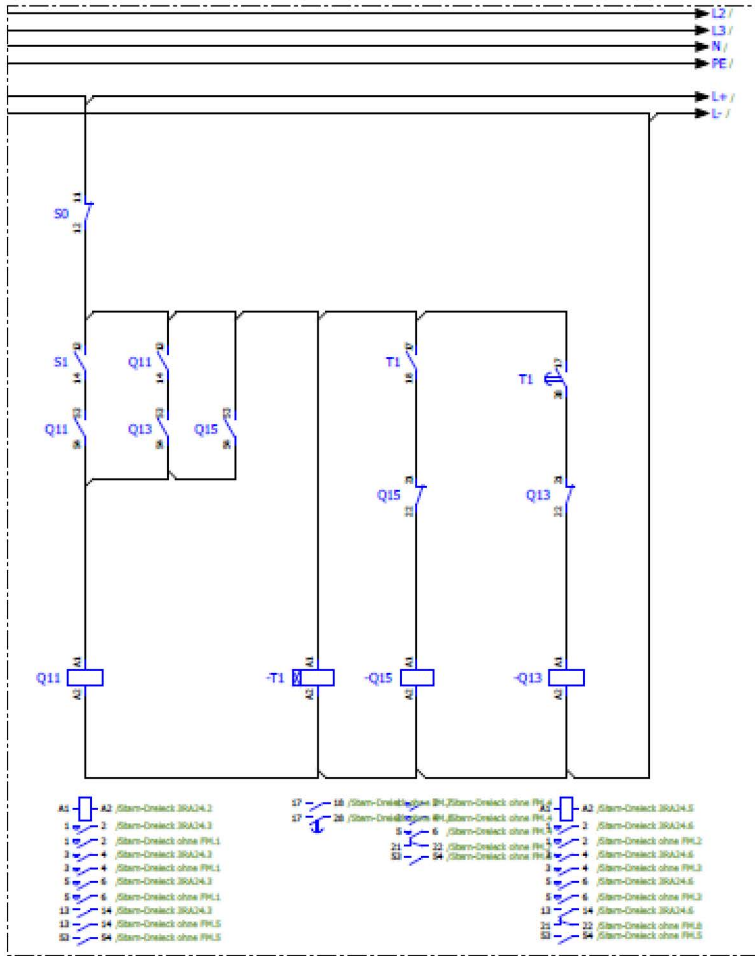


Figure 14-5 Control circuit according to IEC representation

For large systems and machines, a diagram shall be provided for all the connections between the individual system parts and the enclosures. This shall include all external connections for the electrical components.

Interlocking wiring diagrams shall show the devices, relevant functions, and conductors used in each circuit.

If plug/receptacle connections are used, the circuit diagram shall show the pin identification.

14.3.3 Operating manual

The operating manual is intended to provide a description of the machine, its processes, and its associated parts, on the basis of which the electrical equipment has been designed and developed. This also includes the set-up, installation, and operation of the machine.

Where the operation of the equipment is programmable, detailed information on programming methods and program verification shall be provided. Safety procedures shall be provided, where necessary.

Recommendation

Particular attention should be paid to safety measures. This also includes **foreseeable unintended** use and operation.

14.3.4 Maintenance manual

Maintenance manuals are intended to enable systems and machines to achieve a high level of availability. Many components are subject to natural wear during operation. This means that the affected devices and components need to be regularly serviced or replaced (e.g. at specific intervals or after a defined number of operating cycles).

Information on the following shall be included:

- Repairs
- Settings
- Routine inspections
- Service intervals

If verification of proper operation is provided (e.g. test software), a description of the method for obtaining this verification shall be included in the maintenance manual.

Recommendation

The maintenance manual shall include recommendations on how to record maintenance and servicing work. It shall also include information on aspects such as:

- Troubleshooting
- Fault localization
- Replacing defective components
- Preventive maintenance schedules

Performing work while the equipment is energized

It may be necessary to carry out maintenance, adjustment, and servicing work on machines and systems while the electrical equipment is energized.

If this is the case, the maintenance manual shall include information on how to perform these tasks safely and properly.

The standard NFPA 79 contains a reference to the following standards and regulations of the relevant authority (OSHA CFR):

- **NFPA 70E - Standard for Electrical Safety Requirements for Employee Workplaces**

  See also the information in Chapter Standards (Page 35), Section "NFPA 79 (Standard for Industrial Machinery, Edition 2012)"

- **Occupational Safety and Health Administration (OSHA) 29 CFR Part 1910.331 – 335**
  - 1910.331 - Scope
  - 1910.332 - Training
  - 1910.333 - Selection and use of work practices
  - 1910.334 - Use of equipment
  - 1910.335 - Safeguards for personnel protection

  Web address: OSHA Law & Regulations (http://www.osha.gov/law-regs.html) → Subpart S – Electrical

  See also Chapter Laws, general requirements, and rules (Page 32).

14.3.5 Parts list

Parts lists that include the electrical components are part of the technical documentation.

The parts list should, as a minimum, contain information on the following topics:

- Ordering spare and replacement parts (e.g. components, devices, software, testing equipment, technical documentation, etc.), which are required for preventive maintenance or servicing work.
- Recommendations of materials which, from experience, are difficult to obtain and should therefore be kept in stock.

The following information shall be included with every item on the parts list:

- Reference designation used in the documentation
- Equipment identifiers
- Manufacturer and/or supplier, and the associated order number
- A short description of the device characteristics, where appropriate
- Number of components with the same reference designation

Parts list for machine from "Siemens Industry Inc."						
Serial no.	**Qty.**	**Identification**	**Mounting location**	**Manufacturer**	**Order No.**	**Description**
1	2	Q3	Panel 1	SIEMENS	3RV202…	MSP, xx Amp, 65 kA, 480 V
2	2	K2	Panel 2	SIEMENS	3RT201	Cont. xx hp
3	3	Q5	Subpanel	SIEMENS	3RV27	C.B. xx Amp, 50 kA, 480 Y/277 V
4	1	Q1	Machine	SIEMENS	3VL4…	C.B. xx Amp, 65 kA, 480 V
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Testing and verification 15

15.1 General information

The testing and verification requirements described in this chapter refer in full to the requirements of NFPA 79, Chapter 18 "Testing and Verification".

The primary intention is to detect and correct any faults/errors occurring during assembly of the machine and the associated electrical components. Depending on their complexity, machines can contain a host of interfaces at which the most diverse machine components come together, such as the power supply from the building to the actual machine, the associated industrial control panels, up to the individual components (e.g. cables, conductors, switching and protective devices, programmable controllers, motors).

The tests required in NFPA 79 are to be regarded as routine tests. In other words, these tests are to be carried out on every machine, regardless of whether it is a series product or a one-off product. The aim is to detect and correct any quality defects and installation and assembly faults.

15.2 Testing and verification

The following tests and verifications shall be carried out in accordance with NFPA 79:

1. Verification that the electrical equipment is in compliance with the technical documentation (see Chapter Technical documentation (Page 289))
2. Verification of the continuity of the equipment grounding (protective bonding) circuit
3. Insulation resistance test
4. Voltage test
5. Protection against residual voltages test
6. Functional test

Verification that the electrical equipment is in compliance with the technical documentation

The electrical equipment shall comply with the technical documentation. This is essential not only for assembly and commissioning, but also for ongoing operation of the machine, as well as for maintenance and troubleshooting.

Details of this technical documentation requirement are described in Chapter Technical documentation (Page 289).

Verification of the continuity of the equipment grounding (protective bonding) circuit

The continuity of the equipment grounding (protective bonding) circuits shall be verified. The resistance of the equipment grounding (protective bonding) conductor connections shall not exceed a specific maximum value here. The actual aim of this testing and verification is protection against automatic shutdown in the event of a fault.

The following two testing methods are available for verification:

1. **Measuring the resistance in the circuit using an impedance measuring device**

   Measuring the resistance in the respective equipment grounding (protective bonding) circuit taking into account all possible impedances.

   The measured resistance shall be no more than **R ≤ 0.1**.

2. **Calculation of the resistance with current-voltage measurement**

   The voltage drop is measured using a measuring current of at least **I** ≥ 10 amperes, at 50 or 60 Hz.

   This establishes whether a continuous connection exists between the input terminal of the equipment grounding (protective) conductor and all parts of the protective conductor system, or if the measured resistance takes on impermissibly high values. The focus shall be above all on equipment wye-connected with the equipment grounding (protective) conductor system and possibly containing long supply cables.

   An SELV source shall be used for the supply. In comparison with PELV, with which grounding is permitted, these power sources are not grounded on the secondary side, reducing the probability of a measuring error.

   The measured voltage value between the grounding terminal and the respective equipment shall not exceed the values in the following table "Verification of continuity of the equipment grounding (protective bonding) circuit".

Table 15- 1 Verification of continuity of the equipment grounding (protective bonding) circuit

Minimum equipment grounding (protective bonding) conductor cross-sectional area of the branch under test (AWG)	Maximum measured voltage drop [V] *
18	3.3
16	2.6
14	1.9
12	1.7
10	1.4
> 8	1.0

* Values are given for a test current of 10 amperes

Source: NFPA 79, Table 18.2

Insulation resistance test

According to NFPA 79, the insulation resistance test is not one of the mandatory tests for electrical equipment. Rather, it is left to the manufacturer's discretion to carry out the test if it is considered necessary.

If the test is carried out, the required high DC test voltage could result in damage to the components that are not designed for this high voltage. For this reason, these components shall be disconnected before and during the test.

The actual aim is to detect any contamination that could result in creepage paths. The test shall be carried out between the power circuits and the equipment grounding (protective bonding) circuit. Control circuits that are not supplied directly via the system supply but via power supplies or control transformers need not be subjected to this test.

The test is not mandatory for the entire machine, but may be carried out separately on individual sections of the machine.

Overview of the required test parameters:

Test voltage: U = 500 V DC

Minimum insulation resistance: R ≥ 1 MΩ

Measuring points: L1, L2, L3 – PE

Voltage test

According to NFPA 79, the voltage test, like insulation resistance measurement, is not one of the mandatory tests for electrical equipment. Rather, it too is left to the manufacturer's discretion to carry out the test if it is considered necessary.

The aim of the test is to detect any insufficient through air paths and insulation damage occurring during assembly and installation.

Either an AC or DC voltage is used for the test. This voltage shall be increased gradually and applied for at least 1 second when the maximum value is reached. The test is carried out between all conductors of the power circuit and the equipment grounding (protective bonding) circuit.

The test is passed if no flashovers occur during the test.

The supply source for generating the test voltage shall have a rating of at least S ≥ 500 VA.

For this test too, components that are not rated to withstand the high test voltage shall be disconnected in advance.

Overview of the required test parameters:

AC: 0 to 1500 V

DC: 2121 V

Holding time of U_{max} ≥ 1 s

Measuring points: L1, L2, L3 – PE

Measuring process: incremental increase of the voltage

Power supply: S ≥ 500 VA

⚠ CAUTION

Danger of injury due to high voltage

Due to the high test voltage, this test shall be carried out with the relevant precautionary measures by qualified persons only.

Note

NFPA 79 lists the circuits to be tested, referring to "Primary Circuits" with the supply voltage of the machine. "Primary Circuits" can also be circuits connected to the primary side of transformers. "Primary Circuits" ≠ "Power circuits". Since primary circuits carry different voltages, these can differ from the supply voltage.

Protection against residual voltages

Residual voltages can occur after disconnection of electrically operated components, if the relevant capacitors are available.

This inevitably results in the stipulation that the test only has to be carried out if capacitors are installed in the electrical equipment. This involves in particular electronic motor control devices (e.g. variable-speed drives).

The test ensures that the maximum permissible values for protection against direct contact are not exceeded. See Chapter Protection against residual voltages (Page 93).

Functional test

Fundamentally, NFPA 79 requires the electrical equipment to be subjected to a functional test to verify proper functioning.

As well as the operational functionality of the machine, value shall be placed above all on the safety functions.

It is recommended to begin with those protective measure tests that are also relevant to the protection of testing personnel. These are, for example:

- Protective measures against electric shock in the event of a fault; see the section "Verification of the continuity of the equipment grounding (protective bonding) circuit".
- Testing of supplementary protective measures, e.g. residual current protective devices, ground fault protective devices and insulation monitoring devices

Safety-related equipment shall then be tested, e.g.:

- Limit switches
- Equipment for operations in the event of an emergency (EMERGENCY OFF, EMERGENCY STOP)
- Safety interlocks and safety switches

Following these safety-related tests, testing of the operational functionality and the intended use of the machine is recommended.

Retesting

The retests required in NFPA 79 do not refer to regular tests within the scope of the intended use of the machine. Rather, they refer to retesting in the event of changes or modifications to the machine or parts of the machine.

Modifications that can be carried out within the scope of intended use of the machine by the operator and the maintenance personnel shall be recorded accordingly in the documentation. See Chapter Technical documentation (Page 289).

Furthermore, it should be mentioned here that in the case of *essential modifications* to the machine, that is, modifications that also affect the functionality of the machine, new risks can arise that were perhaps not taken into account in the original design and dimensioning of the machine. In this case, a new risk assessment needs to be carried out. This can also mean that parts of the machine, or in some circumstances even the entire machine, need to be adapted to new or modified standards. Since this can often stimulate far-reaching discussions, you are recommended in cases of doubt to consult the local inspector, or also the professional association OSHA in the USA.

Examples of essential functional modifications:

- Additional degrees of freedom
- Additional drive axes
- Increasing of power rating and/or speed, for example
- Each additional function that was not available before the change
- Addition of, or changes to, potential hazards, e.g. by changing the protective equipment

Technical inquiries and hotline

A

International

Questions on automation and drives

SIEMENS AG, Nuremberg-Moorenbrunn

Technical Support for Industry

- Gleiwitzer Str. 555
  90475 Nuremberg
  Germany
- Tel.: +49 (911) 895-7222
- Fax: +49 (911) 895-7223

Internet: Industry Online Support (http://support.automation.siemens.com)

Experts in the area of low-voltage industrial controls

Technical Assistance

- Tel.: +49 (911) 895-5900
  Monday to Friday, 8 am – 5 pm CET
- Fax: +49 (911) 895-5907
- Email: Technical Assistance (mailto:technical-assistance@siemens.com)

USA

Questions on automation and drives

Siemens Johnson City – SIAC Service and Support

SII Call Center

- One Internet Plaza
  Johnson City, TN 37604
  USA
- Tel.: +1-423-262-5710 / 1-800-333-7421
- Fax: +1-678-297-8316
- Email: SII Call Center (mailto:helpline.sii@siemens.com)

Experts in the area of low-voltage industrial controls

- Technical support: +1-800-333-7421
- All others inquiries: +1-800-241-4453

Appendix B

B.1 Conversion tables and factors

Temperature (Celsius / Fahrenheit)

Table B- 1 Conversion of Fahrenheit to Celsius, and Celsius to Fahrenheit

Fahrenheit → Celsius	F - 32 * 5/9 = C
Celsius → Fahrenheit	(C * 9/5) + 32 = F

Table B- 2 Celsius v. Fahrenheit

Celsius	Fahrenheit		Celsius	Fahrenheit		Celsius	Fahrenheit		Celsius	Fahrenheit
-18	0		1	34		20	68		39	102
-17	1		2	36		21	70		40	104
-16	3		3	37		22	72		41	106
-15	5		4	39		23	73		42	108
-14	7		5	41		24	75		43	109
-13	9		6	43		25	77		44	111
-12	10		7	45		26	79		45	113
-11	12		8	46		27	81		46	115
-10	14		9	48		28	82		47	117
-9	16		10	50		29	84		48	118
-8	18		11	52		30	86		49	120
-7	19		12	54		31	88		50	122
-6	21		13	55		32	90		51	124
-5	23		14	57		33	91		52	126
-4	25		15	59		34	93		53	127
-3	27		16	61		35	95		54	129
-2	28		17	63		36	97		55	131
-1	30		18	64		37	99		56	133
0	32		19	66		38	100		57	135

Power classes (kW / HP / PS)

The following factors are designed to help in converting the HP (horsepower) specifications usual in the USA to kW (kilowatts) and PS (German horsepower) and vice versa.

Table B- 3 Converting different power specifications

Unit	PS	kW	HP
1 PS (horsepower)	1	0.735499	0.98632
1 kW (kilowatt)	1.35962	1	1.34102
1 HP (horsepower)	1.01387	0.7457	1

Cross-sections (in metric units and North-American units)

AWG	Cross section		Metric equivalent (mm²)
	kcmil	mm²	
0000 (4/0)	212	107.2	120
000 (3/0)	168	85.01	95
00 (2/0)	133	67.43	70
0 (1/0)	106	53.49	
1	83.7	**42.40**	50
2	66.4	**33.62**	35
3	52.6	**26.67**	
4	41.7	**21.15**	25
5	33.1	16.75	
6	26.2	**13.30**	16
7	20.8	10.55	
8	16.5	**8.37**	10
9		6.63	
10	10.4	**5.26**	6
11		4.17	
12	6.53	**3.31**	4
13		2.62	
14	4.11	**2.08**	2.5
15		1.65	
16	2.58	**1.31**	1.5
17		1.038	
18	1.62	**0.823**	1
19		0.653	0.75
20	1.02	**0.518**	0.75
21		0.410	0.5
22	0.64	0.326	0.34
23		0.258	
24	0.404	0.205	0.25
25		0.162	
26		0.129	0.14
27		0.102	
28		0.0810	0.09
29		0.0642	
30		0.0510	
31		0.0404	
32		0.0320	

B.2 Software tool examples

Below are examples of main and control circuits with commonly used software tools from AutoDesk, EPlan, and 3D control panel design with Siemens NX 8.

