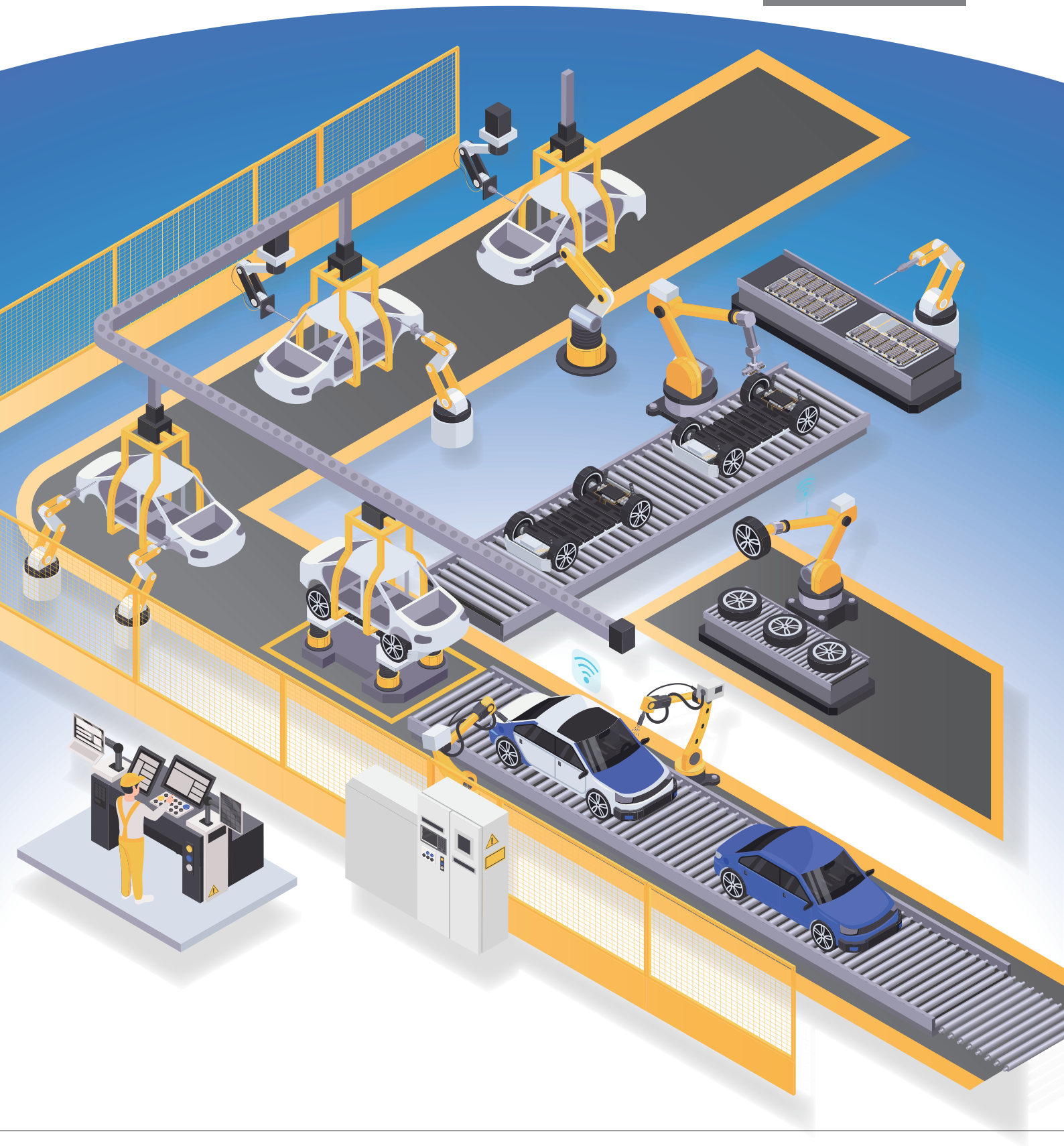
Panasonic
INDUSTRY

Proposal for Establishing Machinery Safety Using Safety Relays

1st edition



2024.1

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Proposal for Establishing Machinery Safety Using Safety Relays

ASCTB459E 202401

Machinery Safety and Safety Equipment

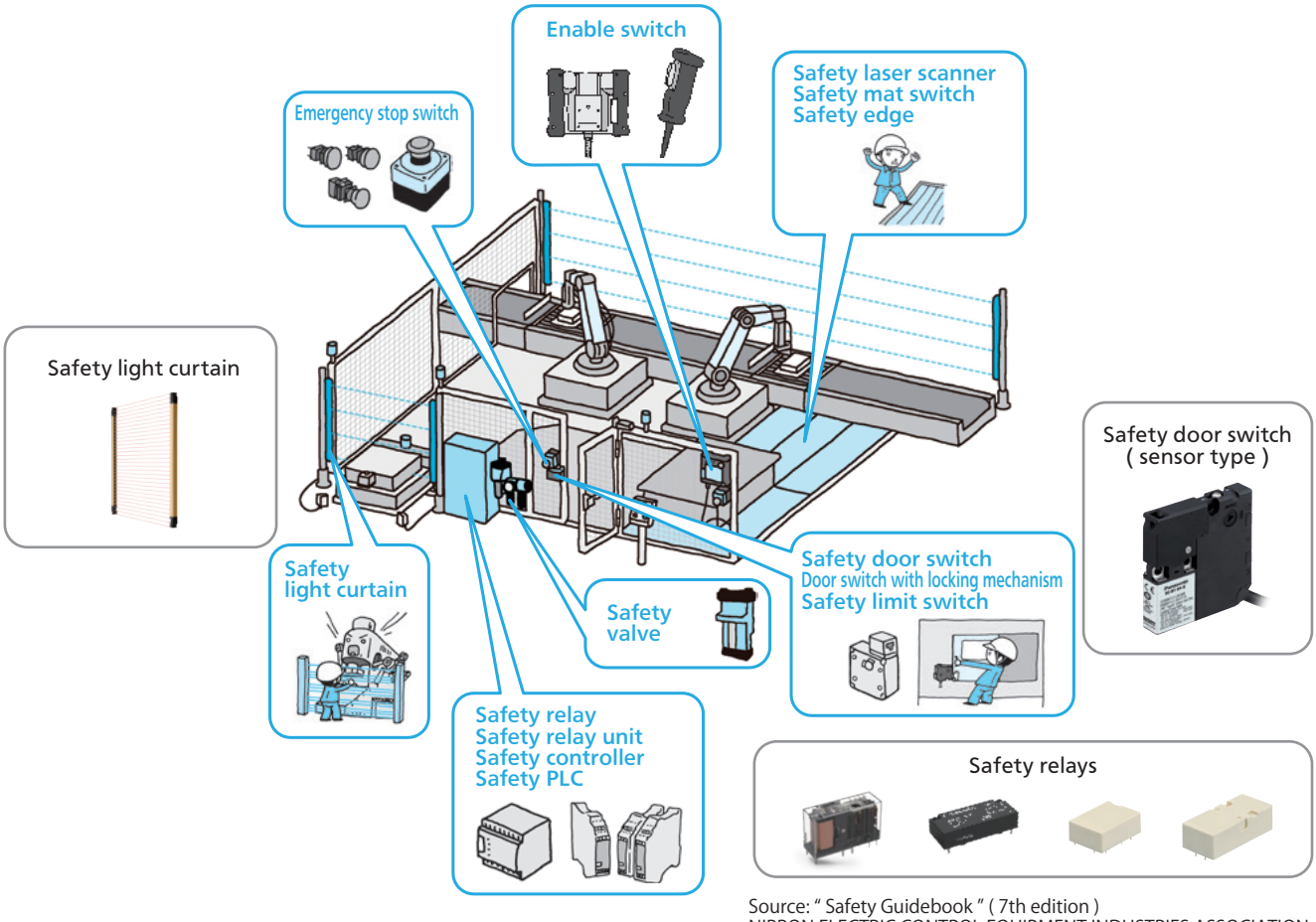
Machinery safety is the concept of designing machinery and constructing structures and mechanisms in a manner that prevents disasters even if a machine breaks down or when an operator makes a mistake. This could also be described as an approach that enables machines to be used safely even in the event of mechanical troubles or human error.
Reducing risks under this concept of machinery safety requires the use of **safety devices**.

1) The term " safety equipment " refers to equipment designed to enable safe operation and maintenance of machinery equipment at factory facilities, chemical plants, and other locations.
2) The purpose of safety equipment is to ensure the safety of workers in the event of machine failure or malfunction. As such, safety equipment differs from ordinary products and requires specific safety functions.
3) The following are used in safety-related electrical control systems: Safety switches, Emergency stop push buttons, Safety light curtains, Safety relay modules, and Safety relays, etc.

This document introduces safety standards and specific applications with a focus on " safety relays, " which are required to ensure machinery safety.

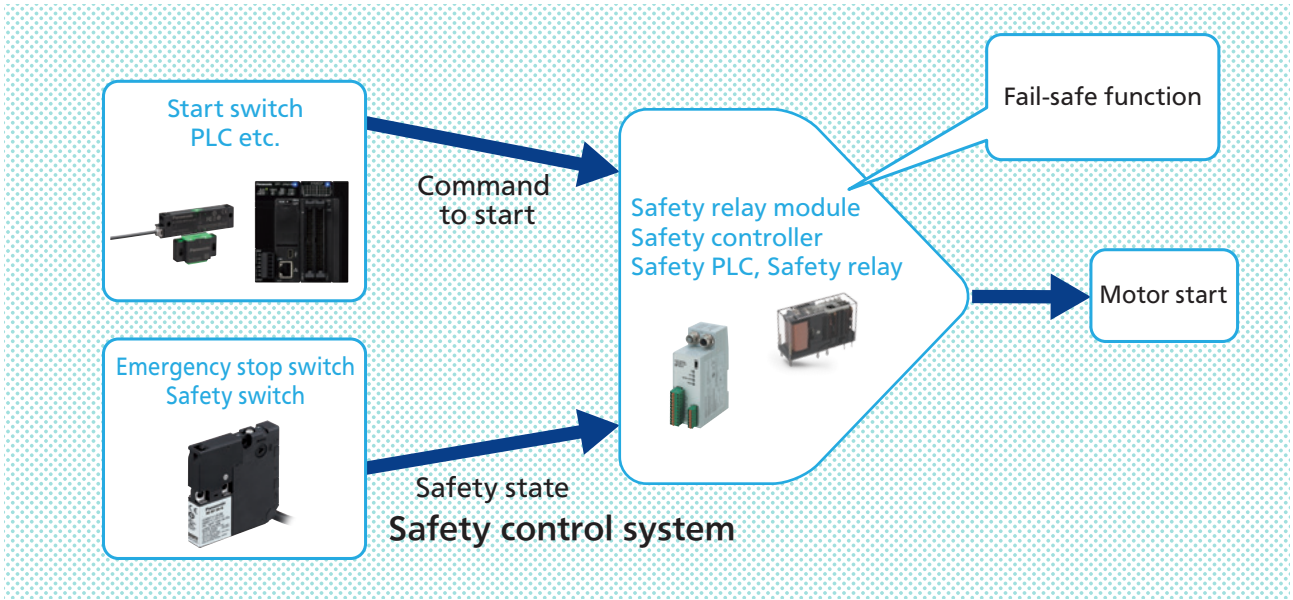
ASCTB459E 202401

Product examples of safety equipment



Source: " Safety Guidebook " (7th edition)
NIPPON ELECTRIC CONTROL EQUIPMENT INDUSTRIES ASSOCIATION

