KEYENCE

Comprehensive Safety Standards Guide,
From History & Laws to Calculation Techniques

Safety Support Guide Book

INDEX

01 History of Safety Standards

Chronology

	International standard
1995	Establishment of the WTO Establishment of TBT agreement
2000	IEC 61508*1
2001	
2003	ISO 12100-1/2*2
2004	
2006	ISO 13849-1:2006*3
2007	
2010	ISO 12100:2010*4 ISO 13855:2010*5
2011	
2013	ISO 14119:2013*6
2015	ISO 13849-1:2015*3

*1 IEC 61508 .... Functional safety of electrical/electronic/programmable electronic safety-related systems

*2 ISO 12100-1/2 .... Safety of machinery-basic concepts, general principles for design — Part 1: Basic terminology, methodology and Part 2: Technical principles

*3 ISO 13849-1............... Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design

*4 ISO 12100:2010......... A standard that integrated, without making changes to, the technical details of the ISO 12100 series established in 2003 and ISO 14121-1 established in 2007

*5 ISO 13855:2010......... Safety of machinery — Positioning of safeguards with respect to the approach speeds of parts of the human body

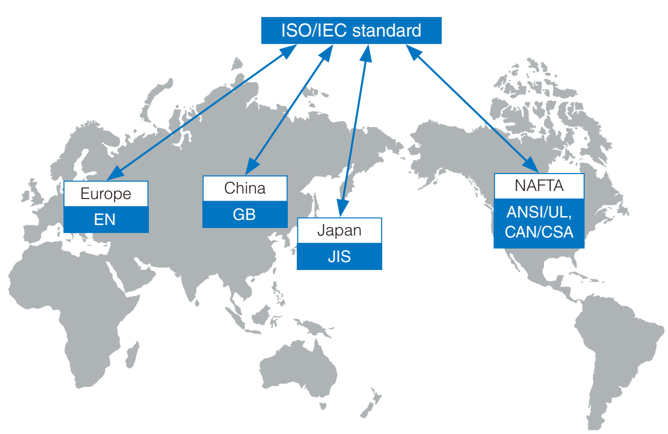
*6 ISO 14119:2013......... Safety of machinery — Interlocking devices associated with guards — Principles for design and selection

Background of Increased Focus on Safety

In 1947, the General Agreement on Tariffs and Trade (GATT) was signed and published by a collaborative group of 23 countries working to establish smooth international trade. Thereafter, in the "GATT Uruguay Round" of 1994, consent was reached for revisions to this agreement to make clear and strengthen its responsibilities. In the same year, the "TBT Agreement" was established. Taking on the establishment of the TBT Agreement, the **WTO** (World Trade Organization) was established in the following year as an international organization whose goal is free trade. As a result, the TBT Agreement was integrated into the WTO Agreement, and these are expressed as the "WTO/TBT Agreement." According to this "WTO/TBT Agreement," member nations are required to establish standards such as compulsory standards, voluntary standards, and conformance assessment processes by integrating these standards with international standards such as the ISO and IEC standards.

Reason for Using **ISO/IEC** Standards

By making facilities and machines conform to the ISO/IEC standards, **it became possible to, in general cases, make these facilities and machines conform to the technical criteria of various countries** in order to increase commonality around the world and thus allow for fewer restrictions to worldwide trade. (Requirements unique to each country are also recognized, so the above is an explanation of the principle.)