Examples from AutoCAD

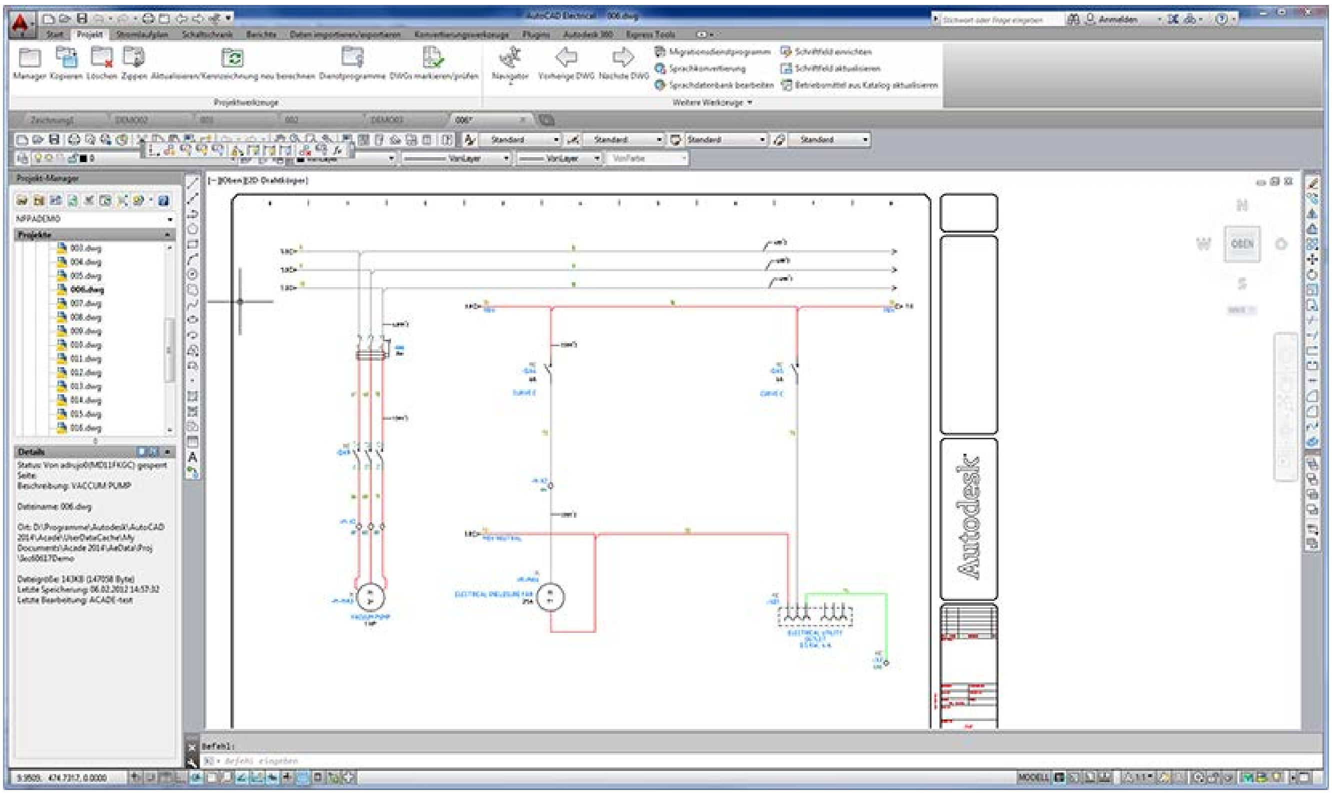


Figure B-1 AutoCAD example 1

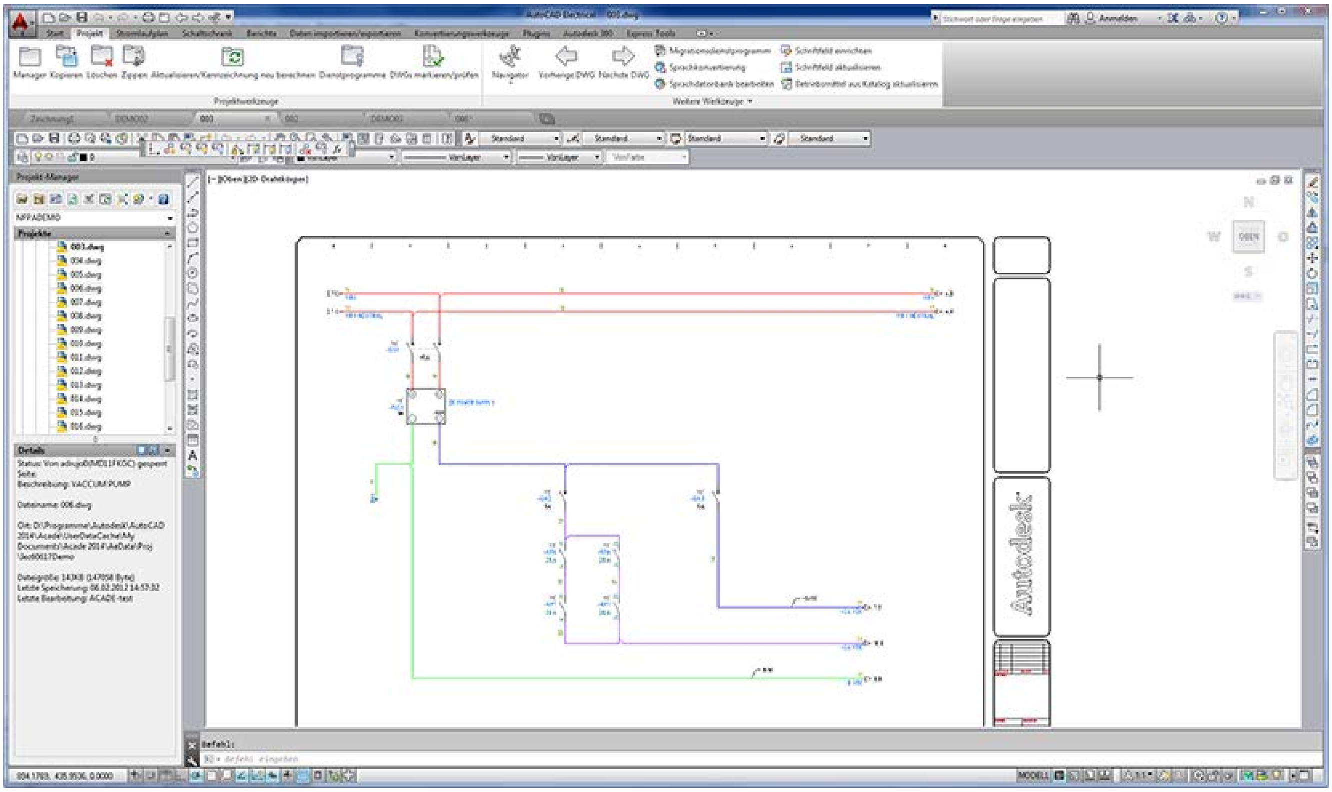


Figure B-2 AutoCAD example 2

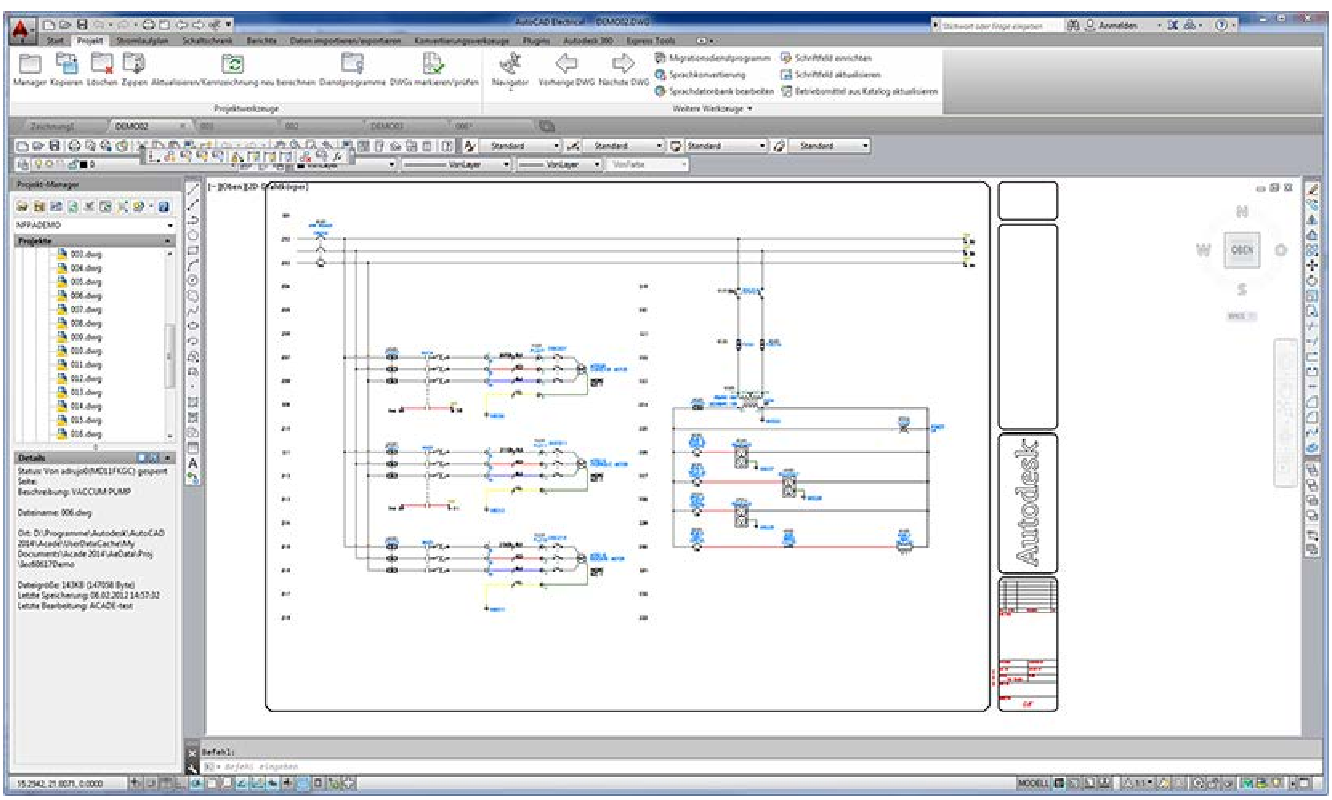


Figure B-3 AutoCAD example 3

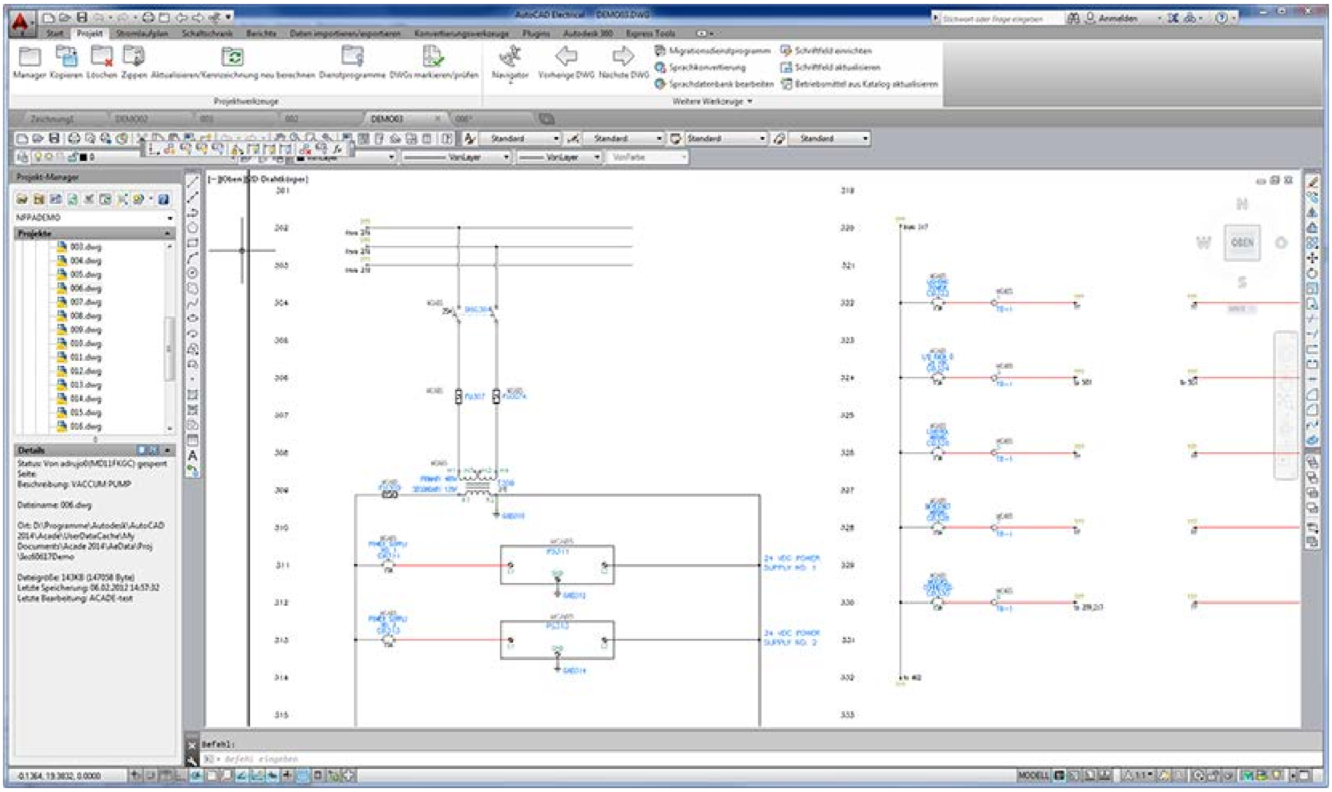


Figure B-4 AutoCAD example 4

Examples from EPLAN

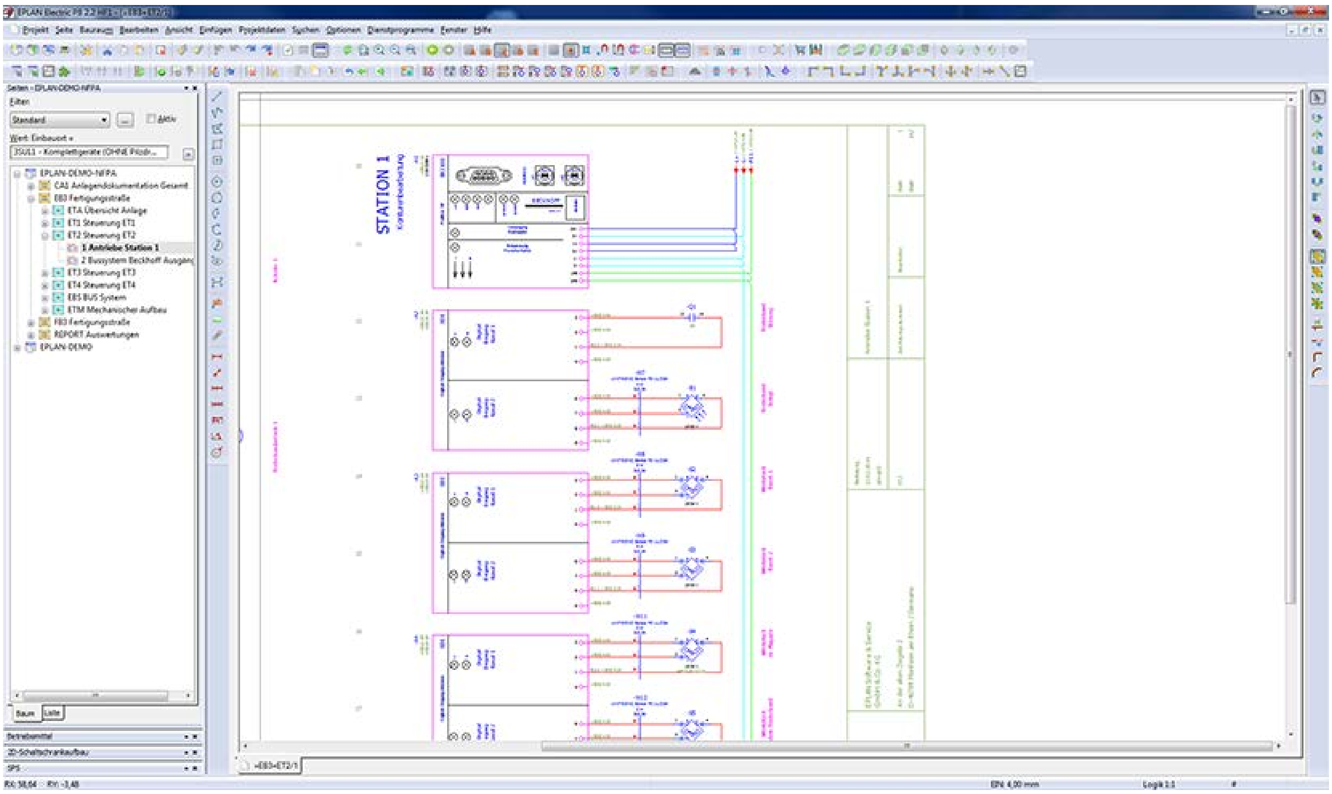


Figure B-5 EPLAN example 1

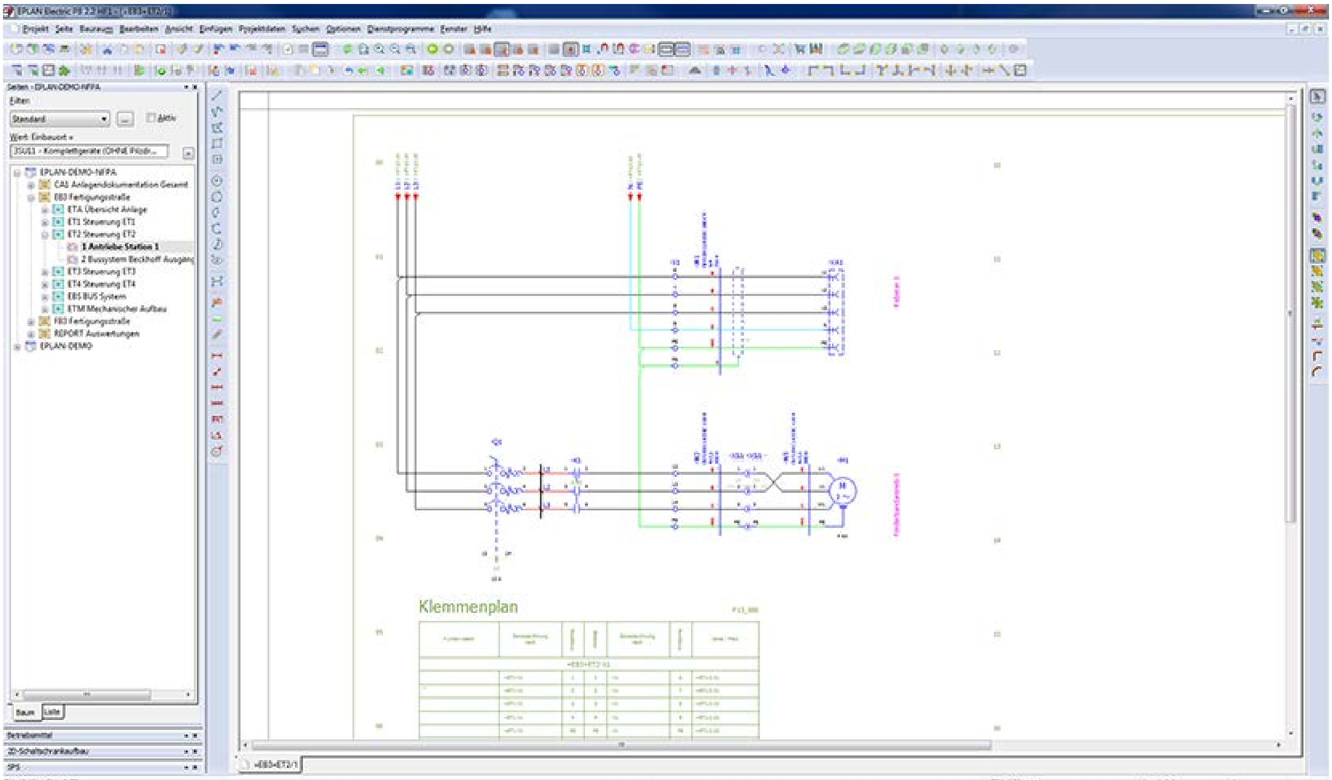


Figure B-6 EPLAN example 2

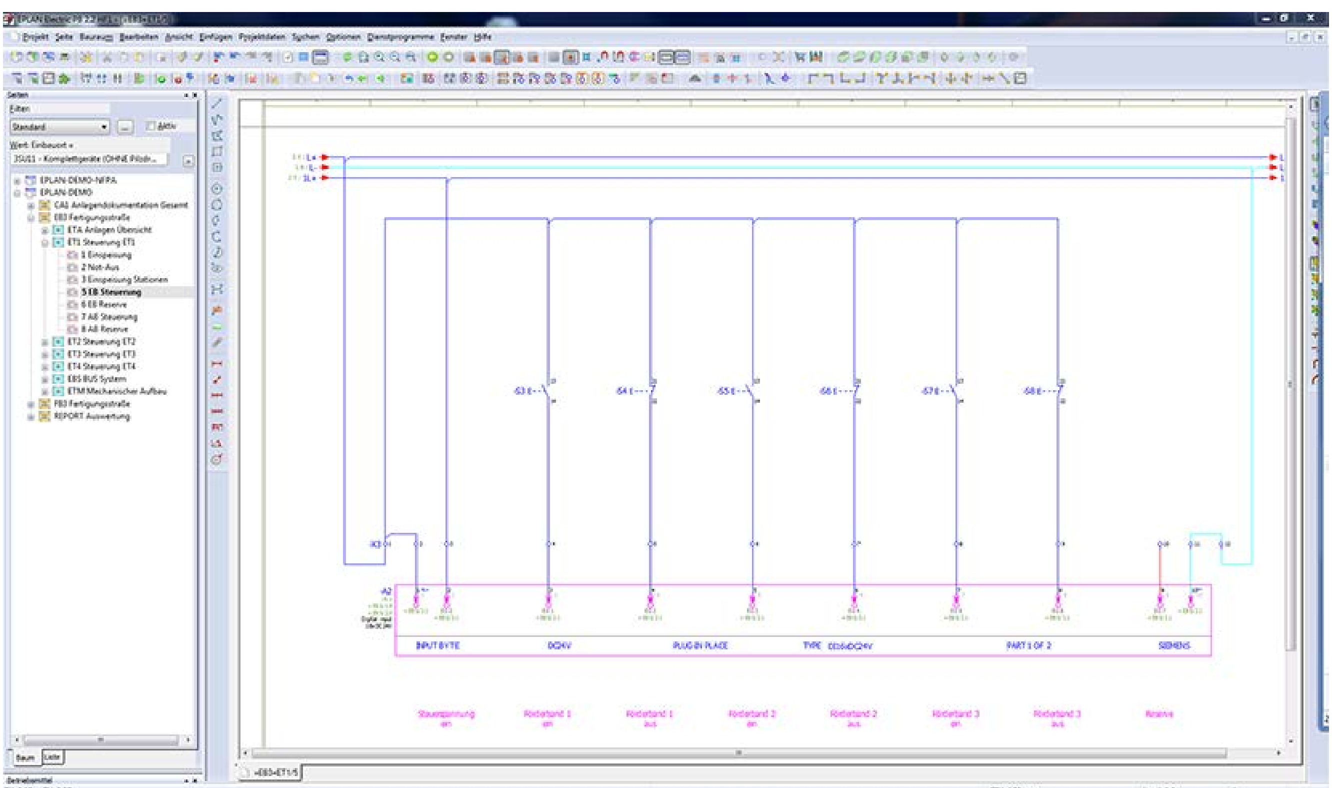


Figure B-7 EPLAN example 3

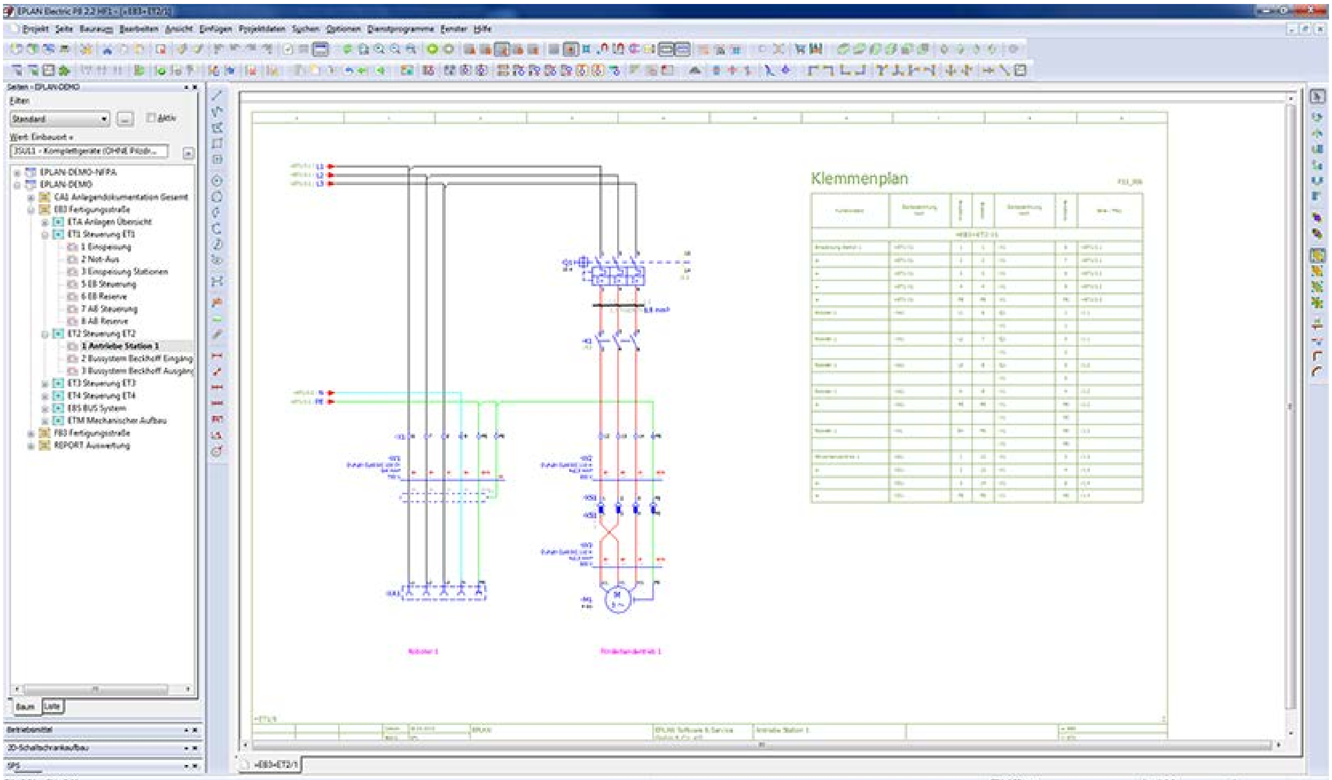


Figure B-8 EPLAN example 4

Examples from NX 8

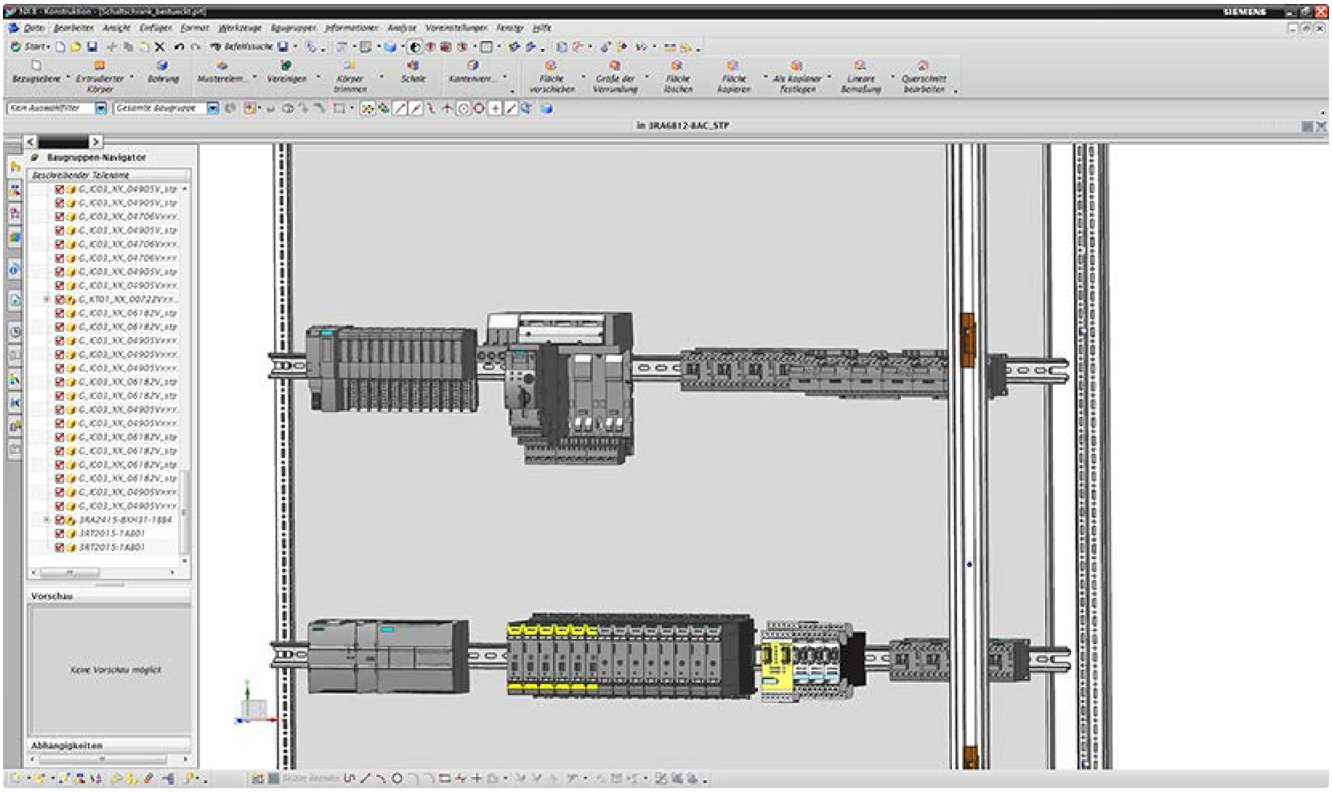


Figure B-9 NX 8 example 1

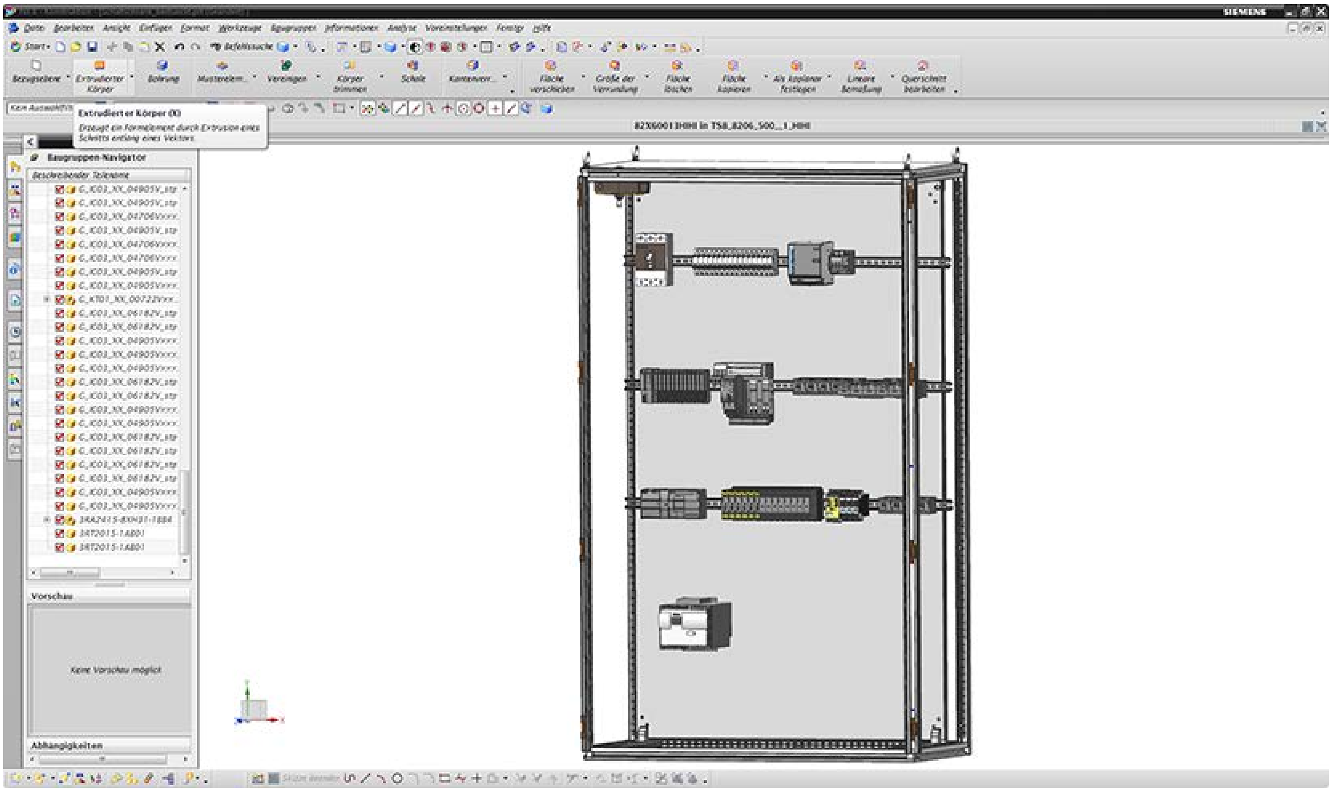


Figure B-10 NX 8 example 2

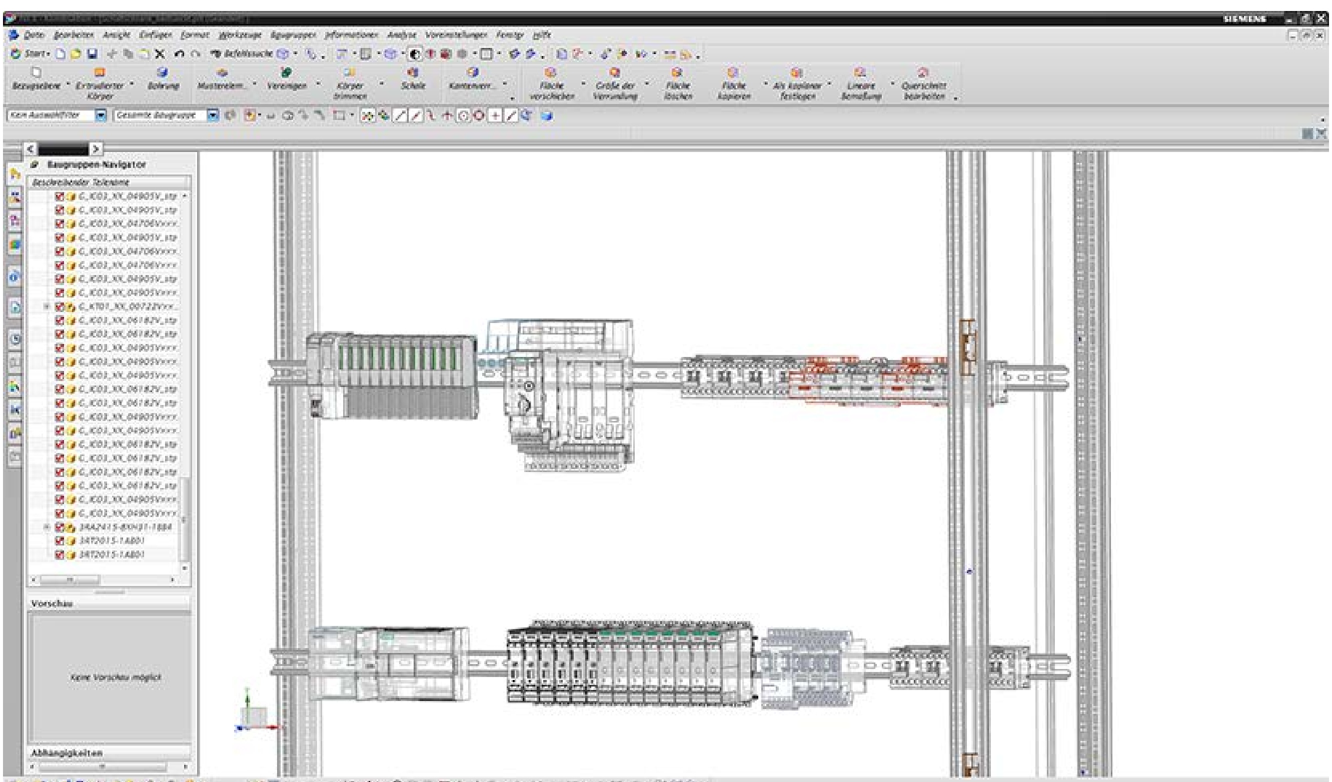


Figure B-11 NX 8 example 3

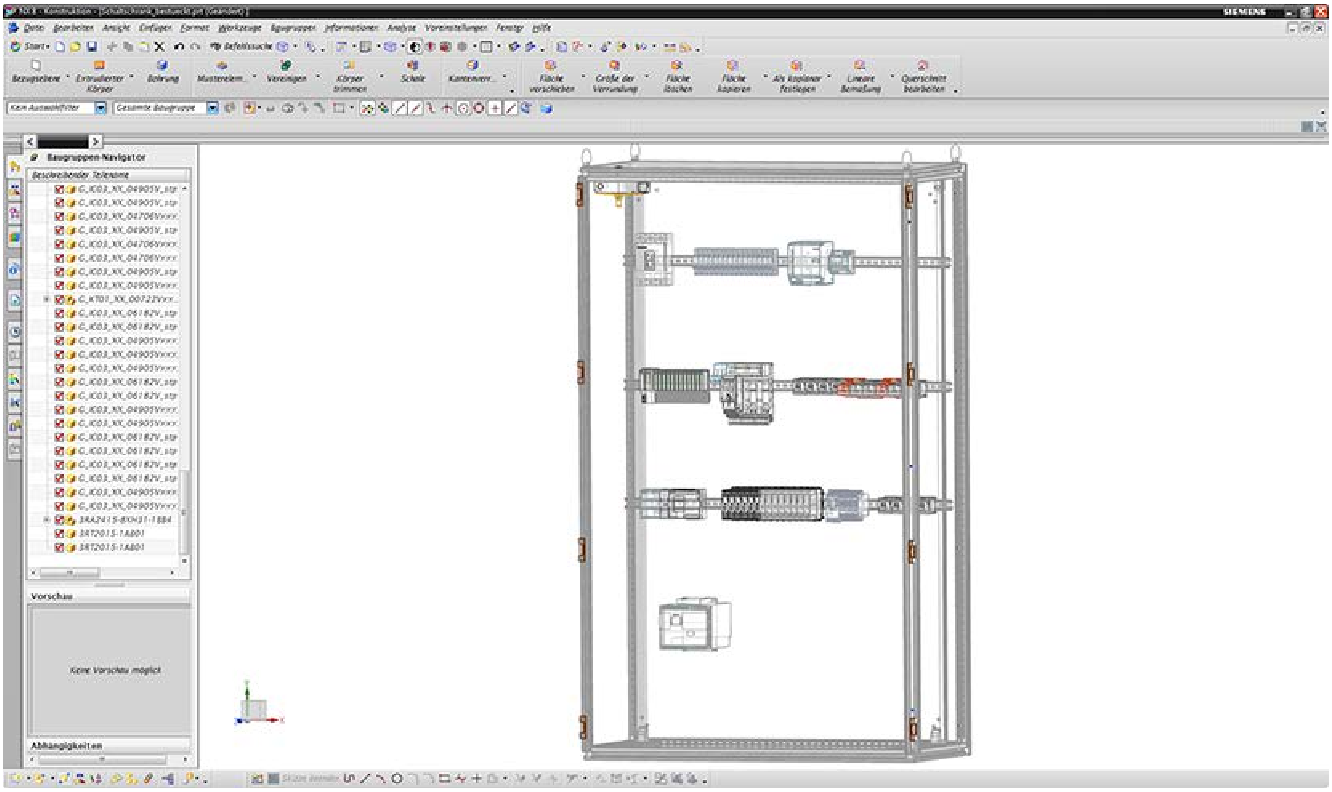


Figure B-12 NX 8 example 4

B.3 Wiring diagram example of electrical door interlocking

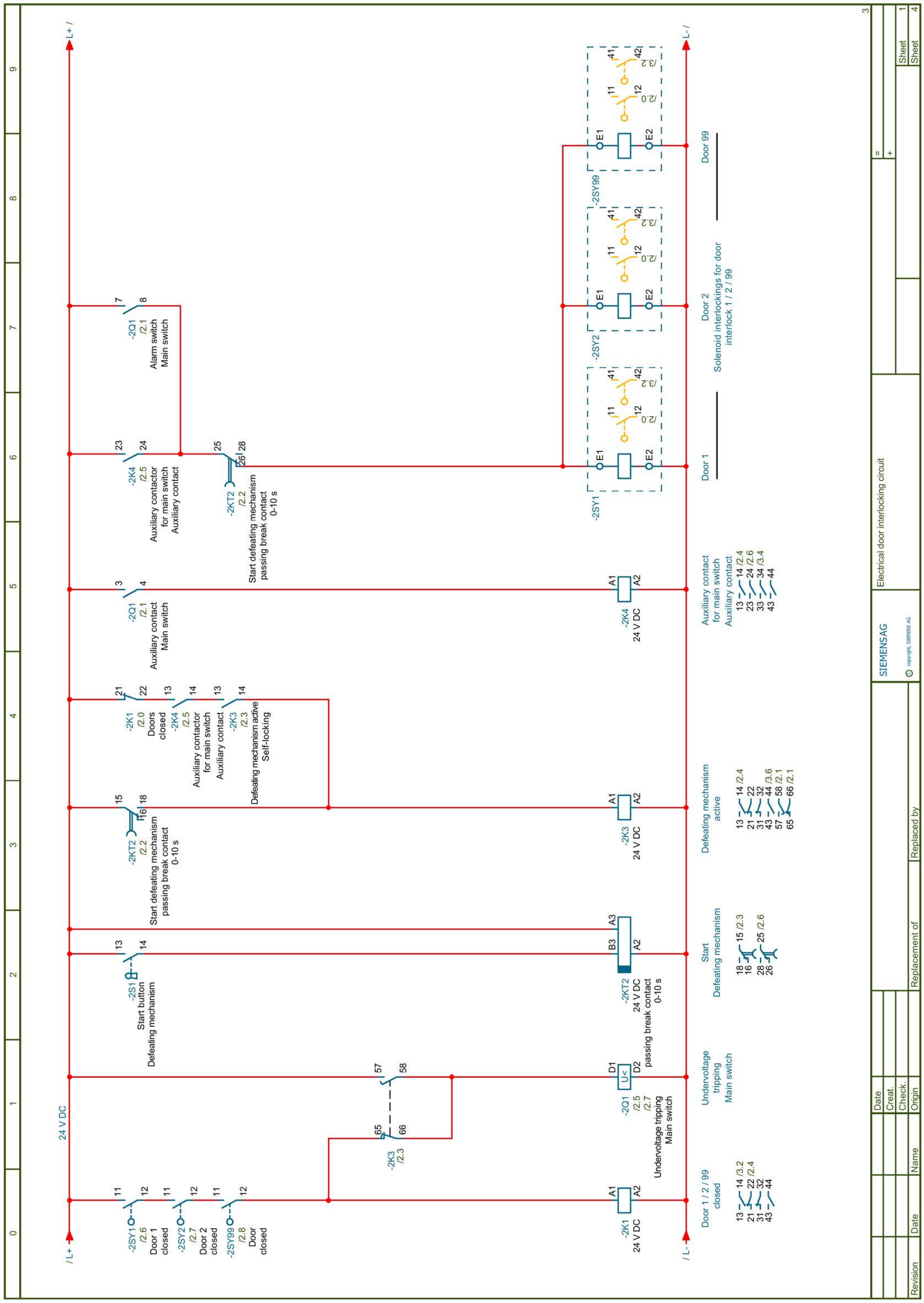


Figure B-13 Wiring diagram example of electrical door interlocking (page 1 of 3)

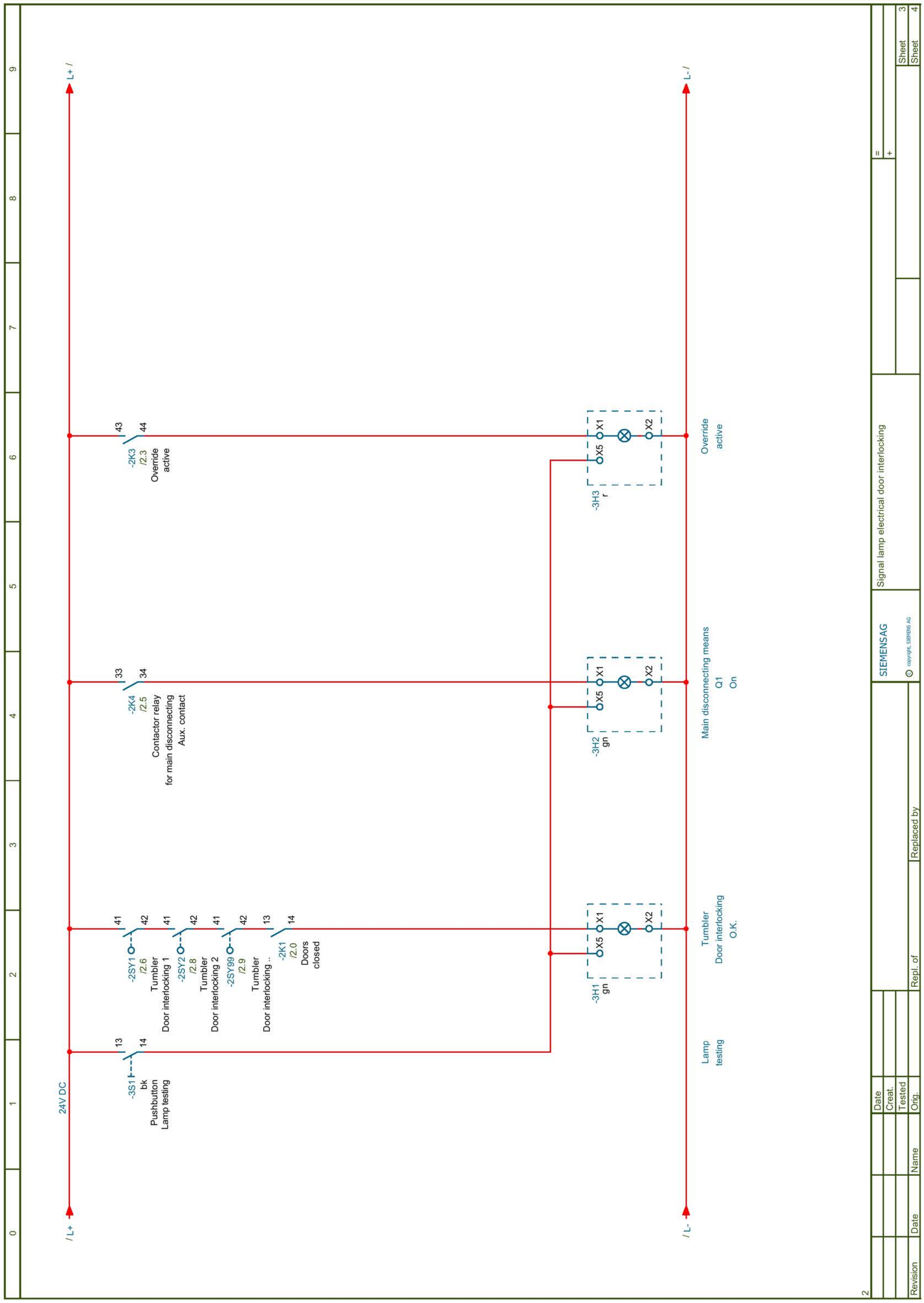


Figure B-14 Wiring diagram example of electrical door interlocking (page 2 of 3)

Parts list

Equipment designation	Quantity	Description	Technical specification	Type number	Manufacturer	
-3H1	1	Lampholder; BA9s	Without lamp, lamp test function			
-3H1	1	Light element	LED; 24V AC/DC; BA9s; green			
-3H1	1	Label holder	Black			
-3H2	1	Lampholder; BA9s	Without lamp, lamp test function			
-3H2	1	Light element	LED; 24V AC/DC; BA9s; green			
-3H2	1	Label holder	Black			
-3H3	1	Lampholder; BA9s	Without lamp, lamp test function			
-3H3	1	Light element	LED; 24V AC/DC; BA9s; green			
-3H3	1	Label holder	Black			
-2K1	1	Contactor relay	2NO+2NC; 24VDC			
-2K3	1	Contactor relay	2NO+2NC; 24VDC			
-2K3	1	Auxiliary switch block	1NO; 1NC; 1CO			
-2K4	1	Contactor relay	4NO; 24VDC			