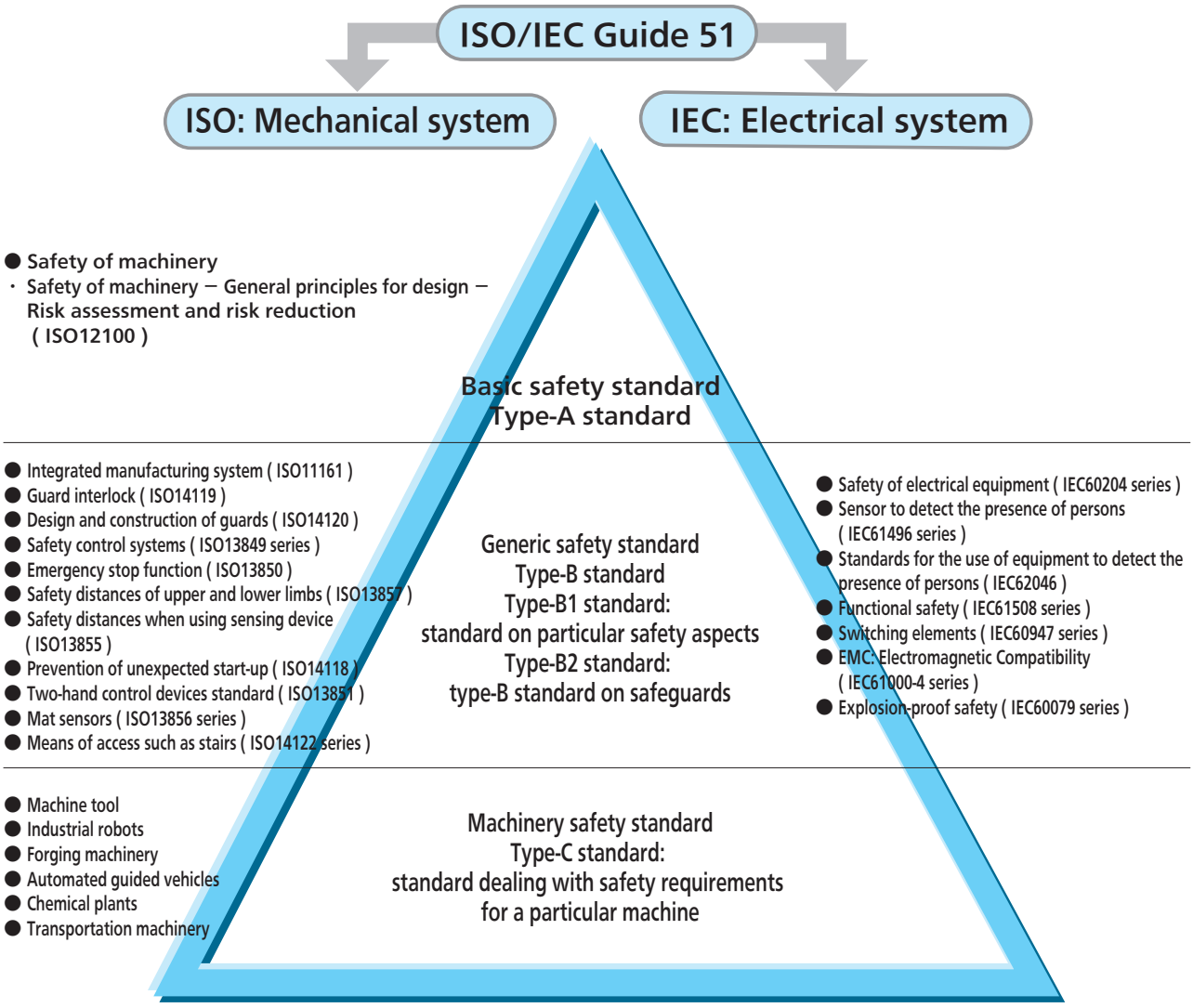
Inside the safety control system



International Safety Standards

System of international standards

International standards for machinery safety are created by the International Electrotechnical Commission (IEC), which conducts international standardization primarily in the fields of electric/electronic technologies, and the International Organization for Standardization (ISO), which conducts international standardization including fields other than electric/electronic technologies (machinery, management, etc.) . In particular, the ISO/IEC Guide 51 is published to indicate the concepts common to safety standards issued by each organization.



Source: " Safety Guidebook " (7th edition)
NIPPON ELECTRIC CONTROL EQUIPMENT INDUSTRIES ASSOCIATION

Safety standards required for machinery safety

Target of application: System

Standard No.	Target of application	Requirements	Description
ISO 13849-1	System	As one of the most important standards among the generic safety standards (Type-B standard), a set of safety-related international standards, ISO 13849-1 sets forth stipulations regarding the safety-related parts of control systems. This standard specifies the Probability of Dangerous Failure per Hour (Performance level) of a system, which is required when a control system is used as a risk reduction measure. Note) Type-B standard deal with a single type of safety device or safety that can be applied to a wide range of machines under general safety standards.	PL (Performance Level)
EN/IEC 62061	System	This refers to three numerical levels used to specify the safety integrity level (SIL) of a safety function assigned to a safety-related electrical control system.	SIL (Safety Integrity Level)
EN/IEC 61511	System	Process engineering application standard This standard describes the specification, design, installation, operation, and maintenance requirements of safety instrumented systems. Note) The term " safety instrumented systems " refers to systems that prevent accidents in plants and processes and prevent the spread of damage in the event of an unexpected accident.	SIL (Safety Integrity Level)

Target of application: Relay

Standard No.	Target of application	Requirements	Description
IEC 61810-1	Relay	This standard applies to electromechanical relays for integration in low-voltage equipment (up to a maximum of 1,000 V for AC circuits or 1,500 V for DC circuits) . It defines the basic functional requirements, safety requirements, and safety-related aspects of applications in all fields of electrical engineering or electronics. For example, general industrial equipment, electrical installations, electrical machinery, electrical equipment for household use and similar applications, information technology and business equipment, building automation equipment, other types of automation equipment, electrical installation equipment, medical equipment, control equipment, telecommunications, vehicles, transportation (e.g., railroads) .	Standard for general mechanical relays
IEC 61810-2-1	Relay	This standard specifies reliability test procedures for basic electromechanical relays when high requirements for reliability verification apply. In accordance with IEC62061 and ISO13849-1, special provisions have been established for relays included in safety-related control systems for machinery. The B10 values (B10d values) for dangerous faults of such relays are derived from the methods specified in this document.	Standard relating to relay reliability of B10 and B10d
IEC 61810-3 (former: EN 50205)	Relay	This standard applies to the structure of forcibly guided contacts. The forced guiding action allows one contact to remain open when the other contact is welded, which enables the control circuit monitoring these contacts to detect welding failures. Relays with this structure are called " Safety relays ".	Standard for forcibly guided relays (safety relays)
IEC 60664-1	Relay System	This standard specifies insulation coordination for equipment within low-voltage systems. This standard applies to equipment used at an elevation of 2,000 m or lower with a rated frequency of no higher than 30 kHz and rated voltages of no higher than 1,000 V AC or 1,500 V DC. This standard specifies requirements for clearance distance, creepage distance, and solid insulation for equipment based on performance criteria, and also specifies electrical testing methods for insulation coordination.	Standard relating to insulation coordination (insulation distance, etc.)

Design Considerations for Safety Systems

Safety standards and safety relays

EN/ISO 13849-1: Performance Level PL

Performance Level (PL)	Probability of Dangerous Failure per Hour (PFHd) 1/h
a	$10^{-5} < PFH < 10^{-4}$
b	$3 \times 10^{-6} < PFH < 10^{-5}$
c	$10^{-6} < PFH < 3 \times 10^{-6}$
d	$10^{-7} < PFH < 10^{-6}$
e	$10^{-8} < PFH < 10^{-7}$

Parts that execute safety functions for machinery are called " Safety-related parts of control system " , and the classification used to regulate the capabilities of these safety-related parts is called " Performance Level (PL) " .

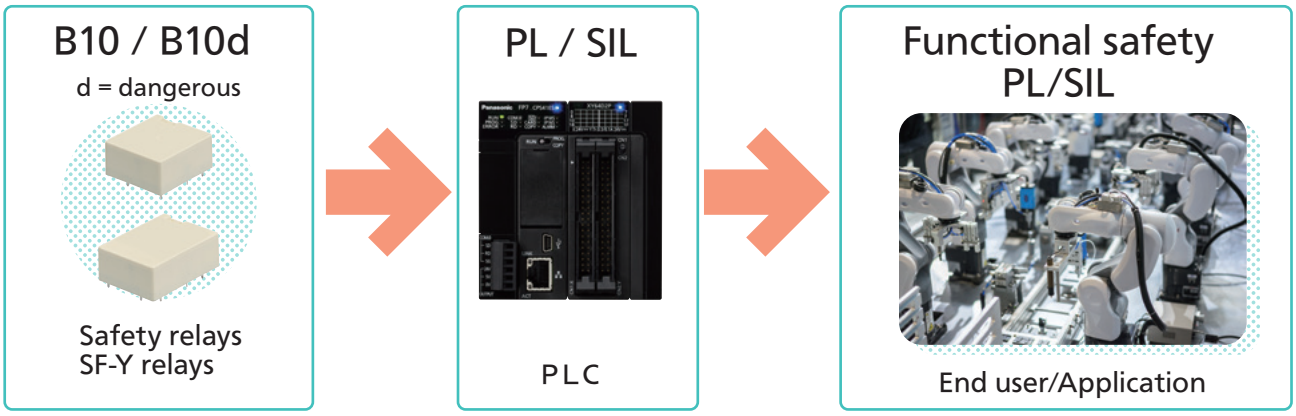
EN/IEC 62061: Safety Integrity Level SIL

Safety Integrity Level (SIL)	Probability of Dangerous Failure per Hour
No special safety requirement	$10^{-5} < PFH < 10^{-4}$
1	$3 \times 10^{-6} < PFH < 10^{-5}$
1	$10^{-6} < PFH < 3 \times 10^{-6}$
2	$10^{-7} < PFH < 10^{-6}$
3	$10^{-8} < PFH < 10^{-7}$

The term " functional safety " refers to achieving a state in which there are no unacceptable risks through the implementation of functions that ensure safety.
In addition, functional safety standards specify effective methods for implementing functional safety. In particular, SIL is determined based on probabilistic indicators (the average probability of dangerous function failure and the average frequency of dangerous failures).