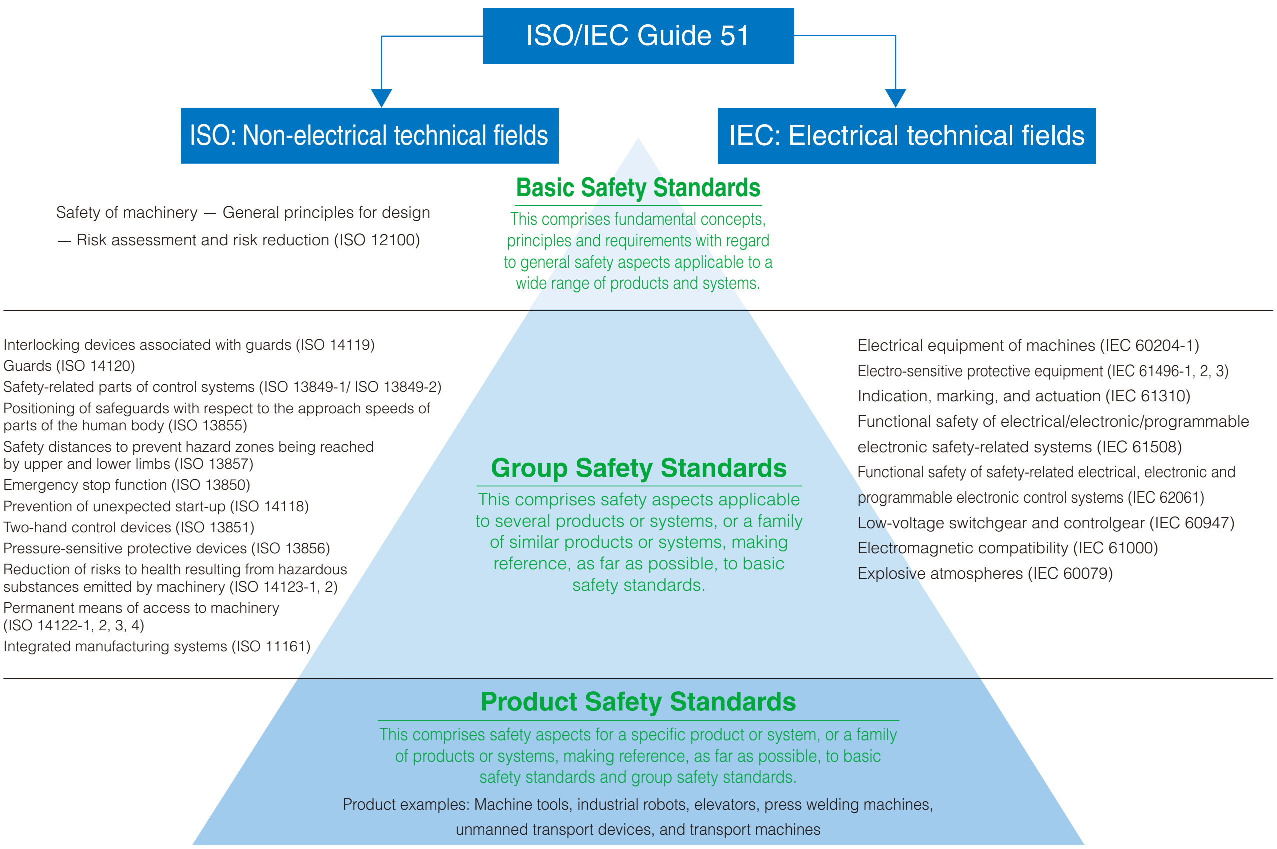


02 Organizational Diagram of Safety Standards

International Standards of Machine Safety

There is no guarantee that an ISO or IEC standard will exist for a given machine. **Realistically speaking, it is not possible** to update standard requirements to match products as they evolve day by day. Therefore, ISO and IEC standards are separated into levels (by way of ISO/IEC Guide 51), and the latest machines **are supported by using combinations of these standards**.

International Standards of Machine Safety, ISO/IEC Standards



ISO

This is the International Organization for Standardization. The ISO is a standardization body established in 1947 that specializes in non-electrical technical fields. Their headquarters are located in Geneva, Switzerland. Some of the most well-known ISO standards include ISO 9001: Quality management systems and ISO 14001: Environmental management systems.

IEC

This is the International Electrotechnical Commission. The IEC is a standardization body established in 1908 that specializes in electrical and electronic technical fields. They are located in Geneva, Switzerland.

Principal Safety Standards [Glossary]

ISO/IEC Guide 51

This Guide provides requirements and recommendations for the drafters of standards for the inclusion of safety aspects in standards. It is applicable to any safety aspect related to people, property or the environment, or to a combination of these. The definition of “safety” is in this document, which means freedom from unacceptable risk.

ISO 12100

This is a basic safety standard for safety of machinery, which specifies principles of risk assessment and risk reduction, such as the 3-step method, to help designers achieve safety in the design of machinery.
The 3-step method is a procedure for risk reduction, consisting of: 1) Inherently safe design measures,
2) Safeguarding and/or complementary protective measures, and 3) Information for use.
In 2010, former basic standards, ISO 12100-1: 2003 and ISO 12100-2: 2003, were integrated in ISO 12100: 2010 without any changes on technical standpoint.

ISO 13849-1

This safety standard provides safety requirements and guidance on the principles for the design and integration of safety-related parts of a control system.
This defines the performance level (PL), which is the discrete level used to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions.

