1- Safety-design: basics

Every product or machine must comply with the Directive 73/23/EEC and subsequent modifications and completions, in order to be marketed freely in the countries of the European Community. This Directive determines the fundamental requirements of quality and safety of products.
In particular, the Machinery 89/392/CEE directive and its subsequent modifications and completions determine the features for the machine in order to guarantee a sufficient safety level for the machine-workers.
The conformity of a machine is certified by the issue of the Conformity Declaration by the manufacturer and by the application of the marking CE on the machine itself. In order to evaluate the risks, that the machine can cause, and to properly implement the safety systems, the European regulation organization CEN / CENELEC issued a series of standards, which translate into technical definitions the contents of the ECC directive mentioned above. These safety standards (harmonized standards) are divided into three groups: A, B and C.
A standards contain the basic concepts and the designing principles for the construction of all machines.
B standards concern common features of groups of machines and are divided in two sub categories:
B1 concerns the general safety condition (electric, hydraulic equipments, etc..)
B2 refers to the devices assigned to the realization of safety circuits.
The last group of standards, C, refers to specific groups of machines, for which the regulation's organizations have issued specific standards, because of their dangerousness nature (e.g. hydraulic presses, injection machines, etc.).

A STANDARDS
- **EN 292-1 and -2:**
- Danger evaluation
- Safety design of the machine
- Description of the protection device
- Check of the residual risk
- **EN 1050:**
- Damage extent
- Risk period
- Possibility to prevent the danger

B1 STANDARDS
- **EN 954-1:**
- cat.B according with basic safety principles
- cat.1 well tested components and principles
- cat.2 cyclic check
- cat.3 system redundance
- cat.4 redundance and self-control

B2 STANDARDS
- **EN 418** device for emergency stop
- **EN 1088** devices for interlock of guards
- **EN 574** device with two hands control
- **EN 457** sound-signals of danger
- **EN 842** optical signals of danger
- **EN 60204-1** electric equipment in the machines

C STANDARDS
- **EN 693** hydraulic presses
- **EN 201** injection machines
- **EN 415** wrapping machines
- **EN 1175** warehouse trucks

2 - Procedure for the choice and the design of safety measures

The following 5 steps are quoted from the standard EN 954-1 par. 4.3 for the correct choice and design of safety measures.

Step 1 Danger analysis and risks computation on the machine.
Step 2 Arrangement of measures for the risk reduction by means of control devices.
Step 3 Specification of the safety requirements in terms of:
- choice of the safety category.
- realization of safety functions;

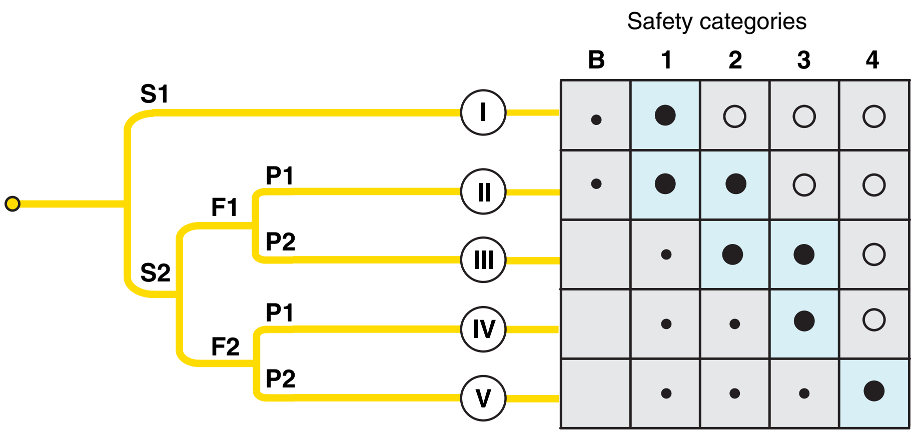
Step 4 Design and check of the relevant parts for the safety of a control system.
Step 5 Validation of the functions and of the achieved categories by their comparison with what previously defined in step 3.

3 - Risk assessment and safety categories

Relevant to the purposes of the design in safety of every machine is the risk rating (**standard EN 1050**) and therefore the choice of the safety category (**standard EN 954-1**).
Some information regarding the choice of proper safety category suitable for the machine being evaluated is quoted below.

Risk table in accordance to the **standard EN 954-1/enclosure B**

Starting point



Legend :

○	Starting point for risk assessment.
S	Accident severity: S1 = reversible (slight) injury (i.e. small cuts, burns, light abrasions, etc..). S2 = irreversible (serious) injury or death (i.e. permanent disability, loss of limbs, breath harms, etc..).
F	Presence in the dangerous zone: F1 = from rare to quite frequent (i.e. weekly or more, to once a day). F2 = from often to continuous (i.e. from many times a day to continuous).
P	Chance to avoid the accident or to reduce significantly its effect: P1 = possible on certain conditions (i.e. possibility of the worker to realize the imminent danger). P2 = quite impossible (i.e. impossibility of the worker to realize the imminent danger).
I-V	Estimate risk level.
B, 1-4	Safety categories of control systems.
●	Preferential category foreseen for this risk level.
○	Choice of an higher category.
•	Choice of a lower categories.

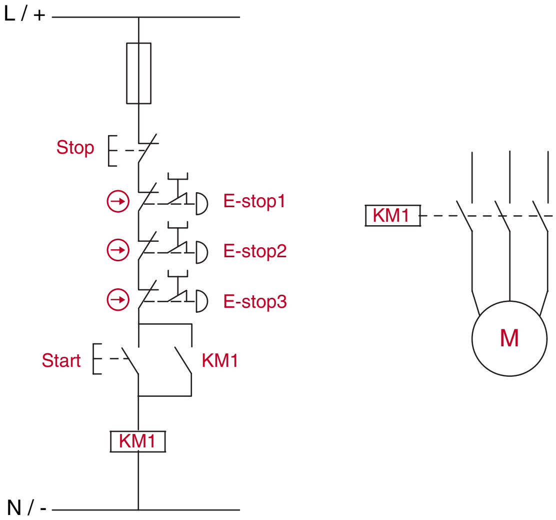
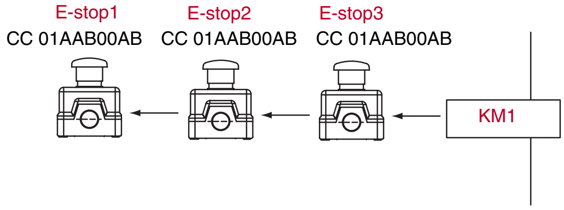
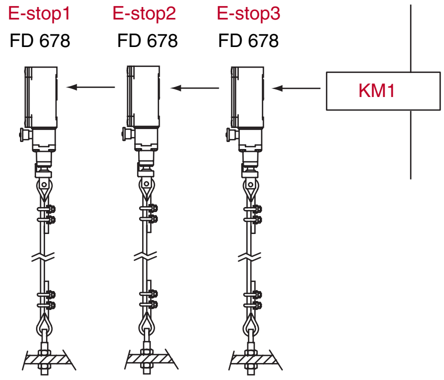
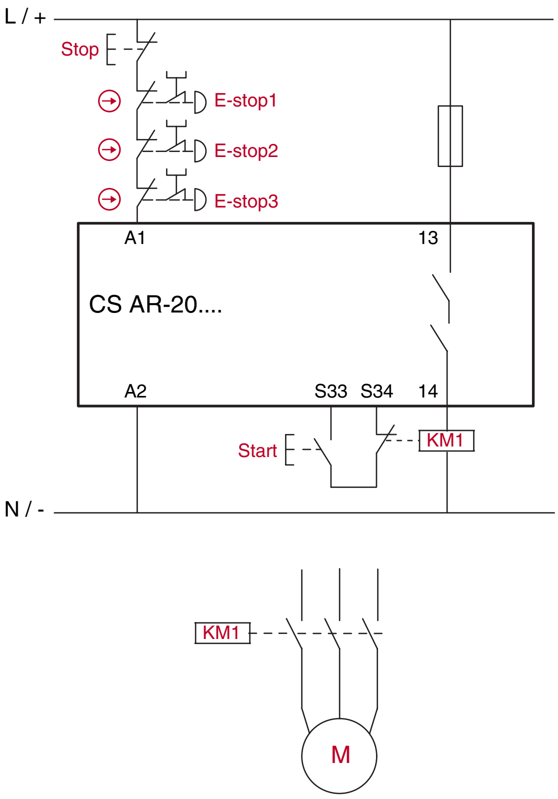
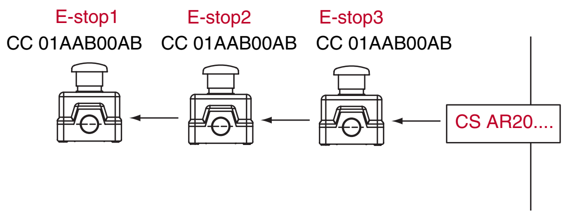
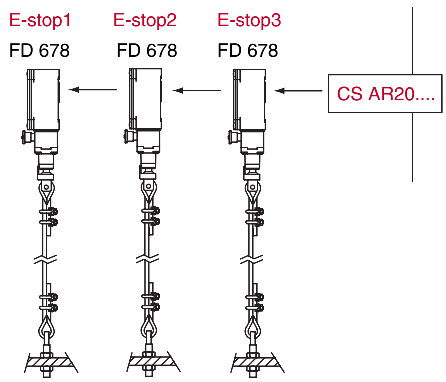
It is possible to use different categories than the preferential ones (big circle ●), but the foreseen behaviour of the system in case of faults, must be taken into consideration. Also, the reasons for the derogation must be indicated by the machine manufacturer.
When categories indicated by a small circle (•) are chosen, some additional measures can be required, as for example:
- over-sizing or use of techniques for the fault elimination;
- use of a dynamic monitoring.