▷ Safety function failure probability is determined by the combination of the parts with safety functions!

Safety relays with forcibly guided structures themselves are originally neither ISO13849-1 (PL) nor IEC62061 (SIL) compliant. For application producers who require a safety standard (e.g., PLC/safety light curtains) , B10/B10d values can be provided to prove the failure probability of safety functions.



- B10 refers to the average number of cycles before 10 % of parts or systems failure (including both safe and dangerous failures).
- B10d refers to the average number of cycles before 10 % of parts or systems failure in a dangerous side.
  Note) When a B10 value is available, the B10d value may in some cases be calculated by doubling the B10 value.

Example SF-Y relays:

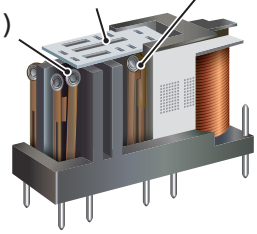
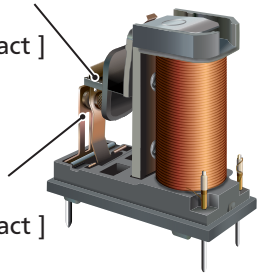
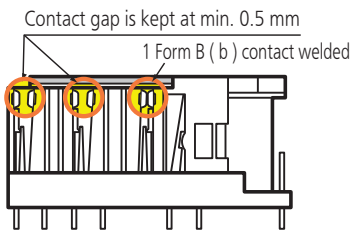
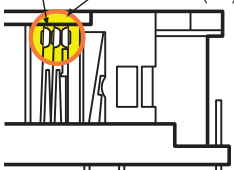
Load	B10d
AC1 230 V 6 A	2 M
AC15 230 V 5 A	35 k
DC1 24 V 6 A	2 M
DC13 24 V 4 A	500 k
DC13 24 V 2 A	1.6 M

Why are safety relays necessary?

There is no obligation to install safety relays in safety equipment. However, installing safety relays facilitates designing safety equipment, simplifies the approval process, and ensures that safety equipment is deployed on time.

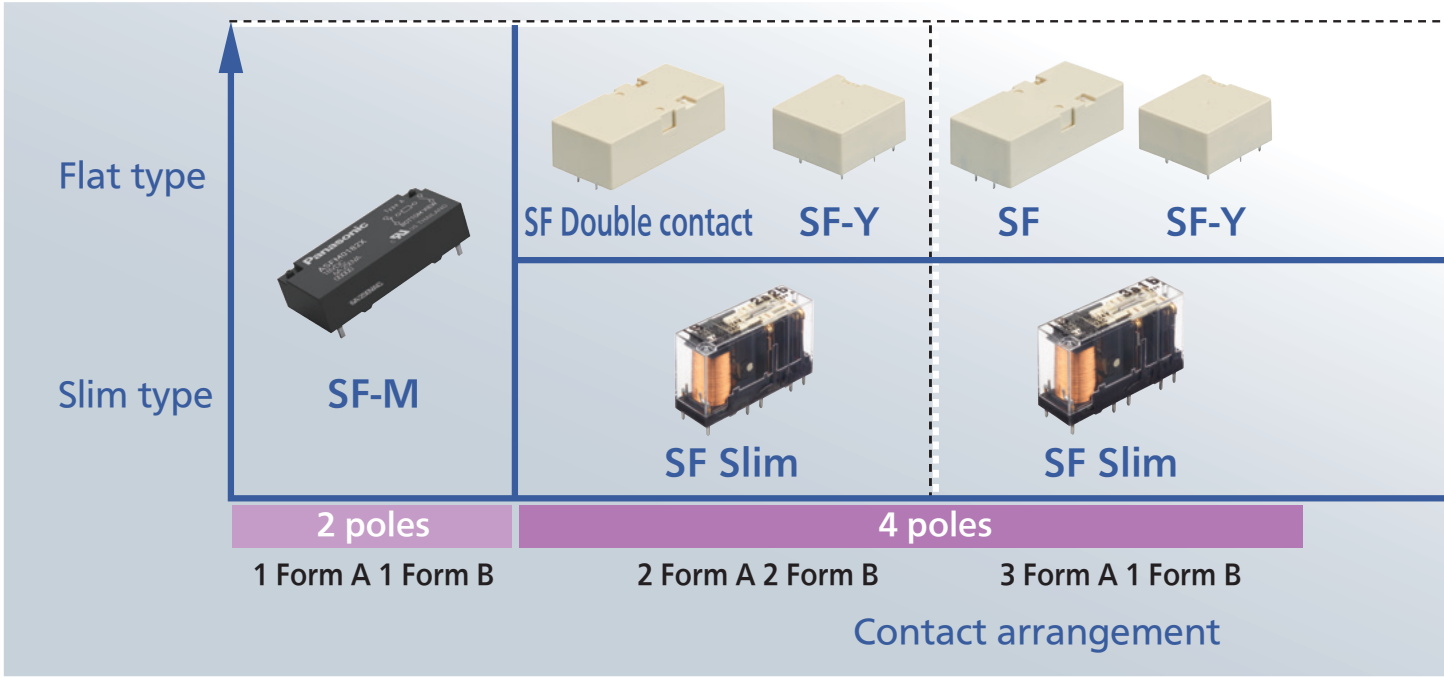
Item	General relay	Safety relay (Forcibly guided contact structure)
Diagnostic coverage & Average DC: Diagnostic Coverage & DCavg	From 0 % Board designers need to increase the DC value using circuits to reach the required PL and SIL.	99 % Enables board designers to reach the required PL and SIL more easily.
Mean cycles to failure (B10/B10d)	Very little information Even if there is only B10.	The measurement method of B10d is compliant with DIN EN 61810-2-1.
Coil failure detection with safe feedback contacts	Board designers need to take appropriate measures.	Compatible with relay structure
Failure detection with safe feedback contacts (contact welding)	Not compatible	Compatible
Other contact gaps at the time of contact welding	Failures due to contact welding cannot be detected due to insufficient contact gap.	Securing of contact gap min. 0.5mm ensures reliable detection of contact welding and other factors. Also, since it is compliant with IEC61810-3, it is ideal for safety circuit design.
Price level	Low price However, other parts and systems are needed in order to achieve machinery safety, which results in additional costs.	Slightly higher price (Due to additional design to ensure compatibility with forcibly guided structures, such as multiple contacts and contact GAP securing, etc.)

Differences between safety relays and general relays

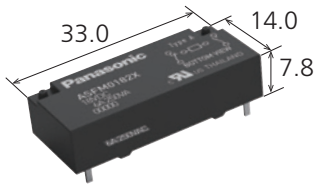
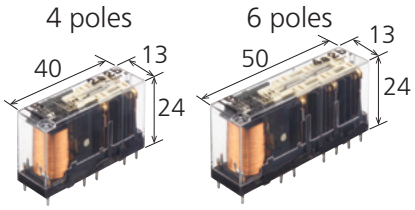
<table>
<tr><th></th><th>Safety relay</th><th>General relay</th></tr>
<tr><td>Structure</td><td>Forcibly guided
1 Form B (b) contact
1 Form A (a) contact
  </td><td>N.C. terminal
[1 Form B (b) contact]
N.O. terminal
[1 Form A (a) contact]
  </td></tr>
<tr><td>Features (1)</td><td>• Safety relays have two types of contacts: N.O. contacts (normally open) and N.C. contacts (normally closed).
• Although these two types of contacts are separated by a wall and do not interfere with each other, they are mechanically connected by a guide.</td><td>The following is not guaranteed.
• Although these two types of contacts are separated by a wall and do not interfere with each other, they are mechanically connected by a guide.</td></tr>
<tr><td>Features (2)</td><td>Forcibly guided structure
Compliant with the IEC/EN61810-3 standard.
 
Contact gap is kept at min. 0.5 mm
1 Form B (b) contact welded
Note) The 1 Form B (b) contact is also forcibly pulled apart by the contact guide when 1 Form A (a) contact is welded.</td><td>General relay structure
 
1 Form B (b) contact gap
1 Form A (a) contact welded
Note) When the contact is welded, both 1 Form A (a) contact and 1 Form B (b) contact will close.</td></tr>
</table>

Product Lineup

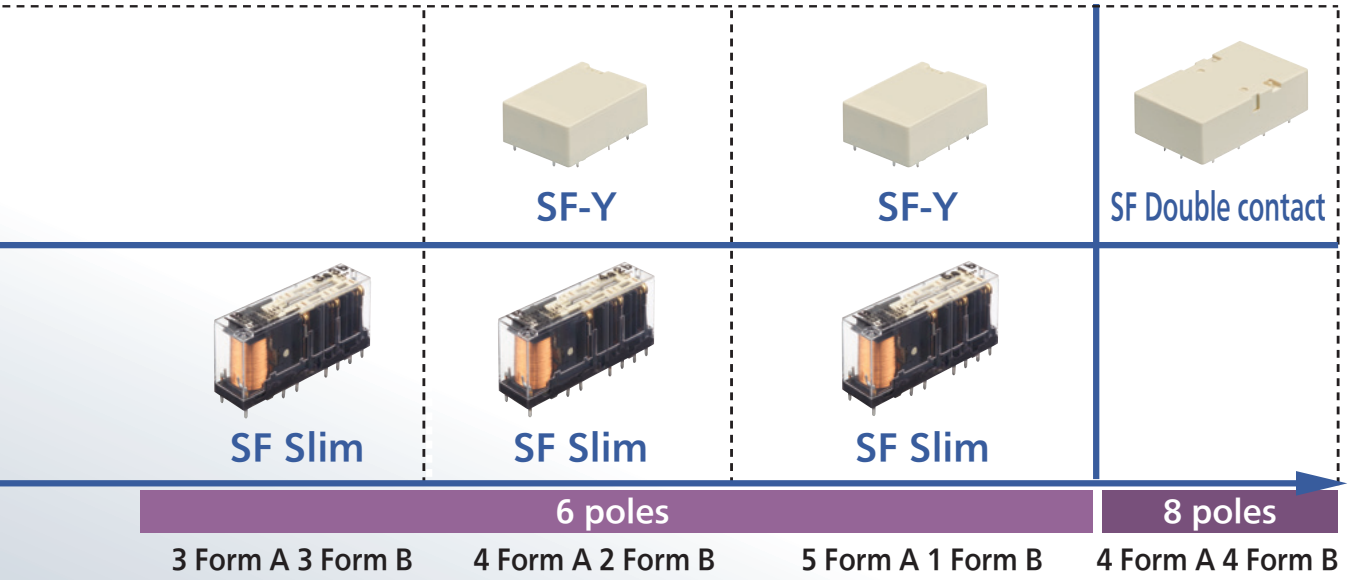
Safety relays Rich lineup

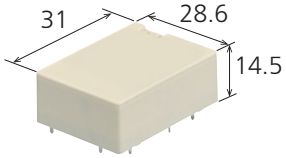
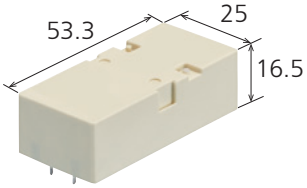
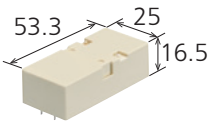
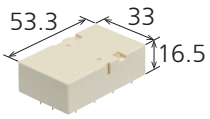