ISO 14121-1

This safety standard had provided general principles intended to be used to meet the risk reduction objectives established in ISO 12100-1: 2003.
In 2010, this standard was also integrated in ISO 12100: 2010 without any changes on technical standpoint.

IEC 60204-1

This safety standard applies to the application of electrical, electronic and programmable electronic equipment and systems to machine not portable by hand while working, including a group of machines working together in a co-ordinated manner.

03 Risk and Safety

What are accurate definitions of risk and safety? ISO/IEC Guide 51, which is an international standard, gives the following definitions.

What is risk?

Risk is defined as the "combination of the probability of occurrence of harm and the severity of that harm." In other words,

Risk = Severity of harm × the probability of the occurrence of harm

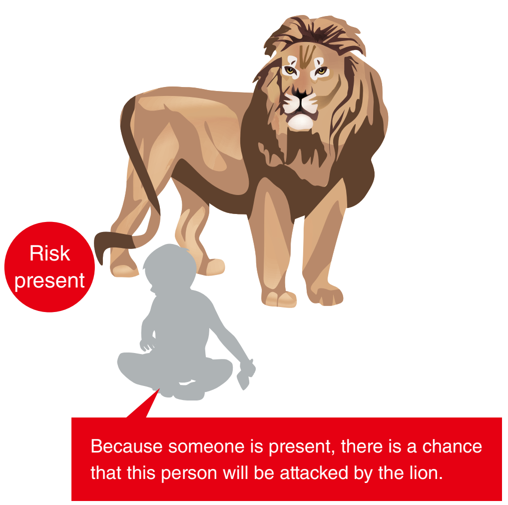
What is safety?

Safety is defined as "freedom from unacceptable risk"
In other words, tolerable risk is still present even when considered "safe".

Occurrence of Risk

What does it mean for risk to be present? Examine the following figure.

Risk only exists when a person is present.



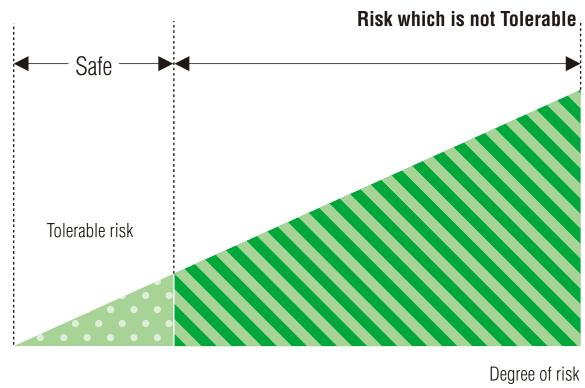
Left: A hazard is present, but there is no chance of harm occurring.

Right: A hazard is present, and there is a chance of harm occurring.

In the picture on the left, there is a lion, which is a hazard, but this alone is not enough to cause harm to occur.
In the picture on the right, a person is present. This introduces the possibility of harm occurring should the lion attack the person.
The picture on the right indicates a situation in which "risk" exists. It is necessary to understand that this situation is distinct from the situation in which a "hazard" exists.

Tolerable Risk

The definition of "safety" is "freedom from unacceptable risk" according to ISO/IEC Guide 51. In other words, safety can be achieved by risk reduction to a tolerable level.



What is Risk Assessment?

What is risk assessment?

Risk assessment is a method for confirming safety in order to ensure the safety of workers and other individuals and to reduce to the absolute minimum the possibility of harm. It indicates the following process.

