

Understanding the Machinery Directive



A Road Map to CE Marking and Safety-Related Control Product Applications



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Control Product Applications

Important notice

This publication contains summary information regarding European Union (EU) directives relevant to industrial control and automation products of the type manufactured by Rockwell Automation/Allen-Bradley. This information is solely based on Rockwell Automation's interpretation of those directives and should not be considered a definitive analysis of all relevant EU directives or their impact on any one company's goods or services. Because of the vast variety of product uses, those responsible for the application and use of those products within the EU should conduct their own independent evaluation to assure that each application and use meets the requirements of all relevant directives, as well as other local and regional codes, laws and regulations.

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Rockwell Automation would like to extend special appreciation to the following individuals for sharing their knowledge of European safety legislation:

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Thank you, everyone, and best regards to safety-conscious managers everywhere.

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Chapter 1 — Introduction

1.0	New laws impact equipment manufacturers and end-users	2
1.1	A global road map	3
1.2	Does the Machinery Directive apply to me?	3
1.3	Good intentions.	5

Chapter 2 — Acronyms? Numbers? Help!

2.0	The European market	8
2.1	So what directives should I examine?	8
2.2	Standards to clarify directives	10
2.3	Sources for standards	11
2.4	CE marking.	13
2.5	Interpretations may vary	14
2.6	Applying components properly	14

Chapter 3 — The Road Map

3.0	Starting out.	19
3.1	EN 292 — Basic concepts of machine safety	19
3.2	The Directives.	23
3.3	EMC Directive	25
3.4	The Low Voltage Directive	25
3.5	The Product Liability Directive	26
3.6	Examining Type A, B and C Standards	27

Chapter 3 — The Road Map (continued)

3.7	Annex I — Essential Health and Safety Requirements	29
3.8	Risk assessment — EN 1050.	30
3.9	Risk estimation — EN 1050 and EN 954	31
3.10	Performance categories — EN 954	33
3.11	Risk, performance and selection	39
3.12	Summary	40

Chapter 4 — Post Design and Construction Requirements

4.0	So you've complied with requirements — now what?	46
4.1	Information for use	46
4.2	Advice for drafting information for use.	47
4.3	The Technical File.	49
4.4	Declaration of Conformity	51
4.5	Can you self-certify?	53
4.6	CE Marking	55

Chapter 5 — Safety Category Requirements

5.0	Why include safety and safety-related components? . .	58
5.1	Well-trying components and design principles.	59
5.2	Direct opening action contacts.	59
5.3	Positively driven contacts	62
5.4	Anti-tease features.	63

Chapter 5 — Safety Category Requirements (continued)

5.5	Redundancy	63
5.6	Normally energized circuits.	64
5.7	Control circuits and performance categories	66
5.8	Category B and Category 1	66
5.9	Category 2	69
5.10	Category 3 and category 4.	70

Chapter 6 — Safety Concerns for Power-Related Products

6.0	Operational functions	76
6.1	Contact reliability	76
6.2	Multiple fault detection	77
6.3	Motor protection	77
6.4	Safe separation of circuits to avoid electric shock	79
6.5	Protection against electric shock	81
6.6	Protection against indirect contact.	81

Chapter 7 — Frequently Asked Questions (FAQs)

- Big Picture FAQs	86
- Component FAQs	91
- Rockwell Automation/Allen-Bradley FAQs	93

Glossary of Terms

.	97
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Appendices

Appendix A — Select Type B standards.	104
Appendix B — Electrical equipment of machines	107
Appendix C — EHSR (Annex I of the Machinery Directive).	128
Appendix D — Some significant faults and failures.	135
Appendix E — Standards and characteristics of safety functions.	137
Appendix F — Sample DOCs	139
Appendix G — Annex IV equipment.	143
Appendix H — IEC Style Diagrams from Chapter 5	145

Introduction

New laws impact equipment manufacturers and end-users	1.0
A global road map	1.1
Does the Machinery Directive apply to me?	1.2
Good intentions	1.3

New laws impact equipment manufacturers and end-users

As a prerequisite to participating in the global marketplace, all machinery manufacturers and end-users should consider machinery safety and control reliability when designing their equipment. One significant force behind this international safety effort is the 1995 European law requiring all machinery built for use in the European Union (EU) and European Economic Area (EEA) to comply with the Machinery Directive on safety. The law mandates that machine builders indicate compliance by placing CE marking on their machinery. CE stands for Communauté Européene, which is French for European Community.



Though European in origin, these safety-related directives impact original equipment manufacturers (OEMs), end-users and multi-national corporations everywhere. With components sourced from around the world, the final destination and use of a product often remains unknown to its manufacturer. Further, companies producing machinery for Europe often turn to their suppliers for information and support as part of their effort to comply with the directives.

1.1

A global road map

The purpose of this book is to provide designers, quality assurance managers, sales directors and others with a road map for understanding the key elements of the CE marking process. It introduces the reader to key European requirements in an easy-to-understand format; it walks OEMs through the basic CE marking steps; it helps establish realistic expectations; and it directs readers to further resources. Where appropriate, much of the language used stays close to the original wording of the directives and standards. The second portion of this book provides safety component application examples.

The authors reiterate that this book serves as a road map for making a comprehensive process more manageable. It is not intended to be a substitute for thoroughly reading all appropriate directives and standards.

1.2

Does the Machinery Directive apply to me?

The definition of machinery is *“An assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control, and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material”* (See Figure 1.0).

This definition also covers an assembly of machines functioning as a whole, as well as interchangeable equipment modifying the function of a machine. Any manufacturer whose “machine” fits the above description would be well-advised to continue reading.

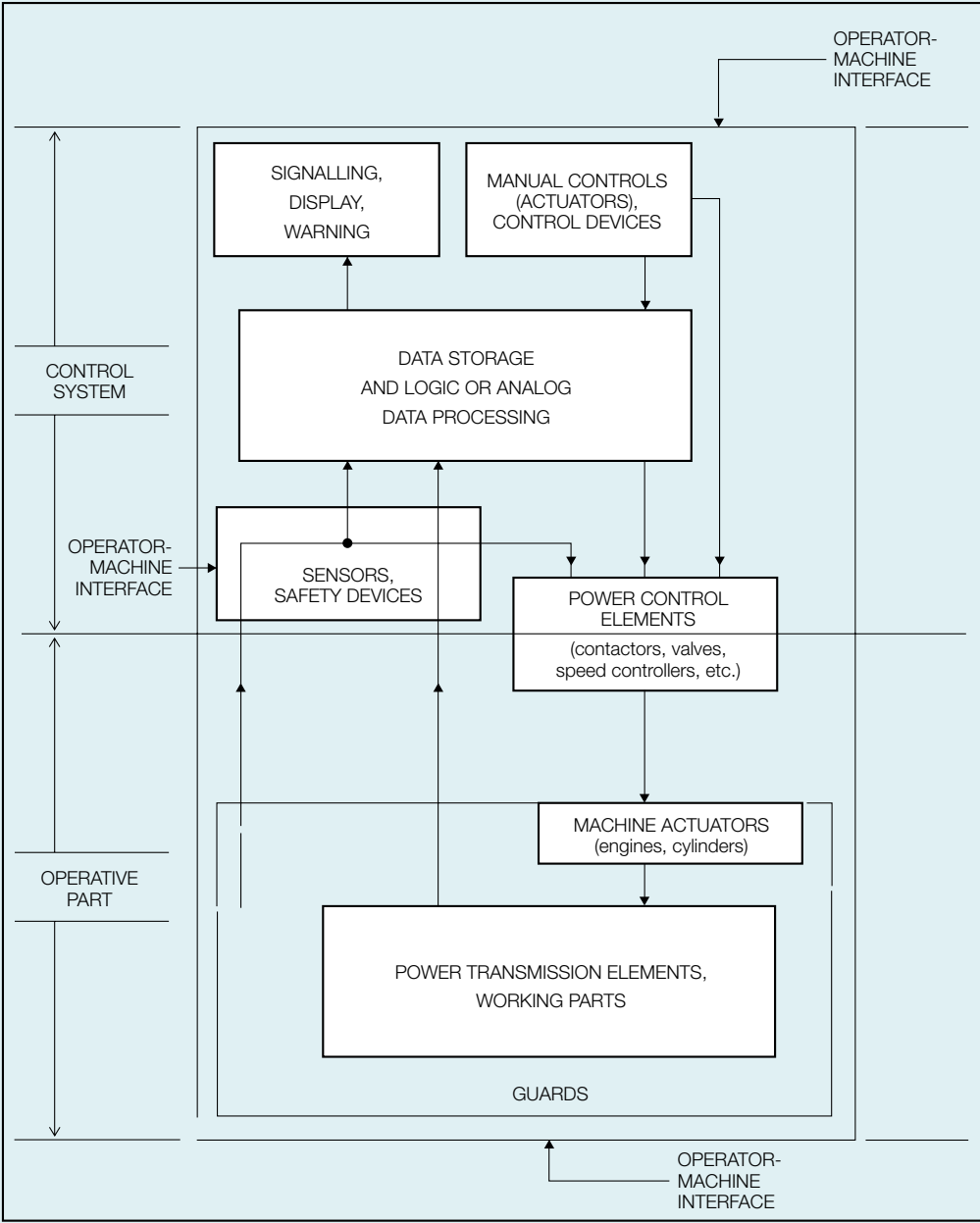


Fig. 1.0 General schematic representation of a machine (from EN 292-1, Annex A).

According to the Machinery Directive, only companies building a “machine” for the EU market need to apply CE marking. Many individual components and sub assemblies — such as those having no independent source of energy or those that are not safety components — may not need marking at all, or they may be CE marked according to other directives.

1.3

Good intentions

The overall charge of the Machinery Directive explains that “...*Member states are responsible for ensuring the health and safety...of workers, notably in relation to the risks arising out of the use of machinery. The social cost of the large number of accidents caused directly by the use of machinery can be reduced by inherently safe design and construction of machinery and by proper installations and maintenance.*”

Further, the directive mandates a common sense approach for addressing safety (e.g., “*Each machine must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted*”). Also helpful are the standards supporting the directive, which provide a process for identifying hazards, assessing risk and implementing measures to improve reliability, reduce the possibility of failure or increase the probability of detecting a failure.

Ultimately, the directives reduce bureaucracy and help OEMs make their products as safe as possible while being realistic about design and usage demands. In the event of an accident, the directives also may offer proof of due diligence.



The designer encountering European safety laws for the first time may feel overwhelmed by all the new safety-related numbers and acronyms.

Acronyms? Numbers? Help!

The European market	2.0
So what directives should I examine?	2.1
Standards to clarify directives	2.2
Sources for standards	2.3
CE Marking	2.4
Interpretations may vary	2.5
Applying components properly	2.6

2

2.0

The European market

The countries of the European Union are (as of January 1, 1997):

Austria	Germany	Netherlands
Belgium	Greece	Portugal
Denmark	Ireland	Spain
Finland	Italy	Sweden
France	Luxembourg	United Kingdom

The EU countries — plus Iceland, Liechtenstein and Norway — form the European Economic Area (EEA). The rules for the free movement of goods that apply to the EU also apply for the EEA. Other countries, such as Switzerland, may adopt some or all of the directives; in this case, the same rules apply. OEMs should check with the specific country for the applicable directives.

2.1

So what directives should I examine?

The directives are legal documents (laws) issued on the authority of the Council of the EU and adopted by the governments of all member countries. They create a uniform level of requirements and regulations for all EEA members and supersede the previous national rules and standards (which varied greatly). The member states are obliged to transfer the directives into national law. This facilitates the free movement of goods across international borders, eliminating trade barriers.

The Machinery Directive (official reference number 89/392/EEC) with amendments is the most comprehensive directive for machinery using control products. It states that all machinery marketed in the EU/EEA must meet certain safety requirements.

These wide-reaching requirements cover every aspect of the machine: mechanical design, electrical design, controls, safety, and the potential for the machinery to create hazardous situations. Note that while the directive discusses controls and safety components, it does so in the context of designing a safe machine.

The Machinery Directive also identifies certain machines, apparatus and applications that do not fall within its scope. For this equipment, other directives may apply, such as the

Electromagnetic Compatibility (EMC) Directive (89/336/EEC) and the Low Voltage Directive (73/23/EEC) as well as directives for batteries, explosive atmospheres, simple pressure vessels, personal protection equipment and dangerous substances. Manufacturers must take care to learn about all directives which apply to their product.



Machinery builders must thoroughly familiarize themselves with the Machinery Directive and associated standards.

Standards to clarify directives

To help clarify and expand on the essential requirements set forth by the directives, and to provide a means of testing/verifying that machinery meets directive requirements, OEMs can refer to a set of harmonized European standards (“European Norms,” or ENs).

Developed by the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC), the standards are voluntary, not law. However, standards are the most expedient means to show compliance with the Machinery Directive. When OEMs design machinery according to EN standards, conformity is presumed.

Two fundamental safety standards apply to all electrical controlled machinery:

- EN 292-1, -2 — Safety of machinery — Basic concepts, general principles for design. Part 1: Basic terminology and methodology. Part 2: Technical principles and specifications.
- EN 1050 — Safety of machinery — Principles for risk assessment.

Two other fundamental standards address specific safety aspects:

- EN 60204-1 — Safety of machinery — Electrical equipment of machines. Part 1: General requirements
- EN 954-1 — Safety of machinery — Safety-related parts of control systems. Part 1: General principles for design

These four standards comprise the base standards to show conformance to the Machinery Directive. The machine designer embarking on the CE marking quest should begin by obtaining the full text of the four standards noted above and the Machinery, Low Voltage and Electromagnetic Compatibility Directives.

Sources for standards

The following organizations and companies provide copies of the standards and directives (as of September 1997):

1. ANSI - American National Standards Institute

11 West 42nd Street New York, NY 10036 USA.

Phone: 1-212-642-4900.

Fax (for ordering): 1-212-302-1286. Fax (general): 1-212-398-0023.

Internet: www.ansi.org

Comments: Now accepts credit cards. ANSI is also the source of IEC & ISO standards, CEN and CENELEC pre-standards (prEN).

2. International Electrotechnical Commission (IEC)

3, rue de Varembe P.O. Box 131 CH 1211 Geneva 20 SWITZERLAND

Phone: 011-41-22-919-0211 Fax: 011-41-22-919-0300

Internet: www.iec.ch/

Comments: Direct source of IEC standards. Will accept credit cards as part of phone order.

3. International Organization for Standardization (ISO)

1, rue de Varembe CH 1211 Geneva 20 SWITZERLAND

Phone: 011-41-22-749-0111 Fax: 011-41-22-733-3430

Internet: www.iso.ch/

Comments: Direct source of ISO standards. Will accept credit cards as part of phone order.

4. British Standards Institution
389 Chiswick High Road, London W4
4AL UNITED KINGDOM
Phone: 011-44-181-996-9000
Fax: 011-44-181-996-7400
Internet: www.bsi.org.uk/
Comments: Source of CEN and CENELEC standards once they are published (English language version).
5. Global Engineering Documents
7730 Carondelet Ave., Suite 407,
St. Louis, MO 63105.
Phone: 1-800-854-7179.
Fax: 1-314-726-6418
Comments: Source for a variety of standards.
6. CEN - European Committee for Standardization Central Secretariat: rue de Stassart 36,
B-1050, Brussels, Belgium.
Phone: 011-32-2-550-0819.
Fax: 011-32-2-550-0811
Internet: <http://tobbi.iti.is/cen/welcome.html>
7. CENELEC - European Committee for Electrotechnical Standardization Central Secretariat: rue de Stassart 35,
B-1050, Brussels, Belgium.
Phone: 011-32-2-51-96-919.
Fax: 011-32-3-51-96-871

Notified Bodies

A Notified Body is a type of independent testing laboratory that an EU member state has determined to be qualified to perform testing and certification functions relating to specified directives. The member state "notifies" the Council of the European Community (EC) and the laboratory of its qualified status. An EC-Type examination is the procedure by which a Notified Body ascertains and certifies that an apparatus satisfies the provisions of the applicable directive(s).

2.4

CE marking

When machinery manufacturers place CE marking (Figure 2.0) on their product, they are stating that the product complies with all applicable directives. To affix CE marking to a product, manufacturers must issue a Declaration of Conformity (DOC). This is a formal, signed statement indicating conformity of the referenced product to the listed provisions of the applicable directive(s) and standards.

Most machine manufacturers — about 95 percent — can self-certify their compliance with the Machinery Directive (i.e., it is not mandatory to use an outside agency in most cases). A few product categories, including high-risk machinery such as punch presses, saws, etc., require third-party certification by a Notified Body.

If the product is not manufactured in the EU/EEA, it may be advantageous for the machine builder to establish an authorized representative located within the EU/EEA. The authorized representative should be easily accessible, have ready access to the DOC, and be able to supply supporting information on request.

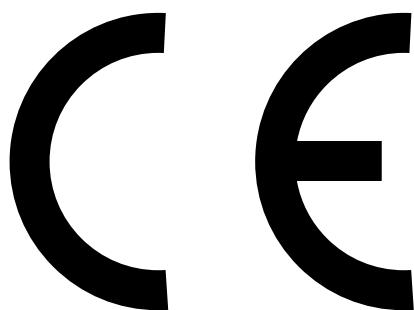


Fig. 2.0

2

2.5

Interpretations may vary

The language of the directives and standards permits a variety of interpretations. This, in turn, has led to misinformation and confusion about what they really require. Since machinery manufacturers have responsibility for the performance level of their equipment, it is mandatory that they read and understand the directives themselves. When in doubt about requirements, machine builders should refer to the directives and standards; do not accept “expert opinion” as fact or as the only possible interpretation.

The role of third-party inspectors also generates many questions. The important things to remember are that most manufacturers can self-certify (the directives clearly cite the exceptions), and that the EU/EEA does not require machines or components to have additional safety marks (e.g., the German “GS” or Danish “Demko” marks) other than CE marking.

Sometimes, machinery buyers request that suppliers meet requirements beyond those for CE marking, such as internal company standards. In such cases, machinery buyers should specify the additional standards to which they want the product tested against or built, and machine builders should clarify this with the customer up front.

2.6

Applying components properly

Confusion can arise when machine designers hear that using control components with CE marking means that their machine meets Machinery Directive requirements. This is not true. CE marking on a control component usually indicates compliance with the Low Voltage or Electromagnetic Compatibility Directive. Machinery Directive requirements for control components are an entirely separate set of concerns.

A good analogy for U.S. audiences might be this: using UL-listed components for a panel does not mean the panel meets UL requirements. To create a UL-approved panel, the components must be wired and installed according to an acceptable methodology, the National Electric Codes. This ensures that components are used for their intended function (or conversely, it helps to prevent unacceptable practices, such as trying to run 200 amps through 16 gauge wire).

While component suppliers can specify application parameters and provide design advice, it is the machinery builder who integrates the components as part of a machine. Thus, the builder must take responsibility for ensuring that the components have been assembled and applied in a manner that meets machine safety requirements.



Machinery builders must apply control components in an appropriate manner to satisfy Machinery Directive requirements. Remember: Simply using components with CE marking does not mean your machine meets CE requirements.



Without a road map, the path to CE conformity can seem long and confusing.

The Road Map

Starting out	3.0
EN 292 — Basic concepts of machine safety	3.1
The directives	3.2
EMC Directive	3.3
The Low Voltage Directive	3.4
The Product Liability Directive	3.5
Examining Type A, B and C Standards	3.6
Annex I — Essential Health and Safety Requirements . .	3.7
Risk assessment — EN 1050	3.8
Risk estimation — EN 1050 + EN 954	3.9
Performance categories — EN 954	3.10
Risk, performance and selection	3.11
Summary	3.12

The Road Map

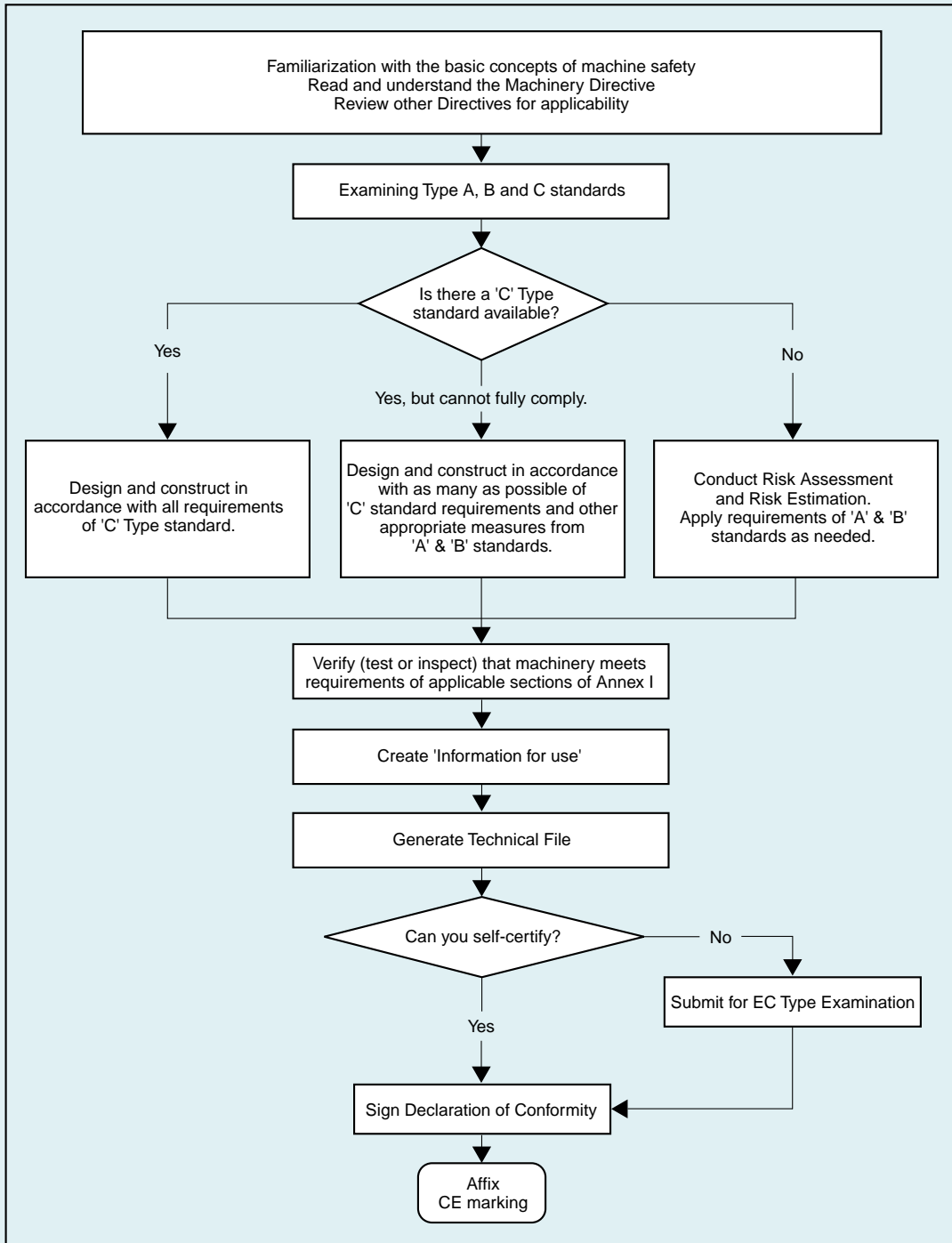


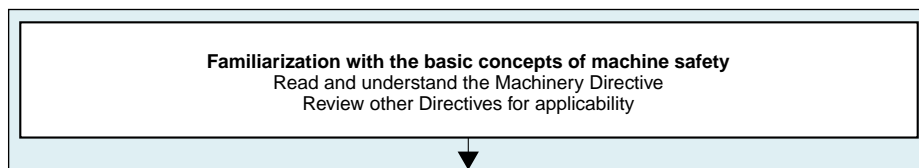
Fig. 3.0 Basic approach to obtaining CE marking [Note: A, B and C standards are explained in section 3.6 of this book].

3.0

Starting out

Viewed graphically (see Figure 3.0), the process of obtaining CE marking looks quite manageable. The authors suggest that manufacturers approach the task as a series of steps and think of it as a process for incorporating safety into machinery.

This section cites specific standards and directives and quotes sections of them. The intent is to expose readers to the standards in a controlled manner, and to direct readers to the sections that will be most helpful to them.



3.1

EN 292 — Basic concepts of machine safety

European Norms (ENs, commonly referred to as “standards”) state specific requirements of the directives. The key standards for clarifying the Machinery Directive are *EN 292-1* and *EN 292-2, Safety of machinery*.

EN 292-1 serves as a good introduction because it provides machine designers with basic concepts and terminology of machine safety (e.g., safety-critical functions, moveable guard, two-hand control devices, trip device), descriptions of hazards (e.g., mechanical, electrical, thermal) and strategies for risk assessment and reduction (see Figures 3.1A and 3.1B). For more information on the terminology used in the standards, obtain a copy of ENV 1070, a provisional standard now being developed on terminology.