Safety relays Specifications

Product name	SF-M	SF Slim
Appearance		
Contact arrangement	1a1b	4 poles: 2 Form A 2 Form B, 3 Form A 1 Form B 6 poles: 4 Form A 2 Form B, 5 Form A 1 Form B, 3 Form A 3 Form B
Contact rating	N.C. : 4 A 250 V AC 30 V DC N.O. : 6 A 250 V AC 30 V DC	6 A 250 V AC 30 V DC
Min. switching load (reference value)	1 mA 10 V DC	1 mA 5 V DC
Rated operating power	Operating: 270 mW Holding : 100 mW	4 poles: 360 mW 6 poles: 500 mW
Rated coil voltage	3, 5, 12, 16, 18, 21, 24 V DC	12, 24, 48 V DC
Ambient temperature	−40 ℃ to +85 ℃	−40 ℃ to +85 ℃
Safety standards	UL/C-UL, TÜV	UL/C-UL, TÜV Korean S, CQC

Product Lineup

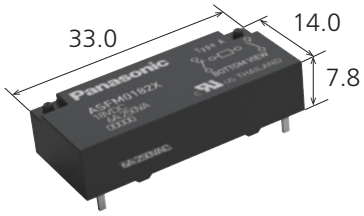


SF-Y	SF	SF Double contact
		2 Form A 2 Form B  4 Form A 4 Form B 
4 poles: 2 Form A 2 Form B, 3 Form A 1 Form B 6 poles: 4 Form A 2 Form B, 5 Form A 1 Form B	3 Form A 1 Form B	2 Form A 2 Form B, 4 Form A 4 Form B
6 A 250 V AC 30 V DC	6 A 250 V AC 30 V DC	6 A 250 V AC 30 V DC
10 mA 10 V DC	100 mA 5 V DC	100 mA 5 V DC
670 mW	500 mW	500 mW
5, 12, 16, 18, 21, 24 VDC	5, 12, 24, 48, 60 V DC	5, 12, 24, 48, 60 V DC
−40 ℃ to +70 ℃	−40 ℃ to +70 ℃	−40 ℃ to +70 ℃
UL/C-UL, TÜV	UL/C-UL, TÜV	UL/C-UL, TÜV

New Product Introduction

Note) Released in October 2020

SF-M relays



(unit: mm)

1. Small size, low profile and low operating power

- Width (14 mm) × Length (33 mm) × Height (7.8 mm)
- Rated operating power: 270 mW (Holding Power: 100 mW)

2. Protective construction

- RT II (Flux-resistant)
- RT III (Sealed)

3. Safety standards

- Forcibly guided contact structure (Compliant with IEC61810-3)
- Contact gap: 0.5 mm

4. Reflow mountable

- Pin-in-paste (Through hole reflow) Note) RT II (Flux-resistant) only

5. Operate time / Release time

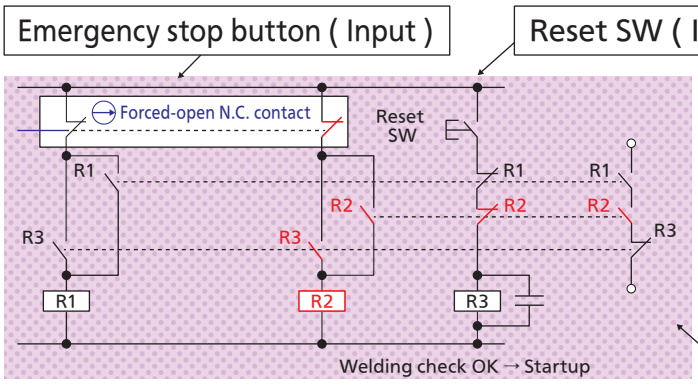
- Max. 15 ms (at 20 ℃)
- Max. 10 ms (at 20 ℃)

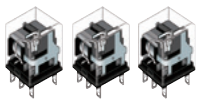
6. Functional shock resistance

- Min. 200 m/s²

Safety relays only → Enable realization of equivalent safety circuits using safety relays together with electronic circuit

☐ Before

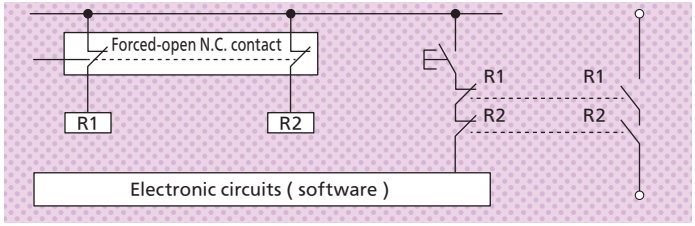




2 Form A 1 Form B × 3 pcs.

1 Safety output

☐ After

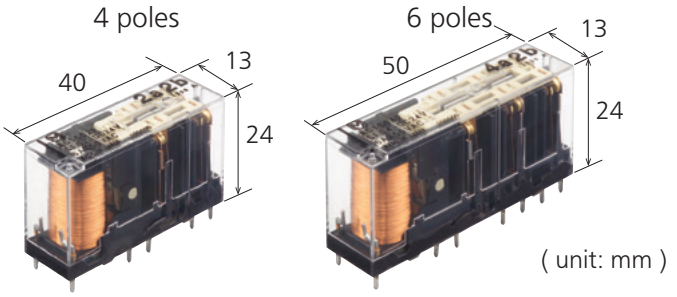


1 Form A 1 Form B × 2 pcs.

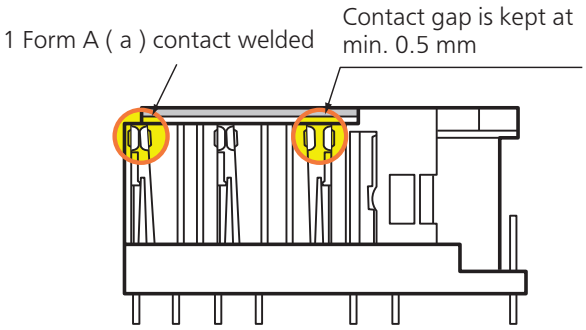
SF Relays Slim type

SF Relays Slim type

■ Forcibly guided contact structure compliant with EN/IEC61810-3
(Ensures contact gaps of 0.5 mm or higher)



(unit: mm)



All types are compatible with forcibly guide contact structure
Contact gaps of min. 0.5 mm
Safety construction

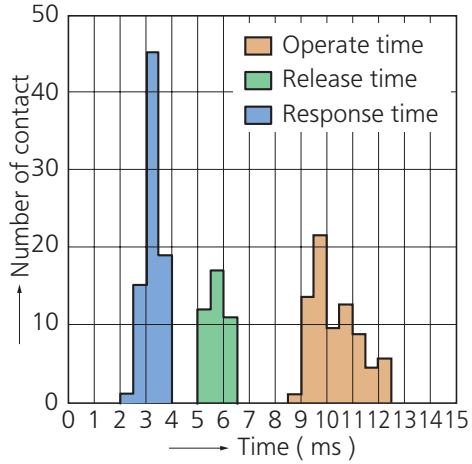
Slim type
(W) : 13 mm × (L) : 40/50 mm × (H) : 24 mm
Space saving

Fast response time is achieved.
Max. 8 ms
Quick response

Quick response

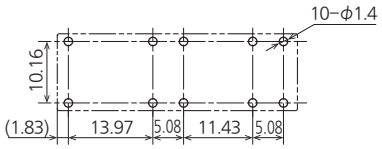
Operate, Response and Release time (reference data)

Sample : AG1S042 (4 Form A 2 Form B)
Quantity: n = 20
(Number of 1 Form A (a) contact: 80,
Number of 1 Form B (b) contact: 40)



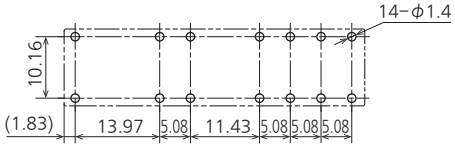
Space saving

■ 4 poles Recommended PC board pattern (BOTTOM VIEW)



Tolerance: ±0.1

■ 6 poles Recommended PC board pattern (BOTTOM VIEW)



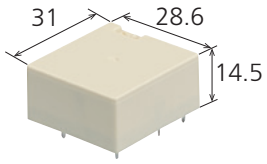
Tolerance: ±0.1

SF-Y Relays

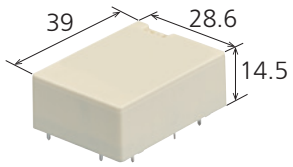
SF-Y Relays

■ Safety relay compliant with European safety standards Type A, IEC61810-3 TÜV certification Forcibly guided contact structure

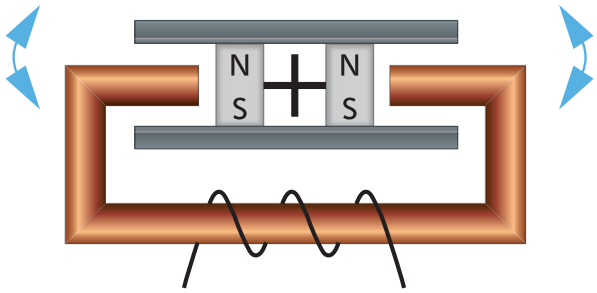
4 poles



6 poles



(Unit: mm)



All types are compatible with forcibly guide contact structures
Contact gaps of min. 0.5 mm

Safety construction

Compact Flat profile
(W): 28.6 mm x(L): 35/31 mm x (H): 14.5 mm

Space saving and compact

Wide variation in contact arrangements
4 poles (2 Form A 2 Form B, 3 Form A 1 Form B)
6 poles (4 Form A 2 Form B, 5 Form A 1 Form B)

Multi-contact control is achieved

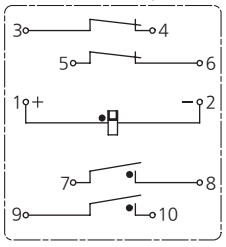
Functional shock resistance:
Min. 200 m/s² (half-sine shock pulse: 11 ms, detection time: 10 µs)