4 - Requirements table for each category according to the standard EN 954-1 par. 6.2

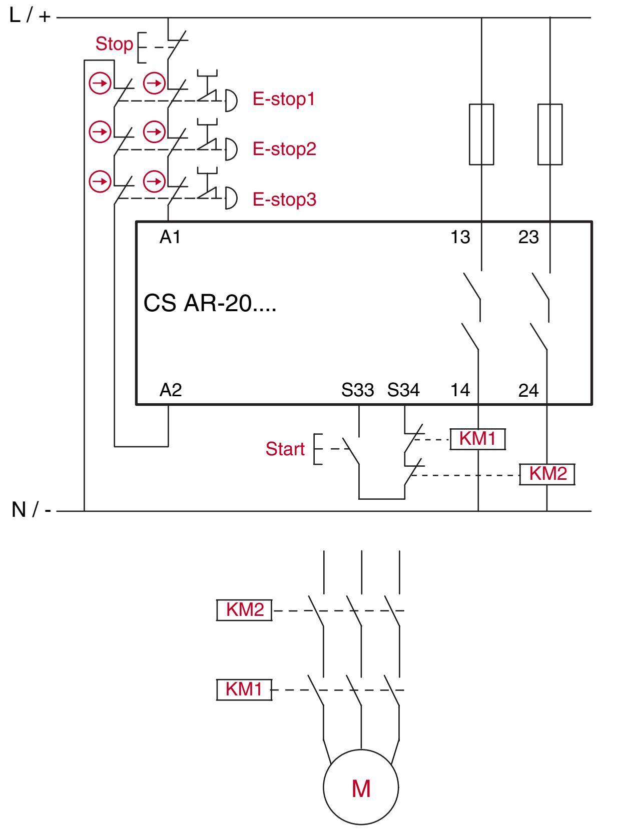
Category	List of the requirements	Behaviour of the system	Safety principles
B	Relevant parts for the safety in the control systems and/or their protection devices, as well as their components have to be designed, manufactured, chosen and combined in compliance with the pertaining standards so that they can resist to the foreseen influence.	An occurring error may cause the loss of the safety function.	Mainly marked by the choice of the components
1	The requirements of the category B are applied. Well tested components and safety principles must be used.	An occurring error may cause the loss of the safety function, but the probability of error occurrence is lower than in category B.	
2	The requirements of the category B and the use of well tested safety principles are applied. The safety function has to be checked by the control system from time to time or at least on every machine start and before any dangerous situation.	An occurring error may cause the loss of the safety function among the controls. The loss of the safety function is detected by the control.	Mainly marked by the structure
3	The requirements of the category B and the use of well tested safety principles are applied. Relevant parts for the safety have to be designed so that: - one single error in one of these parts doesn't cause the loss of the safety function. - Where reasonably practicable, the single error is detected.	When one single error occurs the safety function is always performed. Not all the errors are detected. The accumulation of undetected errors may cause the loss of the safety function.	
4	The requirements of the category B and the use of well tested safety principles are applied. Relevant parts for the safety have to be designed so that: - one single error in one of these parts doesn't cause the loss of the safety function. - the single error is detected in the moment or before the request of the next safety function. If this is not possible, then the accumulation of errors must not cause the loss of the safety function.	When errors occur the safety function is always performed. Errors are detected in time in order to avoid the loss of the safety function.	

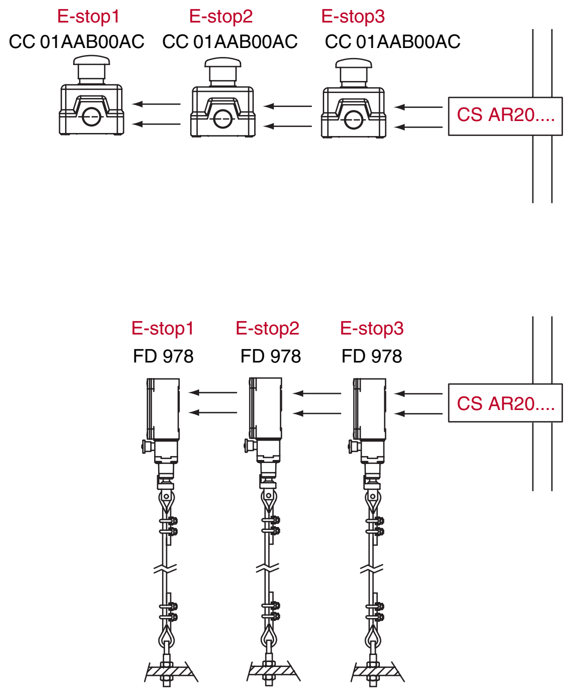
5 - Examples of connections according to the standard EN 954-1 (min. requirements)

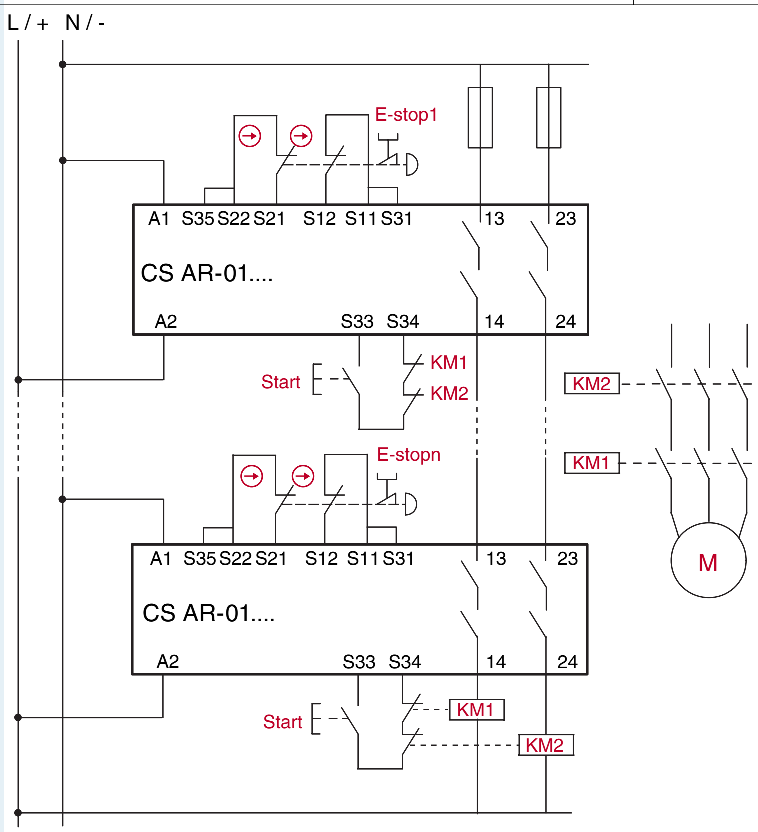
Emergency stop push button and rope safety switches for emergency stop installation.

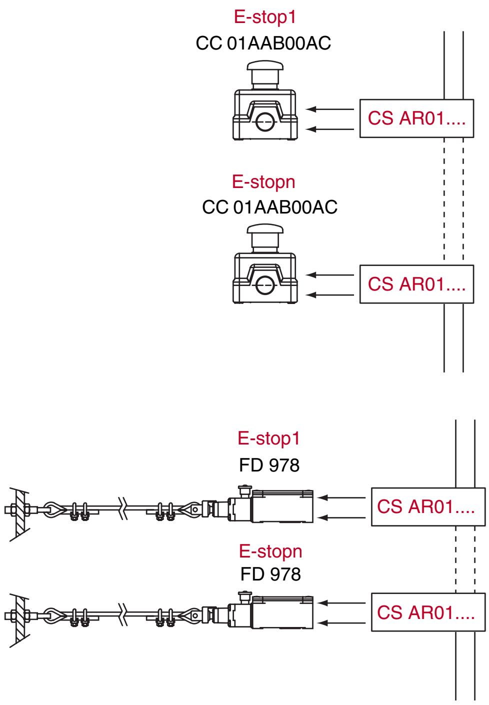
Safety category	Wiring diagram	Circuit structure
B-1		 
2	 If an external contactor (KM1) is used to increase the load capacity of the contacts, this contactor should have forced guided contacts.	 