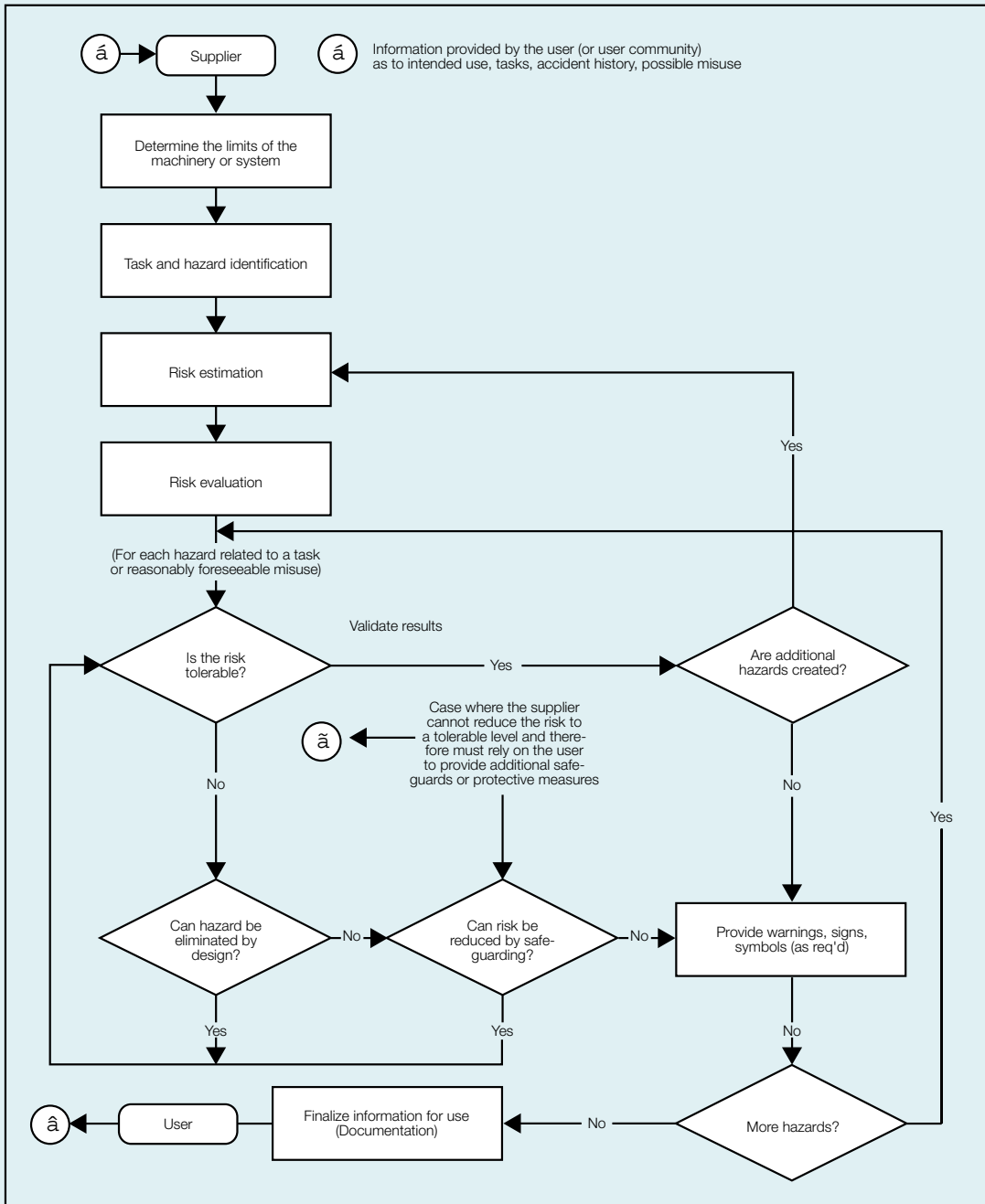


Fig. 3.1A Procedure for suppliers to assess and reduce risk (from proposed update to EN 292-1).

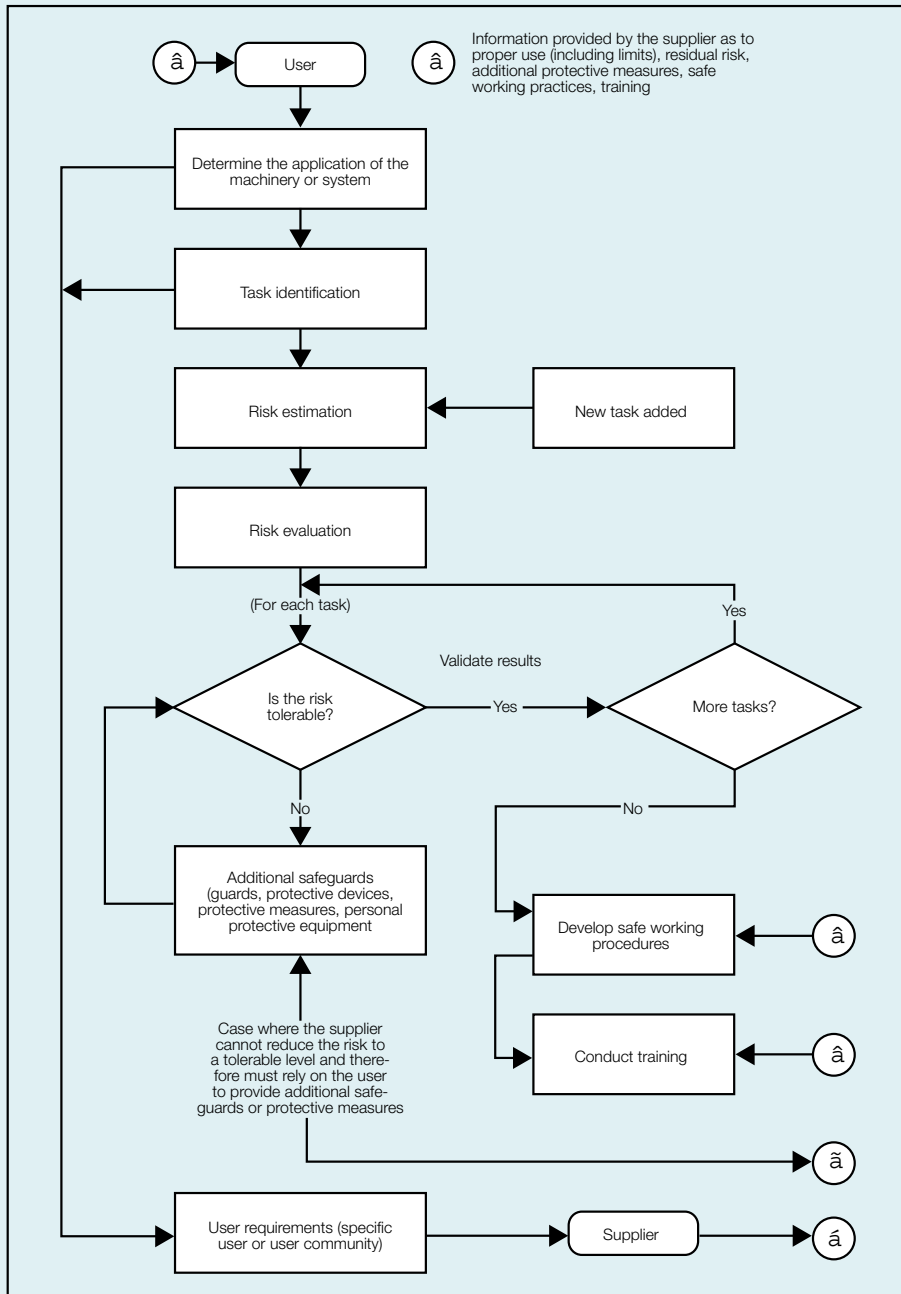


Fig. 3.1B Procedure for users to assess and reduce risk (from proposed update to EN 292-1).

EN 292-2 provides an overview of the technical principles and specifications for incorporating safety into a machine; e.g., avoiding or reducing as many of the hazards as possible by using the most suitable design features, and by limiting a person's exposure to hazards by reducing the need for operator presence/intervention in danger zones.

EN 292-2 addresses risk reduction by design, safeguarding (see Figure 3.2), creating "information for use" (i.e., an owner's manual) and additional precautions designers can take related to improving safety.

Hopefully, just the brief information and charts referenced here have convinced manufacturers that the standards establish a helpful framework for designing safe machines.

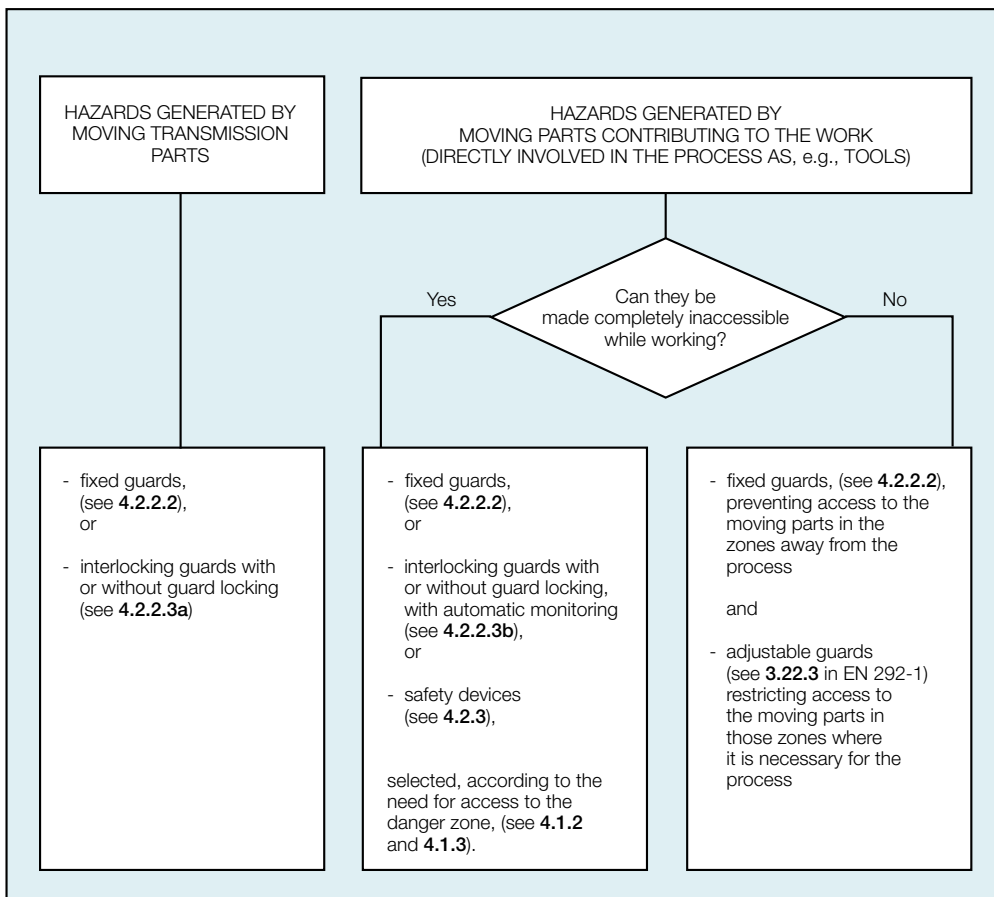


Fig. 3.2 EN 292-2 provides information on how to incorporate safety into a machine, such as this diagram for choosing safeguards.

Familiarization with the basic concepts of machine safety
Read and understand the Machinery Directive
 Review other Directives for applicability

3.2

The Directives

From the definition of “machinery,” to a machinery manufacturer’s ability to demonstrate conformity, to applying the CE marking, the Machinery Directive sets forth the laws with which all manufacturers must comply. Although moderately long (see Figure 3.3) and written like a legal document, all manufacturers must read the Machinery Directive. It is the law, and ignorance of the law is no excuse for failing to comply.

Articles 1-14 of the Machinery Directive are written in legal jargon. Conversely, Annexes I-VII of the Machinery Directive are relatively easy to follow. The Annexes are very important, and particularly Annex I, which covers Essential Health and Safety Requirements (EHSRs).

After the Machinery Directive, manufacturers must review other directives for applicability (note: multiple directives often apply). The three directives most likely to apply to machinery using control products are the Electromagnetic Compatibility (EMC) Directive (89/336/EEC), the Low Voltage (LV) Directive (73/23/EEC), and the Product Liability (PL) Directive (85/374/EEC).

There are also directives for batteries, explosive atmospheres, simple pressure vessels, personal protection equipment and dangerous substances.

Interpreting the Machinery Directive

To clarify the Machinery Directive, the Fédération Européenne de la Manutention (FEM, a federation of manufacturers) has produced a document which quotes the directive, provides valuable comments and lists notified bodies. This document is titled, “Interpreting the machinery directive and affixing the CE mark.” To order, contact FEM at Kirchenweg 4, CH-8032 Zürich, Switzerland. Phone: 011-41-1-384-48-44. Fax: 011-41-1-384-48-48.

Contents of the Machinery Directive

Foreword

Introduction

Glossary of terms

Summary of Machinery Directive

The EC Machinery Directive (89/392/EEC) with amendments and interpretations

Recitals

Article 1: *Scope of the directive*

Article 2: *Primary obligation of the member states*

Article 3: *Obligation of the manufacturer*

Article 4: *Free movement of machinery*

Article 5: *Use of standards as a means of assuring conformity*

Article 6: *Establishment of committees to deal with matters related to the directive*

Article 7: *Establishment of the authority of member states to review conformance of machinery*

Article 8: *Requirements of the manufacturer to demonstrate conformity*

Article 9: *Establishment of the authority of member states to designate Notified Bodies*

Article 10: *CE marking*

Article 11: *Notification and rights of manufacturer in case of claim of non-conformity by member states*

Article 12: *Availability of information on all relevant decisions*

Article 13: *Effective date and transition periods*

Article 14: *Repeal of conflicting directives*

Annex I: *Essential Health and Safety Requirements*

Annex II: *Contents of the EC declaration of conformity*

Annex III: *CE marking (replaced by 93/68/EEC)*

Annex IV: *Types of machinery and safety components for which the procedures in article 8 must be applied*

Annex V: *EC declaration of conformity*

Annex VI: *EC type examination*

Annex VII: *Minimum criteria to be taken into account by member states for the notification of bodies*

Fig. 3.3

3.3

EMC Directive

Apparatus must comply with the EMC Directive when it is liable to cause electromagnetic disturbances or its performance is liable to be affected by such disturbances. This is particularly true if the disturbance results in a sudden risk increase, which then becomes a safety issue (e.g., initiation of an unexpected motion as the result of an inductive proximity sensor triggering “On” accidentally).

The EMC Directive states that all “apparatus” placed in the EU/EEA market shall be constructed so that:

- *“The electromagnetic disturbance it generates must not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended.”*
- *“The apparatus has an adequate level of intrinsic immunity to electromagnetic disturbance to enable it to operate as intended.”*

Most products that make use of electrical energy generate, or are susceptible to, electromagnetic fields. Annex III of the EMC Directive states that electromagnetic disturbance generated by a product should especially not hinder apparatus such as: industrial manufacturing equipment, mobile radio equipment, telecommunications networks and apparatus, information technology equipment, domestic appliances, and lights and fluorescent lamps. Though not called out in the directive, be especially aware of the effects of motors and electric drives, “crosstalk” between power cables, and inadequate or improper grounding.

3.4

The Low Voltage Directive

This directive applies to equipment where the risks are mainly electrical in origin. It covers equipment (including components and assemblies) which operate at 50-1000V AC or 75-1500V DC. The Low Voltage Directive states that, when installed and operated as intended, equipment of this type must not endanger the safety of persons, domestic animals or property. Designers should review Annex I of the Low Voltage Directive, which sets out principle safety objectives.

The Product Liability Directive

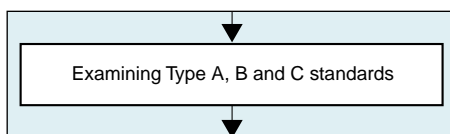
This directive, which addresses liability for defective products, states that the injured persons shall be required to prove the damage, the defect(s) and the causal relationship between the damage and the defect(s). The directive also states that a product is defective when it does not provide the safety a person is entitled to expect, taking all circumstances into account. Further, a product shall not be considered defective for the sole reason that a newer product is subsequently put into circulation.

The Product Liability Directive sets forth circumstances under which a manufacturer shall not be liable:

- That he did not put the product into circulation
- The defect which caused the damage did not exist at the time when the product was put into circulation
- The product was not manufactured for sale for any form of distribution for economic purposes
- The defect is due to compliance of the product with mandatory regulations
- The state of scientific and technical knowledge at the time when the product was put into circulation was not such as to enable the detection of the defect
- In the case of a component used within a product, the defect can be attributed to the design of the product or the instructions provided with the product

Know EMC and LV

Though not the focus of this book, the EMC and Low Voltage Directives often impact machine design quite significantly. Machine builders should thoroughly understand the requirements of these directives.



3.6

Examining Type A, B and C Standards

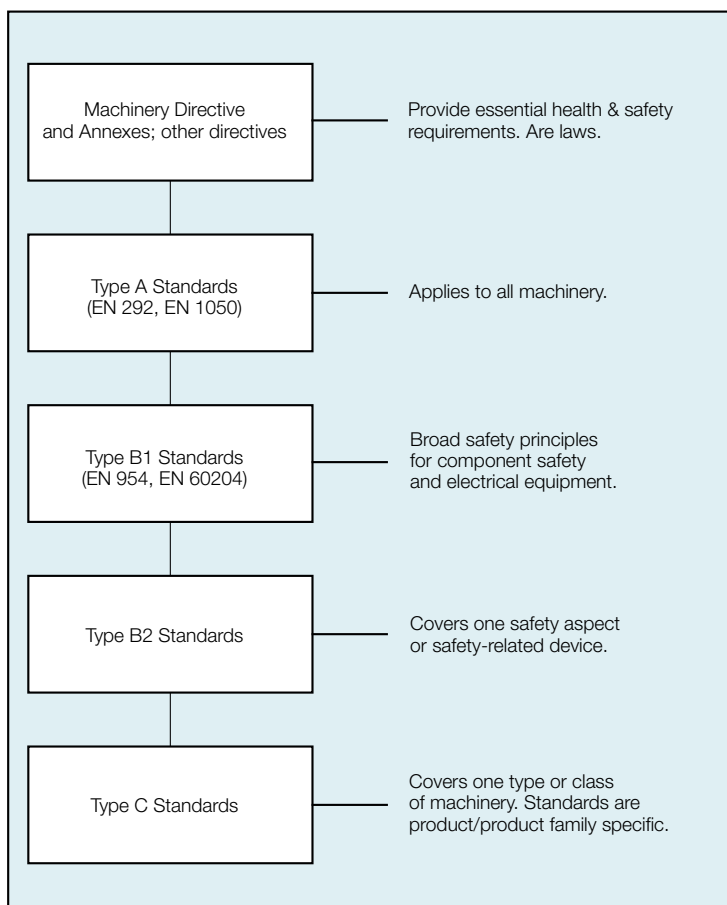


Fig. 3.4 Hierarchy of directives and standards.

CEN/CENELEC divides the EN standards into three groups according to the subject(s) they cover and also makes them hierarchical in nature (see Figure 3.4). To obtain CE marking, manufacturers must determine which standards apply to their products, then review and apply the appropriate ones.

Type A standards cover fundamental safety standards, apply to all types of machinery, and are essential reading. The two most important Type A standards for manufacturers to review are *EN 292 Safety of machinery* (discussed in section 3.1) and *EN 1050 Safety of machinery — Principles for risk assessment* (discussed in section 3.8).

Type B standards are group standards and deal with only one safety aspect or one type of safety-related device (which can be used on a wide range of machinery; see Appendix A of this book for a selected list of B standards). The Type B standards fall into two classes, B1 and B2.

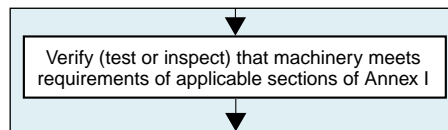
B1 standards deal with one particular safety aspect, such as the effectiveness of safety functions, safety distances, hand/arm speed, noise, etc. The two most encompassing Type B1 standards are *EN 60204-1 Safety of machinery — Electrical equipment of machines*, and *EN 954-1 Safety of machinery — Safety related parts of control systems [Part 1: General principles for design]*. Appendix B of this book provides an electrical equipment checklist (based on EN 60204-1) that will help designers conform with the standard.

B2 standards deal with safety-related devices (e.g., interlocks, emergency stops, various safety switches, two-hand controls, proximity devices — again, see Appendix A). If manufacturers use one of these safety devices on a machine, then the device must be designed and applied according to the relevant standard.

EN 60204 electrical checklist

EN 60204-1 (which is comparable to IEC 204) provides a very comprehensive list of electrical equipment design aspects to which manufacturers should adhere. Appendix 2 of this book provides a checklist for designers based on this standard, as well as an “inquiry form” that OEMs should give to end-users of electrical equipment.

While Type A and B standards cover most types of machines and relevant safety standards, Type C standards give detailed safety requirements for specific types of machines. Type C standards are based on applicable sections of relevant Type A and Type B standards, but the Type C standards may deviate from them where appropriate or necessary.



3.7

Annex I — Essential Health and Safety Requirements

Before building a machine, all designers must thoroughly familiarize themselves with the Essential Health and Safety Requirements (EHSRs) found in Annex I of the Machinery Directive.

This law states that “*Machinery must be so constructed that it is fitted for its function, and can be adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen by the manufacturer. The aim of measures taken must be to eliminate any risk of accident throughout the foreseeable lifetime of the machinery, including the phases of assembly and dismantling.*”

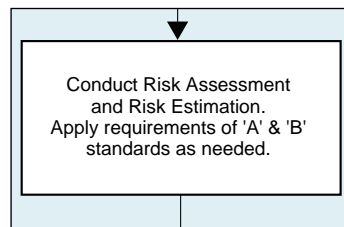
Annex I sets forth laws on:

- Controls: reliability, starting and stopping, energy isolation, control failures
- Protection against mechanical hazards
- Protection against other hazards: electricity, temperatures, fire, explosion, tripping, falling, and others
- Maintenance
- Indicators: warning, marking, instructions

See Appendix C for a more complete listing of EHSRs.

Annex I epitomizes the EU's common sense approach to safety. For example:

- *After an interruption or fluctuation in...the power supply...the machinery must not start unexpectedly.*
- *A fault in the control circuit logic, or failure of or damage to the control circuit must not lead to dangerous situations.*
- *Movable guards must be designed and incorporated into the control system so that moving parts cannot start up while they are within the operator's reach.*



3.8

Risk assessment — EN 1050

Risk assessment is a series of logical steps to enable, in a systematic way, the examination of hazards associated with machinery; it is then followed (when necessary) by risk reduction. Repeating this process eliminates hazards and/or implements safety measures as far as possible. Refer back to Figure 3.1 for a schematic representing this strategy.

EN 1050, a Type A standard, describes principles for a consistent, systematic procedure for risk assessment, and it gives guidance for making decisions during the design of machinery. The five basic components (or steps) of EN 1050 are:

1. Determination of the limits of the machinery. Refer to EN 292.
2. Hazard identification. Refer to Annex A of EN 1050 for examples of hazards; Annex B describes methods for the systematic analysis of hazards (Failure Mode and Effects Analysis, etc.).

3. Risk estimation (described in detail in section 3.9)
4. Risk evaluation — determine if risk reduction is required or whether safety has been achieved. If risk reduction is required, reduce risk by design, safeguarding and/or informing operators.
5. Documentation — demonstrate the procedure followed and results achieved.

3.9

Risk estimation — EN 1050 and EN 954

Since all machinery containing identified hazards presents a risk, machine designers must be able to evaluate the risk. In turn, this will allow designers to employ appropriate levels of safety measures.

The risk associated with a particular situation or process can be represented in an equation where: Risk = Severity + Probability + Frequency. Figure 3.5 gives **guidance only** (it is not a substitute for meeting the standard) for helping the designer to choose a category based on risk assessment.

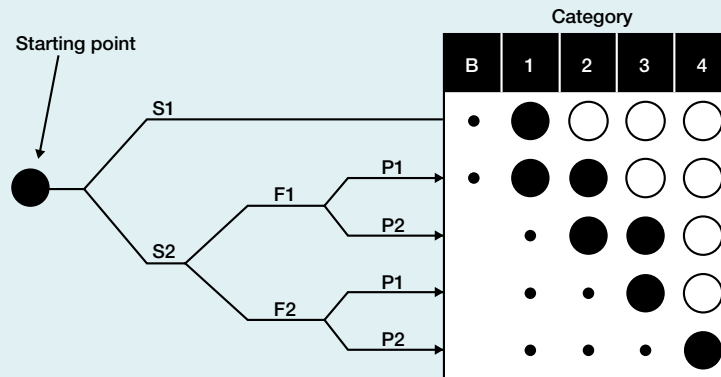
Estimate the severity (possible degree of harm) by considering the:

- Severity of injury:
 - S1** Slight (normally reversible) injury or damage to health
 - S2** Serious injury or damage to health (normally irreversible, including death)

Estimate the probability of harm occurring by considering the:

- Frequency and duration of exposure:
 - F1** Seldom to quite often and/or short exposure time
 - F2** Frequent to continuous and/or long exposure time
- Possibility to avoid or limit the harm
 - P1** Possible under specific conditions
 - P2** Scarcely possible

When a hazardous situation occurs, P1 should only be selected if there is a realistic chance of avoiding an accident or of significantly reducing its effect. P2 should be selected if there is almost no chance of avoiding the hazard.



Category selection

B, 1 to 4 Categories for safety related parts of control systems

- Preferred categories for reference points
- Possible categories which can require additional measures
- Measures which may be overdimensioned for the relevant risk

Fig. 3.5 Guidelines for risk estimation from EN 954-1, Annex B.

NOTES: 1. Annex B is informative, not normative. The correct use of EN 954-1 requires attention to ALL of its clauses, not just the requirements for its categories.

2. Two common misconceptions occur with the categories noted in EN 954-1: that they represent levels of risk and that they are hierarchical. THIS IS NOT TRUE. The categories should be considered as reference points for the performance of a safety-related part of a control system with respect to the occurrence of faults.