Shock resistance

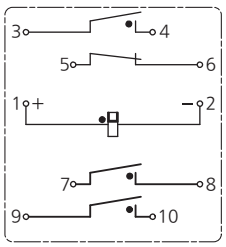
Space saving • compact

■ 4 poles

Schematic
(BOTTOM VIEW)

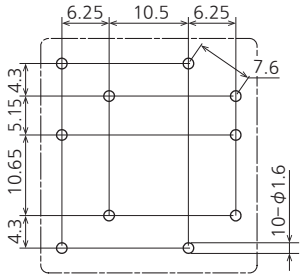


(2 Form A 2 Form B)



(3 Form A 1 Form B)

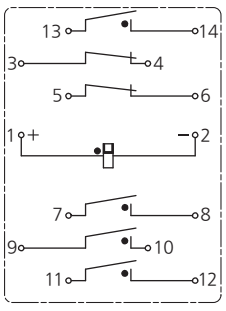
Recommended PC board pattern
(BOTTOM VIEW)



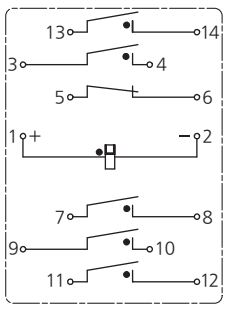
Tolerance: ±0.1

■ 6 poles

Schematic
(BOTTOM VIEW)

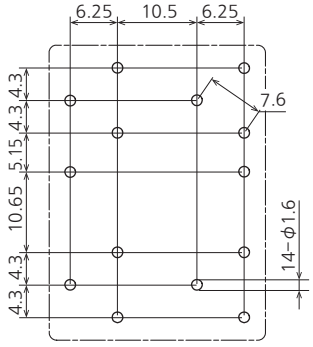


(4 Form A 2 Form B)



(5 Form A 1 Form B)

Recommended PC board pattern
(BOTTOM VIEW)



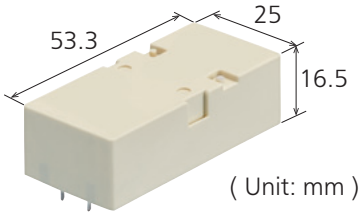
Tolerance: ±0.1

Product Features

SF Relays / SF Relays Double contact type

SF Relays

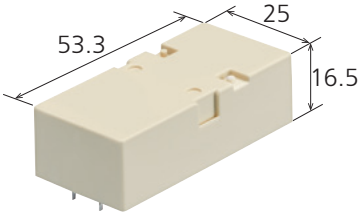
■ Flat type safety relay compliant with safety standards
Forcibly guided contact structure



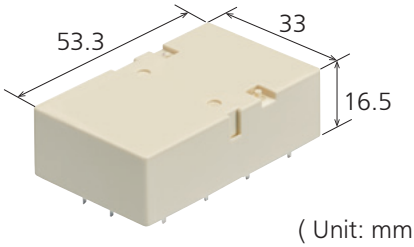
(Unit: mm)

SF Relays Double contact type

2 Form A 2 Form B



4 Form A 4 Form B



(Unit: mm)

■ Flat type safety relay compliant with safety standards
High contact reliability is achieved by double contact.
Forcibly guided contact structure

All types are compatible with forcibly guided contact structures. Contact gaps of min. 0.5 mm

▼

Safety construction

High contact reliability by double contact

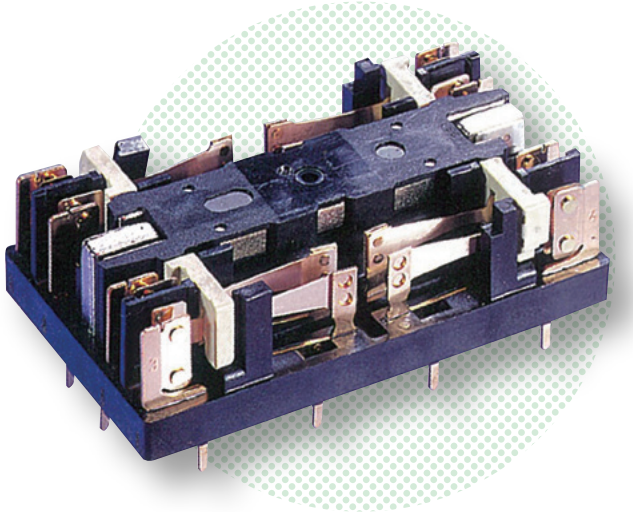
▼

High reliability

Wide variation in contact arrangements
4 poles (2 Form A 2 Form B)
4 poles (3 Form A 1 Form B) Note) SF relays
8 poles (4 Form A 4 Form B)

▼

Multi-contact control is achieved

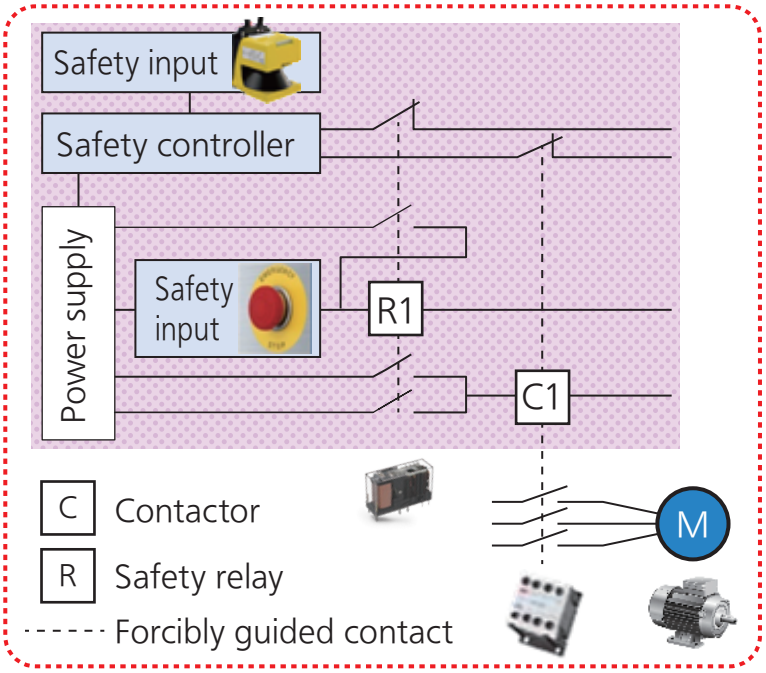


Double contact

● Improved contact reliability

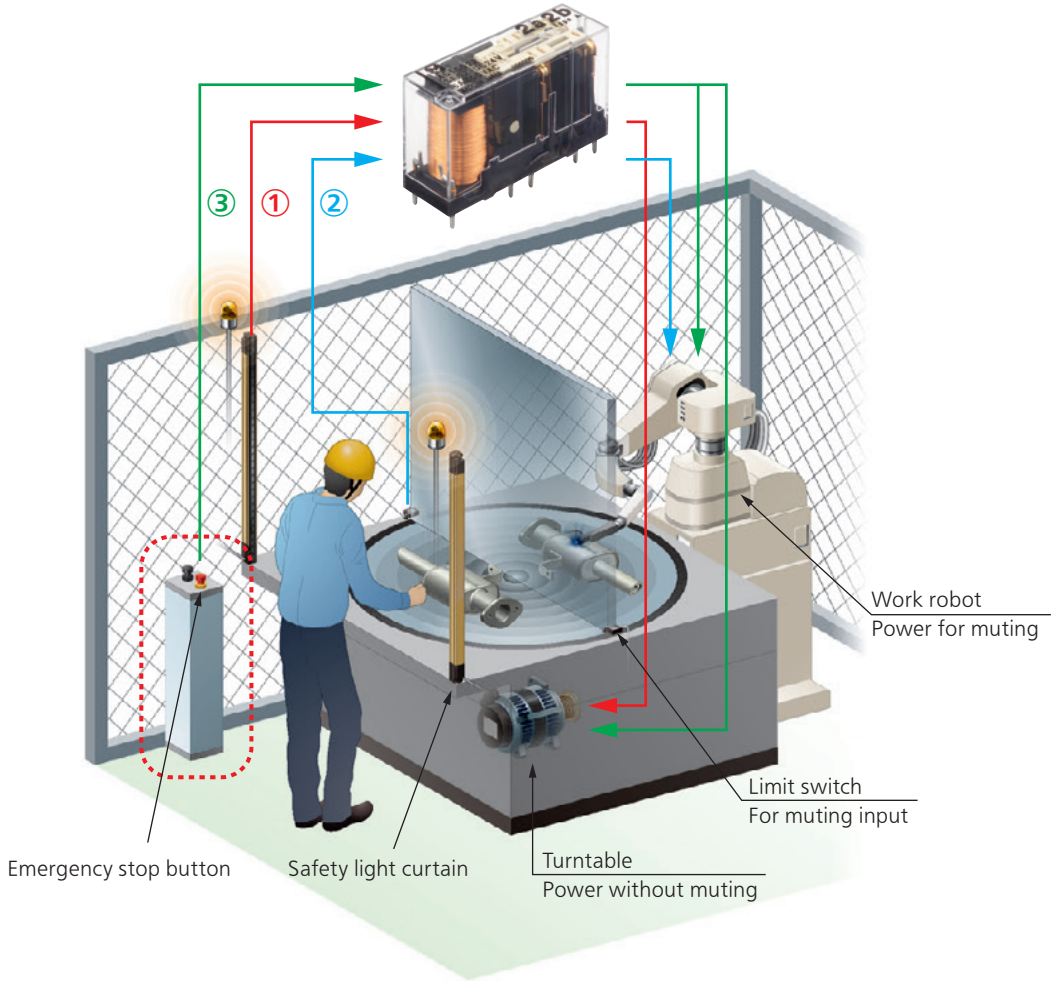
Self-holding Circuit during Emergency Stop

Typical example Production equipment: Emergency stop circuit



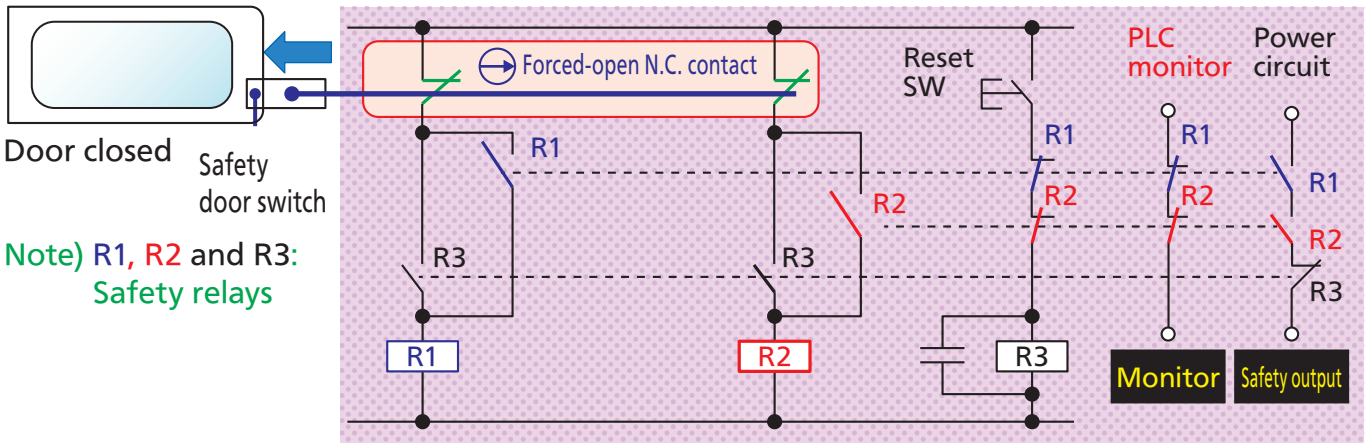
[Explanation]

When an emergency stop button is pressed, the safety relay engages and supplies electric current to the coil of the safety relay (self-hold). Turns OFF the contactor controlling the motor power supply.