-2KT2	1	Timing relay	Multifunction; 2W, 24VDC			
-2S1	1	Key-operated switch 2-position	0-1; momentary contact			
-2S1	1	Contact block	1NO;front			
-2S1	1	Label holder	Black			
-3S1	1	Pushbutton	Black			
-3S1	1	Contact block	1NO;front			
-3S1	1	Label holder	Black			
-2SY1	1	Position switch	24VDC; with tumbler			
-2SY2	1	Position switch	24VDC; with tumbler			
-2SY99	1	Position switch	24VDC; with tumbler			

Revision	Date	Name	Date / Creat. / Tested / Orig.	Repl. of	Replaced by	SIEMENSAG © copyright, SIEMENS AG
Indicator light electrical door interlocking	=	+	Sheet 3	Sheet 4		

Figure B-15 Wiring diagram example of electrical door interlocking (page 3 of 3)

B.4 Checklists

B.4.1 Checklist for industrial control panels and the electrical equipment of machinery for North America (UL 508A and NFPA 79)

INQUIRY FORM FOR THE ELECTRICAL EQUIPMENT OF MACHINES

Name of manufacturer/supplier			
Name of end user			
Tender/Order No.		**Date**	
Type of Machine/Serial Number			

1.	Are there to be modifications as allowed for within this standard?		☐ Yes ☐ No
Operating Conditions – Special requirements			
2.	Ambient temperature range		
3.	Humidity range		
4.	Altitude		
5.	Environmental (e.g., corrosive atmospheres, particulate matter, EMC)		
6.	Non-ionizing radiation		
7.	Vibration, shock		
8.	Special installation and operation requirements (e.g. additional flame-retardant requirements for cables and conductors)		
Power supply(ies) and related conditions			
9.	Anticipated voltage fluctuations (if more than ±10 %)		
10.	Anticipated frequency fluctuations		
	Specification of short-term value		
11.	Indicate possible future changes in electrical equipment that will require an increase in the electrical supply requirements		
12.	Indicate for each source of electrical supply required:		
	Nominal voltage (V)	AC	DC
	If AC, number of phases	frequency	Hz
	Prospective short-circuit current at the point of supply to the machine	kA rms (See also Question 15)	