Emergency stop push button and rope safety switches for emergency stop installation.

<table>
<tr><th>Safety category</th><th>Wiring diagram</th><th>Circuit structure</th></tr>
<tr><td>3</td><td>


If external contactors (KM1-KM2) are used to increase the load capacity of the contacts, these contactors should have forced guided contacts.
</td><td>


</td></tr>
<tr><td>4</td><td>


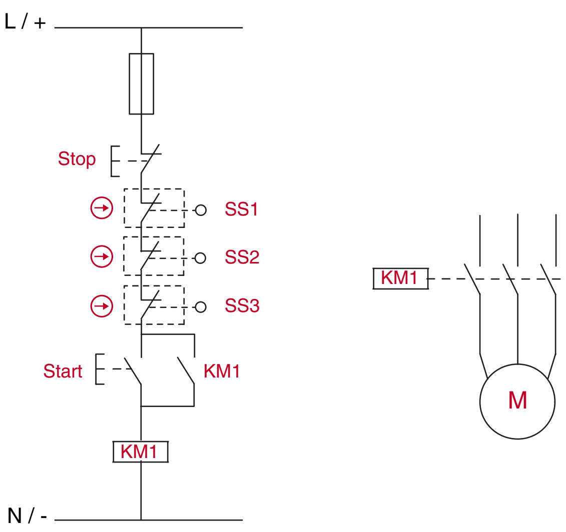
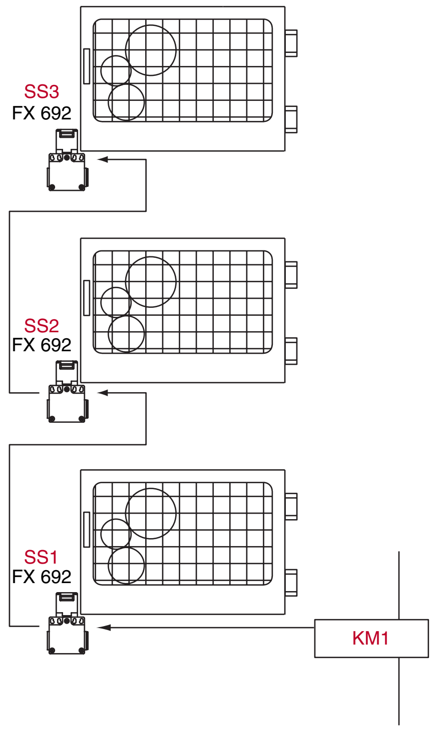
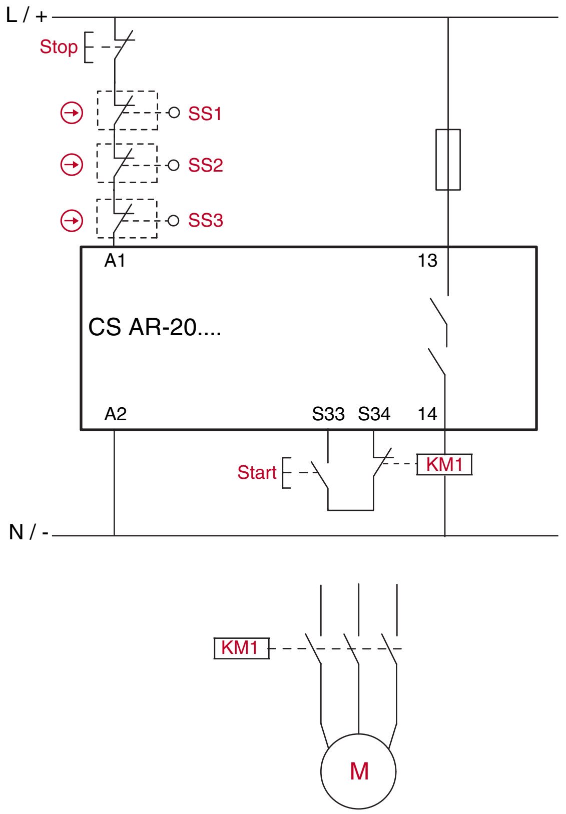
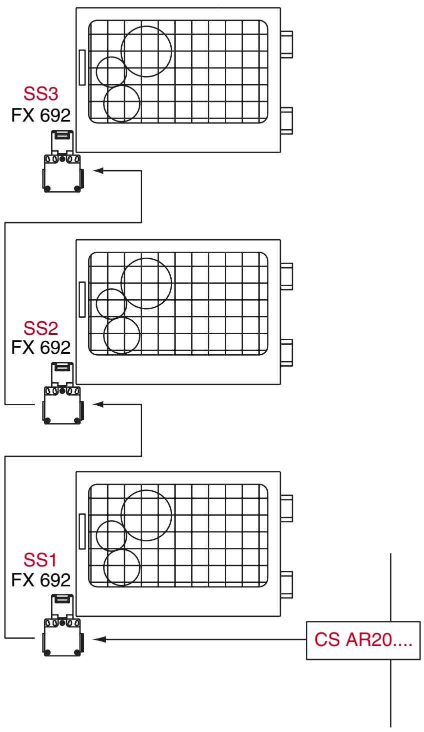
If external contactors (KM1-KM2) are used to increase the load capacity of the contacts, these contactors should have forced guided contacts.
</td><td>


</td></tr>
</table>

Attention: the examples above mentioned are purely descriptive and give only an indication about how to set up a safety circuit according to the categories foreseen by standard EN 954-1. It is responsibility of the manufacturer to control that correct circuits are applied on each specific machine .

5 - Some examples of connections according to the standard EN 954-1 (min. requirements)

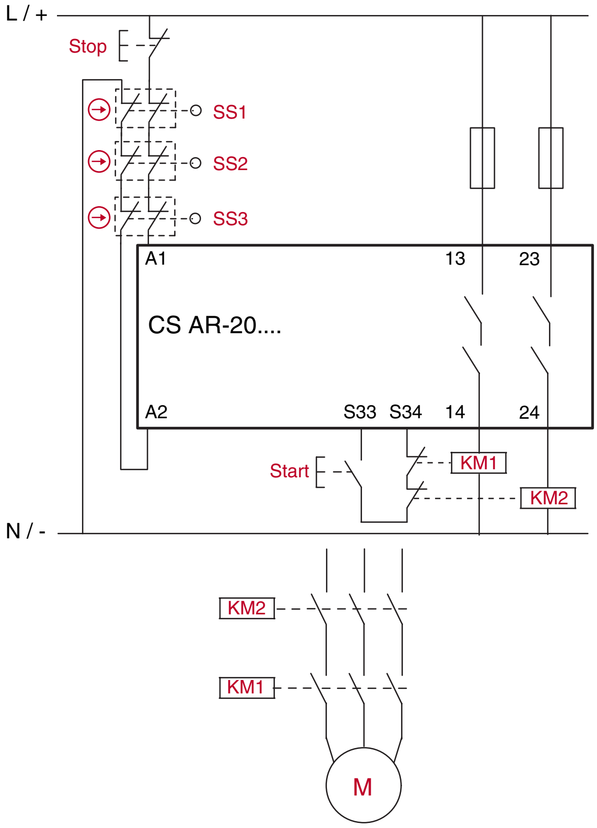
Gate monitoring safety switches applications.

Safety category	Wiring diagram	Circuit structure
B-1		
2	 If an external contactor (KM1) is used to increase the load capacity of the contacts, this contactor should have forced guided contacts.	

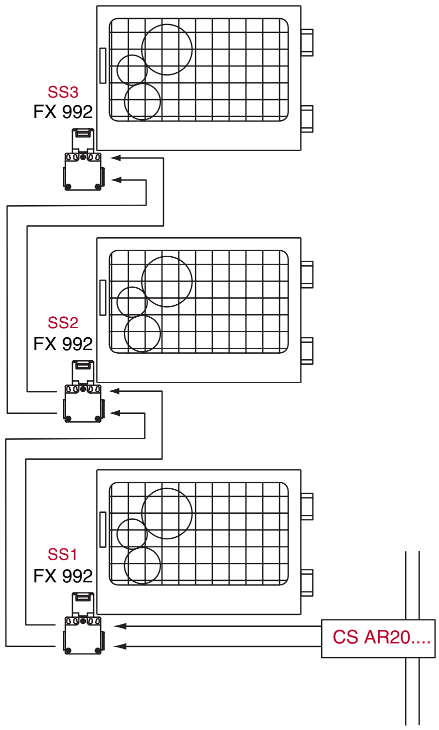
Gate monitoring safety switches applications.