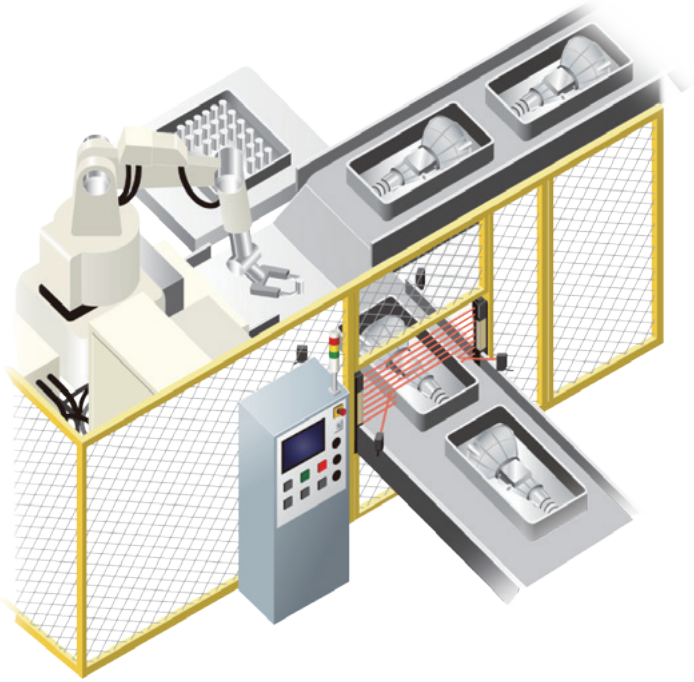
Detect Abnormalities and Stop the System

Typical example Production equipment: Abnormality detection and stop circuit when contact welding occurs.



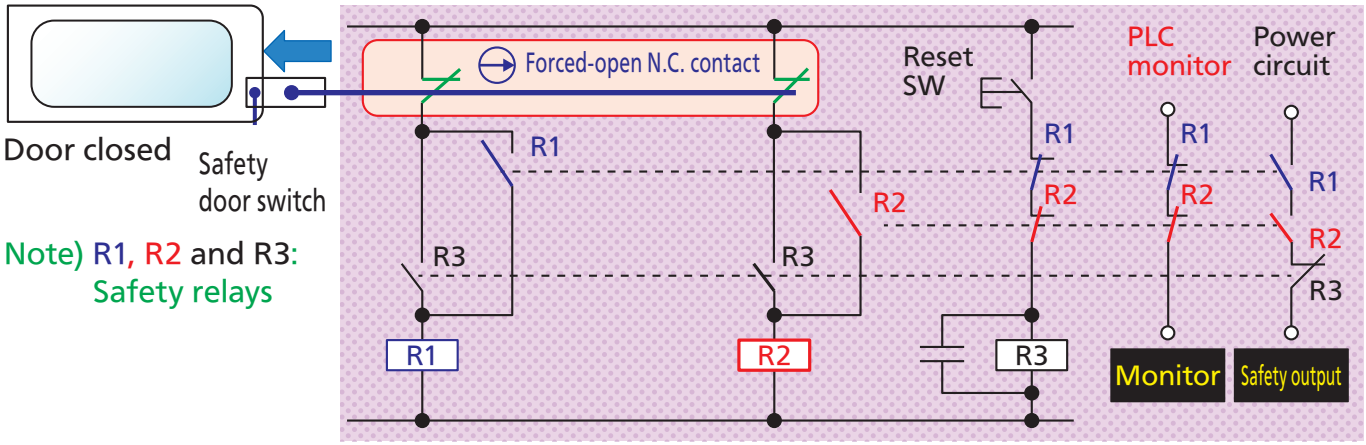
[Explanation]

In the event of an abnormality such as contact welding, system cannot be restarted.



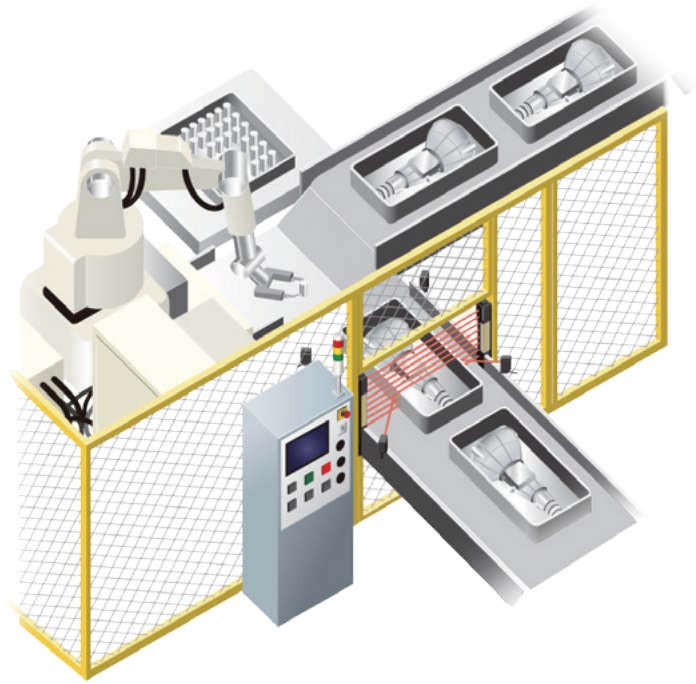
Ensuring Safety through Sequence Control

Typical example Production equipment: Sequence circuit



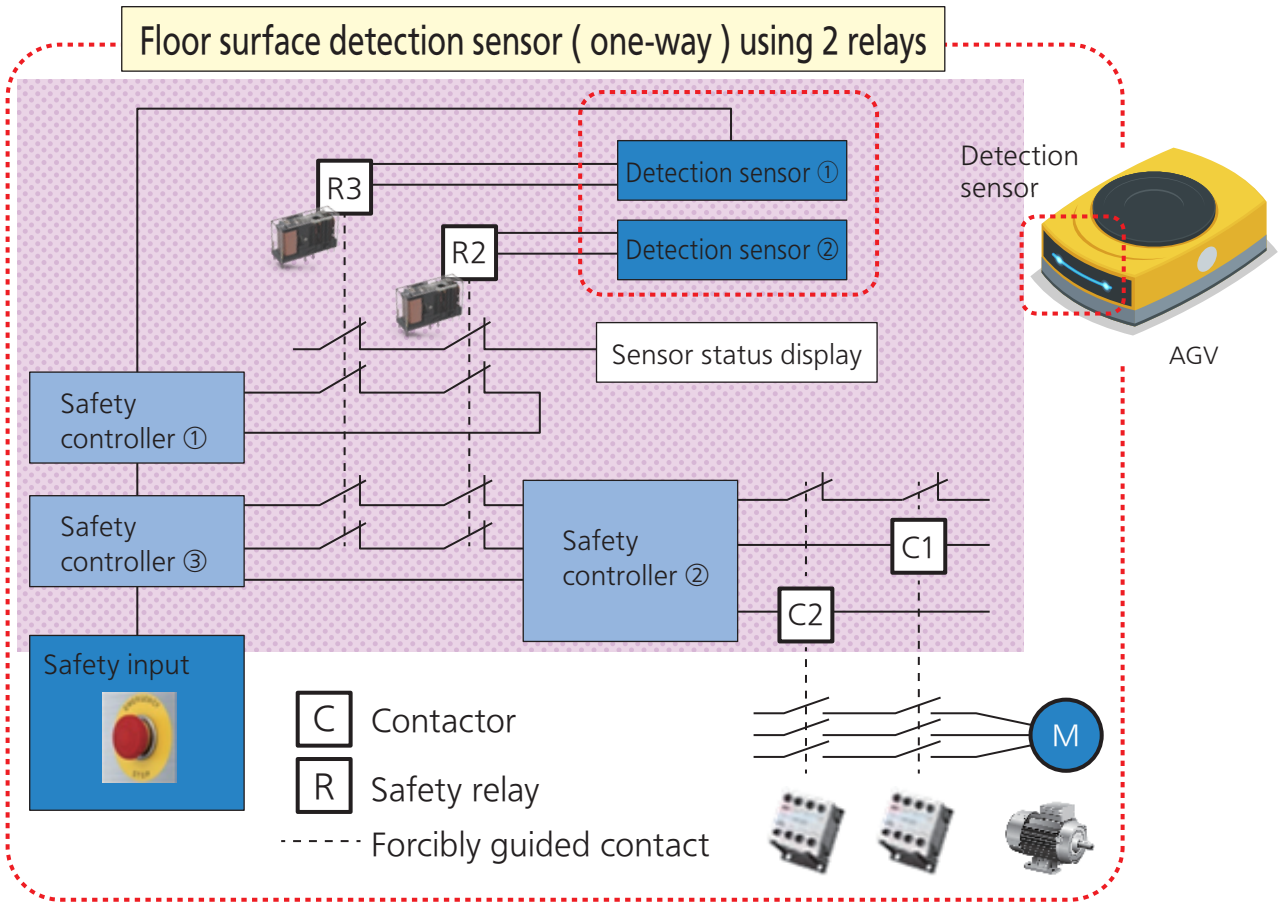
[Explanation]

The system can be restarted only after the safety door switch is engaged and the reset button is pressed.