	Fluctuations outside values given		

13.	Type of power supply system grounding:				
	Wye phases midpoint grounded		Delta phases midpoint grounded		
	Delta phases corner grounded		High impedance grounded		
	Wye phases midpoint un-grounded		Delta phases ungrounded		
14.	Is the electrical equipment to be connected to a grounded supply conductor?			☐ Yes	☐ No
15.	Does the user or the supplier provide the overcurrent protection of the supply conductors?			☐ Yes	☐ No
	Type and rating of overcurrent protective devices				
16.	Supply disconnecting device				
	• Is the disconnection of the grounded conductor required?			☐ Yes	☐ No
	• Is a link for the grounded conductor permissible?			☐ Yes	☐ No
17.	Type of disconnecting device and associated external operating means (e.g. handle) to be provided				
18.	Limit of power up to which three-phase AC motors can be started directly across the incoming supply lines?				HP
19.	Can the number of motor overload detection devices be reduced?			☐ Yes	☐ No
20.	Where the machine is equipped with local lighting:				
	• Highest permissible voltage				V
	• If lighting circuit voltage is not obtained directly from the power supply, state preferred voltage				V
Other considerations					
21.	Functional identification				
22.	Inscriptions/special markings				
23.	Mark of certification	☐ Yes ☐ No	If YES, which one?		
	On electrical equipment?		In which language?		
24.	Technical documentation				
	On what media?		In which language?		
25.	Size, location and purpose of ducts, open cable trays, or cable supports to be provided by the user (additional sheets to be provided where necessary)				
26.	Are locks with removable keys to be provided for fastening doors or covers?			☐ Yes	☐ No
27.	Indicate if special limitations on the size or weight affect the transport of a particular machine or control equipment to the installation site:				
	• Maximum dimensions				
	• Maximum weight				