3. A weakness of EN 954-1 is that the categories are basically defined in terms of performance under fault conditions. As such, there is no mechanism for culturing the choice of a given performance category by the comparative reliability of differing risk abatement options or technologies. The 1996 version of EN 954-1 is currently being reviewed to address this situation.

Once a hazard is identified, it is important to know if it can be identified by physical means (i.e., watching the machine move) or only by technical means (i.e., indicators). Other important aspects which influence the selection of parameter P (Possibility) include:

- Operation with or without supervision
- Operation by experts or non-professionals
- Speed with which the hazard arises
- Possibilities for avoiding the hazard (reaction time, third-party intervention)
- Practical experience relating to the process
- Probability that the harmful event will occur

3.10

Performance categories — EN 954

Parts of machinery control systems (both hardware and software) are frequently assigned to provide safety functions. A safety-related part of the control system means a part or subpart(s) of a control system which responds to input signals and generates safety-related output signals. The combined safety-related parts of a control system start at the points where the safety-related signals are initiated and end at the output of the power control elements. This also includes monitoring systems.

EN 954 (a Type B1 standard) provides requirements and guidance for designing the safety-related parts of control systems. It describes characteristics of safety functions and specifies performance categories, but it does not specify which safety functions and which categories shall be used in a particular case.

Clause 6.2 of EN 954 states that designers should construct safety-related parts of control systems to meet the requirements of one or more of five performance categories. Figure 3.6 summarizes these requirements and the corresponding behavior expected of the safety function principles.

Further explanation of the category requirements will help machine designers select and/or design safety-related components.

Guide to the Categories for Safety-Related Parts of Control Systems From EN 954-1

Category	Basic Requirements	What is achieved	
		At least	At most
B	Components able to withstand expected influences.	Reliability for normal operation.	Reliability for normal operation.
1	<i>Requirements of cat. B together with:</i> Use of well-tried (e.g., tested or provable) components and safety principles.	Enhanced reliability of the safety function from that of a “normal” device or system.	Elimination of fault possibilities (i.e., high level of safety performance).
2	<i>Requirements of cat. B and the use of well-tried safety principles together with:</i> A safety function check at machine start-up and periodically if required.	Machine can only start when system is safe.	Machine can only start up when system is safe and faults will be detected by a frequent check (i.e., high level of safety performance).
3	<i>Requirements of Cat. B and the use of well-tried safety principles together with:</i> A single fault will not cause a loss of safety function.	<ul style="list-style-type: none"> • Detection of some single, <i>safety-critical</i> faults at the next demand on the safety function. • Safety-critical faults can accumulate between demands on the safety function. • Non-detected, non-safety critical faults can accumulate and cause loss of safety function. 	Detection of <i>ALL</i> single faults (safety-critical and non-safety critical) as they occur (i.e., high level of safety performance when it is not feasible to expect multiple independent faults to accumulate within the checking period).
4	<i>Requirements of cat. B and the use of well-tried safety principles together with:</i> Assimilation of faults will not cause a loss of safety function. (the number of faults in accumulation to be considered is normally two but may be more depending on the application circumstances).	<ul style="list-style-type: none"> • Detection of single faults in time to prevent the loss of safety function. • Foreseeable combinations of faults will not cause loss of safety functions. 	<ul style="list-style-type: none"> • Detection of single faults immediately. • No combinations of faults will cause loss of safety functions (this is the ideal but rarely achieved in practice). High level of safety performance.

NOTES: 1. If, as a consequence of a fault, further faults occur, all the linked faults shall be considered as a single fault.

2. Common mode faults are regarded as a single fault.

3. The occurrence at the same time of two independent faults is not considered.

Guide to the Categories for Safety-Related Parts of Control Systems From EN 954-1

Category	Factors affecting the degree of performance	Typical techniques	Validation methods
B	Availability of standards, test data, etc.	Use of materials and components conforming to recognized standards, etc.	Check specifications for conformity and suitability
1	The simplicity or complexity of the system and principle (i.e., fewer components means fewer potential modes of failure and more viable validation).	<ul style="list-style-type: none"> • Positive mode operation, life testing, oriented failure mode (e.g., defined weak link - relevant to simple (e.g., mechanical) equipment • Validation measures are usually too involved or not possible for more complex (e.g., electronic) equipment. 	<ul style="list-style-type: none"> • Fault analysis (e.g., Failure Mode and Effects Analysis or Fault Tree Analysis) • Testing. • Checking of safety margins.
2	The frequency and nature of the check (i.e., more frequent checks allows less time for faults to remain undetected).	Simulation of device actuation and functional check by machine control system or dedicated monitoring unit with start interlock.	Theoretical analysis and/or testing.
3	The frequency and nature of the check (i.e., more frequent checks allows less time for faults to accumulate).	<ul style="list-style-type: none"> • Dual contact (or two separate) devices linked by two circuits to a separate unit which compares operation of each circuit at change of state • Suitable where some faults cannot be prevented and there is relatively frequent actuation —particularly relevant to electro-mechanical technology. 	Theoretical analysis and/or testing.
4	The simplicity or complexity of the system and principle (i.e., fewer or simpler components mean fewer fault combination permutations).	Dynamic techniques. Relevant to equipment which must be complex to perform its primary task. Particularly relevant to electronic technology.	Theoretical analysis and/or testing.

Category B

No special measures for safety apply to parts complying with category B. The parts, when applied according to their specifications, should be able to withstand the expected operating stresses (e.g., load, number of operating cycles), the influence of material processed (e.g., detergents in a washing machine), and the relevant external influences (e.g., vibration, power disturbances).

Category 1

A well-tried component for a safety-related application is a component which has been: 1) widely used in the past with successful results in similar applications; or 2) made and verified using principles which demonstrate its suitability and reliability for safety-related applications. In some well-tried components, certain faults can be excluded because the fault rate is known to be very low.

Well-tried safety principles are, for example:

- avoidance of certain faults; e.g., avoidance of short circuit by separation
- reducing the probability of faults; e.g., over-dimensioning or underrating of components
- orienting the mode of fault; e.g, by ensuring an open circuit when it is vital to remove power in the event of fault
- detecting faults very early
- restricting the consequences of a fault; e.g., grounding of equipment

Newly-developed components and safety principles may be considered equivalent to “well-tried” if they fulfill the above mentioned conditions.

Note: On the level of single electronic components alone, it is not normally possible to meet category 1 requirements. See Appendix D for a list of some significant faults and failures for various technologies.

Safety categories ≠ Safety hierarchy

Designers should note that performance categories do not indicate a safety hierarchy (i.e., category 4 is not necessarily safer than category 1). Rather, these categories state the required behavior for a safety system in relation to its resistance to faults. Thus, according to the performance category required, machine designers must select safety-related parts on their ability to resist faults (i.e., both reliability and availability of the safety function must be considered).

Safety ≠ reliability

However, designers must not confuse reliability and safety. For example, a system with unreliable components in a redundant structure can provide more safety than a non-redundant system with better components. This concept is important because in applications where the consequences of failure are serious, safety requires the higher priority regardless of the reliability achieved. Designers may want to refer to Annex D of EN 954 for more details.

Category 2

Any check of safety functions (which can be automatic or manual) shall either: 1) allow operation if no faults are detected; or 2) generate an output which initiates control action if a fault is detected. When possible, this output shall initiate a safe state (e.g., prevent starting/restarting if the safety function is not available). When not possible, the output shall provide a warning of the hazard. In some cases, category 2 does not apply because checking cannot be applied to all components, e.g., a pressure switch or temperature sensor.

Category 3

Typical examples of feasible measures for fault detection are the connected movement of relay contacts (i.e., “positive guidance”) or monitoring of redundant electrical outputs. “Feasible” means that fault detection measures, and the extent of their implementation, depends mainly on the consequence of a failure and the probability of the occurrence of that failure. The technology used influences the possibilities for implementing fault detection.

Category 4

Fault review may be stopped when the probability of further faults occurring is sufficiently low. The number of faults considered “sufficiently

3

low” varies. For example, in the case of complex microprocessor circuits, a large number of faults can exist. Conversely, in an electro-hydraulic circuit, two or three faults can be sufficient to initiate a safety action.

Fault review may be limited to two faults in combination when: the fault rates of the components are low AND the faults in combination are largely independent of each other AND the faults have to appear in a certain order to jeopardize the safety function.



When making purchasing decisions, consider that well-trying components help meet category 1 and higher requirements.

Risk, performance and selection

To help further guide the designer on how to relate risk and anticipated performance when selecting a performance category, consider three examples.

For the first example, imagine a two-hand control used in connection with a large power press. Risk analysis has determined that if the two-hand control fails it could initiate a power stroke resulting in amputation or death. This extreme risk requires a high performance level for that part of the control system and, in most cases, dictates meeting category 4 requirements.

The second example is a two-hand control used on a packaging machine where the possible severity of injury is not more than a severe cut or bruise with a low to medium probability of occurrence. The minimum performance level for this “medium risk” would be lower than required for the large power press, and meeting category 2 requirements would likely suffice (and depending on design and product selection, category 1 might be sufficient).

The third example is a simple machine used to stake on wire terminals. Any injury that could occur is slight, and the probability of that occurring is low. A less-sophisticated category 1 performance level might be acceptable.

The point of these examples is that it is probably not necessary to select a category 4 performance level when the risk is low. However, even a “well-designed” category 1 system probably cannot be expected to provide the required minimum performance level for high risk machinery. Further, do not assume that a well-designed system meeting category 4 requirements provides adequate safety for a high risk situation. Designers must make a risk evaluation and determine whether there is a need to provide other means of safeguarding (e.g., fixed barriers).

Summary

By using EN 1050 and EN 954, the machine designers' objective is to ensure that the safety-related parts of a control system produce outputs which can achieve risk reduction objectives. The process for selecting and designing safety measures takes five steps.

Step 1: Hazard analysis and risk assessment

- Identify the hazards present at the machine during all modes of operation and at each stage in the life of the machine by following the guidance in EN 292-1 and EN 1050.
- Assess the risk arising from those hazards and decide the appropriate risk reduction for that application in accordance with EN 292-1 and EN 1050.

Step 2: Decide measures for risk reduction by control means

- Determine the design measures at the machine and/or the provision of safeguards to provide the risk reduction. Those parts of the control system which contribute as an integral part of the design measures and/or in the control of the safeguards shall be considered safety-related parts.

Step 3: Specify safety requirements for the safety-related parts of the control system

- Specify the safety functions to be provided in the control system [Appendix E provides a list of typical safety functions which can be provided by the safety-related parts of a control system. The list also references the relevant parts of standards.]
- Specify how the safety functions will be realized and select the category(ies) for each part and combinations of parts within the safety-related parts of the control system.

Step 4: Design

- Design the safety-related parts of the control system according to the specification developed in step 3 and to the general strategy for design. List the design features included which provide the design rationale for the category(ies) used.
- Verify the design at each stage to ensure that the safety-related parts fulfill the requirements from the previous state in the context of the specified safety function(s) and category(ies).

Step 5: Validation

- Validate the achieved safety functions and category(ies) against the specifications in step 3. Re-design as necessary.
- When programmable electronics are used in the design of safety-related parts of the control systems other detailed procedures are required (see Notes 1 and 2).

Note 1: It is believed at present that it is difficult to determine with any degree of certainty, in situations when a significant hazard can occur due to the malfunction of the control system, that reliance on correct operation of a single channel of programmable electronic equipment can be assured. Until such time that this situation can be resolved, it is inadvisable to rely on the correct operation of a single channel device (according to 11.3.4 of EN 60204-1).

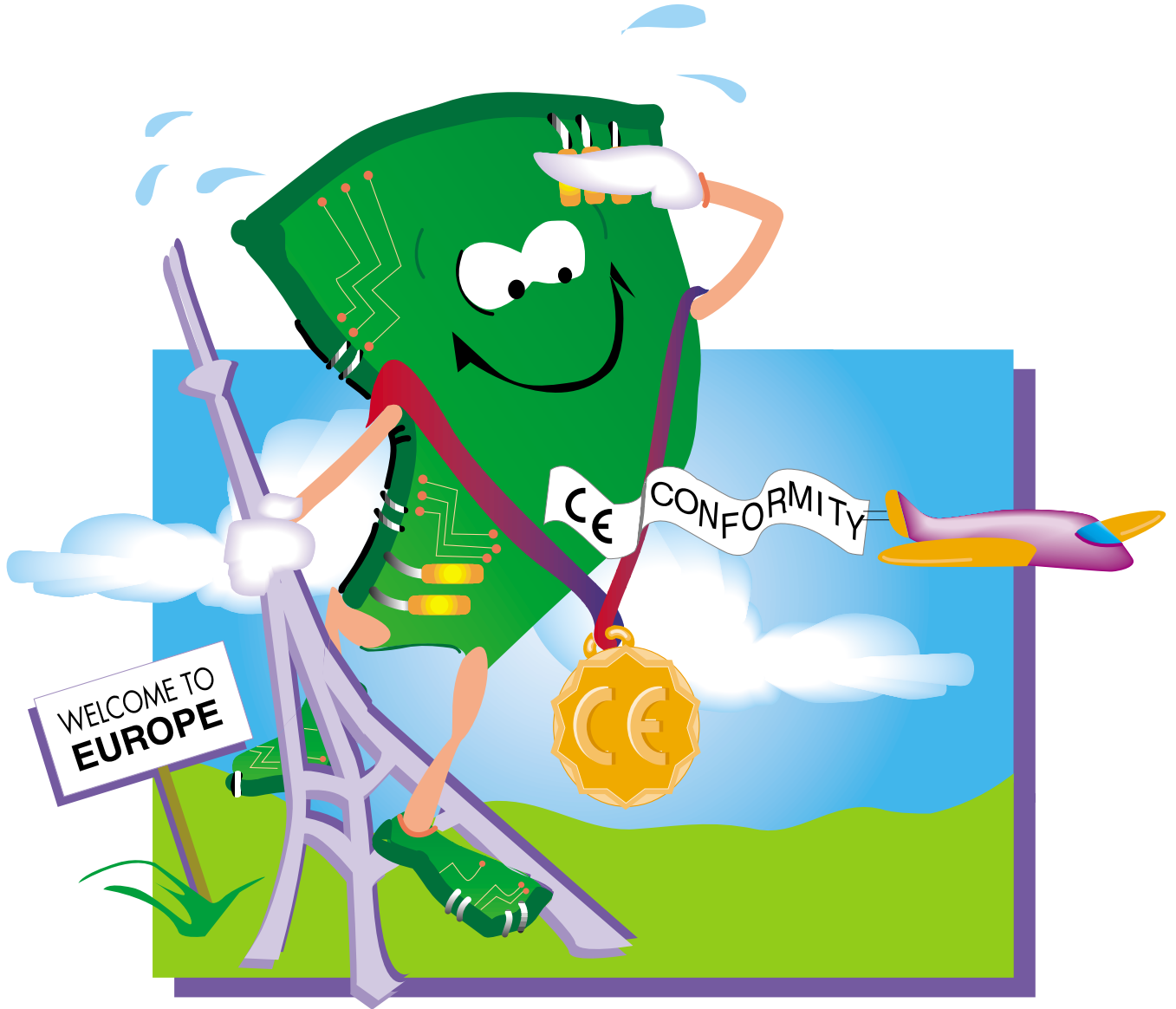
Note 2: A proposed international standard, IEC 1508, may provide more guidelines for the functional safety of programmable electronic systems when such systems are used as safety-related systems.

To facilitate the design process, Annex A of EN 954 lists some important aspects to consider during the design process. These are:

1. What reaction is required from the safety-related parts of the control systems(s) when faults occur?
 - a) No special action required.
 - b) Safe reaction required within a certain time.
 - c) Safe reaction immediately required.
2. In which safety-related part(s) of the control system should faults be assumed?
 - a) Only in those parts in which (by experience) faults occur relatively often; e.g., in the peripheral sensors and wiring.
 - b) In auxiliary parts.
 - c) In all safety-related parts.
3. Have both random and systematic faults been considered?

4. Which faults should be assumed in the components of the safety-related parts of the control system?
 - a) Faults only in components which are not well-tried. [“Well-tried” not in the sense of reliability, but from the view of safety.]
 - b) Faults in all components.
5. Has the correct reference category been selected as it relates to the requirement for detecting faults?
 - a) Normal requirements for fault detection. [This means that all faults which can be detected with relatively simple methods should be detected.]
 - b) Strong requirements for fault detection. [This means that techniques should be used which enable most of the faults to be detected. If this is not reasonably practical, combinations of faults should be assumed (fault accumulation).]
6. What shall be the next action of the control system if a fault has been detected?
 - a) The machine should be brought to a predetermined state as required by the risk assessment.
 - b) Further operation of the machine can be permitted until the fault is rectified.
 - c) The indication of the fault(s) is sufficient (e.g., warning signal by Visual Display Units (VDU)).
7. What is necessary to meet the maintenance requirement?
 - a) Provision of information about the effects of deviations from design specifications.
 - b) Automatic indication of the need of maintenance.
 - c) Setting of maintenance intervals.
 - d) Setting of component life.
 - e) Provision of diagnostic facilities and test points.
 - f) Special precautions for safety during maintenance.

8. What methods should be used for fault detection?
 - a) Automatic fault detection, as far as it is appropriate.
 - b) Manual fault detection; e.g., by periodic inspection.
 - c) By more than one method.
9. Has the risk reduction been achieved?
 - a) Can the risk reduction be achieved more easily with a different combination of risk reduction measures?
 - b) Check that the measures taken . . .
 - do not reduce the ability of the machine to perform its function,
 - do not generate new, unexpected hazards or problems.
 - c) Are the solutions valid for all operating conditions and for all procedures?
 - d) Are these solutions compatible with each other?
 - e) Is the safety specification correct?
10. Have ergonomic principles been considered?
 - a) Are the safety-related parts of the control system, including the protective devices, easy to use?
 - b) Is there safe and easy access to the control systems?
 - c) Are warning signals given priority (e.g. highlighted)?
11. Have the relationships between safety, reliability, availability and ergonomics been optimized in such a way that the safety measures will be maintained during the lifetime of the system, and does not tempt personnel to defeat the safety functions?



CE conformity is your passport to the European market, but you still must create a “Technical File,” produce and sign a “Declaration of Conformity” and adhere to other EU rules.

Post Design and Construction Requirements

So you've complied with requirements — now what?	4.0
Information for use	4.1
Advice for drafting information for use.	4.2
The Technical File.	4.3
Declaration of Conformity	4.4
Can you self-certify?.	4.5
CE marking	4.6

4

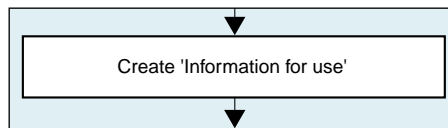
4.0

So you've complied with requirements — now what?

After building a machine and verifying that it complies with the directives and standards, manufacturers need to complete five more steps before affixing CE marking:

1. Create “information for use”
2. Generate a “Technical File”
3. Submit a product sample to a Notified Body, or learn if the product does not have to be submitted to a Notified Body
4. Create the “Declaration of Conformity”
5. Learn how to properly apply CE marking

While much easier and quicker to absorb than the previous material (it's downhill from here!), the post-design and post-construction portions of the directives are still law and, importantly, still contribute significantly to safety.



4.1

Information for use

Creating good “information for use” — instructions for using the machinery — contributes significantly to the safety of machinery. Annex I, clause 1.7.4 of the Machinery Directive states that all machinery must be accompanied by instructions that cover items such as the foreseen use of the machinery; workstation(s) likely to be occupied; instructions and diagrams for safe: putting into service, use, handling, assembly, dismantling, adjustment, and maintenance; and a repeat of information with which the machine is marked.

The Machinery Directive mandates that, on being put into service, instructions accompanying the machinery must be in the language(s) of the country in which the machinery is to be used (this is in addition to instructions in the manufacturer's native language). Further,

Directions and Safety

Machine manufacturers should provide directions for safe and correct use of the machine. The directions and information must not compensate for design deficiencies.

when manufacturers source components from other companies, they must obtain all necessary instructions from suppliers and incorporate those instructions into their own instructions in a logical manner. For example, take the instructions for a piece of machinery using a DC motor with brushes. Motor maintenance procedures and schedules should be included as an integral part of the entire machine's maintenance instructions. Including a line such as "Motor maintenance — see accompanying motor manual" and attaching the motor supplier's owner manual at the end of machinery instructions is generally not sufficient.

Clause 5 of EN 292-2 also details requirements for "information for use." It recommends that instructions contain information in basic areas, e.g., modes for stopping the machine, fault identification and location, nature and frequency of maintenance, permissible environmental conditions, etc. Further, it specifically discusses the location of information (i.e., on the machine itself if the risk warrants); signals and warning devices; markings, signs (pictograms) and written warnings; and accompanying documents (e.g., the instruction handbook).

4.2

Advice for drafting information for use

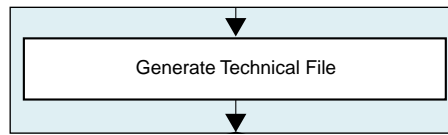
- a) The information for use must clearly relate to the specific model of machine.
- b) When information for use is being prepared, the communication process "see - think - use"

should be followed in order to achieve the maximum effect and should follow sequential operations. The questions “How?” and “Why?” should be anticipated and the answers provided.

- c) Information for use must be as simple and as brief as possible, and should be expressed in consistent terms and units with a clear explanation of unusual technical terms.
- d) When it is foreseen that a machine will be put to non-professional use, the instructions should be written in a form that is readily understood by the non-professional users. If personal protective equipment is required for the safe use of the machine, clear advice should be given and this information must be prominently displayed at the point of sale; e.g., on the packaging as well as on the machine.
- e) Documents giving instructions for use should be produced in durable form (i.e. they should be able to survive frequent handling by the user). It may be useful to mark them “keep for future reference.”



A “Technical File” is the principle means of assessing conformity. Only national authorities of an EU/EEA country have the right to see it.



4.3

The Technical File

Before drawing up the EC declaration of conformity, the machine builder must ensure that certain technical documentation is available for inspection purposes. This documentation is called a “Technical File” (TF), and it is a principle means of assessing product conformity. The TF must contain the following:

- A. An overall drawing of the subject equipment.
- B. Full detailed drawings, accompanied by any calculations, notes, test results, etc., required to check the conformity of the equipment with the EHSRs.
- C. A list of the essential requirements of the Machinery Directive, standards, and other technical specifications, which were followed when the equipment was designed.
- D. A description of methods adopted to eliminate hazards presented by the equipment.
- E. If essential, any technical report or certificate obtained from a competent testing body or laboratory.
- F. Any technical report giving the results of tests carried out internally by engineering or others.
- G. Documentation and test reports on any research or tests on components, assemblies and/or the complete product to determine and demonstrate that by its design and construction the product is capable of being installed, put into service and operated safely.
- H. Determination of the foreseeable lifetime of the product.
- I. A copy of the instructions for the product (Instruction Manuals/Instruction Books).
- J. For serial manufacturing, the internal measures that will be implemented to ensure that the equipment will continue to be manufactured in conformity with the provisions of the Machinery Directive and other applicable directives.

4

- K. Engineering Reports.
- L. Laboratory Reports.
- M. Bills of Material.
- N. Wiring Diagrams.
- O. Sales Order Engineering Files.
- P. Hazard Evaluation Committee Reports, if executed.
- Q. Change Records.
- R. Customer Specifications.
- S. Any Notified Body Technical Reports and Certification Tests (if applicable).
- T. Copy of the Declaration of Conformity.

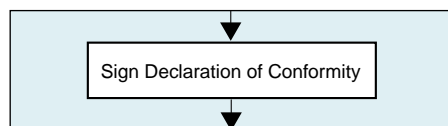
Testing components

Machine manufacturers must evaluate the applicability of components and fittings on the completed machine to determine if the machine can be put into service safely. This helps to ensure that machine manufacturers cannot pass on safety responsibilities to their vendors. For companies that manufacture a series of machines, the company must show the measures it plans to use to ensure that the machinery remains in conformity.

Important items to note about the TF:

- The documentation noted above need not permanently exist in the TF. However, the manufacturer must be able to assemble the documentation (or specific portions of it) and make it available within a period of time commensurate with its importance (one week is considered a reasonable time). As a minimum, each machinery TF must physically contain an index of the applicable documents or material listed above.
- The TF may be in hard copy or software form (provided that the software form can be easily reproduced in hard copy).

- Only the National Authorities (duly authorized agents of member states) have the right to see the contents of the TF. The National Authority must specify what portion of the TF is required and a suitable reason for the request. The Directive does not give the client (user) or others the right to see the file.
- The Technical File must be maintained at the location of the product (machinery) design.
- The TF (including all documentation) must be retained and kept available for 10 years following the date of placing the product in the EU or from the last unit produced in the case of series manufacture.
- The TF must be drawn up in one of the official languages of the EU: English, French or German.
- The EU is currently considering a proposal whereby EU inspection authorities should accept subdivision of the TF into two parts. The first part (A) would consist of a summary of the essential technical data relevant to the conformity assessment procedures (in particular: a product description; the list of harmonized standards followed and/or solutions adopted to satisfy EHSRs; operating instructions, if any; and a blueprint/product plan, if any). The second part (B) would consist of a full file of all data.



4.4

Declaration of Conformity

The EC Declaration of Conformity (DOC) is the procedure by which manufacturers declare that the machinery being placed on the market complies with all the Essential Health and Safety Requirements (EHSRs) applying to it. Signing the DOC authorizes

4

the manufacturer to affix the CE marking to the machinery. A copy of the DOC must accompany each product sold.