Safety category	Wiring diagram	Circuit structure

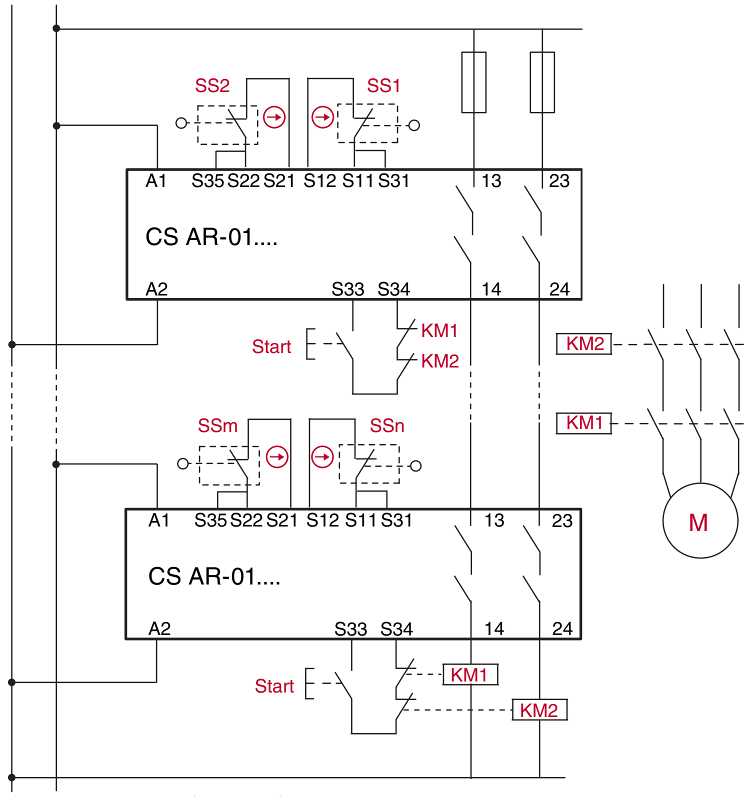
3



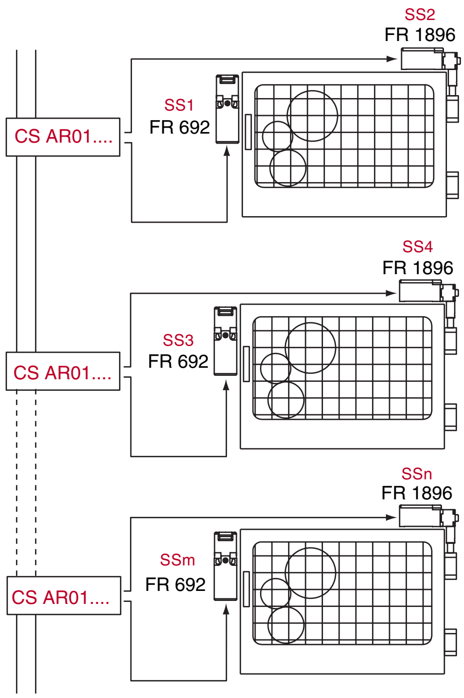
If external contactors (KM1-KM2) are used to increase the load capacity of the contacts, these contactors should have forced guided contacts.



4



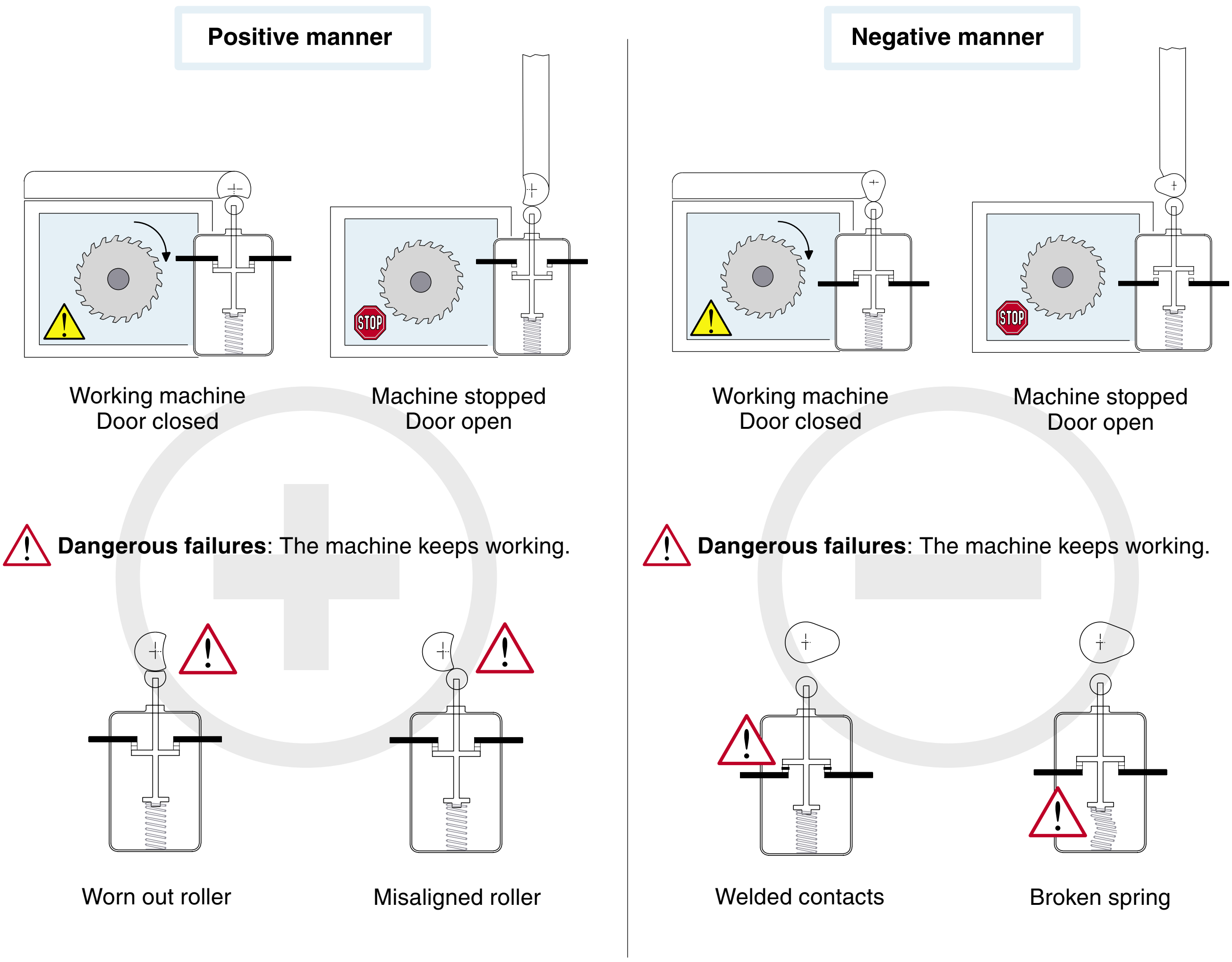
If external contactors (KM1-KM2) are used to increase the load capacity of the contacts, these contactors should have forced guided contacts.



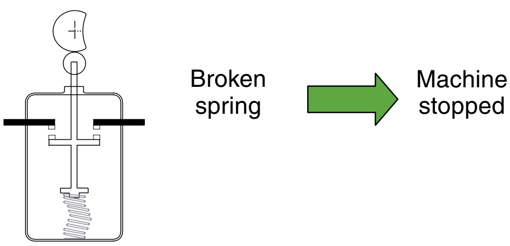
Attention: the examples above mentioned are purely descriptive and give only an indication about how to set up a safety circuit according to the categories foreseen by standard EN 954-1. It is responsibility of the manufacturer to control that correct circuits are applied on each specific machine .

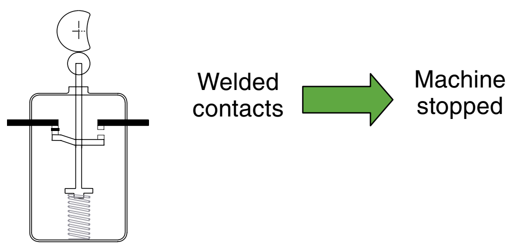
6 - Positive opening, redundancy, diversification and self-control.

Positive manner and negative manner.
According to the standard EN 292-2 point 3.5, if a mechanical component in motion, directly drives another component, through physical contact or a rigid mechanical linkage, that connection is said to be in a **positive manner**. Instead, if the movement of a mechanical component simply allows another element to move freely, without using direct force (for example by gravity force, spring effect, etc.) their connection is in a **negative manner**.