28.	In the case of machines with frequent repetitive cycles of operation dependent on manual control, how frequently will cycles of operation be repeated?		per hour
29.	For what length of time is it expected that the machine will be operated at this rate without subsequent pause?		minutes
30.	In the case of specially built machines, is a certificate of operating tests with the loaded machine to be supplied?		☐ Yes ☐ No
31.	In the case of other machines, is a certificate of operating-type tests on a loaded prototype machine to be supplied?		☐ Yes ☐ No
32.	For cable-less control systems, specify the time delay before automatic machine shutdown is initiated in the absence of a valid signal.		seconds
33.	Do you need a specific method of conductor identification to be used?	☐ Yes ☐ No	
		Type	

B.4.2 Flowcharts for calculating the SCCR value of a component

B.4.2.1 Calculating the SCCR of an individual power circuit component

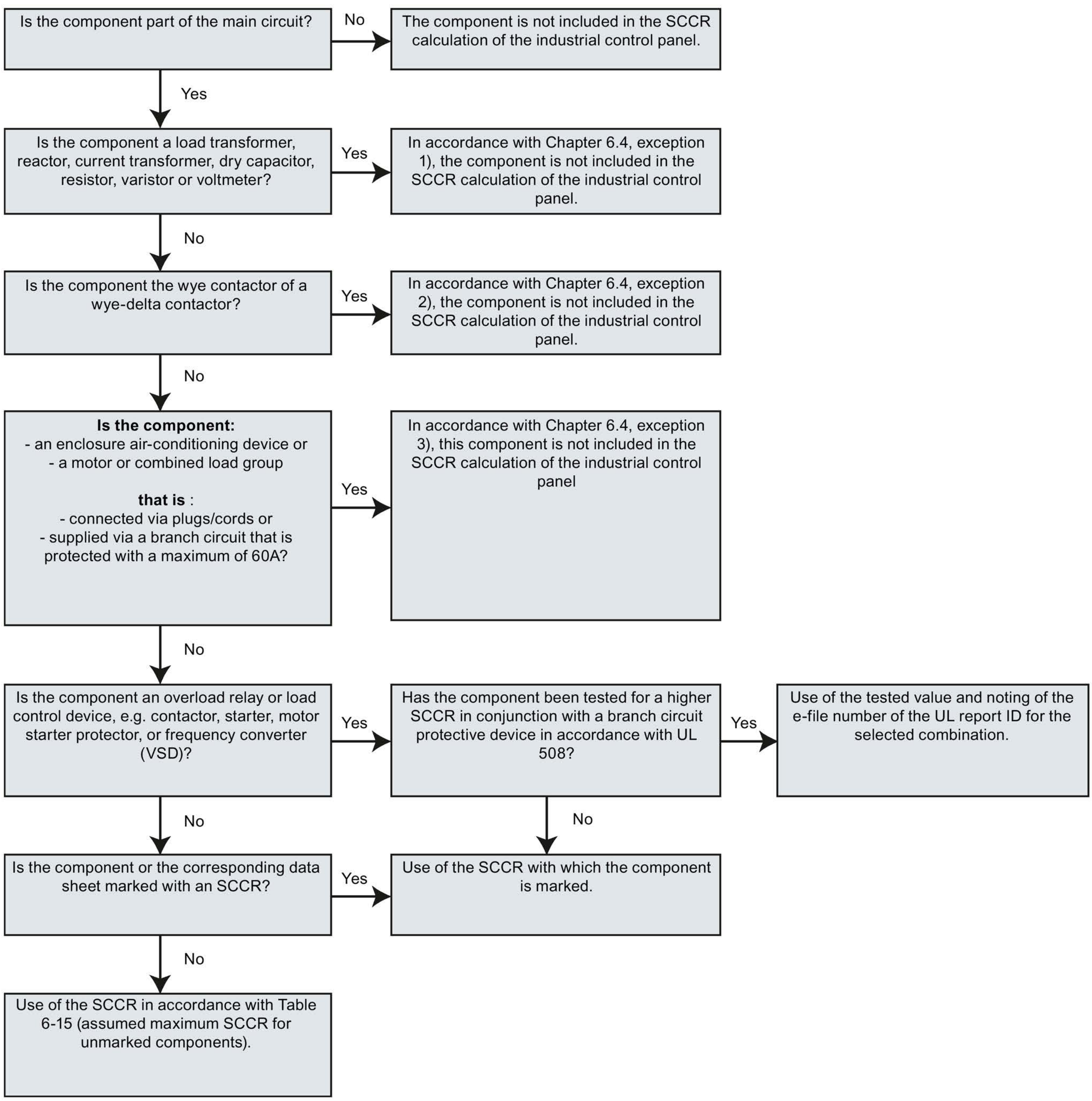


Figure B-16 Calculating the SCCR of an individual power circuit component

B.4.2.2 Calculating an SCCR when using current-limiting components

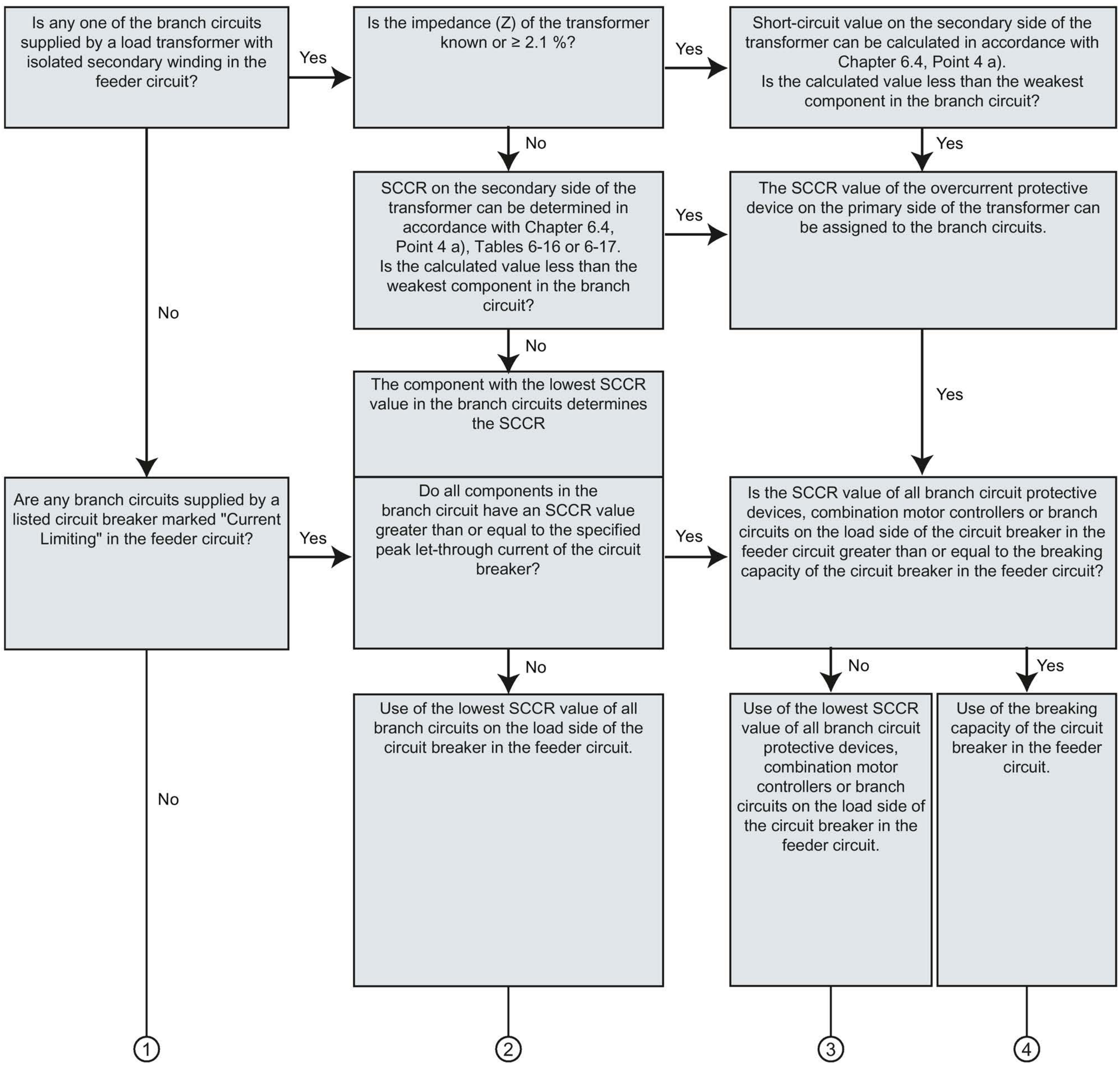


Figure B-17 Calculating an SCCR when using current-limiting components (part 1 of 2)

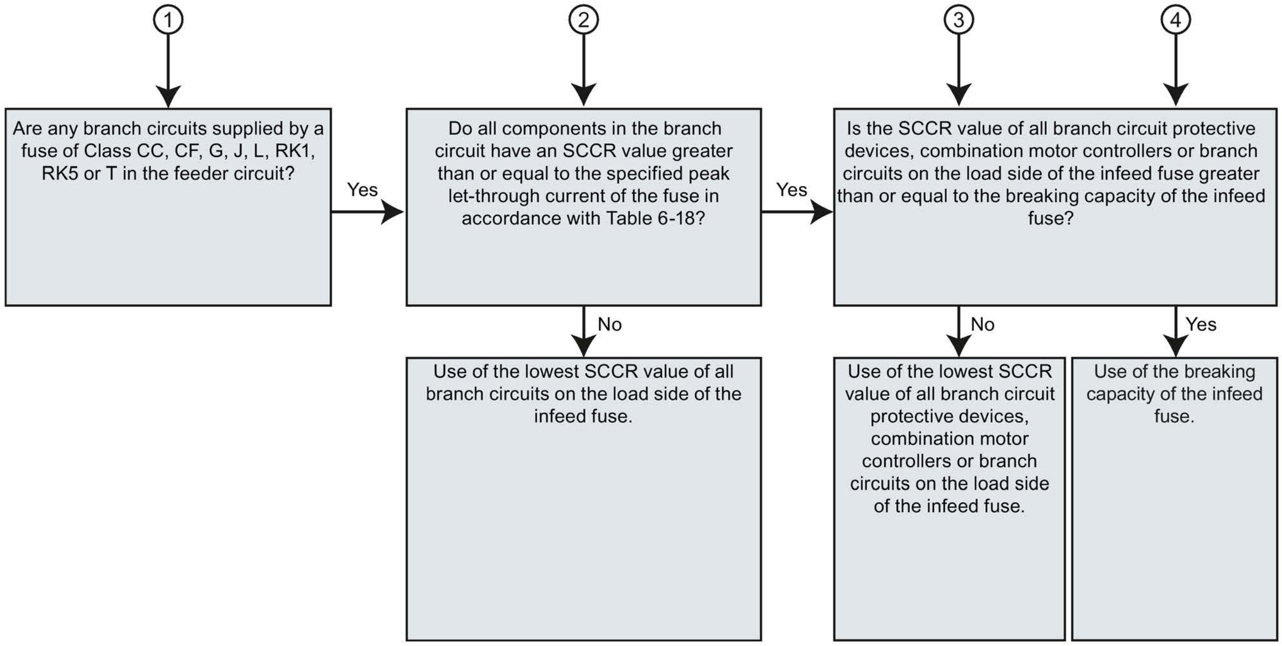


Figure B-18 Calculating an SCCR when using current-limiting components (part 2 of 2)

B.4.2.3 Calculating the SCCR of an industrial control panel

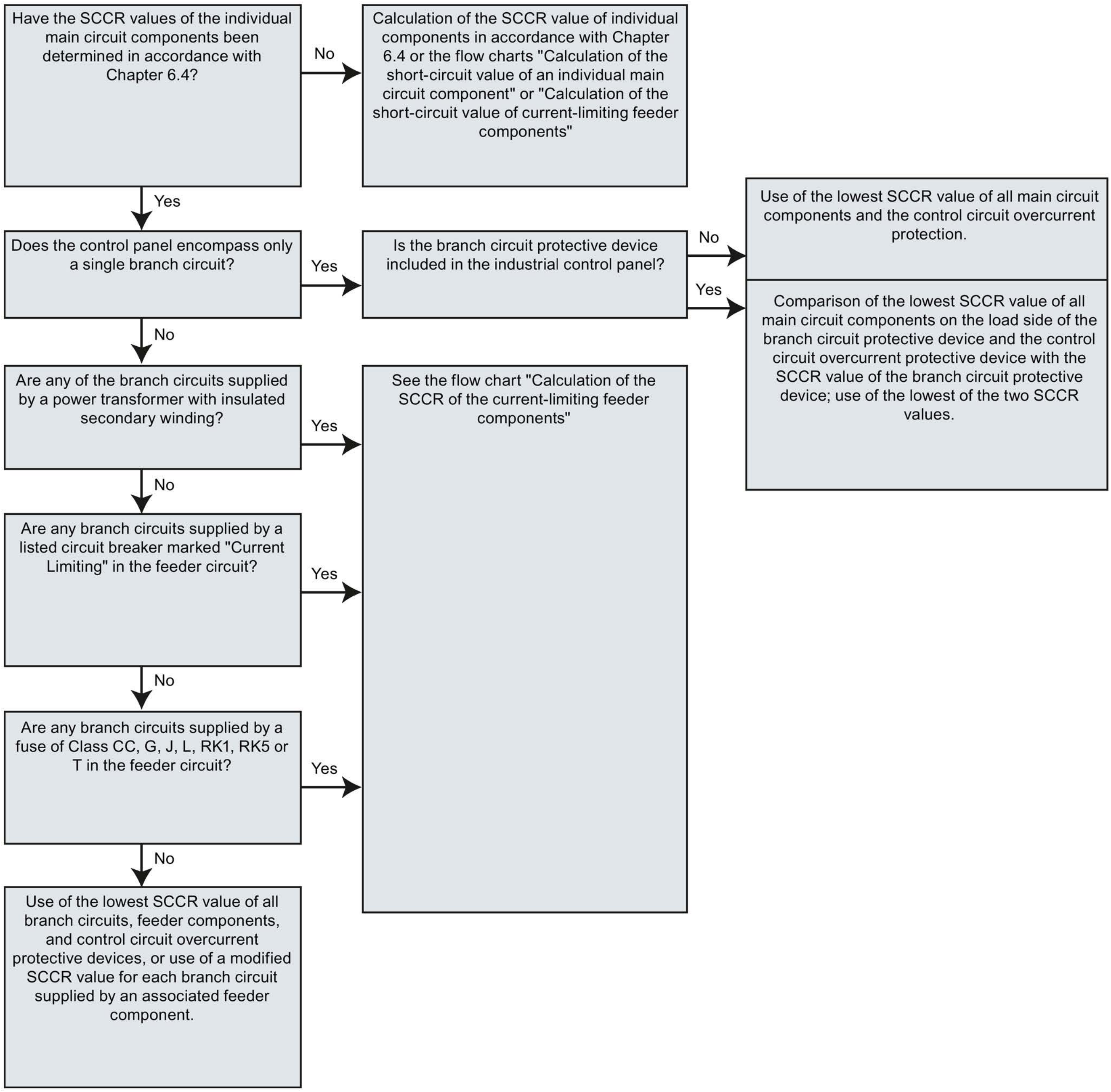


Figure B-19 Calculating the SCCR of an industrial control panel

B.4.3 Flexible cords and cables (NEC, Table 400.4)

Trade name	AWG or kcmil	Number of conductors	Insulation	Use		
Lamp cord	18 … 16 15 … 10	2 or more	Thermoset or thermoplastic	Pendant or portable	Dry locations	Not hard usage
Elevator cable	20 … 2	2 or more	Thermoset	Elevator lighting and control	Unclassified locations	
					Hazardous (classified) locations	
				Hazardous (classified) locations		
Electric vehicle cable	18 … 500	2 or more plus grounding conductors, plus optional hybrid data, signal communications, and optical fiber cable	Thermoset, optionally with nylon	Electric vehicle charging	Wet locations	Extra-hard usage
	18 … 12					Hard usage
	18 … 500		Thermoplastic elastomer with optional nylon			Extra-hard usage
	18 … 12					Hard usage
	18 … 500		Thermoplastic with optional nylon			Extra-hard usage
	18 … 12					Hard usage
Portable power cable	12 … 500	2 … 6 plus grounding conductor(s)	Thermoset	Portable and extra-hard usage		
		3 … 6 plus grounding conductors 1 ground check conductor				
Heater cable	18 … 12	2, 3 or 4	Thermoset	Portable heaters	Dry locations	Not hard usage
Parallel heater cord	18 … 12	2 or 3	Oil-resistant thermoset	Portable	Damp locations	Not hard usage
Thermoset jacketed heater cords	18 … 12	2, 3 or 4	Thermoset	Portable or portable heater	Damp locations	Hard usage
			Oil-resistant thermoset		Damp and wet locations	
					Damp locations	