Contents of the DOC include:

- A. Name and address of the manufacturer.
- B. Description of the machinery.
- C. Where appropriate, the name and address of the Notified Body and the number of the EC type examination certificate.
- D. Where appropriate, the name and address of the Notified Body to which the file has been forwarded in accordance with Article 8 (2) (c) of the Machinery Directive.
- F. Where appropriate, a reference to the harmonized standards.
- G. Where appropriate, the national technical standards and specifications used.
- H. Identification of the person empowered to sign on behalf of the manufacturer or his authorized representative(s) in the EU.

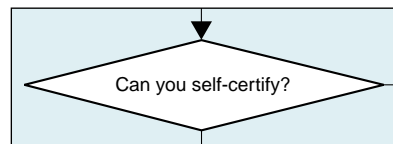
For components that will be incorporated into another machine and do not fully comply with the directives, the manufacturer must make an EC

CE marking & DOC demonstrates conformity

Coupled with CE marking, the DOC indicates that a product complies with the Machinery Directive and all other directives which may apply.

Declaration of Incorporation. This includes providing the same information noted above, as well as a statement that the machinery must not be put into service until it is brought into full compliance, or the machinery in which it is to be incorporated is brought into full compliance.

Manufacturers who offer components for the safety-related parts of control systems must also draw up a DOC, being sure to note the safety function intended if it is not obvious from the description. Samples for all three types of DOCs are given in Appendix F.



4.5

Can you self-certify?

Roughly 95 percent of all manufacturers can self-certify compliance with the directives and standards and affix CE marking without involving a third party (i.e., a Notified Body). To self-declare, manufacturers must: be confident of conformity assessment procedures, provide a TF, make a DOC, and affix CE marking.

The other five percent of manufacturers may have to follow a different procedure. The EU has identified certain types of high-risk machinery (such as presses and saws) and certain safety components (such as logic units and devices designed to detect persons for safety reasons) and listed them in Annex IV of the Machinery Directive (see Appendix G for a complete listing).

Manufacturers of machinery and/or devices listed in Annex IV have two paths to choose from to obtain CE marking.

1) If the manufacturer has fully complied with EHSRs and all relevant standards and is confident of compliance, the manufacturer must either:

- Send a TF to a Notified Body who will A) acknowledge receipt of the file and keep it, or B) verify that the standards are correctly applied and issue a “certificate of adequacy” to that effect. Note that in the case of the former, the Notified Body does not assess the file; it merely keeps it as reference.

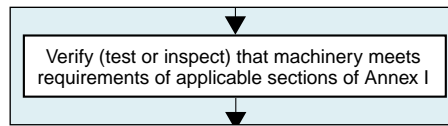
4

- Or, submit an example of the equipment to a Notified Body for an EC-type examination. If the manufacturer has correctly applied the applicable standards, the Notified Body will issue a EC-type examination certificate.

2) If the manufacturer has not fully complied with the EHSRs and relevant standards, or if no relevant standards exist for this type of machinery, the manufacturer must submit an example of the equipment to a Notified Body for an EC-type examination (see Appendix E for a list of information OEMs need to submit for an examination). If the manufacturer has correctly applied the applicable standards, the Notified Body will issue an EC-type examination certificate.



Most manufactures can self-certify conformity with the Machinery Directive.



4.6

CE Marking

Having developed the TF, drawn up a DOC and, if required, passed an EC-type examination, the machinery manufacturer may now legally affix CE marking to its product. CE marking consists of the symbol shown in Figure 4.

If the marking is reduced or enlarged, the proportions given in the drawing below must be maintained. Usually the minimum vertical dimension may not be less than 5 mm, but this may be waived for small-scale machinery.

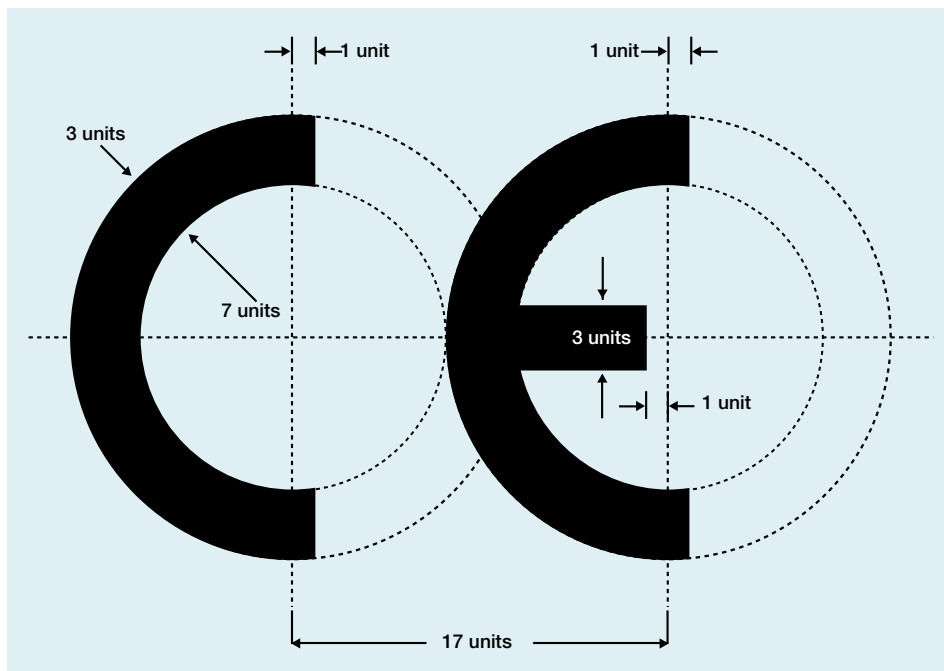


Fig. 4.0 CE marking symbol and its proportions.

Safety Category Requirements

Why include safety and safety-related components?	5.0
Well-tried components and design principles.	5.1
Direct opening action contacts	5.2
Positively driven contacts	5.3
Redundancy	5.4
Normally energized circuits	5.5

Chapters 1 through 4 of this handbook guided readers through the logistics of obtaining CE marking. Now, chapters 5 and 6 will provide information that shows readers how to select and apply control-related products while considering requirements of the directives and standards. Specifically, chapter 5 focuses on the design of safety-related control products, as well as the safety categories introduced in section 3.10. Chapter 6 focuses on the electrical safety of control components.

5.0

Why include safety and safety-related components?

Safety components are included in the Machinery Directive — even though they do not fit the definition of machinery — because there is an important relationship between safety components and machinery.

The definition of safety component is “...a component...which the manufacturer or his authorized representative places on the market to fulfill a safety function when in use and the failure or malfunctioning of which endangers the safety or health of exposed persons.”

Further clarifying this, “A component can be classified as a safety component only if: 1) its omission can endanger the safety or health of a person and 2) the machine could function without them.”

In other words, to be a safety component, the component must have a specific safety function, rather than an operational one. For example, safety relays and two-hand controls are safety components. A machine could equally be operated by other types of components; the safety relays and two-hand controls, as applied by the manufacturer, specifically function to help prevent accidents. Annex IV of the Machinery Directive requires third-party certification for logic units, such as safety relays, and for electrosensitive devices designed to detect and safeguard persons, such as light curtains. However, components generally used in the safety-related parts of control systems, such as gate interlock switches and emergency stop pushbuttons, do not need third-party certification under the Machinery Directive and they are not Annex IV listed.

To minimize risk in case of failure (or put another way, to help ensure the availability of the safety function), the EU standards provide guidance for the design and use of safety components.

5.1

Well-tried components and design principles

Categories 1 through 4 for the safety of control systems require the use of “well-tried components and principles.” Some of these are:

- Direct opening action contacts (positive opening operation); this applies to break contacts (normally closed contacts)
- Positively driven contacts; this applies to devices with make and break contacts (normally open and normally closed contacts)
- Anti-tease features for emergency stop buttons
- Redundancy, diversity and combination of positive and negative modes
- Normally energized circuits for safety functions

5.2

Direct opening action contacts

EN 60947-5-1, which covers electromechanical control circuit devices and switching elements, defines direct opening action as “the achievement of contact separation as the direct result of a specified movement of the switch actuator through non-resilient members (e.g., not dependent upon springs).”

Direct opening action devices couple operating force to the contacts so that the force breaks open contacts that may have welded together (see Figure 5.0). They do not use a spring interface because a spring may have insufficient strength to break a weld or it could fail (see Figure 5.1).

Direct opening action designs are required for disconnect switches, emergency stop switches, safety limit switches, cable pull safety switches and safety gate interlock switches (see Figure 5.2 for some examples). These products will have the symbol for direct opening action on them, shown like this: ⊖

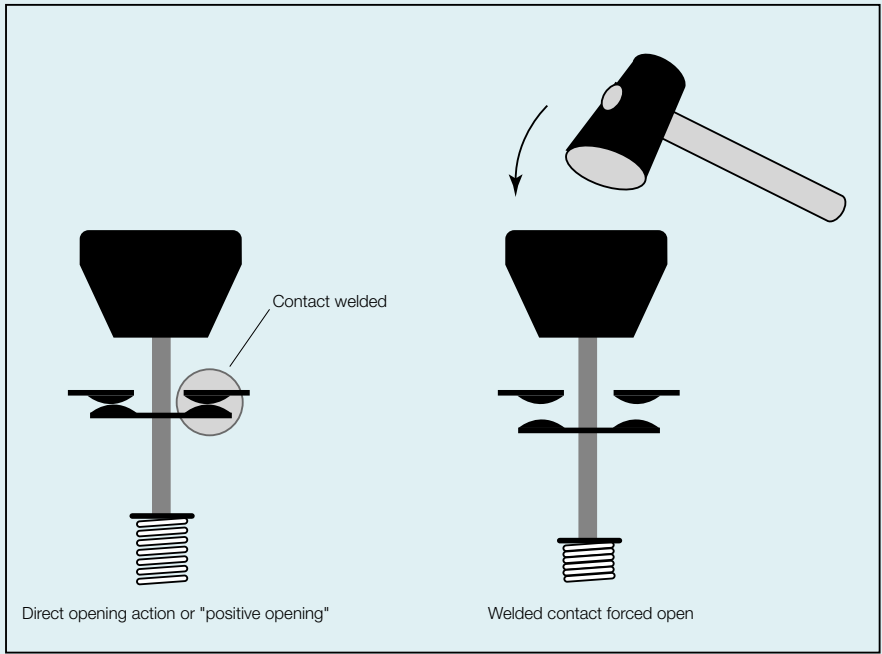


Fig. 5.0 Direct opening action assures safe E-Stop functions.

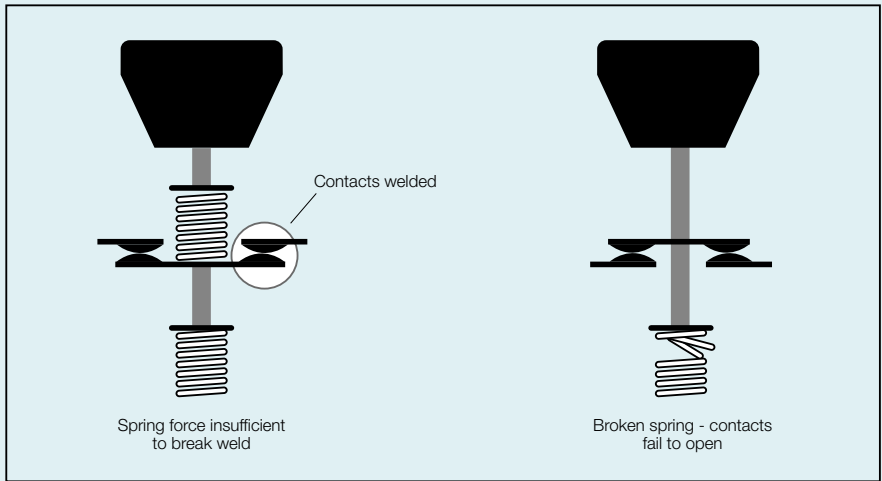


Fig. 5.1 Potential failure modes of "negative opening" contacts.

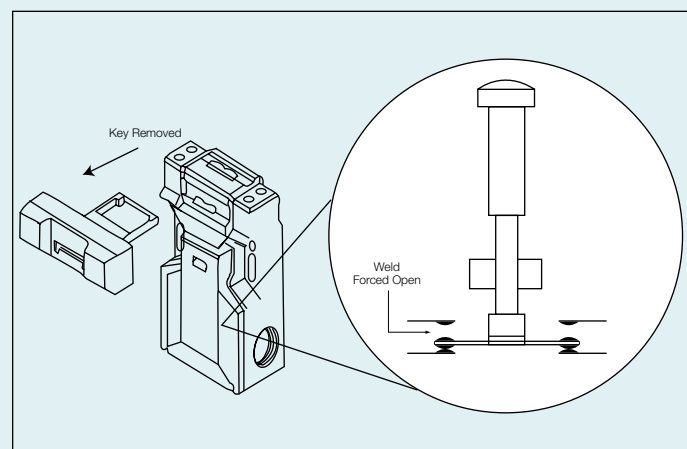
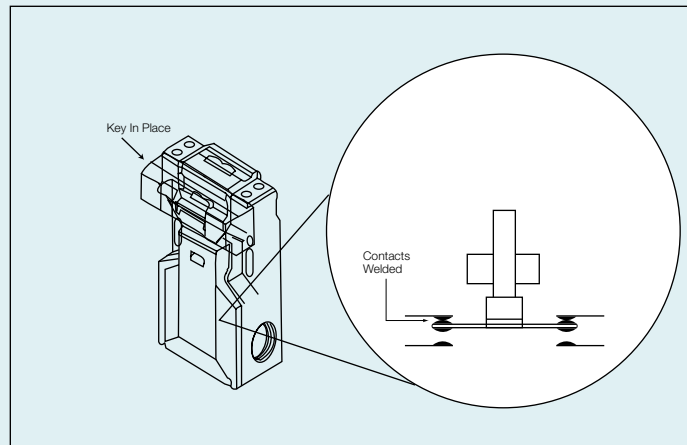
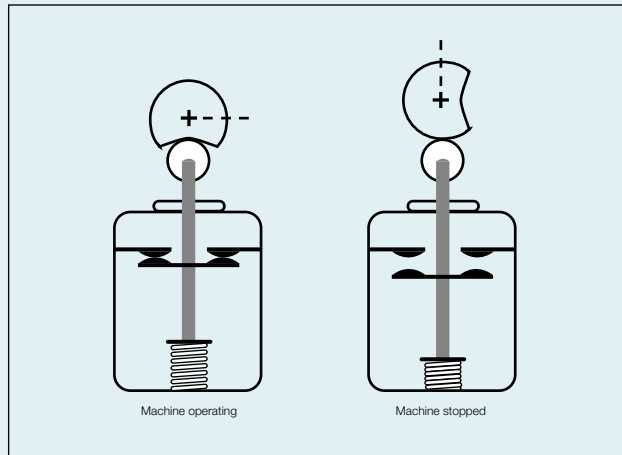


Fig. 5.2 Direct opening action helps assure separation of contacts.

Positively driven contacts

EN 60947-5-1 defines positively driven operation as “*an operation which is designed to ensure that contacts of a mechanical switching device are in the respective positions corresponding to the open or closed position of the main contacts.*”

A draft document of prEN 50205 — “Relays with positively driven contacts” — defines them as “*all-or-nothing relays with a combination of make contacts and break contacts*” where mechanical links ensure that if a Normally Open (NO) contact is closed, then the Normally Closed (NC) contact cannot re-close (see Figure 5.3). If one of the NC contacts stays closed, none of the NO contacts closes. Many standard relays and all safety relays use this technology.

Under all operating and fault conditions, a positively driven relay must have a contact gap of 0.5 mm for single-break contacts and 2 x 0.3 mm for double-break contacts (the gap helps prevent arcing from the stationary contacts to the spanner).

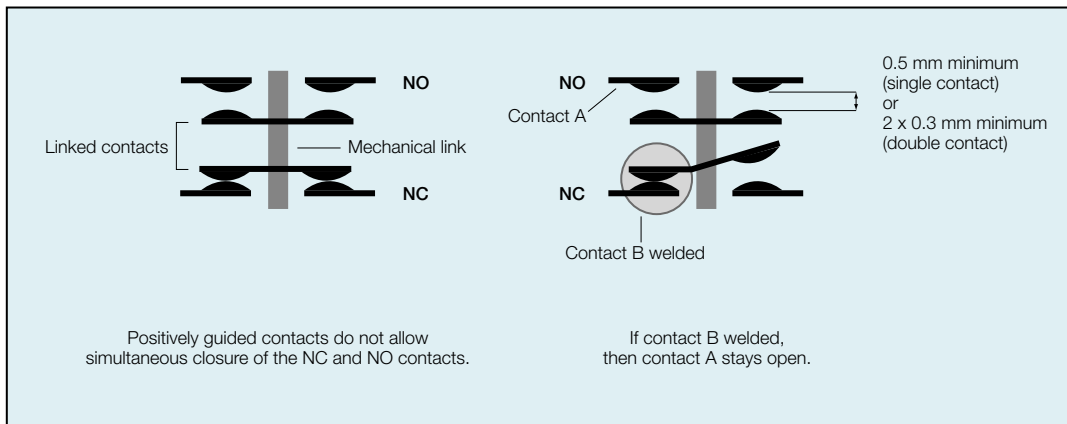


Fig. 5.3 Positively guided relays.

5.4

Anti-tease features

Clause 6.2.1 of EN 60947-5, which covers E-Stops, states that *“it shall not be possible for the emergency stop device to latch-in without generating the emergency stop signal.... In case of failure, the emergency stop device, the generation of the emergency stop signal shall have priority over the latching means.”*

In addition, clause 4.1.1 of EN 418 states that *“any action on the actuator which results in generating the emergency stop command shall also result in the latching-in of the control device so that when the action on the actuator is discontinued, the emergency stop command shall be maintained until the control device is reset (unlatched).”*

These standards require IEC-style E-Stops to provide a means whereby the device’s operator will never be in a latched-in state without the normally closed contact opening. Further, if the contacts are welded or obstructed from opening, the operator should not be allowed to latch.

By convention, manufacturers have used a feature called trigger action to achieve this. Trigger action describes an operator that has a point of no return in its travel, after which the contacts move through their full stroke. Some gate interlock switches also employ a similar “point of no return” feature, and these interlocks are said to be of a “snap acting” design.

5.5

Redundancy

Using devices with different operating principles or using more than one device to perform a control function increases circuit reliability. This is called redundancy, and it is a good design practice that can fulfill category 2 and 3 functions for the safety of control circuits.

Figure 5.4 shows a sliding guard which closes off gears. Notice how it helps avoid failures of the same kind by combining a limit switch with a positive mode NC contact with a second limit switch that has a negative mode NO contact.

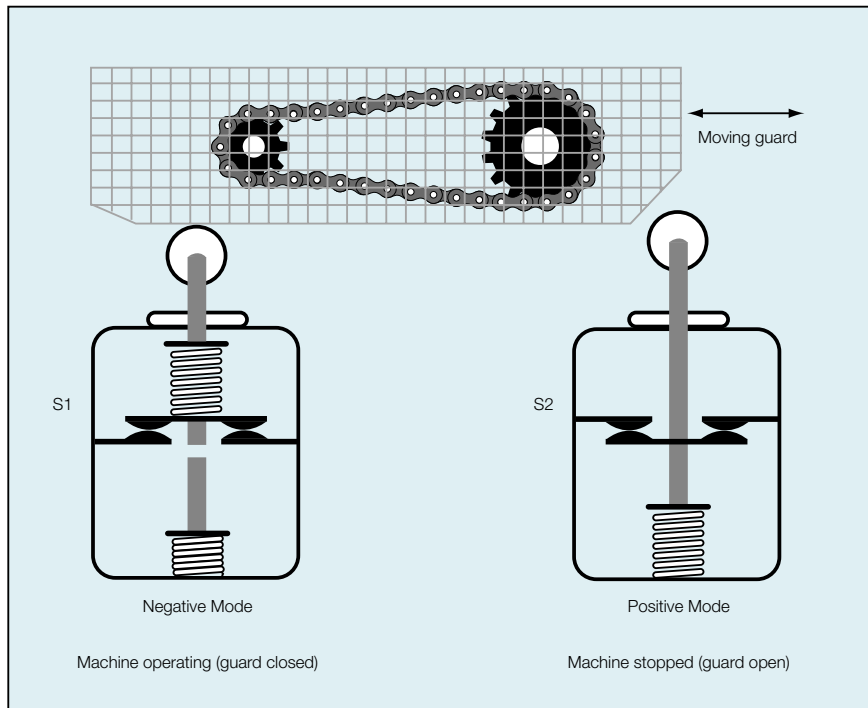


Fig. 5.4 Limit switches operating in combined mode.

5.6

Normally energized circuits

A well-proven principle for safety circuits is to make them function when the electric supply is interrupted (e.g., loose connections, wire breakage, brown-out, etc.). Normally energized circuits detect power loss and ensure that the safety function remains intact.

Examples of these types of circuits are electrically operated brakes, emergency stop circuits and the output relays of electronic motor protection relays. By executing the safety function (i.e., removing power) after detecting a single fault, normally energized circuits can help fulfill Category 2 and 3 safety requirements.

Devices such as E-Stops, limit switches, safety gate interlock switches and cable pull safety switches use direct opening action principles, which is required under EN 60947-5-1. These well-tried components are used in control systems with performance requirements from category B to 4.

Cable pull safety switch



Safety gate interlock switch



Limit switch



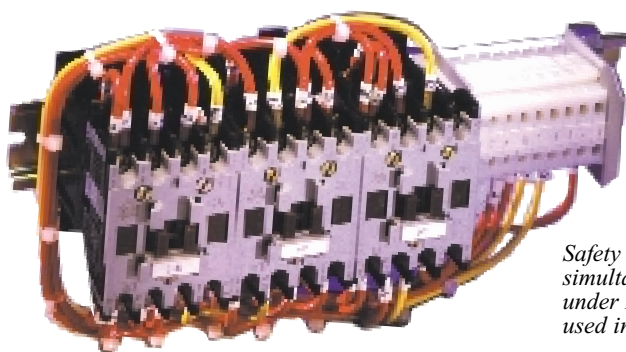
E-Stop



Safety relay — integrated box design



Safety relay — three interwired relay design



Safety relays use positively driven contacts to help prevent the simultaneous closure of NO and NC contacts, which is required under EN 60947-5-1. These well-tried components are most often used in control systems meeting category 3 and 4 requirements.

Control circuits and performance categories

This section of chapter 5 reviews the category requirements, then illustrates control circuits that can fulfill these requirements. Please note that these examples are provided for educational purposes only, and that control circuits using other designs may also fulfill performance requirements.

	B	1	2	3	4
• State of the art components	X	X	X	X	X
• Well-trying components or principles		X	X	X	X
• Check safety functions at suitable intervals			X		
• No loss of safety function through single fault				X	X
• Detection of single faults or					X
• No loss of safety functions through accumulation of faults					X

Fig. 5.5 Safety category requirements; note the cumulative nature of the requirements.

Category B and Category 1

Category B has no specific requirements beyond recommending the use of state-of-the-art components. Category 1 and all higher categories require the use of well-trying components and principles. It focuses on the prevention of faults through the use of well-designed components.

Figure 5.6 shows the circuitry associated with a control relay. The elements of the system include an E-Stop, an On/Off pushbutton, a control relay (contactor), a motor starter (or other load) and an overload relay. Because the E-Stop is relatively simple and tends to operate reliably, the chance of failure leading to a dangerous condition is probably minimal (assuming

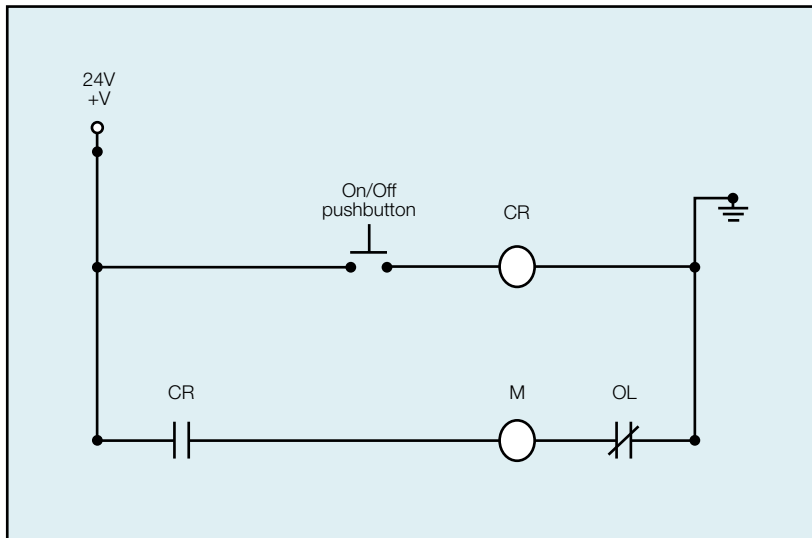


Fig. 5.6 This control circuit can fulfill category B requirements.