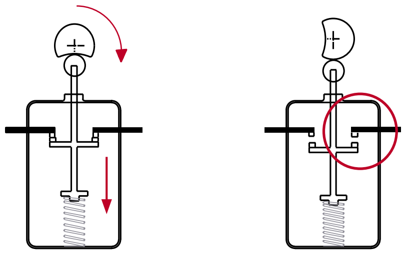
The positive manner avoid, with a preventive maintenance, the dangerous failures indicated above. On the contrary, the negative manner failures occurs inside the switch and are therefore difficult to be detected.
With the positive manner, internal failures (welded contacts or broken springs) allows the opening of the contacts and therefore the machine stops.





Use of switches in safety applications

When a single switch is used in a safety function, it must be actuated in a positive manner. The opening contact (normally closed), must be with “**positive opening**”, to be used for safety applications. All switches with the symbol (→) are provided with NC contacts with positive opening.



Rigid non-flexible connection between the moving contacts and the actuator, where the actuating force is applied.

If the switches are two or more, it is suggested that they should operate in opposite manners, for example:
- One with a normally closed contact (opening contact) actuated by the guard in a positive manner.
- The other with a normally open contact (closing contact), actuated by the guard in a non positive manner.

This is a common practice, however it does not exclude, if justified, the use of two switches actuated in a positive manner (see diversification).

Diversification

Safety in the redundant system is increased by **diversification**. It is obtained by the application of two limit switches with different project and/or technology, in order to avoid failures caused by the same reasons. Some examples of diversification are: the use of a switch working in positive manner togheter with one working in non positive manner; a switch with mechanical actuation and one with non mechanical actuation (e.g. electronic sensor); two switches with mechanical actuator working in positive manner but with different actuation principles (e.g. one actuator operated FR 692 and one hinges operated FR 1896 switch).

Redundancy

Redundancy is the use of many devices or systems in order to guarantee that, in case of a function failure in one of them, another one is available to perform the safety functions. If the first failure is not detected, an eventual second failure may cause the loss of the safety functions.

Self-monitoring

Self-monitoring consists in the automatic checking the right function of every device running in the machine working-cycle. Consequently, the next working-cycle can be either accepted or rejected.

Redundancy and self-monitoring

The combination of both systems, **redundancy** and **self-monitoring** allows that a first failure in the safety circuit doesn’t cause the loss of safety functions. This first failure will be detected at the next re-start or anyhow before a second failure, which may cause the loss of the safety functions.

- Use **only** switches with the symbol “ → “ (see figure on the side).
- Connect the safety circuit to the **NC normally closed contacts (11-12, 21-22 or 31-32).**
- **The NO normally open contacts (13-14, 23-24, 33-34) should be used only for signalling** ; these contacts are not to be connected with the safety circuit. However, if in the same protection two or more switches are used, it is possible to connect the contact NO to safety circuit.
- **The switch must be actuated with the minimum positive opening travel** indicated in the travel diagrams with symbol “ → “.
- **The switch must be actuated with the minimum positive opening force** indicated in brackets below every article, near the value of the min. force.

When the machine guard has been open and during the whole opening travel, **the switch must be triggered directly** (fig. 1) **or through a rigid connection** (fig. 2)**.**

Only in this way the positive opening of the NC normally closed contacts (11-12, 21-22, 31-32) is guaranteed.

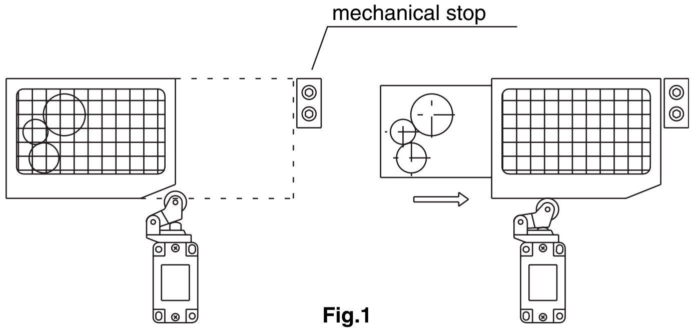


Fig.1

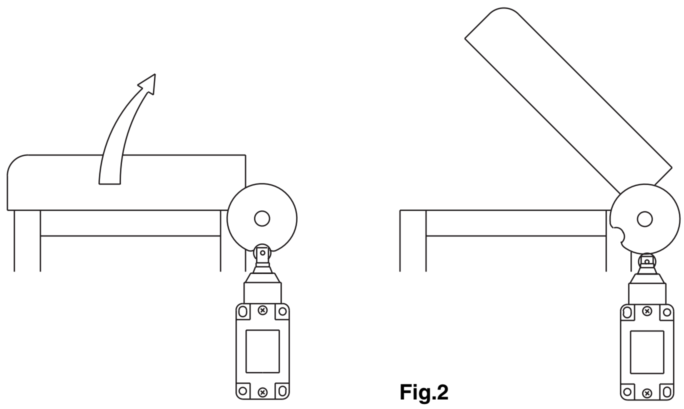


Fig.2

These switches **should not be applied to activate by release** (fig. 3 and 4) or **through a non rigid connection** (i.e. by a spring either external or internal).

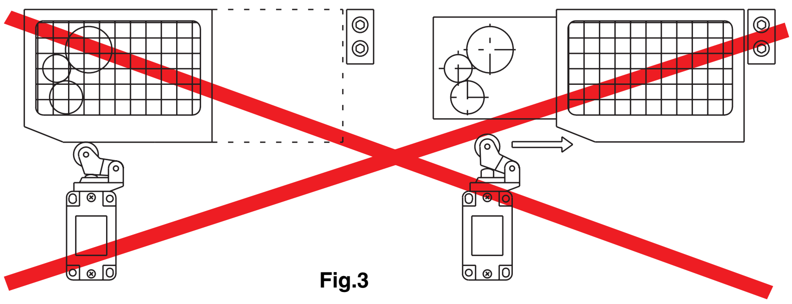


Fig.3

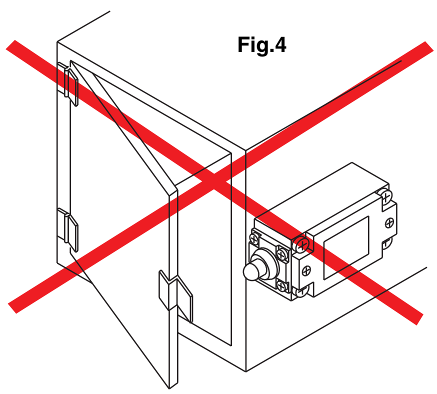
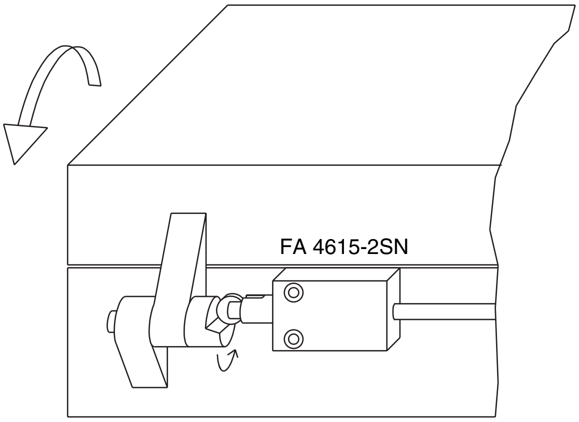
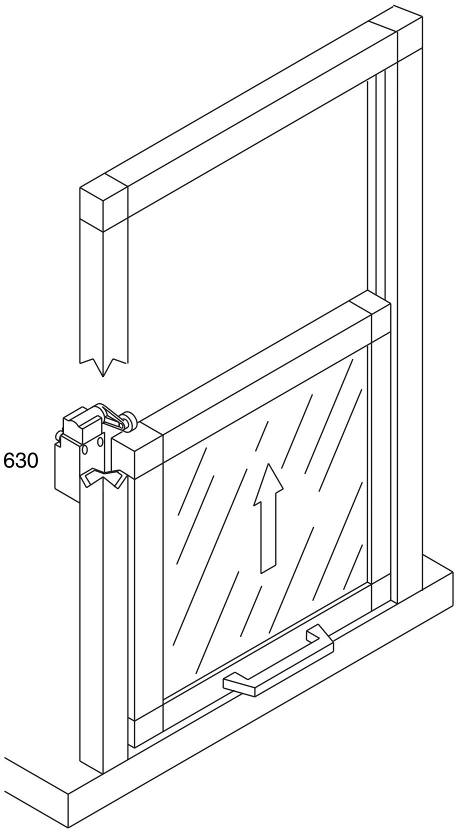
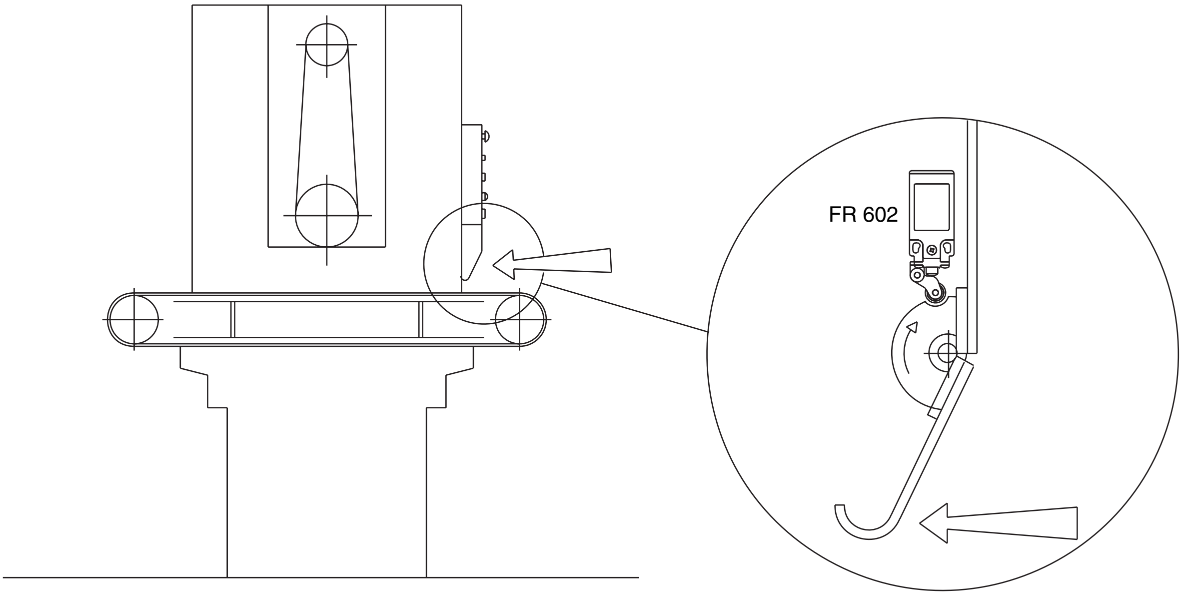