<table>
<tr><th>Trade name</th><th>AWG or kcmil</th><th>Number of conductors</th><th>Insulation</th><th colspan="3">Use</th></tr>
<tr><td rowspan="6">Non-integral parallel cords</td><td>20 … 18</td><td rowspan="6">2 or 3</td><td rowspan="2">Thermoset</td><td rowspan="6">Pendant or portable</td><td rowspan="6">Damp locations</td><td rowspan="6">Not hard usage</td></tr>
<tr><td>18 … 16</td></tr>
<tr><td>20 … 18</td><td rowspan="2">Thermoplastic elastomer</td></tr>
<tr><td>18 … 16</td></tr>
<tr><td>20 … 18</td><td rowspan="2">Thermoplastic</td></tr>
<tr><td>18 … 16</td></tr>
<tr><td>Twisted portable cord</td><td>18 … 16
14 … 10</td><td>2 or more</td><td>Thermoset or thermoplastic</td><td colspan="3">Portable, extra-hard usage</td></tr>
<tr><td>Portable power cable</td><td>12 … 500</td><td>1 … 6 plus optional grounding conductor(s)</td><td></td><td colspan="3">Portable, extra-hard usage</td></tr>
<tr><td>Hard service cord</td><td>18 … 2</td><td>2 or more</td><td>Thermoset</td><td>Pendant or portable</td><td>Damp locations</td><td>Extra-hard usage</td></tr>
<tr><td rowspan="3">Flexible stage and lighting power cables</td><td rowspan="3">8 … 250</td><td rowspan="3">1 or more</td><td>Thermoset</td><td colspan="3" rowspan="3">Portable, extra-hard usage</td></tr>
<tr><td>Thermoplastic elastomer</td></tr>
<tr><td>Thermoplastic</td></tr>
<tr><td rowspan="4">Hard service cord</td><td rowspan="4">18 … 2</td><td rowspan="4">2 or more</td><td rowspan="2">Thermoplastic elastomer</td><td rowspan="4">Pendant or portable</td><td>Damp locations</td><td rowspan="4">Extra-hard usage</td></tr>
<tr><td>Damp and wet locations</td></tr>
<tr><td rowspan="2">Oil-resistant thermoplastic elastomer</td><td>Damp locations</td></tr>
<tr><td>Damp and wet locations</td></tr>
</table>

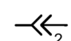
Trade name	AWG or kcmil	Number of conductors	Insulation	Use		
Junior hard service cord	18 … 10	2 … 6	Thermoset	Pendant or portable	Damp locations	Hard usage
					Damp and wet locations	
			Thermoplastic elastomer		Damp locations	
					Damp and wet locations	
			Oil-resistant thermoplastic elastomer		Damp locations	
					Damp and wet locations	
			Oil-resistant thermoset		Damp locations	
					Damp and wet locations	
			Thermoplastic		Damp locations	
					Damp and wet locations	
			Oil-resistant thermoplastic		Damp locations	
					Damp and wet locations	
Hard service cord	18 … 2	2 or more	Thermoset	Pendant or portable	Damp locations	Not hard usage
					Damp and wet locations	
			Oil-resistant thermoset		Damp locations	
					Damp and wet locations	
All thermoset parallel cord	20 … 18	2 or 3	Thermoset	Pendant or portable	Damp locations	Not hard usage
	18 … 16					
	18 … 10			Refrigerators, room air conditioners, and as permitted in 422.16(B)		

Trade name	AWG or kcmil	Number of conductors	Insulation	Use		
All elastomer (thermoplastic) parallel cord	20 … 18	2 or 3	Thermoplastic elastomer	Pendant or portable	Damp locations	Not hard usage
	18 … 16					
	18 … 10			Refrigerators, room air conditioners, and as permitted in 422.16(B)		
All thermoplastic parallel cord	20 … 18	2 or 3	Thermoplastic	Pendant or portable	Damp locations	Not hard usage
		2			Damp and wet locations	
	18 … 16	2 or 3			Damp locations	
		2			Damp and wet locations	
	18 … 10	2 or 3		Refrigerators, room air conditioners and as permitted in 422.16(B)	Damp locations	
Range, dryer cable	10 … 4	3 or 4	Thermoset	Portable	Damp locations	Ranges, dryers
			Thermoplastic elastomer			
			Thermoplastic			
Hard service cord	18 … 12	2 or more	Thermoplastic	Pendant or portable	Damp locations	Extra-hard usage
					Damp and wet locations	
			Oil-resistant thermoplastic		Damp locations	
					Damp and wet locations	

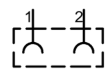
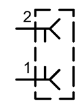
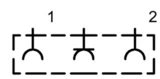
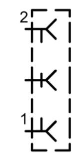
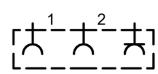
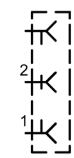
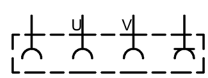
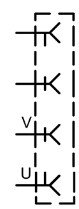
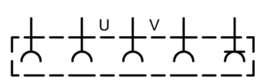
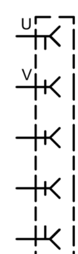
Trade name	AWG or kcmil	Number of conductors	Insulation	Use		
Vacuum cleaner cord	18 … 16	2 or 3	Thermoset	Pendant or portable	Damp locations	Not hard usage
			Thermoplastic elastomer			
			Oil-resistant thermoplastic elastomer			
			Oil-resistant thermoset			
			Thermoplastic			
			Oil-resistant thermoplastic			
Parallel tinsel cord	27	2	Thermoplastic	Attached to an appliance	Damp locations	Not hard usage
Jacketed tinsel cord	27	2	Thermoplastic	Attached to an appliance	Damp locations	Not hard usage
Portable power cable	12 … 500 501 … 1000	1 … 6 1	Thermoset	Portable, extra-hard usage		

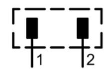
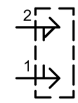
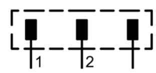
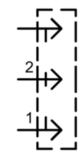
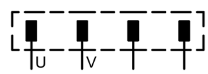
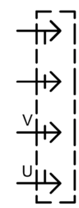
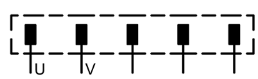
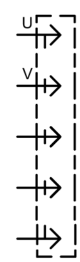
B.5 Graphical symbols and abbreviations in accordance with IEC and UL / NFPA

Terminals and connectors, terminal

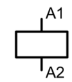
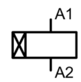
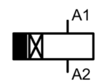
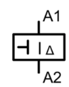
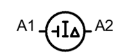
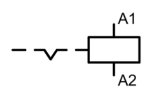
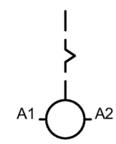
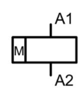
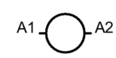
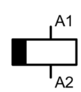
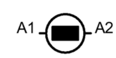
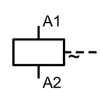
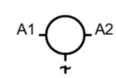
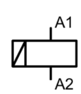
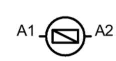
Description	IEC symbol	ANSI symbol
Terminal with 1 connection without plug-and-receptacle (socket) connections	-X1  1	 2
Receptacle of a plug-in connection	-X2  1	 2
Socket (receptacle) and plug	-X3  1	 2
Plug of a plug-in connection	-X4  1	 2

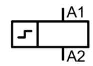
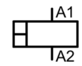
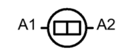
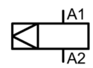
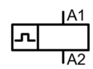
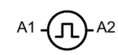
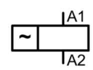
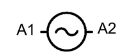
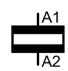
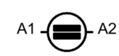
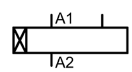
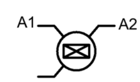
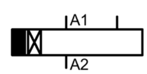
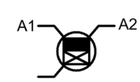
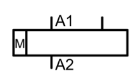
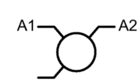
Socket outlet (receptacle)

Description	IEC symbol	ANSI symbol
Receptacle without PE, two-pin		
Receptacle with PE, three-pin		
Receptacle with PE, three-pin		
Receptacle, four-pin with PE		
Receptacle, five-pin (CEE)		

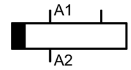
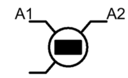
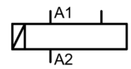
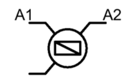
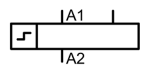
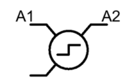
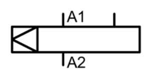
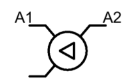
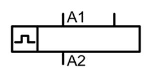
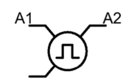
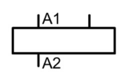
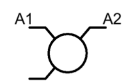
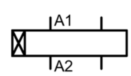
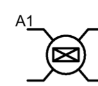
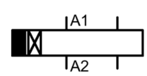
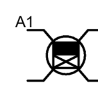
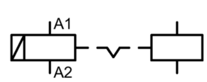
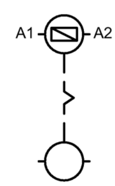
Description	IEC symbol	ANSI symbol
Plug, two-pin		
Plug, three-pin		
Plug, four-pin		
Plug, five-pin (CEE)		

Coils

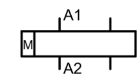
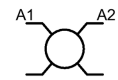
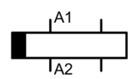
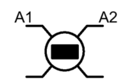
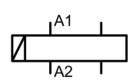
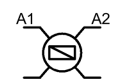
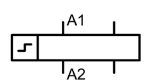
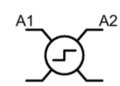
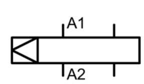
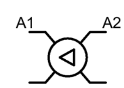
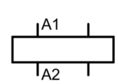
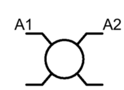
Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism, general / relay coil, general		
Electromechanical operating mechanism with response delay		
Electromechanical operating mechanism with response delay/returning time		
Electromechanical operating mechanism of a residual current release		
Second coil for remanent relay (exploded representati-on)		
Electromechanical operating mechanism of a multifunc-tion relay		
Electromechanical operating mechanism with returning time		
Electromechanical operating mechanism of a resonance relay		
Electromechanical operating mechanism of a remanent relay		

Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism of a current impulse relay		
Electromechanical operating mechanism of an extremely fast-switching relay		
Electromechanical operating mechanism of a backup relay		
Electromechanical operating mechanism of a flasher relay		
Electromechanical operating mechanism of an AC relay		
Electromechanical operating mechanism, impervious to AC		
Electromechanical operating mechanism with response delay		
Electromechanical operating mechanism with response delay/returning time		
Electromechanical operating mechanism of a multifunc-tion relay		

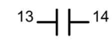
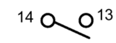
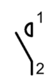
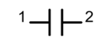
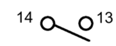
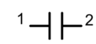
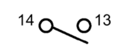
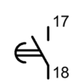
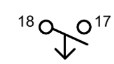
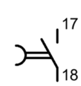
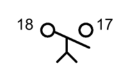
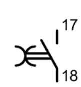
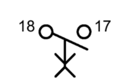
Coils (3 connections)

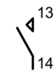
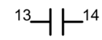
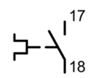
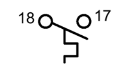
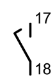
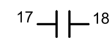
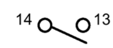
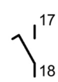
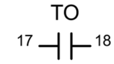
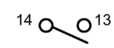
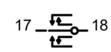
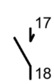
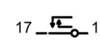
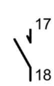
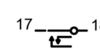
Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism with returning time		
Electromechanical operating mechanism of a remanent relay		
Electromechanical operating mechanism of a current impulse relay		
Electromechanical operating mechanism of a backup relay		
Electromechanical operating mechanism of a flasher relay		
Electromechanical operating mechanism		
Electromechanical operating mechanism with response delay		
Electromechanical operating mechanism with response delay/returning time		
Electromechanical operating mechanism of a remanent relay, exploded representa-tion		

Coils (4 connections)

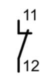
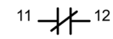
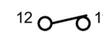
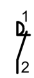
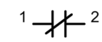
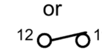
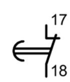
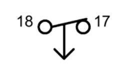
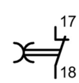
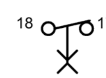
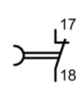
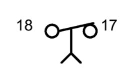
Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism of a multifunc-tion relay		
Electromechanical operating mechanism with returning time		
Electromechanical operating mechanism of a remanent relay		
Electromechanical operating mechanism of a current impulse relay		
Electromechanical operating mechanism of a backup relay		
Electromechanical operating mechanism		

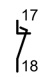
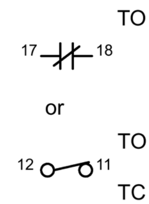
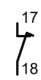
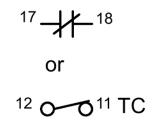
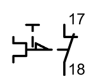
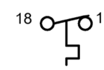
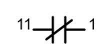
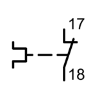
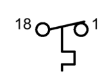
Contacts – NO contacts

Description	IEC symbol	ANSI symbol
NO contact		 or 
NO power contact of a contactor		 or 
NO power contact of a contactor with automatic release		 or 
NO contact, closes with delay		
NO contact, opens with delay		
NO contact, closes and opens with delay		

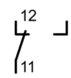
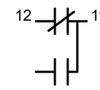
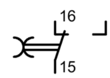
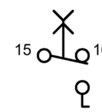
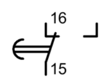
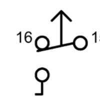
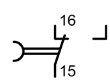
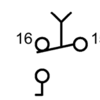
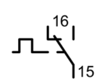
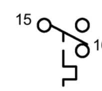
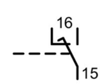
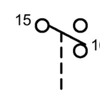
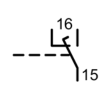
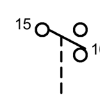
Description	IEC symbol	ANSI symbol
NO contact with automatic return		
NO contact, electrothermal release		 TC
NO contact, leading		 or  TC
NO contact, lagging		TO  or  TO
NO contact, pulse contact element with contacting on actuation and on release (to the right)		
NO contact, pulse contact element with contacting on release (to the left)		
NO contact, pulse contact element with contacting on actuation (to the right)		

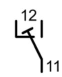
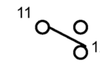
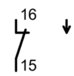
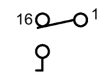
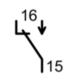
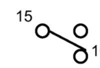
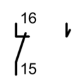
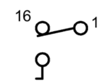
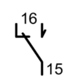
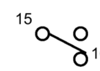
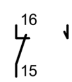
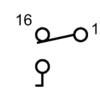
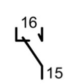
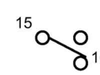
Contacts – NC contacts

Description	IEC symbol	ANSI symbol
NC contact		 or 
NC power contact of a contactor		 or 
Mirror contact (auxiliary NC contact for main current NO contacts)		
NC contact, opens with delay		
NC contact, closes and opens with delay		
NC contact, closes with delay		

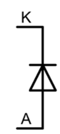
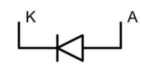
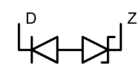
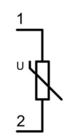
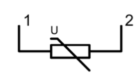
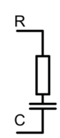
Description	**IEC symbol**	**ANSI symbol**
NC contact, lagging		
NC contact, leading		
NC contact, electrothermal release, inhibit / reset		
NC contact with automatic return		
NC contact, electrothermal release		

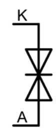
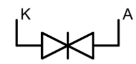
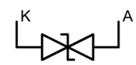
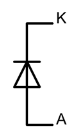
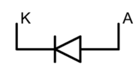
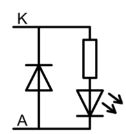
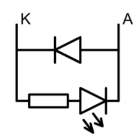
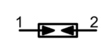
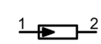
Changeover contacts

Description	IEC symbol	ANSI symbol
Change-over contact with interruption (2-path)		
Change-over contact (2-path), ON and OFF-delay		
Change-over contact (2-path), ON-delay		
Change-over contact (2-path), OFF-delay		
Change-over contact (2-path), with automatic thermal actuation		
Change-over contact (2-path), closes lagging to other contacts of the contact set		TO 
Change-over contact (2-path), closes leading to other contacts of the contact set		TC 

Description	IEC symbol	ANSI symbol
Change-over contact without interruption, subsequent changeover contact element (2-path)		
Change-over contact, pulse contact element with contacting on release (to the right and left)		
Change-over contact (2-path), pulse contact element with contacting on actuation and return (to the right and left)		
Change-over contact, pulse contact element with contacting on release (to the left)		
Change-over contact (2-path), pulse contact element with contacting on return (to the left)		
Change-over contact, pulse contact element with contacting on actuation (to the right)		
Change-over contact (2-path), pulse contact element with contacting on actuation (to the right)		

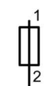
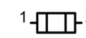
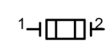
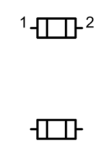
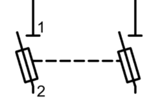
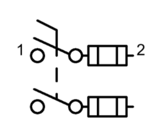
Surge suppressor

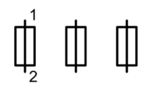
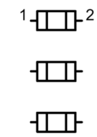
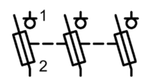
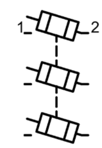
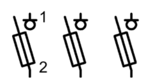
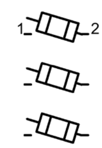
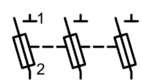
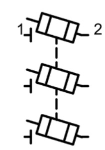
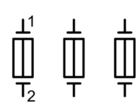
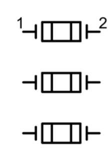
Description	IEC symbol	ANSI symbol
Protective circuit of a coil using a diode		
Protective circuit of a coil using a diode and Z diode		
Protective circuit of a coil using a varistor		
Protective circuit of a coil using an RC element		

Description	IEC symbol	ANSI symbol
Protective circuit of a coil using an avalanche diode		
Protective circuit of a coil using a suppressor diode		
Protective circuit of a coil using a diode		
Protective circuit of a coil using a combination of diode, LED+R		
Lightning conductor		
Surge arrester		

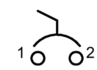
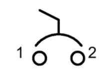
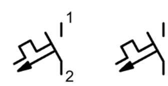
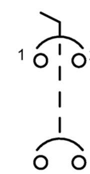
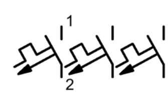
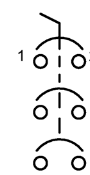
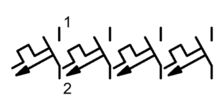
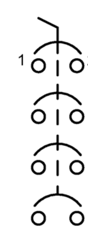
Protective devices