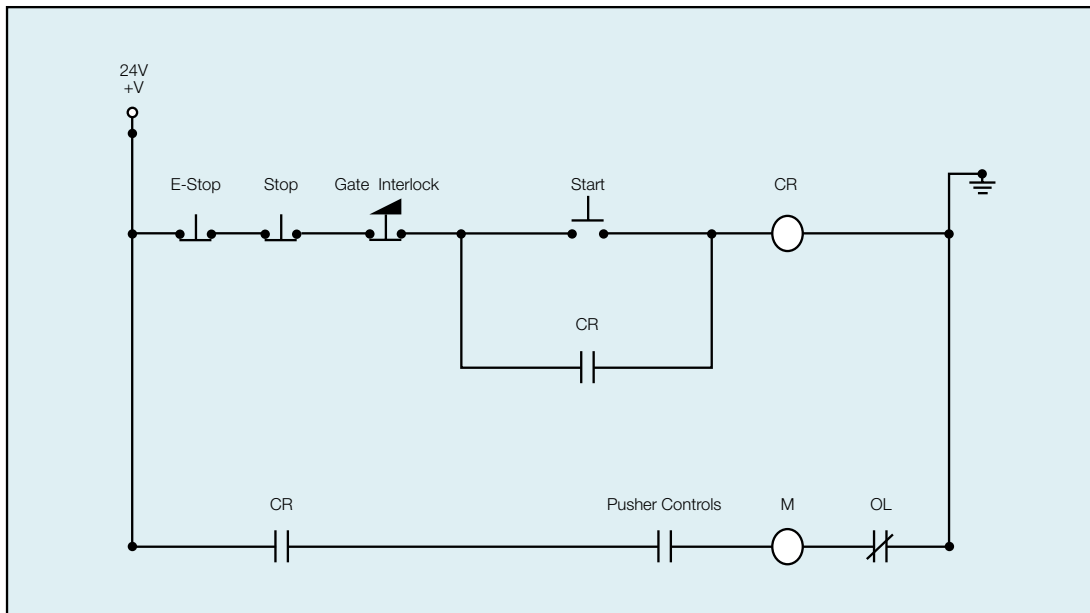


Fig. 5.7 This control circuit can fulfill category 1 requirements.

NOTE: These diagrams conform to NEMA style. For an IEC version, please refer to Appendix H.

5

it has been applied properly). Further, assuming the E-Stop is of the direct opening action type, its normal failure mode is in the open circuit mode. If the contacts are tack welded shut, they should be forced open on actuation, removing power.

Although the conventional relay illustrated in figure 5.6 has no open circuit failure mode, reputable manufacturers produce relays that tend to operate reliably (experience indicates that they rarely weld in the closed state). If the risk assessment is low — say a slow moving conveyor — using a conventional relay may be acceptable.

If the risk assessment indicates category 1 — perhaps the operator needs to be shielded from an arm pushing products onto the conveyor — the designer must take additional precautions. Such precautions could include a moveable guard (which would use a gate interlock switch) and three-wire control (i.e., an auxiliary holding contact).

Figure 5.7 shows a circuit diagram for incorporating a gate interlock and three-wire control. The safety interlock removes power from the system when the guard is opened, disabling the pusher arm. The three-wire control is designed so that after a power loss, the start button must be pushed to restart the system. This protects the operator from accidental or unexpected motion if the power were to come back on while the operator was in the hazard zone.

Designer's Discretion

Machine designers must use their own discretion — after making a risk assessment — when identifying categories and specifying safety functions and components. Remember, the directives and standards do not specify which safety aspects designers shall use; they just provide guidance.

Category 2

From category 2 upward, the higher degree of safety results from the *structure* of the safety circuits and the *prevention and detection* of faults (i.e., not only the choice of components).

This category requires a check of the safety function at suitable intervals; e.g., at the beginning of each operation cycle, upon start-up, or at established times during the cycle (it is the manufacturer's responsibility to specify an appropriate interval). If a fault is detected during start-up, the machine must be prevented from starting. If the safety function is lost during a cycle, the loss must be detected at the next start-attempt.

Circuits for category 2 machinery — perhaps a pick-and-place robot has been added to a fast moving conveyor — must focus on fault prevention. Two fault prevention techniques include adding redundancy and using contactors with normally energized output circuits.

Figure 5.8 shows the circuit diagram of a redundant system. When the start button is pushed under normal operating conditions, current will flow through the NC contacts CR1(a) and CR2(a), energizing output coils CR1 and CR2. Then contacts CR1(b) and CR2(b) close and maintain current flow; the NC contacts CR1(a) and CR2(a) drop out. If one of the contacts welds during operation (e.g., CR1(c)), it is still possible to remove power from the load using the E-stop. A restart would not be possible because the NC contact CR1(a) would remain in an energized (i.e., open) state.

This fulfills category 2 requirements because the safety function is checked at the start of each cycle. It also can fulfill some category 3 requirements because a single fault will not cause the loss of the safety function.

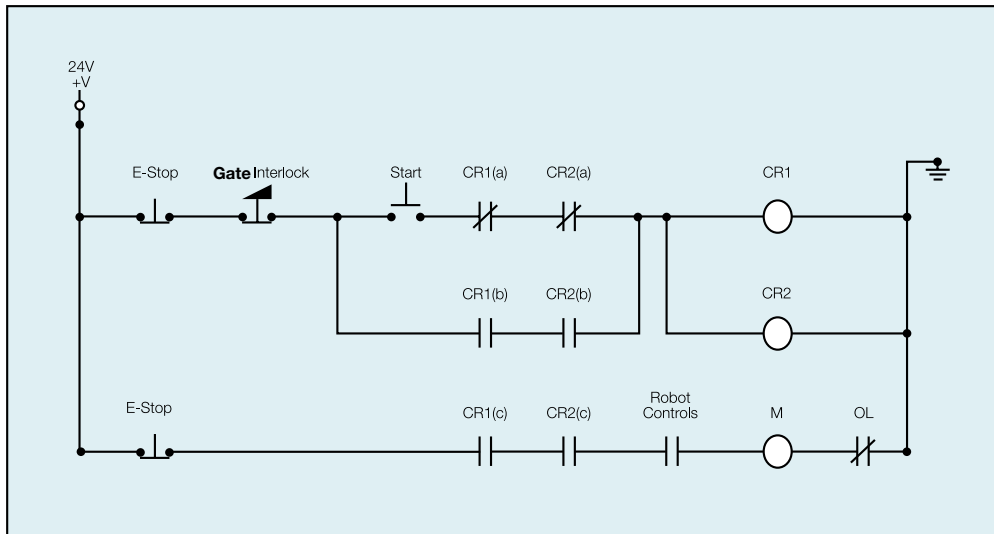


Fig. 5.8 This control circuit can fulfill category 2 requirements.

5.10

Category 3 and category 4

As noted earlier, category 3 requirements state that the safety function cannot be lost as the result of a single fault. Where practical, a category 3 system will detect a single fault, but an accumulation of faults can lead to the loss of the safety function.

To satisfy category 4 requirements, all previous requirements must be met, plus a single fault must be detected at or before the next demand on the safety function. If this is not possible, then an accumulation of faults must not lead to a loss of the safety function. Thus, a fault will not cause the loss of the safety function, and there is an opportunity for repair before the next fault can occur.

There are a number of methods to satisfy category 4 requirements, including interwiring three positively guided relays, or using a “safety relay.” A safety relay incorporates the same circuitry and three interwired relays, but consolidates them in an “integrated box” design. Both designs feature a redundant, self-monitoring circuit with positively guided, normally energized relay contacts.

To achieve redundancy and self-monitoring, a safety relay (see Figure 5.9) operates using the following principles:

Normal operation: When the E-stop is pulled up, power flows through CR3(a) and CR1(b), energizing the coil CR2. When this coil is energized, the NO contact CR2(c) closes, which energizes coil CR3. NO contact CR3(b) closes and holds the coil CR3 energized. At the same time, CR2(a) and CR2(b) close. CR2(b) holds in the coil CR2. The device is now “armed and ready.”

When the operator pushes the start button power flows, NO contact CR2(a) closes and energizes coil CR1. CR1(a) closes to hold in CR1. Then, the NC contact CR1(b) opens and disconnects power from coil CR2. The final state is: coil CR1 on, coil CR2 off, and coil CR3 on. This condition allows the contacts of the output line [CR1(d), CR2(d), CR3(c)] to be closed and the load energized.

Start button welded (fault): If the start button is welded (i.e., held energized) prior to rearming of the system via the E-Stop, coil CR2 will not energize because the circuit is never complete in the rung with CR3(a) and CR1(b). If coil CR2 cannot energize, it is not possible to pull in coil CR3 because CR2(c) will not close.

Output CR2(d) welded (fault): After rearming the system via the E-Stop, power flows and picks up coil CR2. The welded contact, CR2(d), will attempt to change state. If the weld does not break, the NO contact of CR2(c) will not close, thus coil CR3 cannot energize and the system cannot be started again. Likewise, if CR1(d) welds, CR1(b) will be held open. If CR3(c) welds, CR3(a) will be held open. Both situations prevent coil CR2 from energizing, so the system cannot be rearmed.

E-Stop failure: If the lower E-Stop fails (one contact remakes and one does not, or the spanner breaks), coil CR3 will not energize. If the upper E-Stop fails, coils CR2 and CR1 will not energize.

Machine designers can use safety relays to help safeguard human interaction with dangerous equipment. As such, circuits for operator interfaces — palm buttons, pull cords, light curtains and similar devices — are tied into the safety relay circuit.

One classic example of a machine requiring category 4 safety precautions is a large, hand-fed metal stamping press. To ensure that the operator’s body and hands are out of the hazard area during operation, the press uses two-hand control for actuation.

To wire in the relays for the two hand control (or cable pull switch, light curtain, etc.), put two NC contacts in the circuit just prior to CR3(a); that is, replace the jumper. If one of the two relays welds in the energized position, the safety relay will detect failure and prevent the machine from starting.

Note that the objective of the two-hand control/safety relay combination is not to detect a failure while the machine is running (if something fails at this stage, the operator will know it). Rather, if a single contact or an entire relay fails, the multiple, redundant relays in the load circuit are designed so that the load can be de-energized, and the self-monitoring circuit prevents a restart until the fault is corrected.

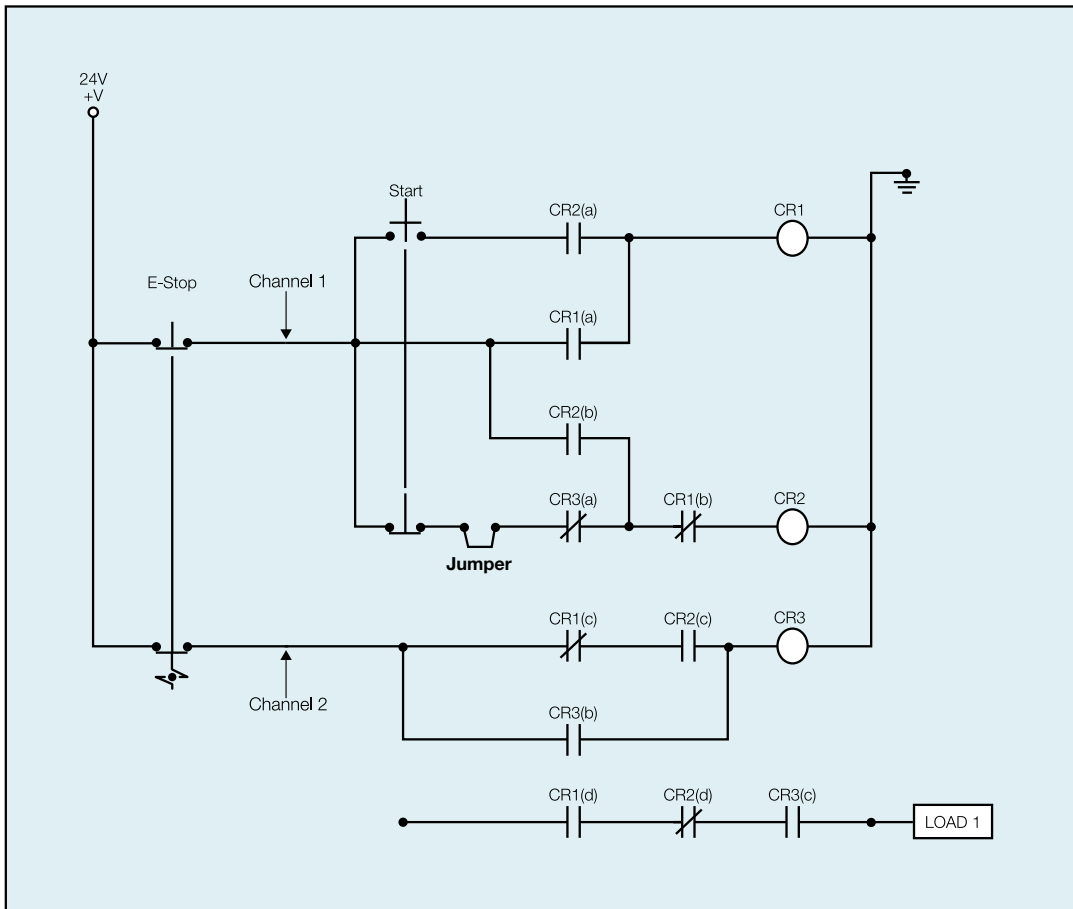


Fig. 5.9 This control circuit can meet category 4 requirements.

Note: In order to minimize the potential for shorting of channel 1 to channel 2, which would not be detected by the circuit, the wiring should be installed in separate conduits.

Safety Concerns for Power-Related Products

Operational functions	6.0
Contact reliability	6.1
Multiple fault detection.	6.2
Motor protection.	6.3
Safe separation of circuits to avoid electrical shock.	6.4
Protection against electric shock	6.5
Protection against indirect contact.	6.6

Operational functions

The European Norms provide both broad guidance and great detail on safety functions “*which are safety critical functions other than safety-specific* functions*” — that is, components which provide critical operational functions. According to EN 60204-1, this includes products such as power supply disconnecting devices, enclosures, power circuits, control circuits and motor overload protection. Properly applying these devices, according to EN 1037, helps assure proper start-up, prevent unexpected start-up, and isolate the machine from its energy supply to enable safe maintenance or other work.

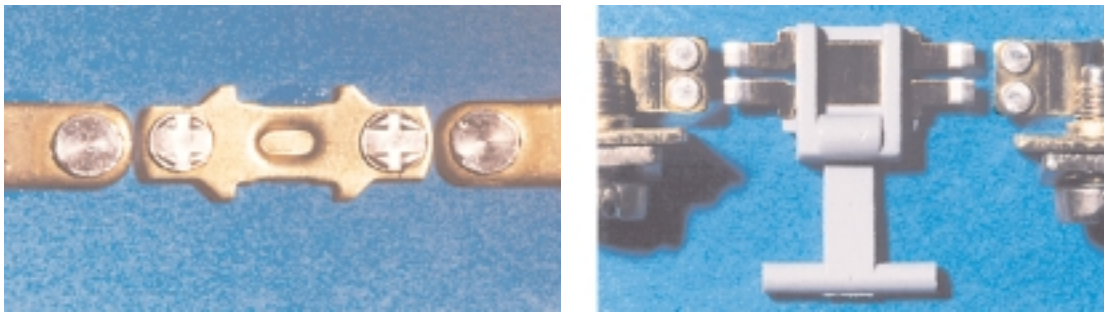
As with the safety components discussed in chapter 5, there are numerous well-trying design principles manufacturers should look for when selecting power-related safety components. Some of these principles are:

- Contact reliability
- Multiple fault detection
- Short-circuit protection for safety
- Safe separation of circuits for avoidance of electrical shock
- Protection against electric shock (“finger proof”)
- Protection against indirect contact

** Recall that the products discussed in the previous chapter provide safety-specific functions (e.g., the primary purpose of a cable pull switch is to serve as a safety-stop device, not as a routine stop button).*

Contact reliability

Many control circuits operate at 24V DC levels, which is common for PLC systems and other electric controls. The contacts of power devices like contactors, circuit breakers or switches, as well as the contacts of relays and sensors, have to work reliably at these signal levels. The same contacts must perform reliably at conventional loads with high AC-15 ratings. Devices using “cross stamped” and “H bridges” (see photo on next page) perform excellently under these conditions and improve reliability and safety control circuits.



Cross stamped (left) and H bridge contacts.

6.2

Multiple fault detection

The EU standards suggest incorporating different types of safety functions to avoid hazards. As an example, a high-end motor protection device offers a number of functions to avoid hazards at an early stage.

Besides overload and short circuit protection, motor protection relays offer stalling protection and underload protection. Stalling protection prevents mechanical parts from breaking by very quickly switching off the motor when it senses excessive torque (i.e., it could avert the breaking of mechanical parts that, if they broke, might endanger persons nearby). Underload protection responds to situations where the failure of mechanical transmission elements or part breakage (e.g., a drill bit, chain, pulley, etc.) could lead to dangerous situations.

6.3

Motor protection

Motor starters (motor protection) are available with short-circuit coordination levels of Type 1, Type 2 and CPS. The contactor and overload relay are tested with appropriate short circuit protective devices, typically fuses or a circuit breaker, to determine the coordination levels. After a short circuit, an interruption of service is unavoidable while the source of the failure is traced and cleared. However, the type of coordination will determine the length of the interruption (see Figure 6.0).

	Type "1"	Type "2"	Type "CPS"
• Trace and clear failure after short-circuit	X	X	X
• Inspect starter	X	X	
• Exchange components	X		
• Break-off welded contacts if any		X	
• Restart operation	X	X	X
• Planned maintenance	X	X	X

Fig. 6.0 Short-circuit coordination levels for motor starters.

After a short circuit with Type 1 coordination, the starter components (contactor, overload, motor protection circuit breaker) may be defective and need replacing. A restart is only possible after replacing starter components, which could take some time if the components are not immediately available.

Type 2 coordination ensures that the starter components stay serviceable after a short circuit (the contacts may weld slightly, but they can be separated with a screwdriver). No replacement parts are needed before restarting the machine.

Type CPS (IEC 947-6-2, Control and Protective Switching devices, CPS) coordination devices ensure that the starter components stay serviceable after a short circuit, that no replacement parts are needed before restarting the machine and that the starter will deliver additional operations at rated load without any inspection of components. [Note: While Type 2 and Type CPS allow component replacement, the components eventually require replacing because short circuits cause heavy contact wear.]

Correctly coordinated motor starters — regardless of their type — ensure that in case of a short circuit, no damage occurs outside the starter. This contributes to the protection of nearby personnel and control components.

In addition, many circuit breakers and fuses for motor protection offer high current limiting capabilities to reduce fault energy to very low levels. These lower energy levels reduce the danger to personnel and damage to surrounding equipment. This enables short restart times, particularly when short circuit coordination Type 2 or Type CPS is chosen. Further, devices with high current limitation do not require oversizing of the contact to achieve Type 2 or Type CPS coordination.

6.4

Safe separation of circuits to avoid electrical shock

PELV and SELV (types of Extra Low Voltage, operating on a maximum of 25V AC or 60V DC) are used to avoid the hazard of electric shock. The PELV/SELV voltage is supplied from a source with an increased safety level, such as from a safety isolating transformer where one side of the circuit is connected to protective earth. All PELV/SELV circuits must be separated from other circuits with the level of separation of a safety isolating transformer. Safe separation between the power and the control circuit is shown in Figure 6.1.

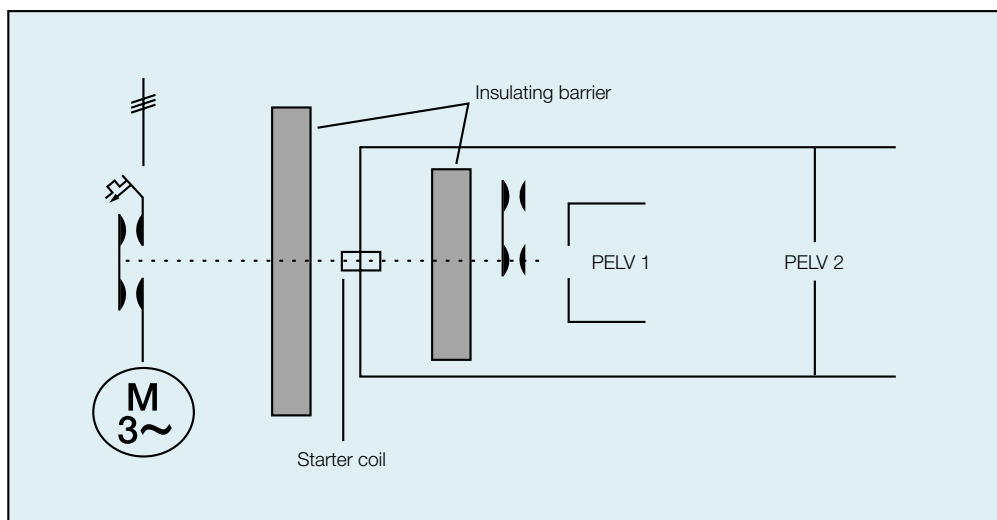


Fig. 6.1 Safe separation between main and logic circuits.

6

PELV/SELV allows technicians to work on 24V circuits (e.g., PLC circuits) without needing protective measures against electric shock.

Thus, control circuit devices (e.g., contactor coils and auxiliary contacts) operating in PELV/SELV circuits require a higher level of physical separation between the main circuits and the control circuits (see Figure 6.2). This can be achieved by reinforced insulation. The safe separation of circuits must be maintained under all conditions. Devices with safe separation preclude the need for interposing relays and contribute to a lower cost control system.

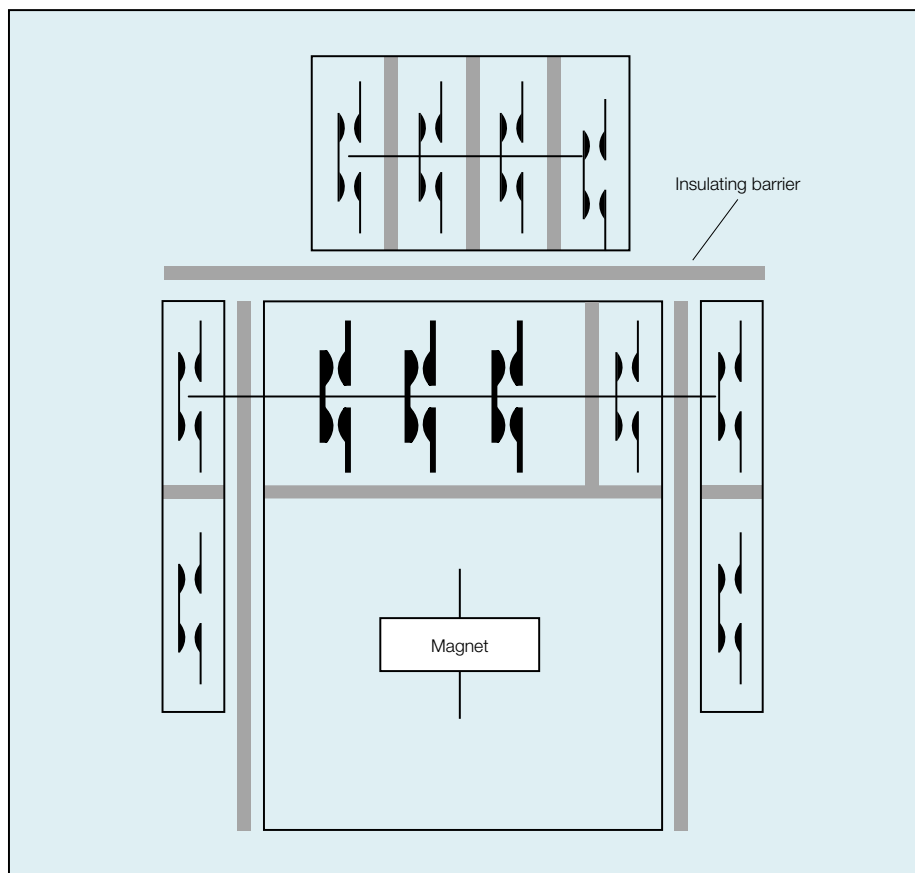


Fig. 6.2 PELV and SELV contactors provide safe separation between circuits.

6.5

Protection against electric shock

EN 60204-1 standard requires that persons are protected against electric shock from direct contact and indirect contact. Protection against direct contact can be accomplished by placing the electrical equipment in a proper enclosure. The standard indicates three ways to achieve protection:

- The enclosure can only be opened with a key or tool, or
- The door is interlocked with the disconnecter, or
- All live parts are protected to IP2X or IPXXB.

Key or tool opened: This assumes that only qualified persons will open an enclosure containing live electrical equipment. The person doing so must follow the proper safety procedures, such as disconnecting power to the enclosure, before working on it.

Interlocked: The enclosure door may be opened only after the disconnecter (handle) is in the open position. The disconnecter must disconnect all electrical power to the enclosure.

The line side terminals of the disconnecter must be protected from accidental touching, which sometimes is stated as being “finger proof.”

IP2X or IPXXB level: If the requirements above are not met (i.e., the enclosure cover has a handle that anyone can open), the live parts must be protected to IP2X or IPXXB level. The explanation for these designations is in the IEC 529 standard, “Degrees of protection provided by enclosure.” A simple explanation for these requirements is that a test finger shall not touch live parts.

An alternate protection is completely enclosing all live parts in an insulating material. In practice, this is possible only if the enclosure contains just conductors.

6.6

Protection against indirect contact

This protection is required in the event of an insulation failure between live parts and exposed conductive parts of electrical equipment. It can be accomplished by preventing hazardous touch voltage or automatic disconnection, as noted in clause 6.3 or EN 60204.

6

One choice for preventing hazardous touch voltage requires the use of circuit breakers or fuses to automatically disconnect the circuit in case of a short circuit. Connecting of exposed conductive parts to a protective earth (grounding) is required.

Another choice for preventing hazardous touch voltage require Class II equipment (double or reinforced insulation) per IEC standard 536. If one insulating system fails, the other insulating system provides full protection against electrical shock. Alternately, preventing hazardous touch requires using assemblies having total insulation per IEC standard 439-1 or using supplementary or reinforced insulation per 413.2 of IEC standard 364-4-41.

IEC Contactor with IP 2LX finger protection against accidental contact with live components.



Control and load switch, which could be applied as a hand-operated disconnect or as an Emergency Stop when using the red actuator (as shown).