Coordinated ON / OFF of Control Circuit that must not Operate Simultaneously

Typical example Production equipment: Switching circuit



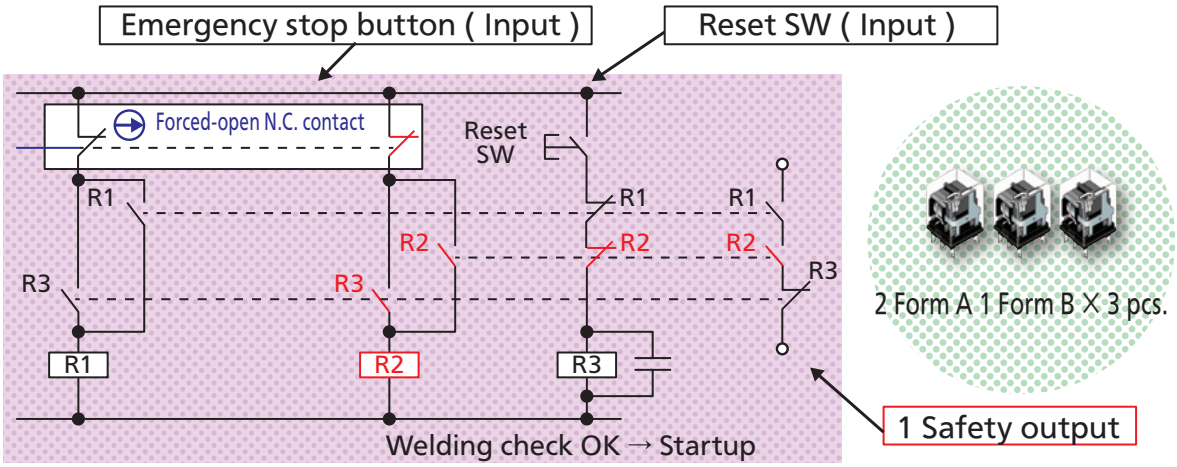
[Explanation]

When the sensor detects an abnormality, the safety relay is activated and the ordinary control is stopped.
Emergency operation control activates to control the motor.

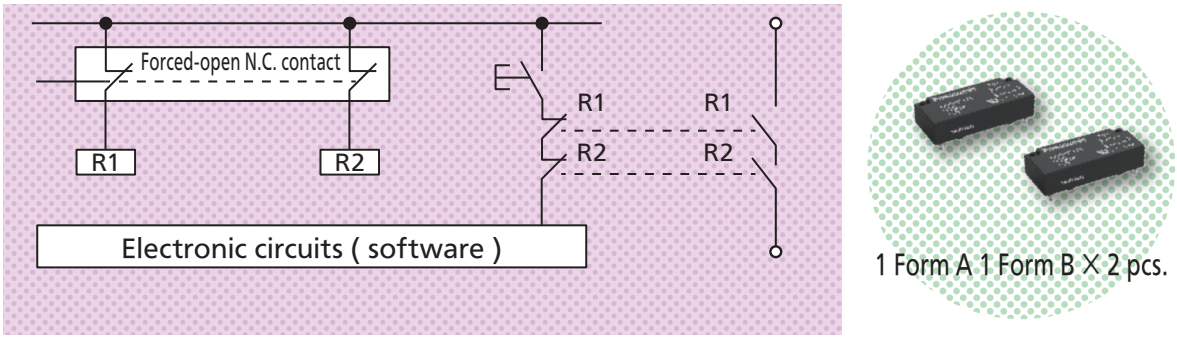
Safety relays only → Enable realization of Equivalent Safety Circuits using Safety Relays together with Electronic Circuit

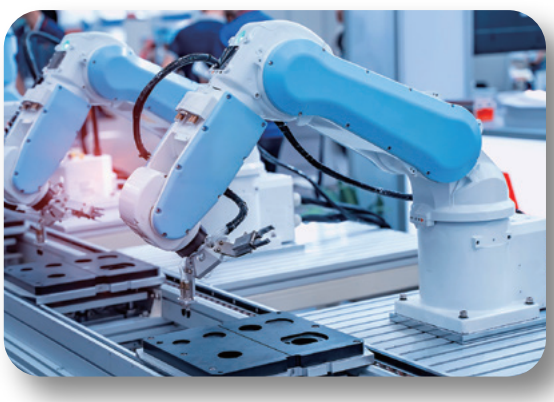
Typical example Production equipment: Abnormality detection circuit

Before



After

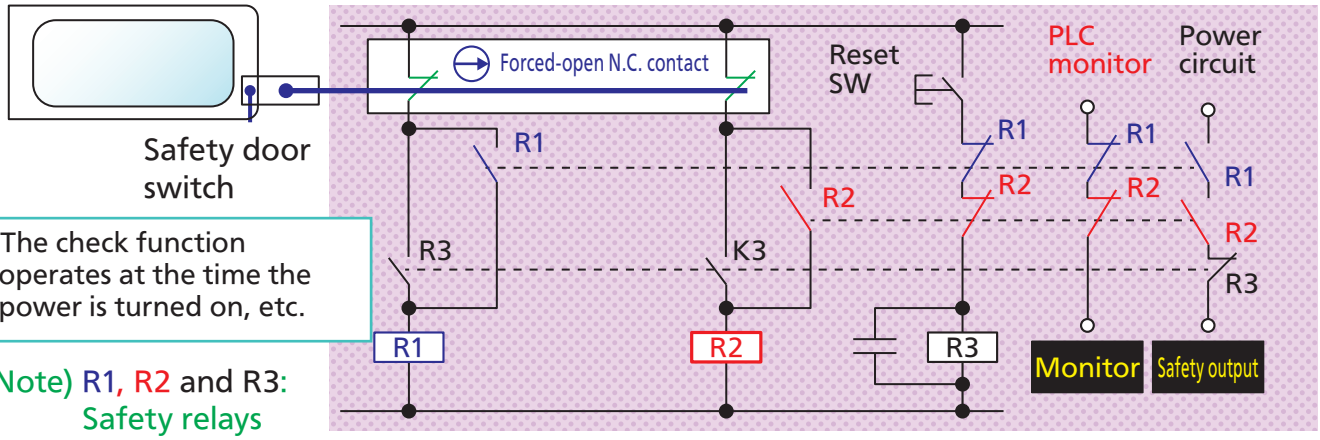




Safety Circuit Construction using Safety Relays and Examples of Functions

Typical example Production equipment: Safety door

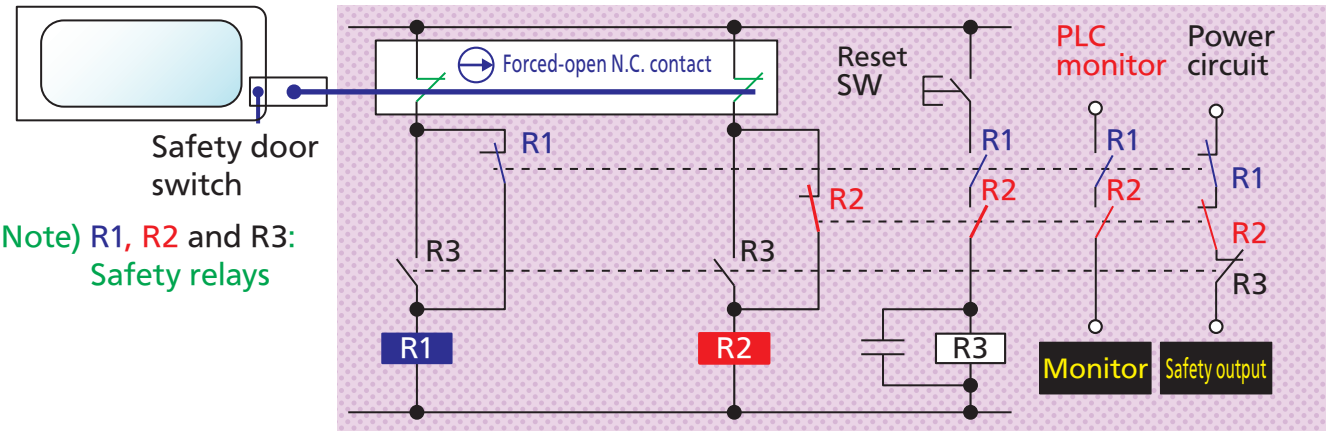
On standby



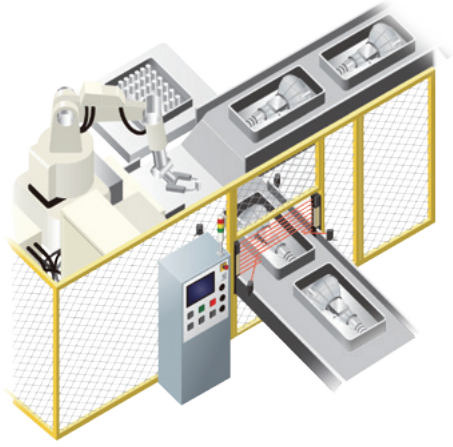
★ The check function operates at the time the power is turned on, etc.

Note) R1, R2 and R3: Safety relays

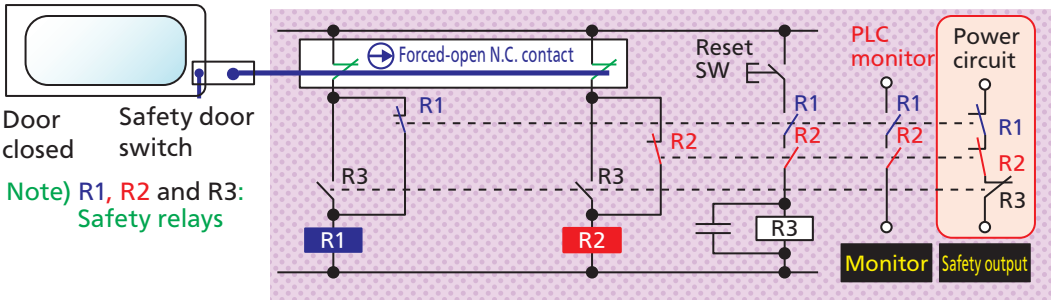
In operation



Note) R1, R2 and R3: Safety relays



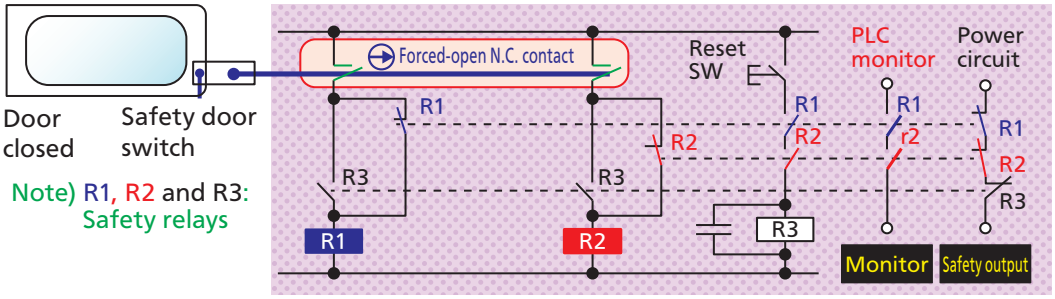
In operation



[Explanation]

The power circuit is connected and in operation.
- Relays R1 and R2 are in the ON state.
- Relay R3 is in the OFF state.