Fuse

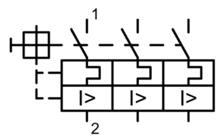
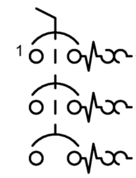
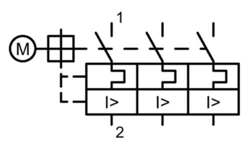
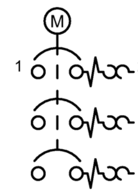
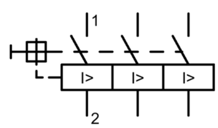
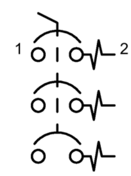
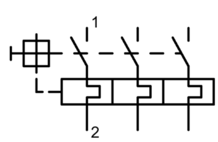
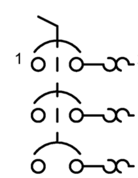
Description	IEC symbol	ANSI symbol
Fuse, single-pole, general		
Fuse switch disconnector, single-pole		
Fuse switch, single-pole		
Fuse switch disconnector, single-pole		
LV HRC fuse switch disconnector, single-pole, general		
Fuse, two-pole, general		
Fuse switch disconnector, two-pole		

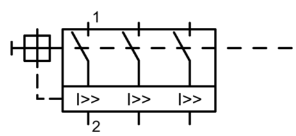
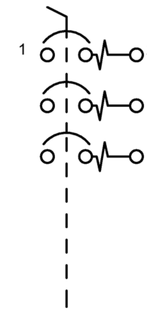
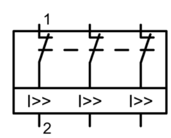
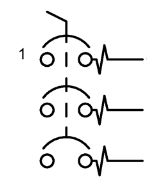
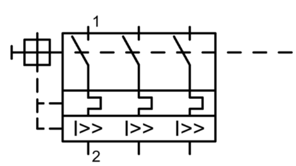
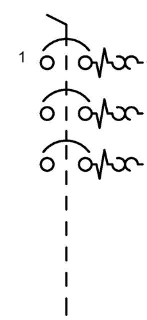
Description	IEC symbol	ANSI symbol
Fuse, three-pole, general		
Fuse switch disconnector, three-pole		
Fuse switch disconnector, three-pole, can be switched singly		
Fuse switch disconnector, three-pole		
LV HRC fuse switch disconnector, three-pole, general		

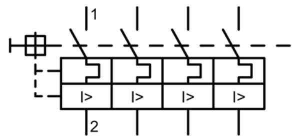
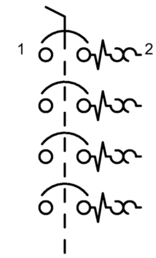
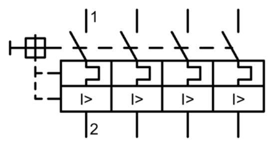
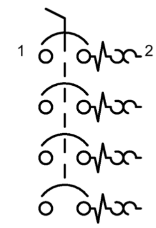
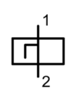
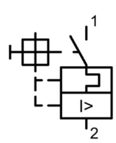
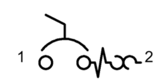
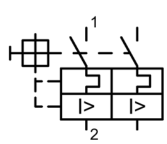
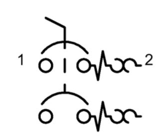
Miniature circuit breaker

Description	IEC symbol	ANSI symbol
Miniature circuit breaker, single-pole		
Miniature circuit breaker, single-pole, tripping through thermal or electromagnetic overcurrent protection		
Miniature circuit breaker, two-pole		
Miniature circuit breaker, three-pole		
Miniature circuit breaker, four-pole		

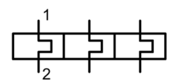
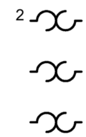
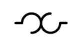
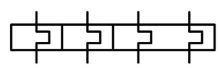
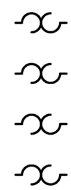
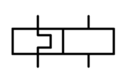
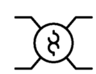
Motor circuit breaker

Description	IEC symbol	ANSI symbol
Circuit breaker / motor starter protector with breaker latching mechanism without line		
Circuit breaker / motor starter protector with breaker latching mecha-nism, motorized operating mechanism		
Circuit breaker / motor starter protector with magnetic trip unit and breaker latching mechanism without line (three-pole)		
Circuit breaker / motor starter protector with breaker latching mecha-nism, thermal trip unit, without line		

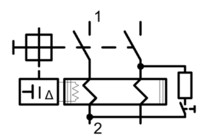
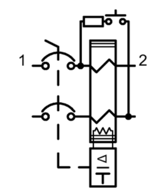
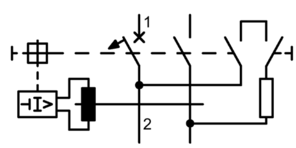
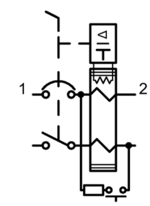
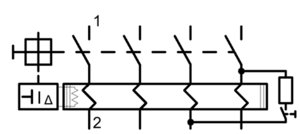
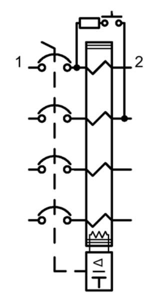
Description	IEC symbol	ANSI symbol
Limiter, without thermo contacts, with breaker latching mechanism and line		
Limiter, without thermo contacts		
Limiter, with thermo contacts, with breaker latching mechanism and line		

Description	IEC symbol	ANSI symbol
Circuit breaker / motor starter protector with breaker latching mechanism and line		
Circuit breaker / motor starter protector with breaker latching mechanism without line		
Electromechanical operating mechanism of a shunt release		
Circuit breaker / motor starter protector with breaker latching mechanism without line		
Circuit breaker / motor starter protector with breaker latching mechanism without line		

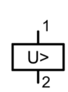
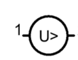
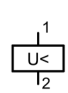
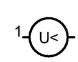
Protective relay

Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism of a thermo relay, three-pole		
Electromechanical operating mechanism of a thermo relay, single-pole		
Electromechanical operating mechanism of a thermo relay, four-pole		
Electromechanical operating mechanism of a protective relay (thermo relay)		

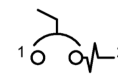
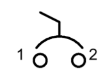
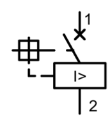
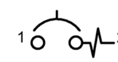
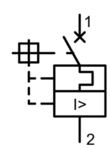
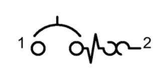
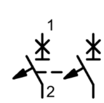
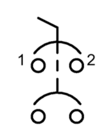
Ground fault circuit interrupter

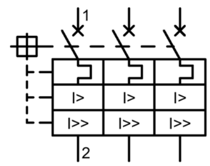
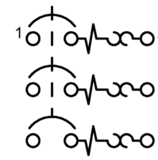
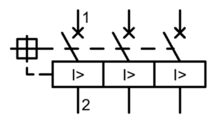
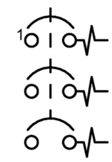
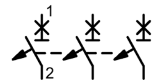
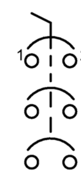
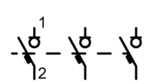
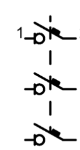
Description	IEC symbol	ANSI symbol
Residual current circuit breaker, two-pole		
Residual current circuit breaker, 2-pole (1-pole protected, 2-pole switching)		
Residual current circuit breaker, four-pole		

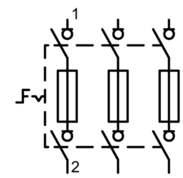
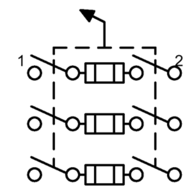
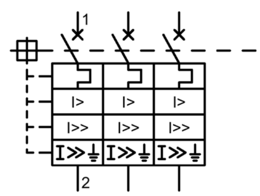
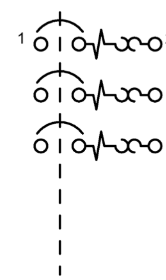
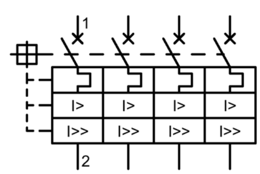
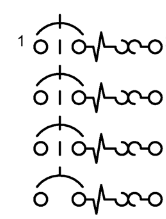
Overvoltage and undervoltage release

Description	IEC symbol	ANSI symbol
Electromechanical operating mechanism of an overvoltage release		
Electromechanical operating mechanism of an undervoltage release		

Circuit breaker

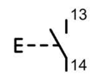
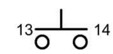
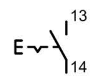
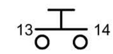
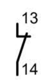
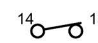
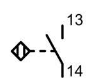
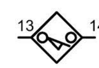
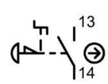
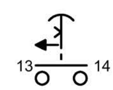
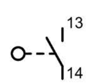
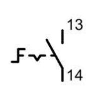
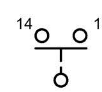
Description	IEC symbol	ANSI symbol
Circuit breaker, single-pole, tripping through thermal or electromagnetic overcurrent protection		
Miniature circuit breaker, single-pole		
Circuit breaker, single-pole (magnetic trip unit)		
Circuit breaker, single-pole (L, I characteristic)		
Miniature circuit breaker, two-pole		

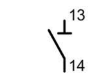
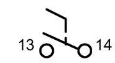
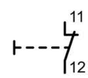
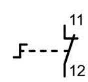
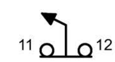
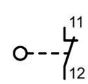
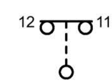
Description	IEC symbol	ANSI symbol
Circuit breaker, three-pole, with breaker latching mechanism		
Circuit breaker, three-pole, with breaker latching mechanism		
Miniature circuit breaker, three-pole		
Switch disconnector, three-pole, with automatic release through built-in measuring relay		

Description	IEC symbol	ANSI symbol
Switch disconnector with fuse element, three-pole (double interruption)		
Circuit breaker, three-pole (L,S,I,G characteristic)		
Circuit breaker, four-pole, with breaker latching mechanism		

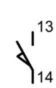
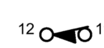
Sensors

Switches, buttons

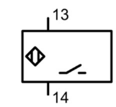
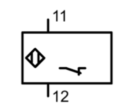
Description	IEC symbol	ANSI symbol
Pushbutton, NO contact by pressing		
Switch, NO contact by pressing		
Switch, NO contact through mechanical operation		
Switch, NO contact through mechanical operation, actuated		
Switch, NO contact, proximity-sensitive		
Emergency off switch/emergency pushbut-ton, NO contact, with rotate to unlatch mechanism		
Switch, NO contact, actuation by roller		
Switch, NO contact by rotating		

Description	IEC symbol	ANSI symbol
Switch disconnector		
Pushbutton, NC contact, general		
Pushbutton, NC contact by rotating		
Switch, NC contact, actuation by roller		

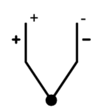
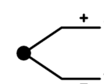
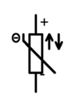
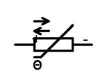
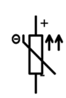
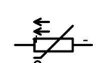
Limit switch

Description	IEC symbol	ANSI symbol
Limit switch, NO contact		
Limit switch, NC contact		

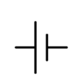
Proximity sensor

Description	IEC symbol	ANSI symbol
Proximity sensor, NO contact		
Proximity sensor, NC contact		

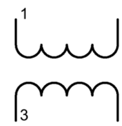
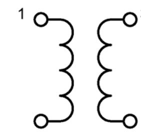
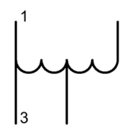
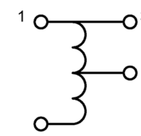
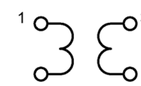
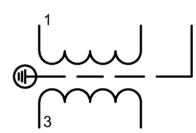
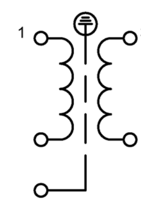
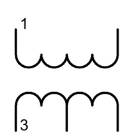
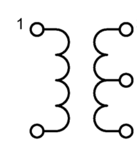
Analog sensor

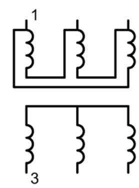
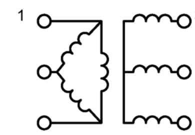
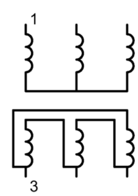
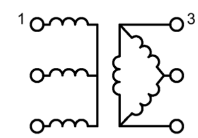
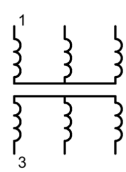
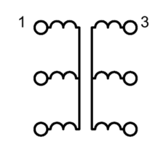
Description	IEC symbol	ANSI symbol
Thermocouple		
Resistor, NTC thermistor		
Resistor, PTC thermistor		

Voltage source

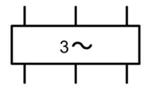
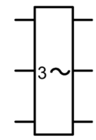
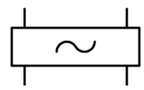
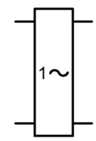
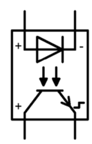
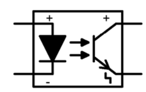
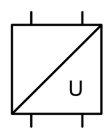
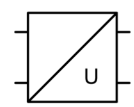
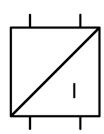
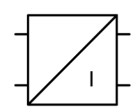
Description	IEC symbol	ANSI symbol
Battery, primary or secondary element, accumulator		

Transformer

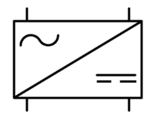
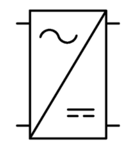
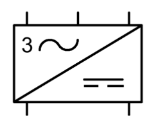
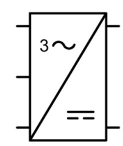
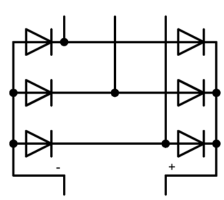
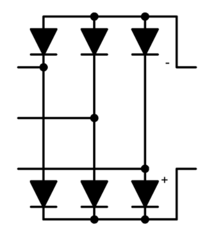
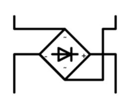
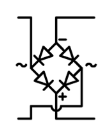
Description	IEC symbol	ANSI symbol
Single-phase transformer with two windings		
Single-phase auto-transformer		
Voltage transformer		
Single-phase transformer with two windings and shield		
Transformer with single-sided center tapping		

Description	IEC symbol	ANSI symbol
Three-phase transformer, delta-wye circuit		
Three-phase transformer, wye-delta circuit		
Three-phase transformer, wye-wye circuit		

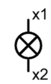
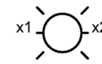
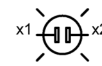
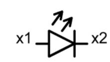
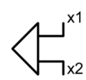
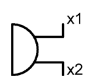
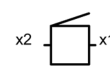
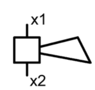
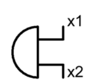
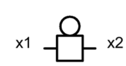
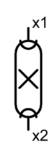
Transducer

Description	IEC symbol	ANSI symbol
Line filter, three-pole		
Line filter, two-pole		
Optocoupler, 4-wire		
Transmitter, ideal voltage source		
Transmitter, ideal current source		

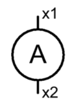
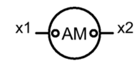
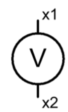
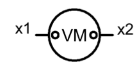
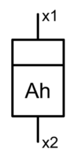
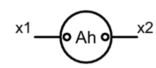
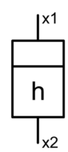
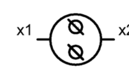
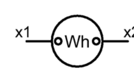
Rectifier

Description	IEC symbol	ANSI symbol
Rectifier, bridge, two-phase, secondary, 2 connections		
Rectifier, three-phase bridge, three-phase, secondary, 2 connections		
Three-phase bridge connection		
Rectifier in bridge connection		

Signaling devices

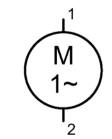
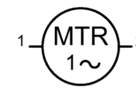
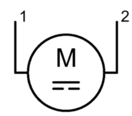
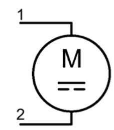
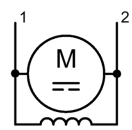
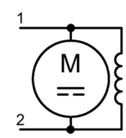
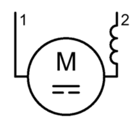
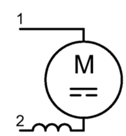
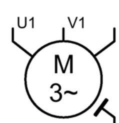
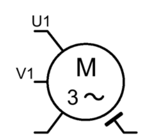
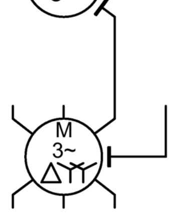
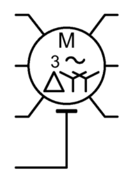
Description	IEC symbol	ANSI symbol
Lamp / indicator light, general		
Glow lamp		
Light emitting diode (LED), general		
Siren		
Buzzer		
Horn		
Alarm / bell		
Fluorescent lamp without PE		

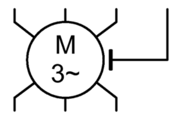
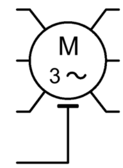
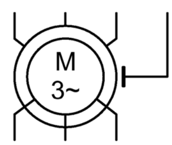
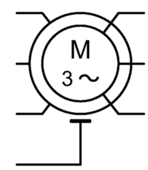
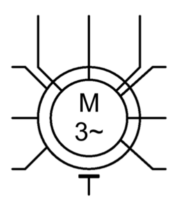
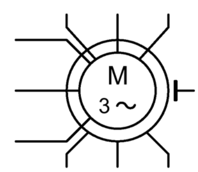
Measuring devices

Description	IEC symbol	ANSI symbol
Ammeter, indicating, ampere meter		
Voltmeter, indicating		
Meter, amperehour meter		
Meter, operating hours		
Meter, watt-hour meter, electricity meter		