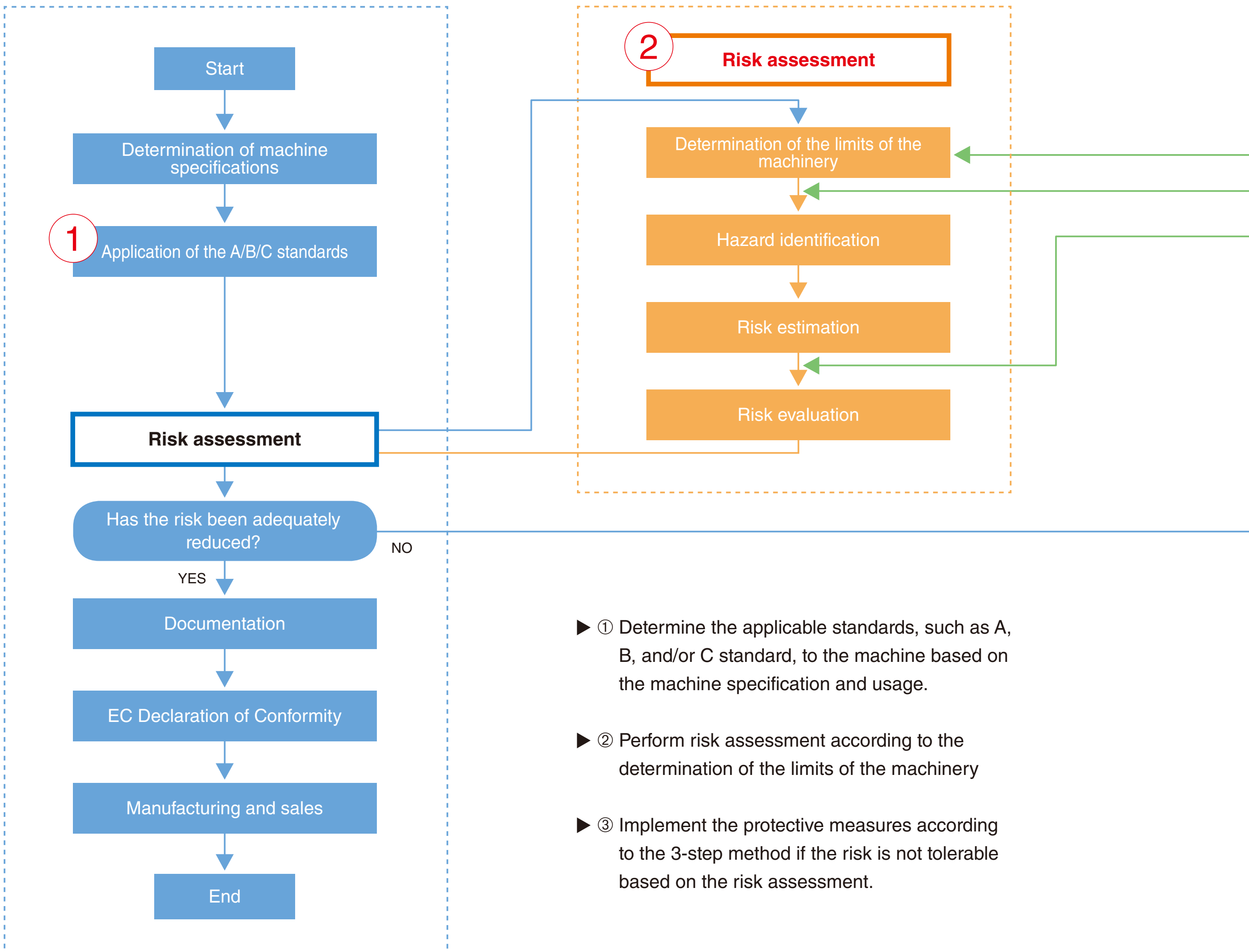
(1) Make clear the intended use and usage conditions of the machine and estimate incorrect usage such as operation mistakes.
(2) Identify the hazards present in the machine.
(3) Estimate the degree of risk and the frequency of situations in which risk is present.
(4) Judge whether the degree of risk has been reduced to an acceptable level.

Even if harm does not occur, there may exist potential for risk and harm. If these are left alone, it can be said that the situation possesses a high **possibility of industrial accidents occurring**. As technology has progressed, a great variety of machines and chemical substances have come to be used, which has led to diversification in the potential for risk and harm. Also, to further reduce industrial accidents, it is necessary to implement safety and sanitation measures in a preemptive, not reactive, manner.

04 Machine Design Process

It is necessary to reduce risk during the design and development processes of a machine in order to create a safe machine. This procedure is shown in the following flowchart.