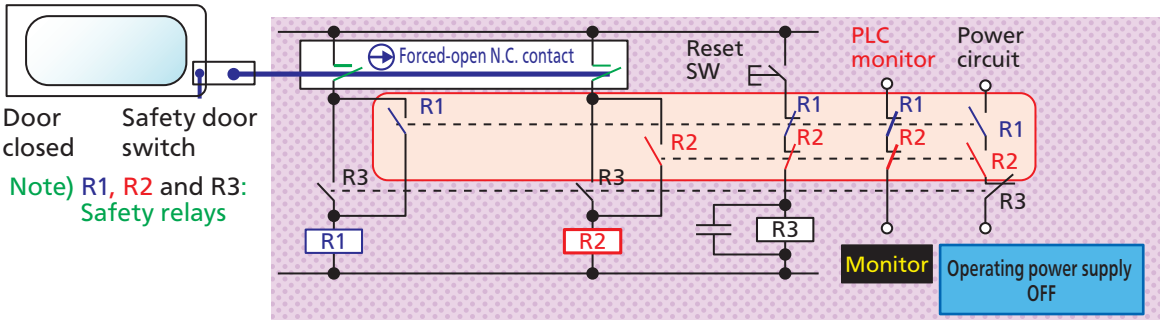
Safety door Open



[Explanation]

When the safety door is opened, voltage is no longer supplied to the coils of relays R1 and R2.

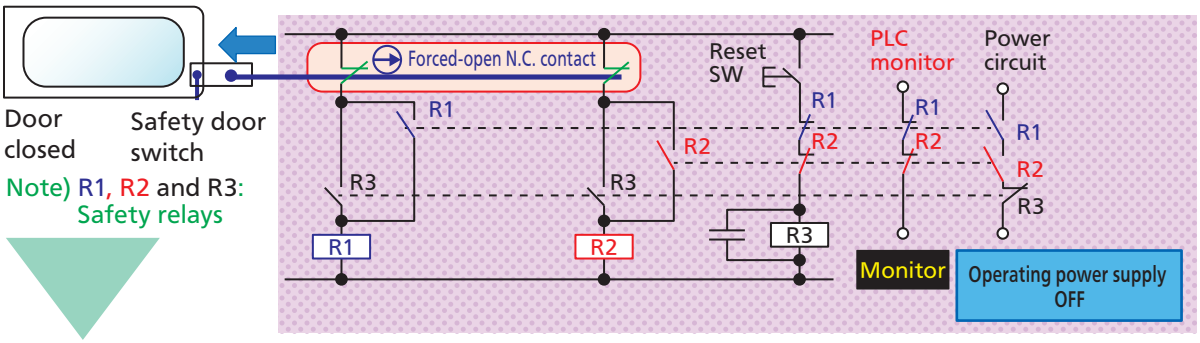
Relays R1 and R2 OFF



[Explanation]

Relays R1 and R2 turn OFF, and the power circuit disconnects, and is placed on standby.

Safety door Closed ⇒ On standby



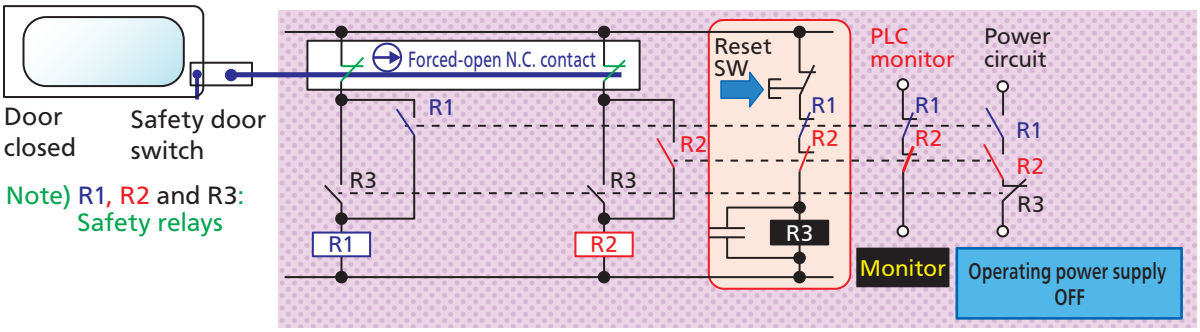
[Explanation]

The safety door is closed for restarting, but the power circuit is not connected because relays R1 and R2 are OFF.

[Explanation]

It will not operate just by closing the safety door.

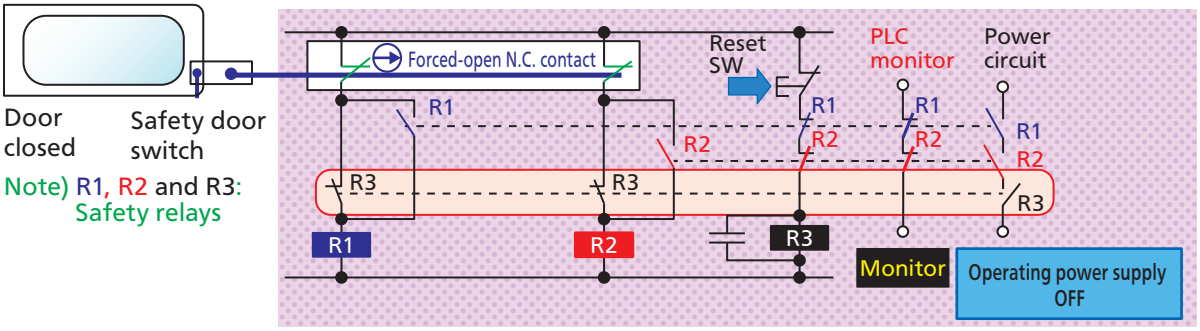
Reset SW ON



[Explanation]

By turning ON the reset SW, voltage is supplied to the coil of R3.

Relay R3 ON

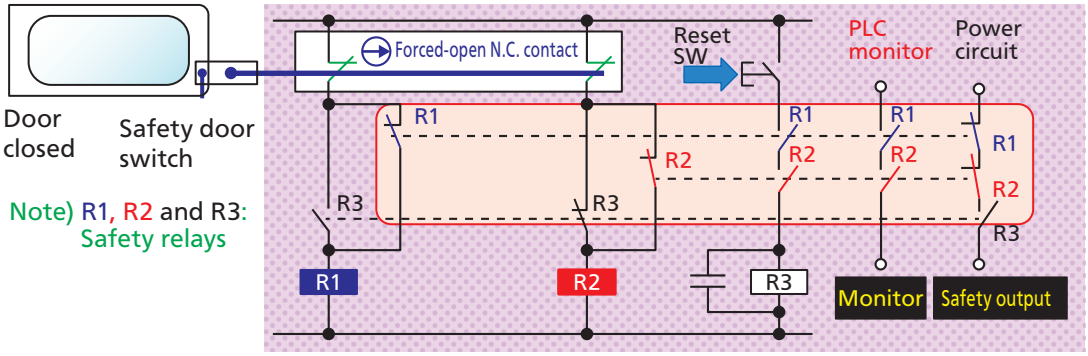


[Explanation]

Relay R3 is turned ON and voltage is supplied to the coils of relays R1 and R2.

Safety Circuit Construction using Safety Relays and Examples of Functions

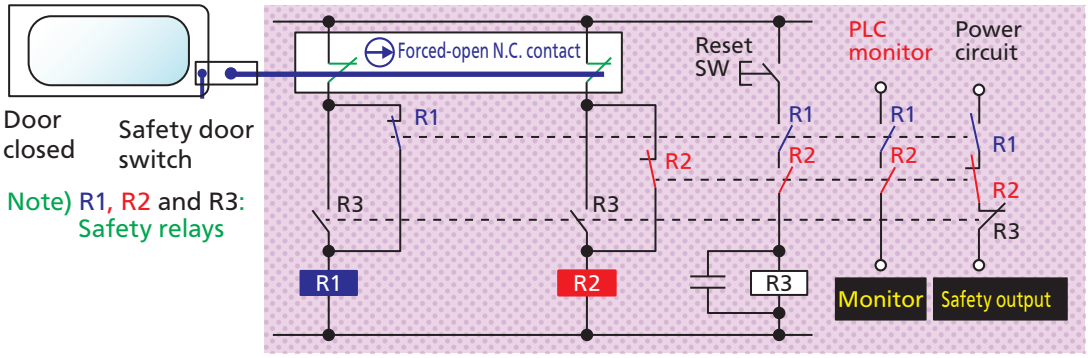
Relays R1 and R2 ON



[Explanation]

Relays R1 and R2 turn ON. Voltage is no longer supplied to the coil of R3, and relay R3 turns OFF.

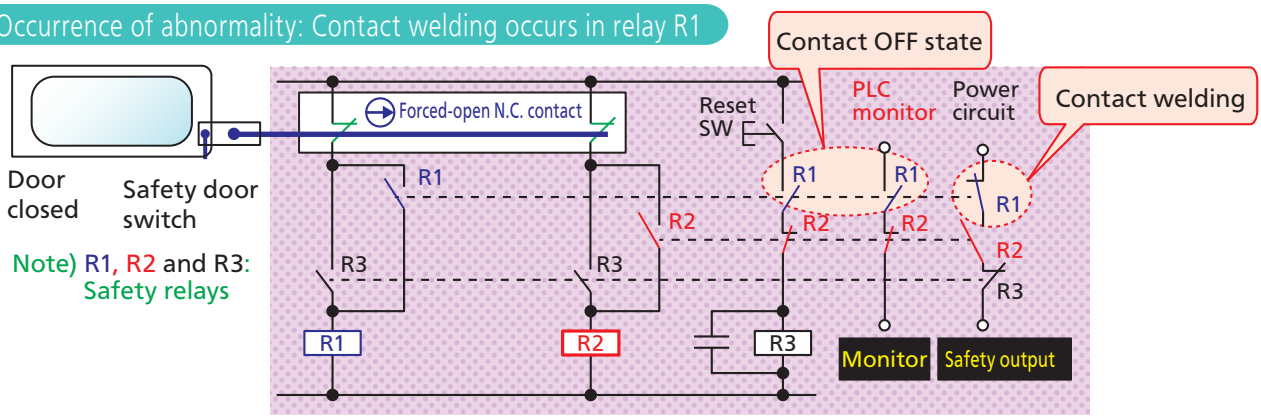
Relay R3 OFF ⇒ Operation



[Explanation]

When relay R3 is turned OFF, the power circuit is connected and operation begins.

Occurrence of abnormality: Contact welding occurs in relay R1



[Explanation]

In the event of an abnormality while on standby (contact welding occurs in relay R1), the contacts of relay R1 of the PLC monitor circuit and the reset SW circuit are turned OFF, and even if the reset SW is turned ON, the stop state is maintained and the monitor circuit detects the abnormality.The same applies when contact welding occurs in the power circuit of relay R2.

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Specifications are subject to change without notice.
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