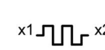
Power loads

Motor

Description	IEC symbol	ANSI symbol
AC motor, ventilator/fan		
DC motor, general		
DC shunt-wound motor		
DC series-wound motor		
Three-phase induction motor, one speed		
Three-phase induction motor, wye-delta circuit		

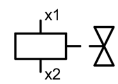
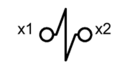
Description	IEC symbol	ANSI symbol
Three-phase induction motor, one winding, pole-changing, two speeds		
Three-phase induction motor, two separate windings, pole-changing, two speeds		
Three-phase induction motor, two separate windings, pole-changing, three speeds		

Heating

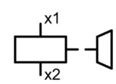
Description	IEC symbol	ANSI symbol
Heater element		

Valve, brake, coupling

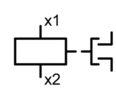
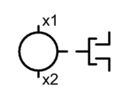
Valve

Description	IEC symbol	ANSI symbol
Solenoid valve, general		

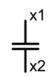
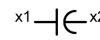
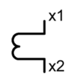
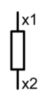
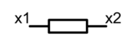
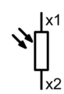
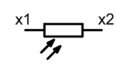
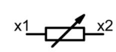
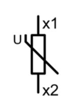
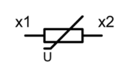
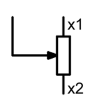
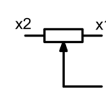
Brake

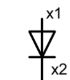
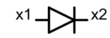
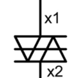
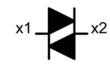
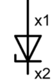
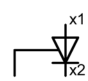
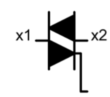
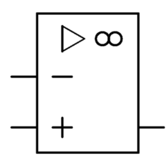
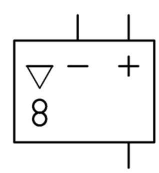
Description	IEC symbol	ANSI symbol
Magnetic brake		

Coupling

Description	IEC symbol	ANSI symbol
Magnetic coupling		

Electronics, logic components

Description	IEC symbol	ANSI symbol
Capacitor, general		
Inductance / coil / winding / reactor		
Current transformer (path 1)		
Resistor, general		
Photoresistor		
Resistor, modifiable		
Resistor, voltage-dependent / varistor		
Resistor with moving contact / potentiometer		

Description	IEC symbol	ANSI symbol
Semiconductor diode, general		
Thyristor diode, bidirectional, diac		
Z diode, avalanche diode, unidirectional, voltage limiting diode		
Thyristor triode		
Operational amplifier		

B.6 Further information and support

B.6.1 General information about automation and drives at Siemens AG and Siemens Industry Inc. USA

Siemens Industry Mall

The Industry Mall is the catalog and ordering system for automation and drives from Siemens. You can find everything you need to know about our range of products – and much more – round the clock. From intelligent tools for simple product and system configuration, to software downloads and documentation.

- International (http://www.siemens.com/industrymall)
- USA (http://www.siemens.com/industrymall/US)

Configurators

Under the category "Configurators", you can find all currently available configurators of the Industry Mall, including their description and start options. The respective configurator can be selected directly or with a default, if available.

- International (https://eb.automation.siemens.com/mall/en/Catalog/Configurators)
- USA (https://eb.automation.siemens.com/mall/en/us/Catalog/Configurators)

Application consulting for standard-compliant industrial control panel manufacture

Further information, practical tips and literature concerning the application of standards and associated training in industrial control panel manufacture, and for the electrical equipment of machinery for the North-American market, as well as for the international IEC markets, can be found at:

- Global (http://www.siemens.com/applicationconsulting)
- USA (http://www.usa.siemens.com/controlpaneldesign)

B.6.2 Information on the Internet about low-voltage industrial controls and power distribution from Siemens

SIRIUS – the world of industrial controls

SIRIUS features a comprehensive portfolio of industrial controls products. Thanks to their modular design, these products can be easily planned and installed in the control panel, and they can be simply integrated into distributed systems and optimally matched to each other.

- International (http://www.siemens.com/industrial-controls)
- USA (http://www.usa.siemens.com/controls)

Low-voltage power distribution and electrical installation

Whether in industrial plants or in buildings: Every technical system is dependent on a reliable supply of electric power. Even just a short power failure can have serious consequences. For this reason, you need products and systems that can cope with every eventuality and always keep you on the safe side. We offer the most comprehensive portfolio for low-voltage power distribution and electrical installation technology worldwide – from the switchgear right down to the socket outlet.

- International (http://www.siemens.com/lowvoltage)
- USA (http://www.usa.siemens.com/lowvoltage)

B.6.3 Industry Online Support

Siemens Industry Online Support offers comprehensive information on products, services, applications and solutions covering all aspects of automation and drives. There is also a forum for discussion and for exchanging ideas with other users.

- International (http://support.automation.siemens.com)
- USA (http://support.automation.siemens.com/US)

B.6.4 Planning Efficiency™ - Quick and easy development of perfect control panels

New standards and directives, time pressure, and rising quality demands: The day-to-day work of panel builders is subject to sweeping changes. Planning Efficiency™ provides round-the-clock support – in every process phase – helping you to save time and structure your processes even more efficiently. Make use of the time gained for new ideas and innovations.

- International (http://www.siemens.com/planning-efficiency)
- USA (http://www.usa.siemens.com/planning-efficiency)

B.6.4.1 My Documentation Manager

Description

My Documentation Manager (http://www.siemens.com/mydocumentationmanager) enables you to compile your own documentation from our standard documents (manuals), which are located in the Product Support section.

Function

In My Documentation Manager, you have the opportunity to create and manage your own compilations in a separate structure. The steps described here are designed to help you get started quickly and simply in My Documentation Manager.

1. Select article

All manuals of the Product Support section marked "Manuals/operating instructions, *configurable*" are suitable for editing with My Documentation Manager. These manuals can also be found using the search function with the setting "Manuals/operating instructions → Configurable only".

2. Select an item in My Documentation Manager

Via the link "Display and configure" in a corresponding manual item, My Documentation Manager is called up and this manual is also entered in the selection list "Last visited".

3. Create / expand your own library

In the central section of My Documentation Manager (My Library), you can create your own folders (right mouse key in this area), or you can delete or rename them. These folders correspond to chapters in your own compilation (library).

4. Transfer to your own compilation

You can now drag and drop parts of these manuals from the "Last visited" list to your own folder tree (library).

5. Export

In your library, you can export parts in different formats (PDF, XML, RTF) at any point. To do so, select the function "Create generated document" using the right mouse key at the relevant point in your library.

Note

You can effectively compile your individual plant documentation with My Documentation Manager. Documentation compiled in one language can be output automatically in another available language.

B.6.4.2 CAx Download Manager

Description

The CAx Download Manager (http://www.siemens.com/cax) provides you with a simple means of gaining access to up-to-date product data for your CAx or CAe system. You configure your own download package with just a few clicks.

You can choose from:

- Product photos, 2D dimension drawings, 3D models, device circuit diagrams, EPLAN macro files
- Manuals, characteristics curves, operating instructions, certificates
- Product master data

Function

The steps described here are designed to help you get started quickly and simply in CAx Download Manager.

1. Choose the product

Use the entry field at top right to search for relevant products. When you enter the article number, products will be suggested in the search result field. Simply click here on your article number.

2. Select the "Technical/CAx data" tab

Depending on the product you have selected, the Technical/CAx Data tab appears. In this tab, select the CAx Data and follow the instructions shown.

3. Compile your own CAx package

Now select all the document types that are relevant to you in the steps that now follow. Other article numbers can be added if desired in Step 1 under Load / enter list of products.

4. Download the CAx package

Reached the end of the selection? Now start the export of your configuration. All the selected documents are compiled in a ZIP archive for your download. You can now close the CAx Download Manager window as processing can take some time. You will be notified by e-mail on completion.

Note

Researching for product-specific CAD and CAE data can be very time-consuming. Now, you can configure your product-specific CAx Download Manager with just a few clicks. Whether you need a 3D model, a 2D dimension drawing, certificates, or product master data sheets – we compile your individual download package for you!

In the Annex at Further information and support (Page 380), you can find examples in which the high data diversity and easy availability of data offered by the CAx Download Manager have been used.

- Creation of circuit diagrams in the ANSI representation usual in North America

- Creation of circuit diagrams in accordance with the common IEC standards

- 3D control panel design

B.6.5 Energy efficiency in industry and in control panel manufacture

Whether you are a plant operator, planner or machine manufacturer: Energy-efficient production is a challenge and an opportunity in equal measure. The Siemens range of products, systems and solutions creates the ideal environment for a systematic continual increase in energy efficiency. This, in turn, opens up completely new perspectives for sustained improvement in competitiveness.

You can find more information at the following Web address:

- Energy-efficient production (http://www.siemens.com/energy-efficiency-production)

B.6.6 Training

SITRAIN offers global training for industry – just about anywhere, and just about any time. You can take the courses in classic attendance training, or you can consolidate your knowledge by using innovative learning and communication media, such as Web-based training. And if you're looking for training on a special product, and you want to know where in the world this course is on offer, you can find an overview of the global training courses here.

- Drive Technology
- Automation Systems
- Building Technologies
- Communication
- Process Control Systems
- Sensor Systems
- Safety Systems – Safety Integrated

- International (http://www.siemens.com/sitrain)
- USA (http://www.usa.siemens.com/sitrain)

Siemens Machinery Safety and Life Cycle Services

Safety training, products and solutions

Ensuring machine safety while maintaining maximum productivity is a fundamental requirement of factory automation. A single system for standard and safety-related automation, one configuring tool, a single network for standard and fail-safe communication, diagnostics of the highest standard, long-term investment security, and sustained competitiveness – the integrated machine safety solutions from Siemens result in significantly lower starting costs and operating costs, including reductions in overall operating costs of up to 30 %. These benefits and our continuous innovations in products and solutions make us the global market leader for machine safety.

- International (http://www.siemens.com/safety-integrated)
- USA (http://www.usa.siemens.com/safety)

Safety Compliance

The Safety Evaluation Tool for the standards IEC 62061 and ISO 13849-1 gets you straight to your goal. Because this TÜV-tested online tool provides you with swift and reliable help in assessing the safety functions of your machine. It provides you with a standard-compliant report that can be integrated into the documentation as a safety verification.

- Safety Evaluation Tool (http://www.siemens.com/safety-evaluation-tool)

International services for functional safety

Siemens supports you in carrying out risk assessments and SIL/PL tests, and in programming and testing safety functions.

- Email: Safety Services (mailto:safety-services.industry@siemens.com)

USA – Services for machine safety, risk assessment and safety validation

Siemens Industry, Inc. offers its customers in the USA machine safety services that are specially tailored to their requirements and specifications.

- Safety (http://www.usa.siemens.com/safety) (under Machine Safety Support)

Safety training

With Safety Integrated, we offer comprehensive and standardized total solutions for the manufacturing and process industries that can be combined with excellent services throughout the entire life cycle of a safety-related plant or machine.

- International (http://www.siemens.com/sitrain-safetyintegrated)
- USA (http://www.usa.siemens.com/sitrain)

Safety implementation

A Siemens Solution Partner, specially qualified for the safety area, can implement a total solution that fulfills all your safety requirements!

- Global (http://www.siemens.com/automation/solutionpartner)
- USA (http://www.usa.siemens.com/safety) (under Machine Safety Support)

Glossary C

Ambient Temperature

Ambient temperature of the air or another medium in which the electrical equipment is operated.

Appliance

Device for a specific application containing both power circuit components and control circuit components.

Examples include industrial control panel air-conditioning devices.

Approved

"Approved" means acceptance by local inspectors has been achieved.

Available Fault Current

Max. fault current that can occur at the point of the supply to the electrical equipment. The SCCR value marked on the industrial control panel nameplate or the electrical equipment shall be equal to or greater than the maximum available fault current.

Branch Circuit

Conductors and devices downstream of the last overcurrent protective device protecting the load branch circuit.

Example: Motor branch or heater branch

Branch Circuit Protection

Overcurrent protective device with a pre-defined or set rated current for protecting the load against overcurrents.

In motor branches, overcurrent protection is only required for short-circuits or ground faults. Separate overload protection is required for motor overload protection.

See the term "Overload Protection" in this context.

Branch Circuit Protective Device

The branch circuit protective device is either a circuit breaker in accordance with UL 489 or a fuse in accordance with UL 248-4 … 12. In motor branch circuits, a motor circuit breaker with separate test can also be used for branch circuit protection.

See the term "Self-protected combination motor controller" in this context

Cable

A cable is a combination of conductors insulated from each other and assembled within a shared protective insulation. A cable is not synonymous with a flexible supply cord (see the glossary entry "Cord").

Class 1 Circuit

Control circuit that is protected against overcurrent at a maximum operating voltage ≤ 600 V. The power is not limited by the standard. The control circuit can also be supplied via a power-limiting source such as a control transformer or a power supply.

Class 2 Circuit

Control circuit that is supplied via a source with limited power and whose maximum operating voltage is ≤ 30 V rms. The circuit is designed to operate special components requiring a Class 2 circuit.

Combination Motor Controller

One or more devices in an assembled state that deliver all four required functions for a single motor installation: Disconnecting, short-circuit protection, control, overload protection.

Control Circuit

A circuit that carries the signals for the controller. These circuits are not used for the actual end application and therefore not for the power circuits.

The rated current is limited in most cases to 15 amperes.

Cord

Flexible supply cord consisting of two or more insulated conductors and covered in a protective insulation for protection against mechanical damage.

Enclosed Industrial Control Panel

Industrial control panel that is already provided with an enclosure.

Equipment

A general term for devices and components used in an electrical installation, for example, materials, devices, instruments, lighting, fixtures, connections, and similar.

Feeder Circuit

All conductors and circuits on the incoming supply side of the branch circuit protection for a load in the power circuit. These include, for example, all upstream circuits of a motor circuit breaker in the power circuit.

Field Wiring

Conductors that are not connected by the panel builder, but instead are connected on-site at the installation location of the control panel or the electrical equipment, for example, incoming supply conductor, or external control circuit devices and loads.

Field Wiring Terminal

Terminal for terminating field wiring.

Fuse for Branch Circuit Protection

Fuses of the class CC, G, H, J, K, L, R and T. These fuses can be used for branch circuit protection.

Fuse, Semiconductor Type

Semiconductor fuses for protecting semiconductor devices. These fuses can be used as branch circuit protection for motor circuits containing power conversion equipment, provided the relevant test has been performed.

Fuse, Supplementary Type

Fuses that are used as supplementary protection. These fuses shall not be used as the only source of branch circuit protection.

General-use Rating

Rating specified in volts and amperes that is assigned to a control device that may be used for the following types of loads:

- Devices with a continuous current or inrush current not exceeding the ampere rating of the control device
- With AC ratings, the power factor of the load shall be between 0.75 and 0.80
- Only resistive loads may be operated with AC ratings

Industrial Control Panel

Assembly of two or more components in the power circuit or the control circuit, or a combination of main and control circuits.

Industrial Machinery

A motor-operated machine or group of machines coordinated to process materials. Transport during operation is not possible here. The machines can also contain associated equipment parts here, for example, material transport, tool provision, testing equipment, or packaging systems.

In Sight From (Within Sight From, Within Sight)

This term indicates the distance between two described items of equipment that are within line-of-sight of each other. The distance shall not exceed 15 m (50 ft), and the other item of equipment shall be visible.

Instantaneous Trip Circuit Breaker

Circuit breakers that only have an instantaneous, magnetic trip unit. These circuit breakers may be used for motor branch circuit protection if they are part of Combination Motor controllers, and have been correspondingly tested.

Inverse-time Circuit Breaker

Circuit breakers with both a delayed, thermal trip unit, and an instantaneous, magnetic trip unit. These circuit breakers are generally suitable for branch circuit protection.

Load

Equipment connected in the power circuit.

Low-voltage limited energy circuit

Control circuit with a maximum peak voltage of 42.4 V (DC or AC instantaneous value) and output current limiting by means of a fuse or by limiting the power of the power supply or control transformer. The power shall be supplied via a battery or a source with galvanic isolation. Voltage dividers are not permissible for supply.

Motor Starter

An assembly of a motor overload relay and contactor.

Overcurrent Protection

Overcurrent protective device with corresponding technical features to enable safe disconnection of a circuit in the event of overload, short-circuit or ground fault if the current of the circuit exceeds a predetermined value.

Overload Protection

Overload protection for motor circuits to prevent overheating during operation or when starting.

Pilot Duty Rating

Utilization categories for relays in control circuits that themselves control other devices.

Qualified person

A qualified person is a person who is familiar with the design of the electrical equipment, and who has the abilities and knowledge to operate the equipment properly. Safety training is necessary to be able to detect and avoid the accompanying hazards that can arise with the equipment.

Safety-related Function

A safety-related function that helps to maintain safe operating conditions for machines, or prevents or at least minimizes hazardous situations.

Self-protected combination motor controller

A motor circuit breaker that can only be controlled manually, or an arrangement of one or more devices for disconnection, short-circuit protection, and overload protection of motor branch circuits in which the motor is controlled, for example, using a contactor.

Short Circuit Current Rating (SCCR)

Available fault current at a specific voltage that the electrical equipment can withstand without undue damage and under specific criteria.

Supplementary Protection

A device intended to provide additional protection subsequent to the actual branch circuit protective device on the load side. These additional protective devices are not permitted to be used as the sole branch circuit protection.

Tap Conductor

Conductor with an upstream overcurrent protection whose rating exceeds the maximum ampacity of the conductor.

Tungsten Rating

Ratings for devices that control incandescent lamp loads.

Service & Support

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Tel.: +49 (911) 895-5900
e-mail: technical-assistance@siemens.com
www.siemens.com/sirius/technical-assistance

Siemens AG
Industry Sector
Postfach 23 55
90713 FUERTH
GERMANY

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