Example of Exporting a Machine to Europe



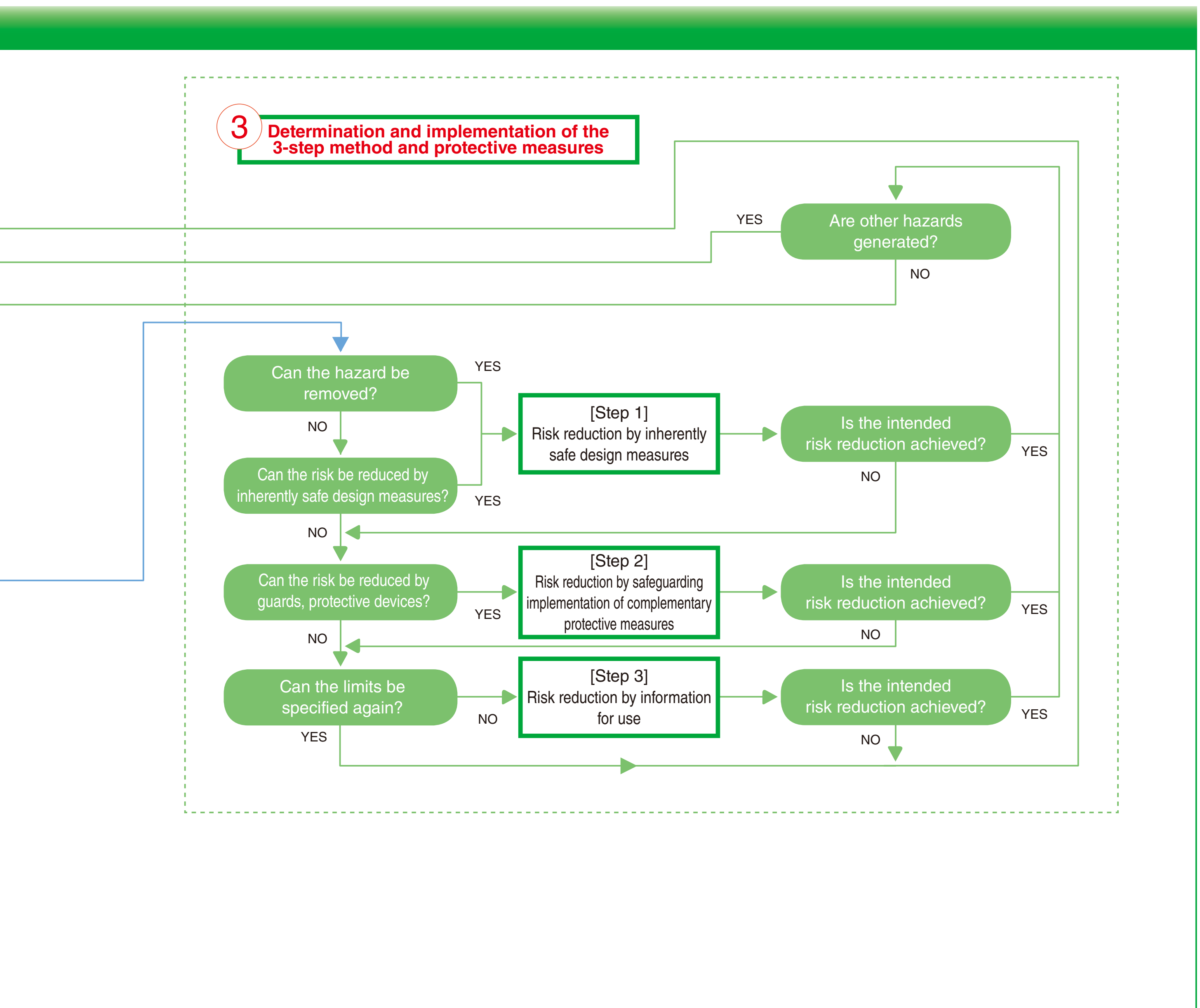
- ▶ ① Determine the applicable standards, such as A, B, and/or C standard, to the machine based on the machine specification and usage.
- ▶ ② Perform risk assessment according to the determination of the limits of the machinery
- ▶ ③ Implement the protective measures according to the 3-step method if the risk is not tolerable based on the risk assessment.

What are the A/B/C standards (Type A/B/C standards)?

ISO/IEC Guide 51 provides a structured approach to ensure that each specialized safety standard is restricted to specific aspects and makes reference to wider-ranging standards for all other relevant aspects.
The structure is built on the following types of standard, Type A, B, and C standard.

What is risk assessment?

Overall process comprising a risk analysis and a risk evaluation.
Risk analysis is a combination of the specification of the limits of the machine, hazard identification and risk estimation.
Risk evaluation is judgment, on the basis of risk analysis, of whether the risk reduction objectives have been achieved.



What are the 3-step method and protective measures?

These refer to the following three methods: inherently safe design measures, safeguarding and complementary protective measures, and the provision of information for use.

What is adequate risk reduction?

Risk reduction that is at least in accordance with legal requirements, taking into consideration the current state of the art.