Manual motor starter with magnetic trip and bi-metallic overload protection. When properly applied with the contactor shown on the left, it provides Type 2 coordination.

The hazardous touch voltage can be avoided by electrical separation per 413.5 of IEC standard 364-4-41, too. Further, it can be avoided with a construction where, in case a live part comes in contact with an exposed conductive part, the contact will not create hazard. An isolating source, like an insulating transformer which is not grounded, or other measures stated in the standard, provides this type of protection. The voltage is limited to 500V in these circuits.



*Electronic motor manager —
an electronic overload
protection relay with
communications capability.*



*Electronic overload relay —
provides Type 2 coordination when
properly applied with the contactor
shown on the facing page.*

Frequently Asked Questions (FAQs)

Big Picture FAQs

1. What do the EU directives address?

Three basic areas: 1) Safety of individuals; 2) Protection of the environment; and 3) Free movements of goods within the EU/EEA geographical regions through harmonization of standards and the elimination of trade barriers.

2. Since these are European standards, isn't it best to use European manufactured components?

No. There are a significant number of non-European manufactured products which comply with all aspects of European standards. Further, a larger variety and better products may be available if designers do not limit their selection to any one region.

3. Do I need to have a third-party inspect my machine to obtain CE marking?

Most machinery manufacturers — about 95 percent — can self-certify compliance with the Machinery Directives. A few product categories (i.e., high-risk machinery like punch presses, saws, etc.) require third-party certification. However, note that meeting EMC Directive requirements often involves a third party.

4. Do I need to buy components with additional safety on them besides CE marking (e.g., the German “GS” safety mark or Danish “Demko” mark)?

No. Any product bearing CE marking is held out to meet EU safety requirements.

5. Do I need to use components with CE marking on them to meet Machinery Directive requirements?

This is an “apples to oranges” comparison. CE marking on a component indicates compliance with an EU directive that applies to components, such as the Electromagnetic Compatibility (EMC) Directive or Low Voltage (LV) Directive. The Machinery Directive has requirements for controls and safety components (e.g., “must use positively guided contacts”), and these are an entirely separate set of concerns from the EMC and LV Directives.

6. What is the difference between the LV and EMC Directives?

The Low Voltage Directive covers electrical equipment between 50 - 1000V AC and 75 - 1500V DC. The Electromagnetic Compatibility Directive covers electrical equipment which emits or is influenced by certain types of electromagnetic radiation.

7. If all components in my control panel are CE marked, is my machine automatically CE certified?

No — absolutely not. Component installation must be verified, and there are other requirements that apply to the entire assembly. For example, using a safety relay with CE marking has nothing to do with whether you've properly guarded against a dangerous motion.

Secondly, there is no such thing as “CE certified” or “CE approved.” Machine builders must “comply with” or “show conformity to” to the Machinery Directive, any other directives that apply, and any harmonized standards they choose to use to show conformity.

8. What relationships are there between EU directives and CE marking?

The directives state the EU law, while CE marking indicates that the product meets the directives applicable to it. To find out which directives apply to a product, examine its Declaration of Conformity (DOC).

9. Are directive requirements equivalent to UL standards?

No. Directives are laws of the European Community, where UL standards are standards put forth by a company.

10. What are “harmonized” and “national” standards? How do they impact my efforts to be compliant with the EU directives?

The European Norms are harmonized standards, which means that they are applicable in, and recognized by, all EU countries. Showing conformity with harmonized standards is considered the easiest way to demonstrate compliance with the EU directives.

National standards are standards within a country that are singular to that country, and they may differ from the harmonized standards. National standards have no impact on complying with the EU directives.

11. What is the relationship between the Machinery Directive and OSHA requirements for safety? Does having one mean you comply with the other?

The EU directives and OSHA requirements are independent of one another, so having one does not mean that you comply with the other. If you want to sell your machine in both the EU and the U.S., you need to understand both sets of requirements.

12. Will the Machinery Directive ever displace OSHA or ANSI design guidelines?

No, because the electrical codes and installation requirements differ between North America and Europe. However, they are getting closer over time.

13. Does CE marking or the DOC certify compliance with the no PCBs/no asbestos requirement of Europe?

The use of asbestos is covered by one of the Marketing Directives and Use of Dangerous Substances Directive. Where asbestos is used, these directives apply. These directives do not mandate CE marking, but a machine bearing CE marking must meet their requirements.

14. What impact do the EU safety directives have on equipment built in, and destined for, the U.S.?

Legally, the directives have no impact on the U.S. In practice, however, manufacturer's may try to build one piece of equipment that satisfies both EU and U.S. requirements to improve manufacturing efficiency.

15. How do I self-certify my machine to obtain CE marking?

Start with this safety handbook and follow the road map provided. Obtain the directives and standards that apply to your machinery and **thoroughly digest and apply them** (this point cannot be overstated). Ultimately, you must be able to prove (if called upon to do so) to an authorized body that you have met the Essential Health and Safety Requirements in Annex I of the Machinery Directive.

16. Where do I get the necessary documentation related to CE marking my machine?

Section 2.3 of this handbook provides sources for purchasing the directives and standards.

17. Can I use Rockwell Automation to get my machine CE marked?

No. **Only a machine's manufacturer can apply CE marking to the machine.** A common misconception is that a Notified Body can CE mark a machine. A Notified Body assesses whether the manufacturer has adequately satisfied the directives/applied the standards appropriately, taking the burden of proof off the manufacturer.

18. What are the costs involved with complying with the Machinery Directive?

Theoretically, there should be no additional manufacturing cost, as safety is an integral component of the design process. Realistically, the directives require more documentation than most companies normally develop.

19. How do I assess my risk category?

EN 1050 provides principles for risk assessment and examples of hazards. Annex B of EN 954 provides a flow chart for assessing risk and assigning categories. See chapter 3 of this handbook for more details.

20. How do I know if my risk assessment is accurate? How do I know when I'm done?

EN 292-1 and EN 292-2 discuss risk in great detail, and Annex B of EN 1050 covers methods for analyzing hazards and estimating risk. Figure 3.1 in this handbook depicts the strategy for selecting designed-in safety measures and indicates when you should ask yourself “Is safety adequate?”

21. Isn't it easier to just make everything risk category 4?

No. First, why make a machine more complicated and expensive than necessary? Second, the ultimate objective is to offer a machine which functions reasonably safely. Thus, a well-designed machine using highly-reliable components and a well-designed category 1 control system could perform better than, and satisfy reasonable safety expectations as well as, a machine with a category 4 control system.

22. Who can help me evaluate my machine?

Numerous companies and organizations provide this service. Many of them originated in Europe. Also, some organizations specialize in a specific class of machinery.

23. Do I need to hire a consultant?

The choice is yours. If a manufacturing company feels it does not possess or cannot acquire the necessary expertise in-house, a consultant may prove valuable.

24. Can Rockwell Automation recommend a Notified Body?

Rockwell Automation does not endorse any particular Notified Body; also, the list of Notified Bodies changes frequently. However, searching the Internet is a good place to start. The FEM brochure noted in section 3.2 of this book lists Notified Bodies, and consultants also can provide recommendations.

7

25. Can manufacturers do testing on site (e.g., tests related to the Low Voltage and EMC Directives)?

Yes. However, manufacturers may not possess the necessary test equipment. In such a case, they often turn to a third party or independent laboratory to perform the test.

26. Are the EU directives spreading to other countries (i.e., Australia)?

No. The directives are laws specific to the EU. The European Norms, most of which are based on IEC standards, naturally resemble standards used by many countries.

27. What standards address which products? Do the standards vary by location?

The list of standards is exhaustive. Appendix B of this handbook provides a short, partial list of those most likely to relate to machine builders. Section 2.3 of this handbook notes sources that can provide you with the complete standards list.

For any country requiring CE marking, use the European Norms. IEC or ISO standards may also be acceptable.

28. What is the penalty for not having CE marking on my machine?

EU customs officials will not allow the machine to enter the market, nor will they permit such a product to be placed into service in the EU.

29. What is the penalty for failing to comply with the Machinery Directive but placing CE marking on the machine?

Article 7.3 of the Machinery Directive, a law, states that “*where machinery which does not comply bears CE marking...the Member State shall take appropriate action against whomsoever has affixed the marking...and shall so inform the Commission [of the EU] and the other Member States.*”

30. How do I minimize my legal exposure?

Meet the requirements stated in the directives.

31. How are the standards being enforced?

The EU does not enforce standards; they enforce directives.

Component FAQs

32. When selecting components, is the answer application dependent? Do you need to apply components differently for different applications?

Yes. Start by asking two questions: What is the function of the entire assembly? How are you applying the component to the assembly? Next, look to the directives and standards for guidance. By way of example, the stop button and related circuits for a copy machine differ greatly from the stop button and related circuits for a saw mill or a large compression molding machine.

33. Do safety relays replace a master control relay?

Yes. Safety relays replace a master control relay (MCR) because they provide functions an MCR cannot.

34. Why are safety relays needed?

Strictly speaking, machine builders need the **function and performance** capabilities of a safety relay, not the product itself.

Safety relays are designed to eliminate the potential for a single contact to cause a failure that would not allow the system to shut down. This function helps meet risk category 3 or 4 requirements: detection of a single failure, maintenance of the integrity of the E-Stop function and prevention of a restart until the fault is cleared. A safety relay is really a combination of several relays wired into a circuit that provides the safety functions noted above. Remember, the Machinery Directive does not require the use of any particular product; it specifies function and performance requirements. A safety relay is a means to this end.

35. Can I just replace my MCR with a safety relay?

No. Simply replacing the MCR with a safety relay does not directly correlate with making the machine comply with the Machinery Directive. The safety relay must be applied according the relevant directives and standards.

7

36. How do safety interlock switches interface with a safety relay? Are they an input to the relay or are they a load?

A safety interlock interfaces the same way an E-Stop button interfaces: as an input to the relay. In some applications, the interlock contacts will be wired in series with the E-Stop.

37. Can I use a standard magnetic switch?

It depends on the application. Provided that its function and design meets the performance level indicated by the risk analysis, manufacturers can select any component they like.

38. In which application should I use “safety controls”?

An application should use the type of controls needed to make the application as safe as reasonably possible. Whether you use “safety controls” or not skirts the core issue, which is to understand what the machine’s risks are and design the machine and its controls accordingly.

39. Do I have to use a safety relay in conjunction with every electrical safety device, e.g., safety interlock switch, light curtain, safety mat, E-Stop, etc.?

Not necessarily, as it depends on the application and the control system. The risk associated with your machine might not require a safety relay. Also, you may not have to use a separate safety relay with **each** input device. For example, a safety interlock switch, light curtain and E-Stop **related to the same hazard** may be wired in series to one safety relay.

40. If I have redundant safety input devices, does this eliminate the need for a safety relay?

No. Redundancy does not deliver the same function as a safety relay.

41. What is the current OSHA ruling on safety relays and switches?

Just like the European directives and standards, the OSHA requirements look to a certain level of performance for the control system. It does not specify products. By design, a safety relay can help provide the performance OSHA seeks.

Rockwell Automation/Allen-Bradley FAQs

42. What do “positively guided” and “positive break” mean and how do they differ? Does Rockwell Automation offer products with these features?

Positively guided refers to the electronic actuation of relay contact/auxiliary contact actuation on starters. Positive break refers to the mechanical actuation of devices like an interlock switch or E-stop button. Chapter 5 of this book provides detail on their differences.

Rockwell Automation offers a variety of safety components employing these operating principles.

43. Can customers build their own safety relay using Rockwell Automation components, and will it be approved?

Yes, they can build their own safety relay using Rockwell Automation components (or any other components, and using any other design) provided that resulting performance meets the performance required by the applicable directives. It will be approved if they can prove compliance with the directives.

44. Can I obtain a list from Rockwell Automation of all its CE marked control components? What other CE information does Rockwell Automation have?

Yes. Please ask your local Rockwell Automation representative for a list. Information about our products and the CE mark in general is available on Rockwell Automation’s Internet site at www.ab.com. Click on the “Allen-Bradley and the CE mark” button.

45. What type of approval does A-B have?

Most Rockwell Automation products of the type discussed in this handbook are covered by the Low Voltage and EMC Directives. Products meeting these directives bear the CE mark. A Declaration of Conformity statement is available for these products.

7

46. How can I obtain the Declaration of Conformity (DOC) for a Rockwell Automation product?

If you would like a DOC, ask your local Rockwell Automation representative. The information is also available on Rockwell Automation's Internet site at www.ab.com. Click on the "Allen-Bradley and the CE mark" button.

47. What NEMA designed products will A-B have CE marked?

Various products from each major business group carry CE marking. Please ask your local Rockwell Automation representative for a list. The information is also available on Rockwell Automation's Internet site at www.ab.com. Click on the "Allen-Bradley and the CE mark" button.

48. Do the new MCS control relays, including Adder Decks, incorporate positively guided contacts?

Yes.

Glossary of Terms

ANNEX - An appendix, as might be used with a Council Directive.

ANNEX IV-EQUIPMENT - Machine types which are considered to be particularly dangerous. Also includes safety components. Such equipment must undergo a more stringent conformity assessment procedure, including an EC type-examination by a third party.

AUTHORIZED REPRESENTATIVE - Person appointed by the manufacturer to act on its behalf in carrying out certain tasks required by the directive, which the manufacturer has delegated to the representative. At this time, the authorized representative must be established in the European community to be able to act on the manufacturer's behalf. It can be advantageous to establish an authorized representative.

CE MARKING (CE mark) - The identifying mark, consisting of the letters "CE" that, together with an EC Declaration of Conformity, indicates conformity of the product to which it is affixed to the essential health and safety requirements of the relevant directive(s). Allows products to be sold anywhere in the EU. CE Marking is mandatory for most products in the EU. CE stands for European Community in French

CEN, CENELEC - European Committee for Standardization (CEN); European Committee for Electrotechnical Standardization (CENELEC).

CERTIFICATE OF ADEQUACY - The type of certificate issued when a Notified Body determines that the applicable national standards have been correctly applied to the design and manufacture of the machinery under review.

COUNCIL OF THE EUROPEAN COMMUNITIES - The legislative body of the EU.

DECLARATION OF CONFORMITY - A formal signed statement indicating conformity of the referenced product to the listed provisions of the applicable directive(s). Entitles manufacturer to affix CE Marking.

DIRECTIVE - Legislation which is binding on all Member States that has been adopted by the Council of the European Communities.

EC TYPE-EXAMINATION - The procedure by which a notified Body ascertains and certifies that an example (sample) of machinery satisfies the provisions of the applicable directive(s).

ESSENTIAL HEALTH AND SAFETY REQUIREMENTS (EHSRs) - To comply with the Machinery Directive, machinery must satisfy the essential health and safety requirements set out in Annex I. The requirements are wide-ranging, and take into account potential

dangers to operators and other exposed persons within a “danger zone.” Aspects covered in Part 1 include: the materials used in the construction of the machinery; lighting; controls; stability; fire; noise; vibration; radiation; emission of dust, gases etc.; maintenance; and instruction handbooks. Part 2 has additional requirements for agri-foodstuffs machinery, portable hand-held machinery, and machinery for working wood and analogous materials. Part 3 deals with particular hazards associated with mobility, Part 4 with those associated with lifting, Part 5 those with underground working and Part 6 those associated with the lifting and moving of persons.

EUROPEAN NORM (EN; also called a HARMONIZED EUROPEAN COMMUNITY

STANDARD) - Voluntary guidelines (not laws) that clarify and expand on the essential requirements of the directives. Standards provide the most expedient means of testing or verifying conformity to a directive. They are developed by CEN and CENELEC. These organizations have pledged to use international standards (ISO and IEC) whenever possible. Harmonized standards supersede individual country requirements.

EUROPEAN UNION (EU) - The regional geographic and economic union formed by 15

European nations bound by treaty to form a single European Economic Community. The countries are (as of January 1, 1997) Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

HAZARD - An event that can cause physical injury and/or damage to health or property.

Annex A of EN 1050 provides examples of hazards, hazardous situation and hazardous events.

MACHINERY - An assembly of linked parts or components, at least one of which moves, which have been combined to process, treat, move or package a material. Also an assembly of such machines.

MACHINERY DIRECTIVE - EU legislation (law) that lays down the essential health and safety requirements applying to machinery, as defined in Annex I. It also covers safety components placed on the market separately.

MANUFACTURER - Person responsible for designing and manufacturing a product covered by the directive(s), with a view to placing it on the community market. The manufacturer is responsible for designing and manufacturing products in accordance with the directives and following the certification procedures (declaration, type-exam, CE Marking and preparation of files).

MEMBER STATES - Those nations that make up the EU.

NOTIFIED BODY - An independent testing laboratory that a Member State has determined to be qualified to perform testing and certification functions relating to specified EC Directives. The Member State “notifies” the EC and the laboratory of the laboratory’s qualified status as tester and certifier.

PERFORMANCE CATEGORIES - EN 954 states that safety-related parts of control systems shall be in accordance with the requirements of one or more of the five categories (B, 1, 2, 3, 4). The categories state the behavior required of safety-related parts of control systems with respect to its resistance to faults.

RISK ASSESSMENT (or risk analysis) - From EN 1050, which establishes general principles and procedures for identifying hazards and evaluating risks as they relate to decisions made on the safety of machinery.

RISK ESTIMATION - The risk associated with a particular situation or process is derived from a combination of the severity of harm and the probability of occurrence of that harm. Probability of occurrence involves the frequency and duration of exposure, probability of the event occurring, and probability of avoiding or limiting the harm. Based on risk level (Annex B of EN 954 provides a decision tree), a machine can be required to have control systems that meet the requirements of a particular safety category.

RISK REDUCTION - Manufacturers must apply the following principles when designing a machine: eliminate or reduce risks as far as possible; take the necessary protection measures in relation to risks that cannot be eliminated; and inform users of the residual risks due to any shortcomings of the protection measures, indicate whether any particular training is required and specify any need to provide personal protection equipment.

SAFETY COMPONENT - A component, provided that it is not interchangeable equipment, which the manufacturer or his authorized representative established in the Community places on the market to fulfill a safety function when in use and the failure of which endangers the safety or health of exposed persons (i.e., not standard components). Safety components shall not carry CE marking for complying with the Machinery Directive; other directives may apply.

SELF-CERTIFICATION - A procedure whereby the manufacturer or its designated representative in the EU can themselves certify conformity of the product to the essential health and safety of the applicable Directive(s) and to other relevant requirements.

STANDARDS - See EUROPEAN NORM.

TECHNICAL FILE - Documentation required by directives. File compiled by the manufacturer and placed at the disposal of the national authorities should they so request. Note: the term Technical Construction File (TCF) is referred to in the EMC directive.

TYPE A STANDARDS - Fundamental safety standards that cover the basic concepts, principles and general aspects of all machinery.

TYPE B STANDARDS - Group safety standards. They cover one safety aspect, one type of safety-related device and a wide range of machinery.

TYPE C STANDARDS - Detailed safety requirements for a particular machine or class of machines.

WELL-TRIED - A well-tried component for a safety-related application is a component which has been widely-used in the past with successful results, or made and verified using principles which demonstrate its suitability and reliability for safety-related applications.

APPENDICES

Appendices

A

Appendix A — Select Type B standards

Type B1 and B2 standards (basic safety standards) deal with one safety aspect or one type of safety-related device for a range of machinery. The following is a brief list (as of March 1, 1997):

General

EN 954-1:	Safety-related parts of control systems
EN 953:	Design and construction of guards
EN 1088:	Interlocking devices w/& w/o guard locking
EN 982, 983:	Fluid power systems
EN 294, 349, 811:	Safety distances
EN 999:	Hand/arm speed
EN 626:	Hazardous substances
EN 1093:	Emission of hazardous substances from machines
EN 1127-1:	Fire and explosions (this work is now part of CEN/TC 310)
EN 1760: (2)	Pressure-sensitive protective devices (mats, bumpers, edges, etc.)

Electrical

EN 60204-1:	Basic electrical requirements
IEC 1131:	Programmable controllers
IEC/CD 1508:	Safety-related systems — electrical, electronics, programmable electronics
EN 418:	Emergency stop equipment
EN 574:	Two-hand control devices
EN 50100:	Electrosensitive protective equipment
EN 61310 (50099):	Visual, tactile, and audible signals
EN 60947:	Low-voltage switch gear and control gear
	Part 1: General rules
	Part 2: Circuit breakers
	Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units
	Part 4: Contactors and motor starters
	Part 5: Control circuit devices and switching elements
	Part 6: Multiple function equipment
	Part 7: Ancillary equipment
EN 60947-5-2:	Proximity devices

Ergonomics

EN 614-1:	Ergonomic design principles — terminology & general principles
EN 547:	Human body dimensions
EN 563:	Temperature of touchable surfaces
EN 894:	Ergonomic requirements for the design of displays & control actuators
EN 981:	System of danger and non-danger signals with sound & light
EN 1005:	Human physical performance (3 parts)

Acoustics

EN 2374X:	Acoustics — Determination of sound power levels of noise sources
EN 24871:	Acoustics — Noise labeling of machinery and equipment

Electromagnetic Compatibility

EN 50081-2:	Electromagnetic compatibility — Generic emission standard — Part 2: Industrial environment
EN 50082-2:	Electromagnetic compatibility — Generic immunity standard — Part 2: Industrial environment

Vibration

EN 1031:	Measurement of whole body vibration — General requirements
EN 1032:	Testing of machinery in order to measure the whole-body vibration emission value — General requirements

Appendix B — Electrical equipment of machines

After completing a risk assessment (covered in sections 3.8 - 3.12 of this book), OEMs should fill out an “Inquiry form for the electrical equipment of machines.” This is reproduced from the EN 60204-1 standard, where it is designated as Annex B. The form follows the standard, and covers the sections which require special attentions. The purpose of the form is to facilitate an agreement between the machine manufacturer and the control manufacturer. The form is an excellent guide to cover all aspects of control product used on machinery and eliminate future disagreements.

Inquiry form for the electrical equipment of machines

It is recommended that the following information be provided by the intended user of the equipment. It facilitates an agreement between the user and supplier on basic conditions and additional user requirements to ensure proper design, application and utilization of the electrical equipment of the machine (see 4.1 of EN 60204-1).

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 (4.4)

2. Ambient temperature range _____

3. Humidity range _____

4. Altitude _____

5. Environmental (e.g. corrosive atmospheres, particulate matter, EMC) _____

6. Radiation _____

7. Vibration, shock _____

8. Special installation and operation requirements (e.g. flame retardant requirements for cables and conductors) _____

Power supply(ies) and related conditions (4.3)

9. Anticipated voltage fluctuations (if more than $\pm 10\%$) _____
10. Anticipated frequency fluctuations (if more than in 4.3.2) _____

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 in 4.3.2 _____
13. Type of power supply earthing:
 - TN (System with one point directly earthed, with a protective conductor (PE) connected directly to that point) _____
 - TT (System with one point directly earthed but the protective conductor (PE) not connected to that earth point of the system) _____
 - IT (System that is not directly earthed) _____
14. Is the electrical equipment to be connected to a neutral (N) supply conductor?
 (5.1) _____ YES _____ NO _____
15. Does the user or the supplier provide the overcurrent protection of the supply conductors? (7.2.2) _____
 Type and rating of overcurrent protective devices _____
16. Supply disconnecting device _____
 - Is the disconnection of the neutral (N) conductor required?
 YES _____ NO _____
 - Is a link for the neutral (N) permissible? YES _____ NO _____

17. Type of disconnecting device to be provided _____
18. Limit of power up to which three-phase AC motors may be started directly across the incoming supply lines _____kW
19. May the number of motor overload detection devices be reduced? (7.3)
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 (17.3) _____
22. Inscriptions/special markings _____
23. Mark of certification? YES _____ NO _____ If YES, which one? _____
On Electrical Equipment? _____ In which language? _____
24. Technical documentation (18.1)
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 (18.5) (additional sheets to be provided where necessary) _____
26. For which of the following classes of persons is access to the interior of enclosures required during normal operation of the equipment?
- Skilled persons _____
- Instructed persons _____
27. Are locks with removable keys to be provided for fastening doors or covers? YES _____ NO _____
28. If “two-hand control” is to be provided, state the type: _____

B

After the inquiry form has been completed (and the risk assessment performed), machine manufacturers should fill out the “Electrical equipment checklist,” which follows the EN 60204-1 standard. The checklist has three columns. The Applicable and Not Applicable columns are filled out as a reminder that these sections of the standard apply to the machinery. The Approved column is provided for checking. After the control equipment is completed, it provides a place for the inspectors, or approving persons, to check that the applicable sections of the standard were properly applied.

ELECTRICAL EQUIPMENT CHECKLIST — based on EN 60204-1

For control panels, with CE marking according to the Machinery Directive, this checklist must be filled out by marking the Applicable and Not Applicable columns. The purpose of the Approved column is that the item checked and it is according to the requirement during final inspection.