Fig.4


FA 4615-2SN


FR 630


FR 602

Definitions complying with the standards EN 60947-1 and EN 60947-5-1

Ambient air temperature
The temperature determined under prescribed conditions, of the air surrounding the complete switching device.

Break-contact element (normally closed)
Contact element which open a conducting path when the control switch is actuated.

Change-over contact elements
Contact element combination which includes one-make-contact element and one break-contact element.

Contact element
The parts, fixed and movable, conducting and insulating, of a control switch necessary to close and open one single conducting path of a circuit.

Control switch
A mechanical switching device which serves the purpose of controlling the operation of switch gear or control-gear, including signalling, electrical interlocking, etc.

Conventional free air thermal current Ith
Max value of current to be used for temperature-rise tests of enclosed equipment in free air. Its value shall be least to equal to the maximum value of the rated operational current **Ie** of the enclosed equipment in eight-hour duty.

Cycle of operation
Succession of two movements, one for closure and second for opening.

Dependent action contact element (slow action)
Contact element of a manual or automatic control device which contact's motion velocity depends on the actuator's motion velocity.

Double gap contact element
Contact element which opens or closes the conducting path of its circuit in two locations in series.

Electrical durability
Number of on-load operating cycles, corresponding to the service conditions given in the relevant product standard, which can be made without repair or replacement.

Electrically separated contact elements
Contacts elements belonging to the same control switch, but adequately insulated from each other so they can be connected to electric circuits with different tension.

Foot-switch
Control switch having an actuator intended to be operated by force exerted by a foot

Independent action contact element (snap action)
Contact element of a manual or automatic control device in which the velocity of contact motion is substantially independent of the actuator's motion velocity.

Make-contact element (normally open)
Contact element which closes a conducting path when the control switch is actuated.

Mechanical durability
Number of no-load operating cycles (e.g. without current at the main contacts) which can be effected before it becomes necessary to service or replace any mechanical parts.

Minimum actuating force
The minimum force value to be applied to the actuator that will cause all contacts to reach their closed (open) position.

Position switch
Pilot switch the actuating system of which is operated by moving part of the machine, when this part reaches a pretermined position.

Pre-travel of the actuator
The maximum travel of the actuator which causes no travel of the contact elements

Rated operational current Ie
A current that takes into account the rated operational voltage, the rated frequency, the utilization category and the type of protective enclosure, if appropriate.

Rated insulation voltage Ui
Voltage which dielectric tests voltage and creepage distances are referred.

Rated operational voltage Ue
Voltage which, combined with the rated operational current, determinates the application of the equipment and the referred utilization categories.

Single gap contact element
Contact element which opens or closes the conducting path of its circuit in one location only.

Unit contact
Contact element or contact elements combination which can be combined with similar units, operated by a common actuating system.

Utilization category
A combination of specified requirements related to the conditions in which the switching device fulfils its purpose.

Markings and quality marks

CE marking

The CE marking is a mandatory declaration made by the manufacturer of a product purpose to indicate that product satisfies all requirements foreseen by the directives (regulated by the European Community) on subjects of safety and quality. Its function therefore is to guarantee to the governing authorities of the various countries the fulfilment of their obligations under the law.

IMQ marking

The IMQ (Italian Institute of the Quality Mark) is the organization in Italy (third and independent) whose task is to check and certify the compliance of the materials and the equipments with the safety standards (CEI standards in the electric and electronic branch). This voluntary conformity certification is a guarantee of quality, safety and technical value.

UL marking

UL (Underwriters Laboratories Inc.) is an independent non-profit laboratory that test materials, devices, products, equipment, constructions, methods and systems with regard to their risk for human life and goods according to the standard in force in the United States. Regulations and testing made by UL is often taken as valid by many governing authorities regarding conformity with local regulations on the subject of safety.

CSA marking

The CSA (Canadian Standard Association) is an association which has the power to determine whether electrical products comply with the standards of quality and safety required in Canada. The majority of the Canadian province's required that all electrical/electronic products manufactured and utilized in Canada, are tested to and comply with the CSA standards.

EZC marking

The EZC is the organization in Czech Republic (third and independent) whose task is to check and certify the compliance of the materials and the equipments with the safety standards. This voluntary conformity certification is a guarantee of quality, safety and technical value.

International, European and Italian standards

IEC 947-1 (equivalent to EN 60947-1, **CEI EN 60947-1 and CEI 17-44):** Low voltage equipments. Section one: general standards.
IEC 947-5-1 (equivalent to EN 60947-5-1, **CEI EN 60947-5-1 and CEI 17-45):** Low voltage equipments. Section five: devices for control and operation circuits. Section one: electromechanical devices for control circuits.
EN 50041 (equivalent to CEI 17-31): Industrial equipments with low voltage. Control accessories. Position switches 42,5x80 mm. Dimensions and features.
EN 50047 (equivalent to CEI 17-33): Industrial equipments with low voltage. Control accessories. Position switches 30x55 mm. Dimensions and features.
IEC 204-1 (equivalent to EN 60204-1 and CEI 44-5): Electric equipments of industrial machines. Section one. General standards.
EN 1088: Interlock devices with or without lock of the guard. Concepts and projects.
EN 292: Machinery safety. Basic concepts and design principles.
IEC 529 (equivalent to EN 60529 and CEI 70-1): Protection degree of the housings (IP codes).
EN 418: Machinery safety. Devices for the emergency stop, functional aspects. Design principles.
EN 50081-1 (equivalent to CEI EN 50081-1): Electromagnetic compatibility - generic emission standard - part one: residential, commercial and light industry.
EN 50082-2 (equivalent to CEI EN 50082-2): Electromagnetic compatibility - generic emission standard - part two: industrial environment.
IEC 326-3 (equivalent to CEI 52-21): Printed boards - Part three: design and use of printed boards.
IEC 664 (equivalent to CEI 28-6): Insulation coordination for equipment within low-voltage systems.
IEC 249 (equivalent to CEI 52-10): Base materials for printed circuits.
CENELEC EN 50013: Industrial equipments with voltage lower than 1000 VAC. Location of the clamps.
NFC 63-140: Control accessories. General prescriptions. (French standard).
BG-GS-ET-15: Prescriptions about how to test switches with forced contacts opening to be used in safety applications (German standard).
VDE 0660-200: Control and checking devices. Low voltage control and checking devices. Checking switches. General requirements. (German standard).
VDE 0113: Specifications for electrical equipments of machines for the production or the manufacturing with rated voltage up to 1000 V. (German standard).
UL 508: Standard for equipments of industrial controls. (American standard).
CSA 22-2 nr.14: Standard for equipments of industrial controls. (Canadian standard).