Customer: _____ Order No: _____
 Cat No: _____ Abecos/COPS File: _____ Date: _____
 Enc. Type: _____ Enc. Dimensions (in.): _____
 Rated Voltage: _____ Phase: _____ Hz: _____ DC: _____

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
4.1.0.0.0	Annex B has been completed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.1	Risk assessment has been performed by the customer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.2.2.3.4	Selection of equipment (List of equipment, CE marked add DOC, not CE marked TCF number)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.3	Electrical supply (Standard or Annex B, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4	Physical environment and operating conditions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.2	Electromagnetic compatibility (EMC), devices not marked with CE, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
4.4.3	Ambient air temperature (+5 to 40° C or Annex B, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.4	Humidity (50% at 40° C or equivalent, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.5	Altitude (up to 1000 m or Annex B, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.6	Contaminants (enclosure type, IP rating)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.7	Ionizing and non-ionizing radiation (microwave, ultraviolet, lasers, X-rays, etc., see Annex B, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4.8	Vibration, shock and bump (including machine generated, see Annex B, stated in the instruction manual)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.5	Transportation and storage (-25° C to +55° C)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.6	Provisions for handling (see also 14.4.6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.7	Installation and operation (installation drawing required)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1	Incoming supply conductor termination marking (single power source). Multiple power source, see 5.3.1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Neutral conductor, color, marking, terminal marking N (see Annex B)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	No connection between N and PE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2	Terminal for connection to the external protective earthing system: terminal marked with PE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Terminal size	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Conductor size, material copper, insulation green-and-yellow	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Load PE connectors, marking 417-IEC 5019	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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5.3	Supply disconnecting (isolating) device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3.1	Disconnect for each incoming source	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3.4	Exceptions: lighting circuits for maintenance, plug and sockets for maintenance, undervoltage protection, circuits to remain energized for satisfactory operation, control circuits for interlocking. Excepted circuits require warning labels and statement in the maintenance manual	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3.1	Disconnecting required for: Collector bars	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Slip-rings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Flexible cables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	On-board power supply	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	For two or more, disconnect interlocks may be required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3.2	Type of disconnecting device: IEC 947-3 AC 23B or DC 23B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Disconnecter without fuses, IEC 947-3 with interlock to the load switch	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Circuit-breaker IEC 947-2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Plug and socket for 16 A or 3 kW max. load, for motors kW or HP rated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3.3	Disconnecter marked with O and I	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	External operating handle (except power operated)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	For an Emergency Stop, the operator handle is red and the background yellow (see 10.7.5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Means for locking in the OFF position, disconnect all live conductors, switch for motors kW or HP rated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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5.3.4	Handle location between 0.6 and 1.9 m	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.4	Prevention of unexpected start-up (disconnect)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Protection against electric shock 6.2.2 or 6.2.3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.2.2	Protection by enclosures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Top surfaces of enclosures are protected IP4X or IPXXD	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	All live parts are protected to IP2X or IPXXB, or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Use of key or tool is necessary for access, or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Door mounted live parts protected to IP1X or IPXXA, or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	All live parts are disconnected before the door can be opened (defeater allowed). Live parts are protected to IP2X or IPXXB, or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	All live parts are protected to IP2X or IPXXB	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.2.3	All live parts are completely covered by insulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.2.4	Residual voltage discharged to 60 V in 5 seconds	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3	Protection against indirect contact (insulation failure), 6.3.2 or 6.3.3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3.2.2	Use of Class II equipment, or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3.2.3	Electrical separation (see 413.5 of I EC 364-4-41), or	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3.2.4	Isolated supply (one insulation failure not create danger)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3.3	Automatic disconnection in case of insulation failure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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6.4	Protection by PELV	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Nominal voltage 25 V a.c. or 60 V d.c. dry location, or 6 V a.c. or 15 V d.c. and	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	One side of the circuit is earthed, and	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Electrically not connected to other circuits, and	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Conductors physically separated from other conductors, and	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Plugs and sockets are not interchangeable with other voltages	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.4.2	Source of PELV: isolating transformer or battery or other equivalent means	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2	Overcurrent protection	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.2	Supply conductors (provided or requirements are in the installation instructions)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.3	Power circuits per 7.2.10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Neutral conductor same as phase conductors no protection required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Neutral conductors smaller than phase conductors see 473.3.2.1 of IEC 364-4-473	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.4	Control circuits	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Directly connected to the supply, see 7.2.3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Supplied through a transformer, required in the non-earthed conductor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.5	Conductors feeding outlets, all non-earthed conductors must be protected	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.6	Lighting circuits, all non-earthed conductors must be protected, separately from other circuits	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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7.2.7	Transformers protected per IEC 76-5 and IEC 742	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.8	Overcurrent protective devices are located where the conductor is connected to the supply	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2.9	Short-circuit rating is equal with the available short-circuit current	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Availability of fuses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.3	Overload protections of motors more than 0.5 kW, where required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Automatic restart shall be prevented	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.4	Abnormal temperature protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.5	Undervoltage protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.6	Overspeed protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.7	Earth-fault protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.8	Phase sequence protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.9	Surge protection, when required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.2	Protective conductors, cross section per IEC 364-5-54 or 7.4.3.1.7 of IEC 439-1 (see Table 1), material copper	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.3	Continuity of the protective bonding. All exposed conductive parts are connected to PE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.4	In the PE circuit switching devices are not allowed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Links in the PE circuit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.5	Connection to PE is not required for conductive parts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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8.2.5	Small sizes, less than 50 x 50 mm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Can not be grasped	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Unlikely to contact live parts (screws, nameplates, electromagnets, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.6	Interruption of protective circuit possible only after the live circuits have been interrupted, reconnection is in reverse order (plugs, sockets)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2.7	Protective conductor connecting points, see 14.1.1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Identified by PE or 417-IEC-5019 or green-and-yellow	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.5	Bonding to a common earth terminal is permitted for creating a noiseless earth identified by 417-IEC-5018	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.6	To reduce electrical disturbances low resistance may be used to PE connection marked with 417-IEC-5020	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.1.1	Control circuit supply shall be a separate winding transformer, except for a single motor starters with two external control	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.1.2	Control circuit voltage 277 V max. when supplied by a transformer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.1.3	Control circuit protection per 7.2.4 and 7.2.10	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.1.4	In one side earthed control circuits the control circuit switching devices connected in the live circuit, except overload relay contacts and control devices in the same enclosure when earth fault is unlikely	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.2	Stop functions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Category 0, uncontrolled stop (see 3.62)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Category 1, controlled stop (see 3.12) power available during the stopping process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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9.2.2	Category 2, controlled stop, power is available after the stopping process	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.3	Operating modes, when more than one and hazard may result, mode selector with lock may be required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.4	Suspension of safeguards, mode selector with lock is required (see standard)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.1	Protective interlocks (see 9.3), prevent unintended movement in case of power supply fault, battery replacement, lost signal, etc.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.2	Start possible after safeguards are in place	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Are hold-to-run controls required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Correct sequential starting (see 3.7)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.3	Stop (see 9.2.2) function shall override the start function	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.4.2	Emergency stop	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Shall override all functions and operations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Category 0 or 1 (see risk assessment)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Category 0, only hard-wired electromechanical components	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Category 1, final removal of power by electromechanical components	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.4.3	Emergency switching off (see IEC 364-4-46 and Annex E)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.5	Monitoring of command actions (hazardous conditions)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.7	Hold-to-run controls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Two-hand control, see risk assessment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Type 1, machine stops when either released	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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9.2.5.7	Type 2, both must be released before machine can restarted	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Type 3, the control must be initiated within set time limit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.5.8	Enabling device, continuously actuated start control, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.6	Combined start and stop controls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.7.1	Cableless control (remote, radio, infrared, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Power disconnection required at the operator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Prevent unauthorized use the control station	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Mark on the operator the operated machine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.7.2	Control limitation, only the intended function on the proper machine shall react to remote control	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.7.3	In hazardous condition the remote control require an emergency stop device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.7.5	Use of more than one remote operator control station, only one control station is operable at the same time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2.7.6	Battery-powered remote operator control station, variation in battery voltage shall not create hazard. Low battery warning required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.3.1	Restoration of interlocked safeguards shall not initiate machine motion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.3.2	Overtravel limits, required when hazardous condition can occur	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.3.3	Operation of auxiliary functions. Functions causing hazard shall have interlocks (pressure, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.3.4	Interlocks required between control elements which can cause hazardous condition, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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9.3.5	When reverse current breaking is used the motor starting in the opposite direction shall be prevented, if hazard could result	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4	Control functions in the event of failure, see risk assessment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.2.1	Use of proven circuit techniques and components	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.2.2	Provisions for redundancy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.2.3	Use of diversity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.2.4	Functional tests	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.3.1	Earth faults in the control circuit shall not cause starting, hazardous motion and shall not prevent stopping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.3.2	Voltage interruptions, see 7.5 and memory loss shall not create hazard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4.3.3	Loss of circuit continuity in safety circuits shall not result in hazard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	Operator interface and machine mounted control devices, devices mounted outside or partially outside the control enclosure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.1.2	Location and mounting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Accessible for servicing and prevent damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Hand-operated control: above 0.6 m and reachable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.1.3	Enclosure protection, IP rating, minimum IPXXD	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.1.4	Position sensors not damaged by overtravel, for safety related functions direct acting or equivalent	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.1.5	Portable and pendant control stations shall be shock and vibration resistant	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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10.2	Push-buttons	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.2.1	Colors per Table 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.2.2	Markings IEC 417 symbols 5007, 5008, 5010 or 5011	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.3.2	Indicator lights colors per Table 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.3.3	Flashing lights allowed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.4	Illuminated push-buttons color coded per Tables 2 and 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.5	Rotary control devices mounted to prevent rotation of the stationary member	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.6	Start devices, minimize inadvertent operation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7	Devices for emergency stop	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7.1	Located at each control station and readily accessible	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7.2	Types: push-button, pull-cord, pedal operated (no guard), disconnect switch, positive (direct) operation per IEC 947-5-1 and self latching	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7.3	Restoration of normal function after emergency stop only after manual reset	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7.4	Actuators colored red, background yellow, push-button mushroom type	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.7.5	Disconnect may be used when it is readily accessible and it is according to 5.3.2 type a), b), or c), red operator, yellow background	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.8	Devices for emergency switching off	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.8.1	Location as necessary	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.8.2	Types: push-button, pull-cord, positive (direct) operation per IEC 947-5-1 and self latching. Glass enclosure allowed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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10.8.3	Restoration of normal function after emergency switching off only after manual reset	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.8.4	Actuators red, background yellow, push-button mushroom type	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.9	Visual displays visible from the position of the operator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	Electronic equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.2.1	The status of the digital inputs and outputs should be indicated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.2.2	Equipotential bonding:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	All input/output, processor, power supply racks shall be bonded and earthed, see 8.2.3 and exclusions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.3	Programmable equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.3.1	Programmable controllers per IEC 1131-1 and -2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.3.2	Memory retention and protection per 9.4.3.2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.3.3	Software verification required for reprogrammable logic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11.3.4	Use in safety-related functions, shall not be used for Category 0 emergency stop function	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	Control gear location, mounting and enclosures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.1	Accessible for use	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Accessible for maintenance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Protected against external influences	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.2.1	Accessibility and maintenance: located between 0.4 and 2.0 m above service (floor) level, plugs not interchangeable, test points marked	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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12.2.2	Physical separation and grouping:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Non-electrical devices are not permitted in the electrical enclosure, terminals grouped: power circuits, associated control circuits, other control circuits (external sources, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.2.3	Heating effects, each components remain within permitted temperature limit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.3	Degrees of protection IP22 minimum	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.4.1	Enclosures, doors and openings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Captive door fasteners	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Windows (polycarbonate 3 mm)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Doors 0.9 m wide max.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12.4.2	Access to control gear per 2.4 of IEC 364-4-481	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13	Conductors and cables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.1	Voltage, current, temperature	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.2	Conductors, copper, temperature per Table 4, for frequent movement flexible Class 5 or 6 (Table C.4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.3	Insulation, approved	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.4	Current carrying capacity in normal service:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Temperature in Table 4 is not exceeded	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Current rating is per Table 5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.5	Cable voltage drop less than 5%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.6	Smallest cross section per Table 6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.7	Flexible cables, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13.8	Collector wires, collector bars and slipping assemblies, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
14	Wiring practices	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.1.1	Terminal blocks identified	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Liquids drain away from flexible wires	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Crimp connections crimp conductor and insulation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Wiring does not cross over terminal blocks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.1.2	Conductors and cable runs:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Avoid splices from terminal to terminal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Extra length for termination	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	PE conductors routed with phase conductors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.1.3	Conductors of different circuits may be in the conduit or cable, insulation for the highest voltage in the group	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.2	Identification of conductors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.2.1	Identified at each terminals, for color coding see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.2.2	Identification of PE conductor is green-and-yellow throughout the length of the conductor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.2.3	Identification of the neutral conductors, color light blue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.2.4	Identification of other conductors, power circuits: black, a.c. control circuits: red, d.c. control circuits: blue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.3	Wiring inside the enclosure, conductors supported, non-metallic channels flame retardant, door mounted devices wired with flexible conductors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.4	Wiring outside the enclosure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
14.4.1	IP protection at the wiring entrance is not reduced	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.4.2	External ducts, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.4.3	Connection to moving elements of the machine, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.4.5	Plug/socket combinations:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Male plug on the load side	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Over 16 A retaining type	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Over 63 A interlocked with a switch type	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	If more than one each identified by marking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	For control circuits no domestic type	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.4.6	Dismantling for shipment:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Terminals or plug/sockets required at sectional points	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5	Ducts, connection boxes and other boxes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.1	IP 33 protection minimum, drain holes 6 mm dia. allowed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.3	Rigid metal conduit and fittings, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.4	Flexible metal conduit and fittings, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.5	Flexible non-metal conduit and fittings, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.6	Cable trunking systems, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.7	Machine compartments and cable trunking systems, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.8	Connection boxes and other boxes, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14.5.9	Motor connection boxes shall be used only for conductors going to the motor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
15	Electric motors and associated equipment, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16	Accessories and lighting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.1	Socket-outlet per IEC 309-1 or marked with voltage and current	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Unearthed conductors protected for overcurrents	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.2	Local lighting of the machine and equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.2.1	On-off switch not in the lamp holder or in the cord	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.2.2	Supply voltage 50 V or less preferred, not over 250 V, isolating transformer may be required, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.2.3	Protection per 7.2.6	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16.2.4	Fittings (lamp holders) approved, lamp protected, if out of reach the section does not apply	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17	Markings, warning signs and item designations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17.1	Supplier's name or trade mark	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17.2	Warning signs; for enclosures not clearly shown to contain electrical equipment, use black lightning flash on yellow background per 417-IEC-5036	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17.3	Functional identification, control devices, indicators, displays marked per IEC 417 and ISO 7000	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17.4	Marking of control equipment:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Supplier's name or trademark	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Certification mark	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Serial number (if applicable)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
17.4	Voltage, phases, frequency, full load current	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Short-circuit rating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Electrical diagram number	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17.5	Item designation (not applicable to a single motor controller)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	All components identified with the same designation as on the drawing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	Technical documentation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.1	Installation, operation and maintenance information supplied in an agreed language (see Annex B)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.2	Information to be provided, see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.3	Requirements applicable to all documentation per IEC 750 and IEC 1082-1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.4	Basic information, minimum information:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Electrical supply requirement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Handling, transportation and storage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Inappropriate use of the equipment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.5	Installation diagram, preliminary work, supply cables, overcurrent protective devices, foundation, space for removal and servicing, interconnection diagram	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.6	Block (system) diagrams and function diagrams, see IEC 1082-1 Section 2 and IEC 1082-2 Section 3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.7	Circuit diagrams required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.8	Operating manual for set-up and use of the equipment required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18.9	Maintenance manual required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

204-1 Ref.	Description of Standards	Applicable	Not Applicable	Approved
18.10	Part list for spare and replacement parts required	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19	Testing and verification	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.1	Product standards apply; if product standard is not available the following tests apply:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Equipment and technical documentation is in agreement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Continuity of the PE circuit	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Insulation resistance (see 19.3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Dielectric voltage test (see 19.4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Protection against residual voltages (see 19.5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Functional test (see 19.6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.2	Continuity of the protective bonding circuit:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	After installation loop impedance test per 6.1.2 of IEC 364-6-61	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	For small machines, less than 30 m bonding loop, not connected to the power source, inject 10 A from a PELV source and the measured voltage drop shall not exceed Table 9 values	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.3	Insulation resistance tests:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Measured with 500 V d.c. not less than 1M Ω	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	For exception see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.4	Dielectric voltage tests between circuits and bonding:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Twice the rated voltage or 1000 V for 1s, for details see standard	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.5	Protection against residual voltages, see 6.2.4	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.6	Functional tests related to safety	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19.7	Retesting after changes or modifications	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Appendix C — EHSR (Annex I of the Machinery Directive)

From a control systems perspective, Section 1 of Annex I is probably the most important part of the EHSR. To give readers an idea of what to expect when reading the EHSRs, this Appendix notes some of the topics in Section 1.

OBTAINING AND UNDERSTANDING THE COMPLETE EHSRs IS AN ABSOLUTE REQUIREMENT OF THE LAW. THE FOLLOWING LIST SHOULD NOT BE CONSTRUED AS COMPLETE OR A SUBSTITUTE FOR THE EHSRs.

ESSENTIAL HEALTH AND SAFETY REQUIREMENTS

(From 89/392/EEC, Annex I — as of September 1997)

1.1 General remarks

1.1.1. Definitions.

1.1.2. Principles of safety integration

- (a) Machinery must be so constructed that it is fitted for its function, and can be adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen by the manufacturer. The aim of measures taken must be to eliminate any risk of accident throughout the foreseeable lifetime of the machinery, including the phases of assembly and dismantling, even where risks of accident arise from foreseeable abnormal situations.
- (b) In selecting the most appropriate methods, the manufacturer must apply the following principles, in the order given:
 - eliminate or reduce risks as far as possible (inherently safe machinery design and construction),
 - take the measures in relations to risks that cannot be eliminated,
 - inform users of the residual risks due to any shortcomings of the protection measures adopted, indicate whether any particular training is required and specify any need to provide personal protection equipment.

- (c) When designing and constructing machinery, and when drafting the instructions, the manufacturer must envisage not only the normal use of the machinery but also uses which could reasonably be expected. The machinery must be designed to prevent abnormal use if such use would engender a risk. In other cases the instructions must draw the user's attention to ways — which experience has shown might occur — in which the machinery should not be used.
- (d) Under the intended conditions of use, the discomfort, fatigue and psychological stress faced by the operator must be reduced to the minimum possible taking ergonomic principles into account.
- (e) When designing and constructing machinery, the manufacturer must take into account the constraints to which the operator is subject as a result of the necessary or foreseeable use of personal protection equipment (such as footwear, gloves, etc.).
- (f) Machinery must be supplied with all the essential special equipment and accessories to enable it to be adjusted, maintained and used without risk.

1.1.3. Materials and products

1.1.4. Lighting

1.1.5. Design of machinery to facilitate its handling

1.2 Controls: Reliability, starting and stopping, energy isolation, control failures

1.2.1. Safety and reliability of control systems

Control systems must be designed and constructed so that they are safe and reliable, in a way that will prevent a dangerous situation arising. Above all they must be designed and constructed in such a way that:

- they can withstand the rigors of normal use and external factors,
- errors in logic do not lead to dangerous situations.

1.2.2. Control devices

Control devices must be:

- clearly visible and identifiable and appropriately marked where necessary.



- positioned for safe operation without hesitation or loss of time, and without ambiguity,
- designed so that the movement of the control is consistent with its effect,
- located outside the danger zones, except for certain controls where necessary, such as emergency stop, console for training of robots,
- positioned so that their operation cannot cause additional risk,
- designed or protected so that the desired effect, where a risk is involved, cannot occur without an intentional operation,
- made so as to withstand foreseeable strain; particular attention must be paid to emergency stop devices liable to be subjected to considerable strain.

1.2.3. Starting

It must be possible to start machinery only by voluntary actuation of a control provided for the purpose. The same requirement applies:

- when restarting the machinery after a stoppage, whatever the cause,
- when effecting a significant change in the operating conditions (e.g., speed, pressure, etc.), unless such restarting or change in operating conditions is without risk to exposed persons.

Where machinery has several starting controls and the operators can therefore put each other in danger, additional devices (e.g., enabling devices or selectors allowing only one part of the starting mechanism to be actuated at any one time) must be fitted to rule out such risks.

1.2.4. Stopping device — Normal stopping

Each machine must be fitted with a control whereby the machine can be brought safely to a complete stop. Each workstation must be fitted with a control to stop some or all of the moving parts of the machinery, depending on the type of hazard, so that the machinery is rendered safe. The machinery's stop control must have priority over the start controls.

Once the machinery or its dangerous parts have stopped, the energy supply to the actuators concerned must be cut off.

Stopping device — Emergency stop

Each machine must be fitted with one or more emergency stop devices to enable actual or impending danger to be averted.

The stopping device must:

- have clearly identifiable, clearly visible and quickly accessible controls,
- stop the dangerous process as quickly as possible, without creating additional hazards,
- where necessary, trigger or permit the triggering of certain safeguard movements.

The stop command must be sustained by engagement of the emergency stop device until that engagement is specifically overridden; it must not be possible to engage the device without triggering a stop command; it must be possible to disengage the device only by an appropriate operation; and disengaging the device must not restart the machinery but only permit restarting.

1.2.5. Mode selection

1.2.6. Failure of the power supply

The interruption, re-establishment after an interruption or fluctuation in whatever manner of the power supply to the machinery must not lead to a dangerous situation. In particular:

- the machinery must not start unexpectedly,
- the machinery must not be prevented from stopping if the command has already been given,
- the protection devices must remain fully effective.

1.2.7 Failure of the control circuit

A fault in the control circuit logic, or failure of or damage to the control circuit must not lead to dangerous situations. In particular:

- the machinery must not start unexpectedly,
- the machinery must not be prevented from stopping if the command has already been given,
- no moving part of the machinery or piece held by the machinery must fall or be ejected,



- automatic or manual stopping of the moving parts wherever they may be must be unimpeded,
- the protection devices must remain fully effective.

1.2.8. Software

1.3 Protection against mechanical hazards

1.3.1. Stability

1.3.2. Risk of break-up during operation

1.3.3. Risks due to falling or ejected objects

1.3.4. Risks due to surfaces, edges or angles

1.3.5 Risks related to combined machinery

1.3.6. Risks relating to variations in the rotational speed of tools

1.3.7. Prevention of risks related to moving parts

The moving parts of machinery must be designed, built and laid out to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way as to prevent all risk of contact which could lead to accidents.

1.3.8. Choice of protection against risks related to moving parts

Guards or protection devices used to protect against the risks related to moving parts (such as pulleys, belts, gears, rack and pinions, shafts, etc.) must be selected on the basis of the type of risk. Fixed or movable guards can be used; movable guards should be used where frequent access is foreseen.

Guards or protection devices designed to protect exposed persons against the risks associated with moving parts contributing to the work (such as cutting tools, moving parts of presses, cylinders, parts in the process of being machined, etc.) must be fixed guards wherever possible. Otherwise, use movable guards or protection devices such as sensing devices (e.g., non-material barriers, sensor mats), remote-hold protection devices (e.g., sensing device, two-hand controls), or protection devices intended automatically to prevent all or part of the operator's body from encroaching on the danger zone.

1.4 Required characteristics of guards and protective devices

- 1.4.1. General requirements
- 1.4.2. Special requirements for guards
 - 1.4.2.1. Fixed guards
 - 1.4.2.2. Movable guards
 - 1.4.2.3. Adjustable guards restricting access
- 1.4.3. Special requirements for protection devices

Protection devices must be designed and incorporated into the control system so that:

- moving parts cannot start up while they are within the operator's reach,
- the exposed person cannot reach moving parts once they have started up,
- they can be adjusted only by means of an intentional action, such as the use of a tool, key, etc.,
- the absence or failure of one of their components prevents starting or stops the moving parts.

1.5 Protection against other hazards

- 1.5.1. Electricity supply
- 1.5.2. Static electricity
- 1.5.3. Energy supply other than electricity
- 1.5.4. Errors of fitting
- 1.5.5. Extreme temperatures
- 1.5.6. Fire
- 1.5.7. Explosion
- 1.5.8. Noise
- 1.5.9. Vibration
- 1.5.10. Radiation



- 1.5.11. External radiation
- 1.5.12. Laser equipment
- 1.5.13. Emissions of dust, gases, etc.
- 1.5.14. Risk of being trapped in a machine
- 1.5.15. Risk of slipping, tripping or falling

1.6 Maintenance

1.6.1. Machinery maintenance

It must be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while machinery is at a standstill. If one or more of the above conditions cannot be satisfied for technical reasons, these operations must be possible without risk.