Technical concepts

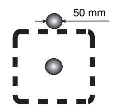
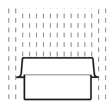
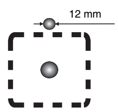
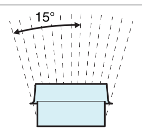
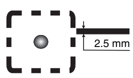
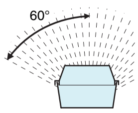
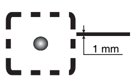
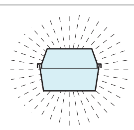
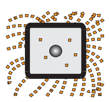
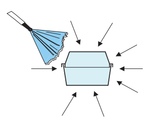
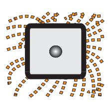
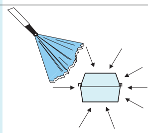
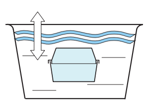
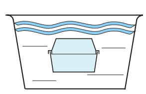
European directives

73/23/CEE	Directive on low voltage of electrical equipments
89/392/CEE	Machinery directive
98/37/CEE - 93/68/CEE	Machinery directive updating
89/336/CEE	Electromagnetical compatibility directive

Regulation Organisation

CEI	Comitato Elettrotecnico Italiano (I)	**NF**	Normes Françaises (F)
CSA	Canadian Standard Association (CAN)	**VDE**	Verband Deutscher Elektrotechniker (D)
CENELEC	Comité Européen de Normalisation Electrotechnique	**UNI**	Ente Nazionale Italiano di Unificazione (I)
IEC	International Electrotechnical Commission	**UL**	Underwriter's Laboratories (USA)

Protection degree of the housings for electrical material according to IEC 529 standard

1° number	Description	Protection for the machine	Protection for the people	2° number	Description	Protection for the machine
0		No protection	No protection	**0**		No protection
1		Protected from a hand or material that is as large as 50 mm in diameter	Not accessible to hazardous parts with back of the hands (ø 50 mm)	**1**		Protected from drops of water that falls vertically
2		Protected from a finger or material that is as large as 12 mm in diameter	Not accessible to hazardous parts with a finger (ø 12 mm)	**2**		Protected from drops of water that falls from 15° max.
3		Protected from a tool or material that is as large as 2.5 mm in diameter	Not accessible to hazardous parts with tool (ø 2.5 mm)	**3**		Protected from sprayed water that falls from 60° max.
4		Protected from a wire or material that is as large as 1 mm in diameter	Not accessible to hazardous parts with wire (ø 1 mm)	**4**		Protected from splashes of water around it
5		Protected from dust or wire that does not endanger the safety of the product	Not accessible to hazardous parts with wire (ø 1 mm)	**5**		Protected from jets of water discharged around it
6		Totally protected from dust or wire that does not endanger the safety of the product	Not accessible to hazardous parts with wire (ø 1 mm)	**6**		Protected from strong jets of water around it
				7		Protected from temporary water immersion
				8		Protected from continuous water immersion

This table indicates the protection degrees according to IEC 529, EN 60529, CEI 70-1 standards.
The degrees are identified by the letters IP and two numbers. Two more letters can be added, in order to give the protection degree for people or other features.
The first number means the degree of protection against penetration of external solids materials.
The second one indicates the degree of protection against penetration of water.

Housing features according with UL approvals (standard UL 508) and CSA approvals (C22-2 nr.14)

The features required for an housing are determined by a specific environmental designation and other features like the kind of gasket or the use of solvent materials.

Type	Use guidance and description
1	Mainly for indoor utilization, supplied with protection from contact with the internal mechanism and against a limited quantity of falling dirt.
4X	Both indoor and open-air utilization, supplied with a protection degree against falling rain, sprinkling of water and direct water from the pipe. It is not damaged by the frozing of the housing and it is rust-proof. It is not damaged by corrosion.
12	Indoor utilization, supplied with a protection degree against dust, dirt, flying fibers, dripping water and outside condensation of non-corrosive fluids.
13	Indoor utilization, supplied with a protection degree against blast, dust penetration, outside condensation and sprinkling of water, oil and non-corrosive fluids.

Pollution degree (of environmental conditions) according to IEC 947-1 standard

According to the standard IEC 947-1, the pollution degree is the conventional number based on the quantity of conducting hygroscopic dust, ionized gas or salt, on the relative humidity and on the frequency of occurrence, that is translated into hygroscopic absorption or humidity condensation, which has the effect to reduce the dielectric rigidity and/or surface resistivity. In equipment to be used inside a housing or having an integral enclosure as part of the device, the pollution degree applies to the inner part of housing. With the purpose of evaluate the air and surface insulation distances, the following four pollution degrees are defined:

Degree	Description
1	No pollution or dry and non-conductive pollution occurs.
2	There is only presence of a non-conductive pollution. Occasionally some temporary conductivity caused by condensation may occur.
3	Some conductive pollution is present, or some dry non-conductive pollution that becomes conductive because of condensation is present.
4	Pollution causes persistent conductivity for instance because of conductive dust or rain or snow.

Where not otherwise specified by the applicable standard for the product, equipments for industrial applications are generally intended for their use in ambients with pollution degree 3. Nevertheless other degrees can be considered depending on the environment or on the particular applications.

Utilization categories for switching elements according to CEI EN 60947-5 and IEC 947-5 standards

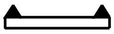
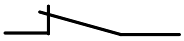
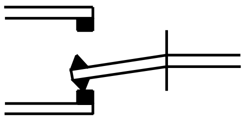
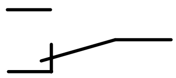
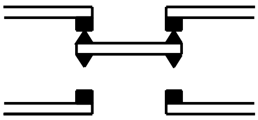
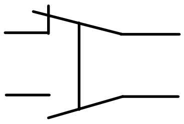
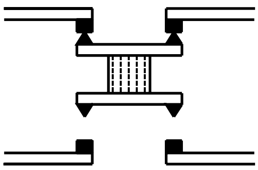
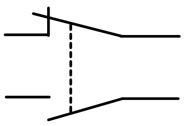
Alternate current utilization

Utilization category	Description
AC12	Control of resistive loads and solid state loads with insulation by optocouplers
AC13	Control of solid state loads with transformer isolation
AC14	Control of small electromagnetic loads (72 VA)
AC15	Control of small electromagnetic loads (72 VA)

Direct current utilization

Utilization category	Description
DC12	Control of resistive loads and solid state loads with insulation by optocouplers
DC13	Control of electromagnets
DC14	Control of electromagnets loads having economy resistors in circuit

Classification of the contact blocks according to the standard IEC 947-5-1

Form	Figure	Symbol	Description
X			Contact component having double cutoff with two terminals.
Y			
C			Change-over contact component having simple cutoff with three terminals.
Za			Shifting contact component having double cutoff with four terminals. **Contacts have the same polarity**
Zb			Shifting contact component having double cutoff with four terminals. **Moving contacts are electrically separated**

Symbol “+” between contact forms (e.g. X+X, Za+Za, X+X+Y, etc.) means that contacts have electrical separation between each other. The **electrically separated contacts allow** the application of different voltages and polarities between the contacts (fig. a).

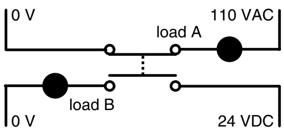


fig. a: **correct**

Prescriptions and restrictions for Za contacts
Electrical loads must be connected to the same phase or polarity. The contacts **are not** electrically separated, so you can not connect different voltages between the NC contact and the NO contact. Also, as prescribed by the standard IEC 947-5-1 paragraph K.7.1.4.6.1, if you use Za contacts with positive opening for safety applications, the following restrictions have to be adopted:
“ If the control accessory has shifting contacts components with form C or Za, **you have to use only one contact component** (closure or cutoff). In case of shifting contact with form Zb, both contacts may be used...”

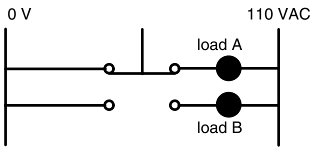


fig. 1: **correct**

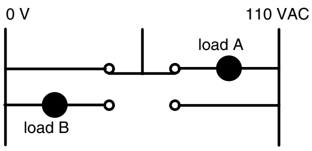
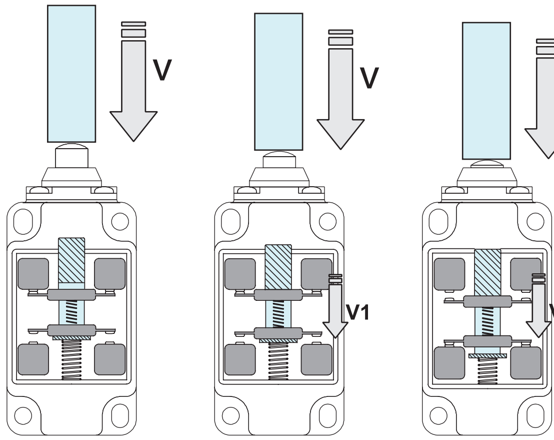


fig. 2: **incorrect**

Contact block with dependent action: slow action

Contact blocks with slow action: component where the speed of the contact **(V1)** depends on the speed of the actuator **(V)**. The contact armature advances at a rate proportional to the actuation speed. The slow action contact block is suitable for applications having low to medium currents and quick actuation movements. It has no differential travel.

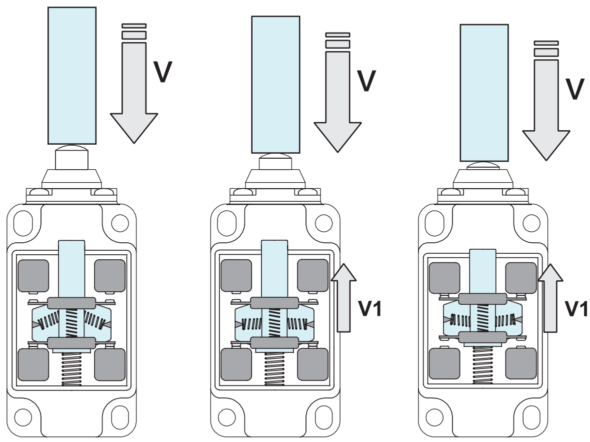
V = V1



Contact block with independent action: snap action

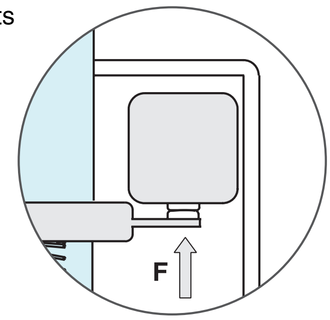
Contact block with snap action: component where the speed of the contact **(V1)** doesn't depend on the actuator speed **(V)**. After reaching a predetermined point in travel, the contact armature snaps causing the contacts switch the position. The snap action contact block is suitable for applications having high currents and/or slow actuation movements. This kind of contact block has a differential travel.

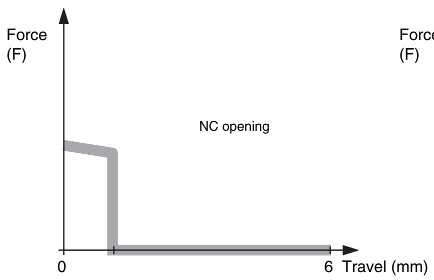
V ≠ V1

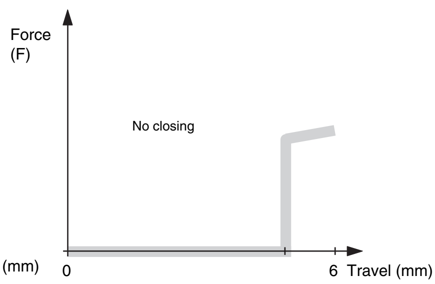


Contact blocks: diagrams of the force on the contacts

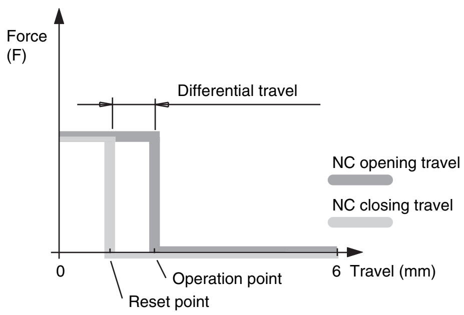
The following diagrams shows the relationship between of the force exerted on the contacts **(F)** compared to the switch armature travel.



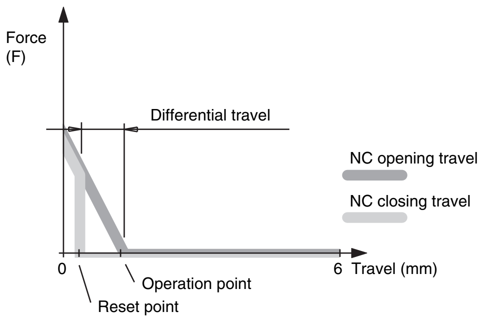




Contact blocks with slow action 6, 7, 9, 10, 14, 15, 16, 18, 20, 21, 22, 33, 34



Contact blocks with snap action 5, 11.
The pressure on the contact keeps constant while approaching to the snap point.



Contact blocks with snap action 2, 3.
The pressure on the contact decreases while approaching to the snap point.

Contact blocks 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 17, 18, 20, 21, 22, 28, 29, 30, 33, 34 features

Fingers protection terminals
All terminals in the contact blocks have a protection degree IP 20 according to the standard IEC 529, therefore they are protected against the access to dangerous parts with diameter over 12 mm.

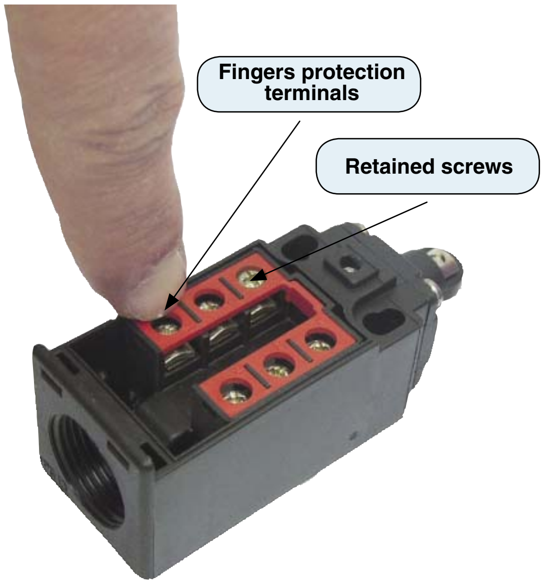
Retained screws
All the screws in the contact blocks, even if completely loose, can not leave their seat, so it is impossible to lost them during the wiring.

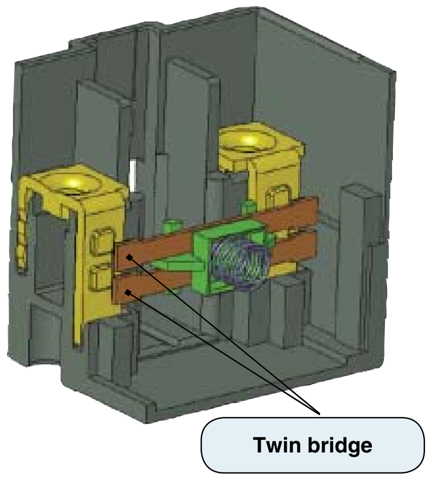
Contacts reliability
Some times, hardly ever, an electric contact could not work. A commutation failure is a typical consequence of an occasional presence of an high resistance over the contacts due to dust, a slight layer of oxidation, or impurity of any kind that remains inside the switch during its wiring. The repeatability of this type of phenomena depends not only of the switch but also from the environmental working conditions and the type of load the switch drives. These effects are more evident with low electrical loads, when the electric voltage does not succeed in perforate thin layers of oxide or small dust grains.

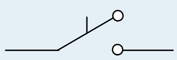
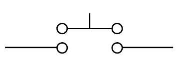
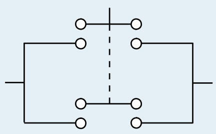
This type of malfunction may be accepted in the hand operated devices because it is enough to repeat the operation and then everything works again. This is not the case of position switches where a failure in a switch could bring to large damages on the machinery.

In the following table we refer to the typical contacts structure (type A and B) normally used in the industry and the one that Pizzato Elettrica uses since several years in most of the range of switches: movable contacts with double interruption and twin bridge (type C).
As you can see from table below, this last structure (type C) feature the same contact resistance (R) of the simple mobile contact (type A) but with a really lower probability of failure (fe).
In fact, defined x the probability of a single interruption failure it results that in the contact type A the commutation failure probability $fe=x$, in the type B $fe \cong 2x$ meanwhile in the type C $fe \cong 4x^2$.

This means that if in one certain situation the probability of a single interruption failure is equal, for instance, to $1x10^{-4}$ (1 fail interruption every 10.000) we will have:
- In the type A one failed commutation every 10.000
- In the type B one failed commutation every 5.000
- In the type C one failed commutation every 25.000.000





Type	Figure	Description	Contact resistance R	Commutation failure probability fe
A		simple contact	$R=Rc$	$fe=x$
B		contacts with double interruption	$R=2\cdot Rc$	$fe=2x-x^2$
C		contacts with double interruption and twin bridge	$R=\frac{2\cdot Rc}{2}=Rc$	$fe=4x^2-4x^3+x^4$

Note