- 1.6.2. Access to operating position and servicing points
- 1.6.3. Isolation of energy sources
- 1.6.4. Operator intervention
- 1.6.5. Cleaning of internal parts

1.7 Indicators (warning, marking, instructions)

- 1.7.0. Information devices
 - 1.7.1. Warning devices
 - 1.7.2. Warning of residual risks
 - 1.7.3. Marking
 - 1.7.4. Instructions

Appendix D — Some significant faults and failures

Electrical/electronic components

- short circuit or open circuit; e.g., each fault (short circuit to the protective conductor or a conductive part), open circuit of any conductor
- short circuit or open circuit occurring in single components; e.g., in position switches, control and regulation equipment, machine actuators, relay contacts
- non drop-out or non pick-up of electromagnetic elements; e.g., contactors, relays, magnetic valves
- non-starting or non-stopping of motors; e.g., servo motors
- mechanical blocking of moving elements, loosening or displacing of fixed elements; e.g., position switches
- drift beyond the tolerance values for analogue elements, e.g. resistors, capacitors, transistors
- oscillation of (unstable) output signals in integrated components
- loss of entire function or of partial functions (worst-case behavior) in complex integrated components e.g., microprocessors, programmable electronic systems, application-specific integrated circuits

Hydraulic and pneumatic components

- no switching or incomplete switching of the moving element; e.g., sticking of a valve piston
- drift in the original control position of the moving element e.g., directional control valves
- leakage and modification of the leakage volume flow; e.g., directional control valves
- unstable control characteristics in servo-valves and proportional valves;
- loss of pressure or bursting of lines; e.g., of hose pipes and at the hose coupling
- clogging of the filter element (in particular caused by solid substances);

D

- abnormal pressure and/or volume flow; e.g., hydraulic pumps, hydraulic motors, compressors, cylinders
- failure or abnormal modification of the input or output signal characteristics in sensors; e.g., pressure switches

Mechanical components

- spring fracture
- stiffness or sticking of guide-moving components
- loosening of fixtures; e.g., by vibration
- wear; e.g., runners, latches, rollers
- misalignment of parts
- environmental influences; e.g., corrosion, temperature

Appendix E — Standards and characteristics of safety functions

Reference list of some standards giving requirements for characteristics of safety functions
(as of March 1, 1997)

Safety Function Characteristic	Requirements				Further Standards	Additional Information (Not Requirements)
	EN 954-1	EN 292		Annex A Part 2		
		Part 1	Part 2			
Definitions	3	3			clause 3 of EN 60204-1	clause 2 of EN 60335-1
Design principles	4.2		3	1.2.1, 1.2.2 1.2.7, 1.5.4	9.4 of EN 60204-1	clause 22 of EN 60335-1, cl 5, 6 of EN 775, cl 5 of prEN 1921
Ergonomic principles	4.4	4.9	3.6, 3.7.8a	1.2.2 ¶ 1	clause 10 of EN 60204-1	6.2 of EN 775, 4.6 of prEN 1921
Stop function	5.2		3.7.1 3.7.8b	1.2.4 1.3.5	9.2.2, 9.2.5.3 of EN 60204-1	7.12 of EN 60335-1 5.11 of prEN 1921
Emergency stop function	5.3		6.1.1	1.2.4	EN 418, 9.2.5.4 of EN 60204-1	6.4.2, 7.2.5 of EN 775, 5.11.2 of prEN 1921
Manual reset	5.4		6.1.1	1.2.4	EN 418, 9.2.5.4 of EN 60204-1	6.4.2, 6.4.3, 7.6 of EN 775, 6.4.3 of prEN 1921
Start and restart	5.5		3.7.1 3.7.2	1.2.3, 1.3.5	9.2.1, 9.2.5.1, 9.2.5.2, 9.2.6 of EN 60204-1	6.10, 7.2.5, 7.3.1, 9.3.4 of EN 775
Response time	5.6				3.2, A.3, A.4 of prEN 999	
Safety-related parameters	5.7		3.7.9e		7.1, 9.3.2, 9.3.4 of EN 60204-1	4.2 of EN 775, 11.8 of EN 60335-1
Local control function	5.8		3.7.9, 3.7.10			3.2.9, 7.2.6 of EN 775, 3.13, 4.5, 5.9, 6.2, of prEN 1921
Muting	5.9					
Manual suspension of safety functions	5.10		3.7.10 4.1.4	1.2.5	9.2.4 of EN 60204-1	6.10 of EN 775, 5.8 of prEN 1921

Safety Function Characteristic	Requirements					Additional Information (Not Requirements)
	EN 954-1	EN 292			Further Standards	
		Part 1	Part 2	Annex A Part 2		
Fluctuations, loss and restoration of power sources	5.11		3.7.8e	1.2.6 1.5.3	4.3, 7.1, 7.5 of EN 60204-1	
Unexpected start-up			3.7.2	1.2.3, 1.2.6, 1.2.7	EN 1037, 5.4 of EN 60204-1	
Indications and alarms			3.6.7 5.3	1.2.2, ¶ 4, 6 1.7.0, 1.7.1	EN 457, prEN 842, prEN 981, 10.4, 11.3 of EN 60204-1, EN 60447	5.6 of prEN 1921
Escape and rescue of trapped persons			6.1.2	1.2.2, ¶ 5, 6		
Electrical equipment		3.9		1.5.1, 1.5.7	EN 60204-1	
Electrical supply				1.5.1	4.3 of EN 60204-1	
Other supply				1.5.3	5.1.4 of EN 982 5.1.4 of EN 983	
Covers and enclosures					13.4 of EN 60204-1, EN 60529	
Pneumatic and hydraulic equipment			3.8	1.5.3	EN 982, EN 983	
Isolation and energy dissipation			6.2.2	1.6.3	EN 1037, 5.3, 6.3.1 of EN 60204-1	
Physical environment and operating conditions			3.7.11		4.4 of EN 60204-1	6.9 of EN 775, 4.3, 4.5 of prEN 1921
Control modes and mode selection			3.7.9 3.7.10	1.2.5	9.2.3 of EN 60204-1	6.10 of EN 775
Interfaces/connections				1.5.4 1.6.1 ¶ 3	9.1.4, 11, 15.4 of EN 60204-1	
Interaction between different safety-related parts of control systems			3.7.8e		9.3.4 of EN 60204-1	
Man-machine interface			3.6.6, 3.6.7	1.2.2	clause 10 of EN 60204-1, EN 60447	

Appendix F — Sample DOCs

Words printed in italics are instructions for the person drawing up this declaration and should be deleted in the actual text of this declaration; this model is to be used for machinery which is not mentioned in Annex IV of Directive 89/392/EEC. In case of Annex IV-machinery, this model should be amended to account for the special conditions in Annex II of Directive 89/392/EEC.

EC DECLARATION OF CONFORMITY FOR MACHINERY

(Directive 89/392/EEC, Annex II, sub A)

Manufacturer: (business name) _____

Address: _____

Herewith declares that _____

(description of the machinery: make, type, serial number, etc.)

- is in conformity with the provision of the Machinery Directive (Directive 89/392/EEC), as amended, and with national implementing legislation;
- is in conformity with the provisions of the following other EEC directives *(only to be mentioned where appropriate)*:

 and furthermore declares that

- the following (parts/clauses of) harmonized standards have been applied *(only to be mentioned where appropriate)*:

- the following (parts/clauses of) national technical standards and specifications have been used *(only to be mentioned where appropriate)*:

 (place)

 (date, but only optional)

 (Signature)

 (full name and identification of the person empowered to sign on behalf of the manufacturer)

Please note that this declaration must be drawn up in the same language as the original instructions (see Annex I, Section 1.7.4.b) and must either be typewritten or handwritten in block capitals. It must be accompanied by a translation in one of the official languages of the country in which the machinery is to be used. This translation must be done in accordance with the same conditions as for the translation of the instructions.

DECLARATION BY THE MANUFACTURE (Variant 1)

(Directive 89/392/EEC, Art. 4.2 and Annex II, sub B)

PROHIBITION TO PUT INTO SERVICE

Manufacturer: (business name) _____

Address: _____

Herewith declares that _____

(description of the machinery: make, type, serial number, etc.)

- is intended to be incorporated into machinery or to be assembled with other machinery to constitute machinery covered by Directive 89/392/EEC, as amended;
- does therefore not in every respect comply with the provisions of this directive;
- does comply with the provisions of the following other EEC directives *(only to be mentioned where appropriate)*:

and that

- the following (parts/clauses of) harmonized standards have been applied *(only to be mentioned where appropriate)*:

- the following (parts/clauses of) national technical standards and specifications have been used *(only to be mentioned where appropriate)*:

and furthermore declares that it is not allowed to put the machinery into service until the machinery into which it is to be incorporated or of which it is to be a component has been found and declared to be in conformity with the provisions of Directive 89/392/EEC and with national implementing legislation, i.e. as a whole, including the machinery referred to in this declaration.

(place)_____
(date, but only optional)_____
(Signature)_____
(full name and identification of the person empowered to sign on behalf of the manufacturer)

DECLARATION BY THE MANUFACTURER (variant 2)

(Directive 89/392/EEC, Art. 4.2 and Annex II, sub B)

PROHIBITION TO PUT INTO SERVICE

Manufacturer: (business name) _____

Address: _____

Herewith declares that _____

(description of the machinery: make, type, serial number, etc.)

- is intended to be incorporated into machinery or to be assembled with other machinery to constitute machinery covered by Directive 89/392/EEC, as amended;

and that

- the following (parts/clauses of) harmonized standards have been applied *(only to be mentioned where appropriate)*:

and that

- the following (parts/clauses of) harmonized standards have been applied *(only to be mentioned where appropriate)*:

and furthermore declares that it is not allowed to put the machinery into service until the machinery into which it is to be incorporated or of which it is to be a component has been found and declared to be in conformity with the provisions of Directive 89/392/EEC and with national implementing legislation, i.e. as a whole, including the machinery referred to in this declaration.

(place)_____
(date, but only optional)_____
(Signature)_____
(full name and identification of the person empowered to sign on behalf of the manufacturer)

EC DECLARATION OF CONFORMITY FOR SAFETY COMPONENTS

PLACED ON THE MARKET SEPARATELY

(Directive 89/392/EEC, Annex II, sub C.)

Manufacturer: (business name) _____

Address: _____

Herewith declares that _____

(description of the machinery: make, type, serial number, etc.)

which has the following safety function *(if not already obvious from the description)*:

-
- is in conformity with the provisions of the Machinery directive (Directive 89/392/EEC), as amended, and with national implementing legislation;
 - is in conformity with the provisions of the following other EEC directives *(only to be mentioned where appropriate)*:
-

and furthermore declares that

- the following (parts/clauses of) harmonized standards have been applied *(only to be mentioned where appropriate)*:
-

- the following (parts/clauses of) national technical standards and specifications have been used *(only to be mentioned where appropriate)*:
-

(place)

(date, but only optional)

(Signature)

(full name and identification of the person empowered to sign on behalf of the manufacturer)

Appendix G — Annex IV equipment

The following types of machinery and safety components may require an EC-type examination:

Machinery

1. Circular saws (single or multi-blade) for working with wood and analogous materials or for working with meat and analogous materials.
 - A) Sawing machines with fixed tool during operation, having a fixed bed with manual feed of the workpiece or with a demountable power feed.
 - B) Sawing machines with fixed tool during operation, having a manually operated reciprocating saw-bench or carriage.
 - C) Sawing machines with fixed tool during operation, having a built-in mechanical feed device for the workpieces, with manual loading and/or unloading.
 - D) Sawing machines with movable tool during operation, with a mechanical feed device and manual loading and/or unloading.
2. Hand-fed surface planing machines for woodworking.
3. Thickeners for one-side dressing with manual loading and/or unloading for woodworking.
4. Band-saws with a fixed or mobile bed and band-saws with a mobile carriage, with manual loading and/or unloading, for working with wood and analogous materials or for working with meat and analogous materials.
5. Combined machines of the types referred to in 1 to 4 and 7 for working with wood and analogous materials.
6. Hand-fed tenoning machines with several tool holders for woodworking.
7. Hand-fed vertical spindle moulding machines for working with wood and analogous materials.
8. Portable chain saws for woodworking.
9. Presses, including press-brakes, for the cold working of metals, with manual loading and/or unloading, whose movable working parts may have a travel exceeding 6 mm and a speed exceeding 30 mm/s.



10. Injection or compression plastics-moulding machines with manual loading or unloading.
11. Injection or compression rubber-moulding machines with manual loading or unloading.
12. Machinery for underground working of the following types:
 - machinery on rails: locomotives and brake-vans,
 - hydraulic-powered roof supports,
 - internal combustion engines to be fitted to machinery for underground working.
13. Manually loaded trucks for the collection of household refuse incorporating a compression mechanism.
14. Guards and detachable transmission shafts with universal joints
15. Vehicles servicing lifts.
16. Devices for the lifting of persons involving a risk of falling from a vertical height of more than 3 meters.
17. Machines for the manufacture of pyrotechnics.

Safety components

1. Electrosensitive devices designed specifically to detect persons in order to ensure their safety (non-material barriers, sensor mats, electromagnetic detectors, etc.).
2. Logic units which ensure the safety functions of bi-manual controls.
3. Automatic movable screens to protect the presses referred to in 9, 10, and 11.
4. Roll-over protective structures.
5. Falling-object protective structures.

Appendix H — IEC Style Diagrams from Chapter 5

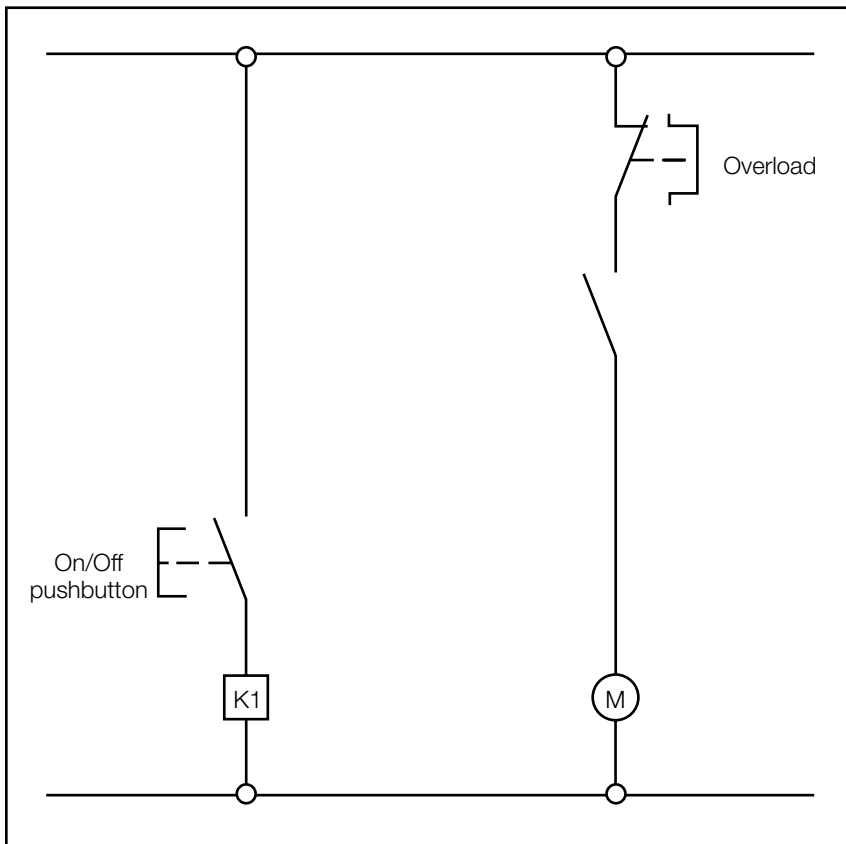


Fig. 5.6 Potential category B control circuit.

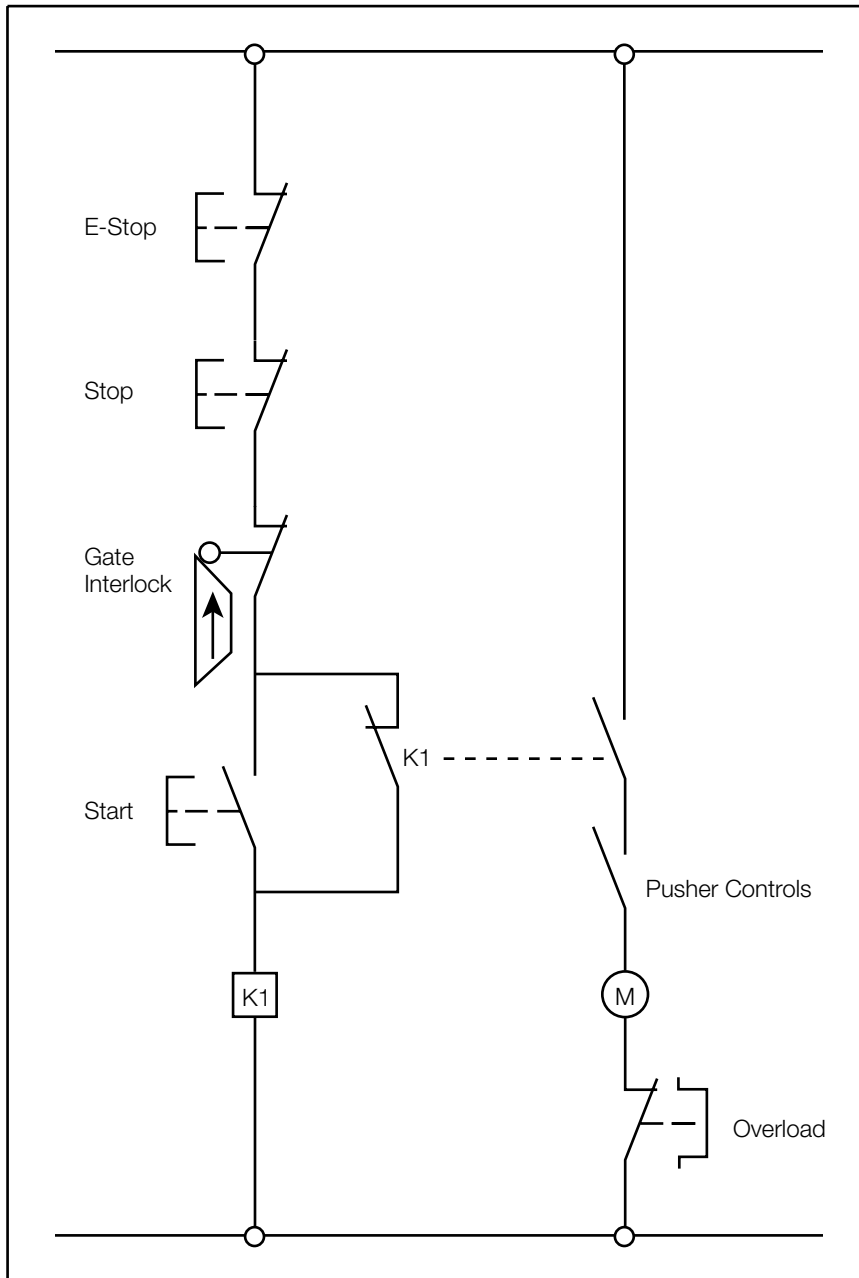


Fig. 5.7 Potential category 1 control circuit.

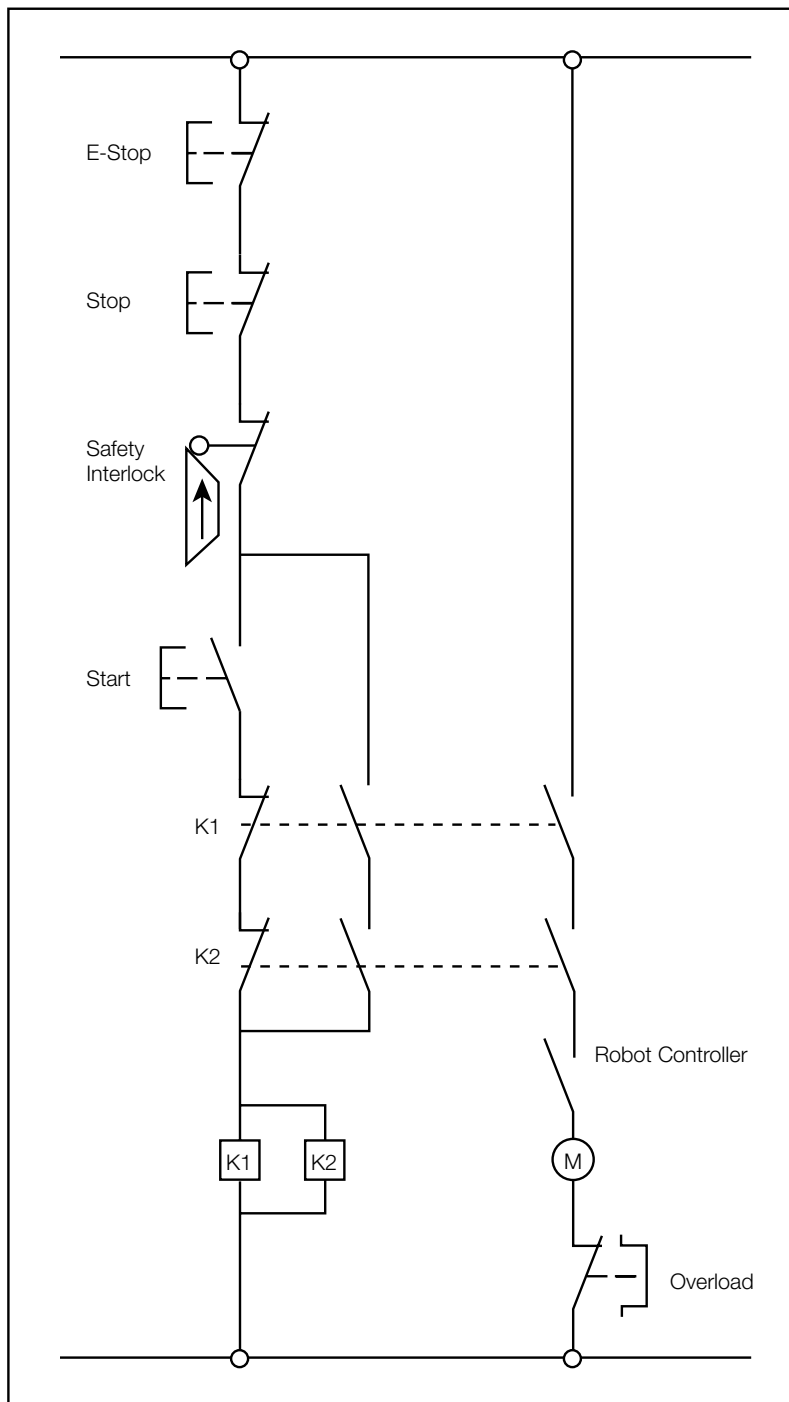


Fig. 5.8 Potential category 2 control circuit.

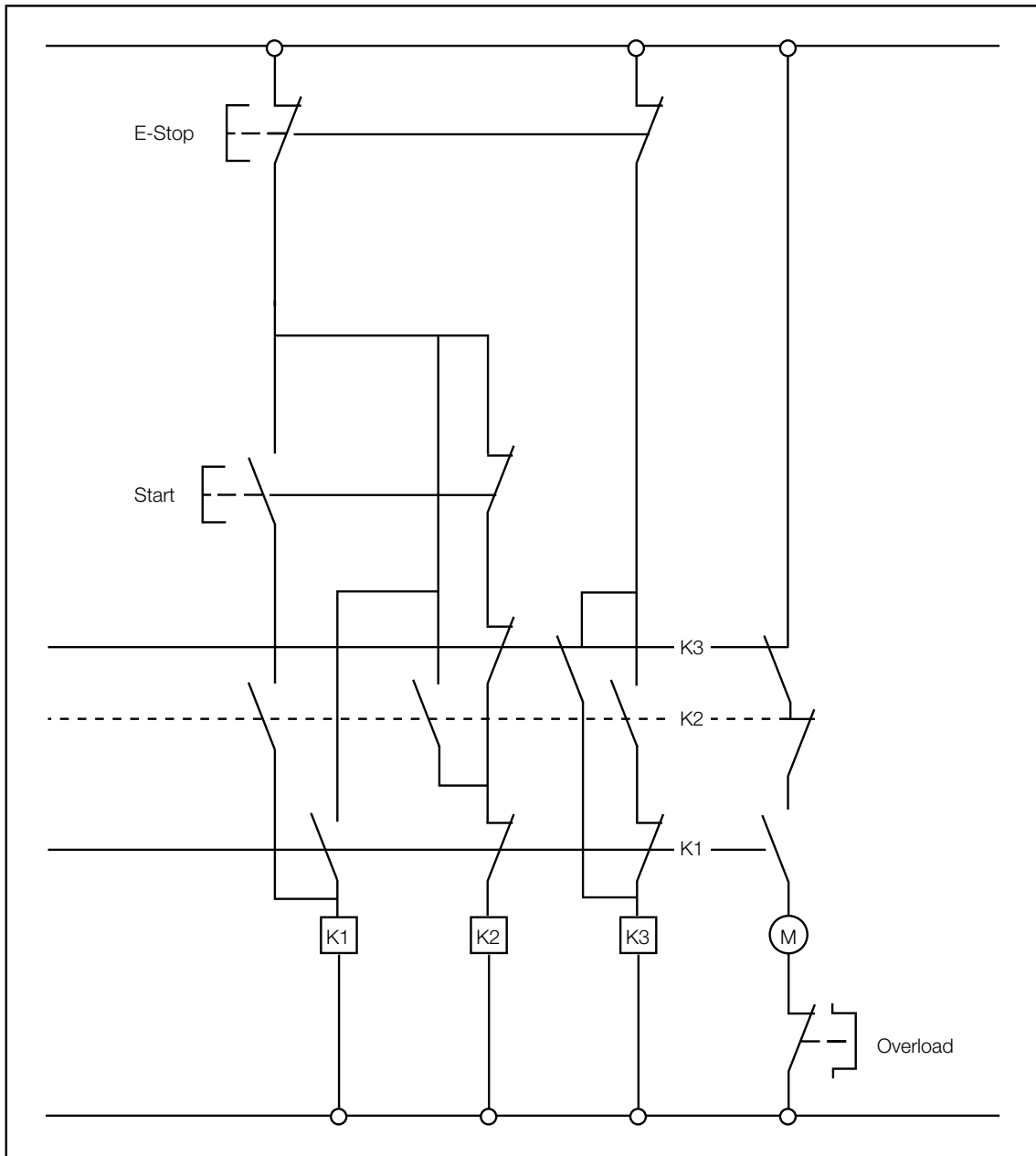


Fig. 5.8 Potential category 4 control circuit.

The Road Map

This handbook provides machine designers, quality assurance managers, sales directors and others with a road map for understanding the Machinery Directive and CE marking process. Its contents include:

- An easy-to-follow introduction to the Machinery Directive and key European Norms (standards)
- The basic CE marking steps
- Direction to further resources
- Important guidance on risk estimation and assessment
- A review of safety and safety-related components for control systems
- Answers to frequently asked questions
- Excerpts from selected directives and standards

Most importantly, *Understanding the Machinery Directive* provides some straight talk about what the language of the directives and standards really requires.



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