04 Machine Design Process

Determination of Applicable Safety Standard

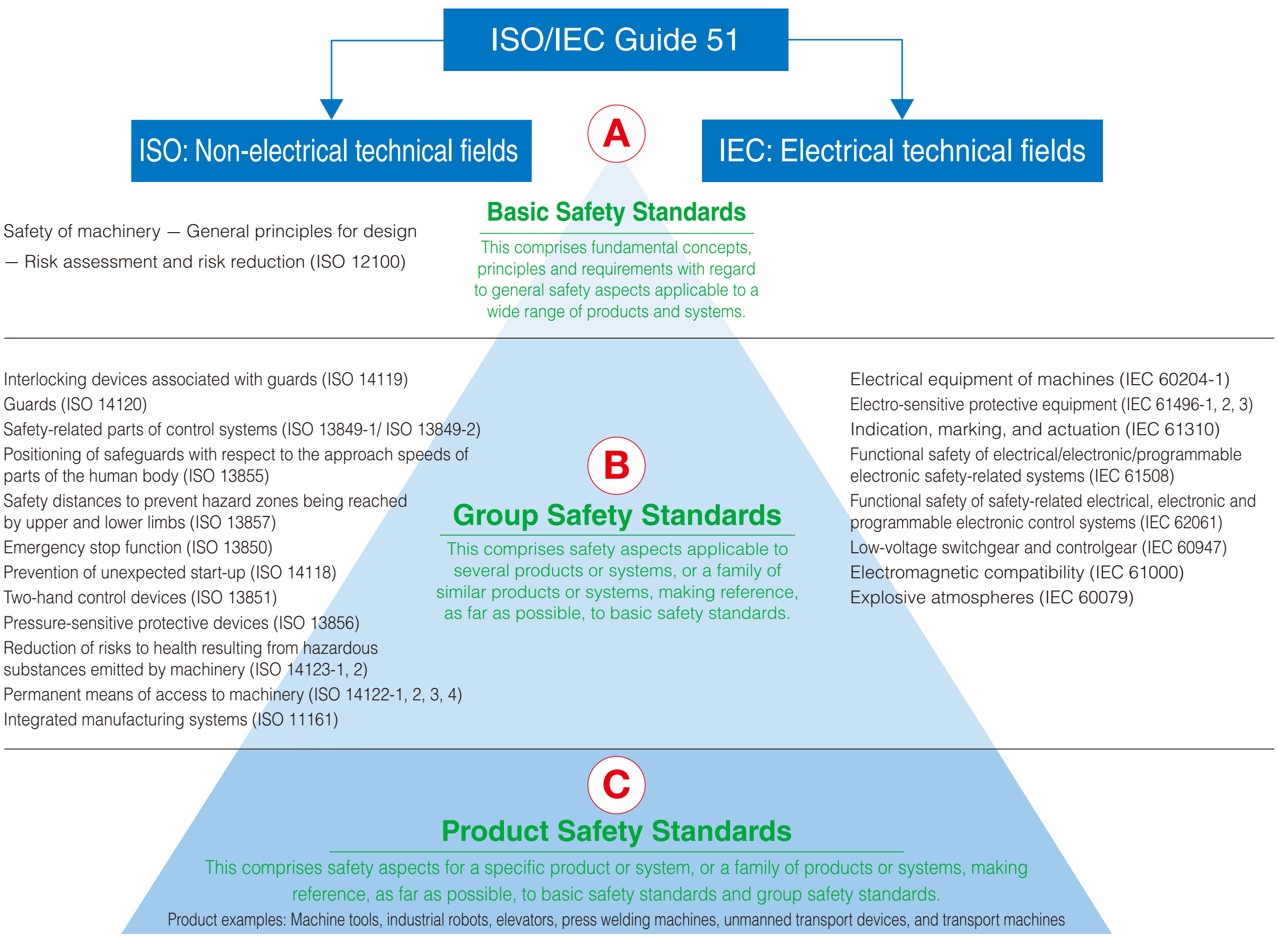
Close coordination is necessary within and among technical committees in the ISO and/or IEC responsible for preparing standards on different products and systems, in order to achieve a coherent approach to the reduction of risk.
ISO/IEC Guide 51 provides a structured approach to ensure that each specialized safety standard is restricted to specific aspects and makes reference to wider-ranging standards for all other relevant aspects.
The structure is built on the following types of standards: Type A, B, and C standards.

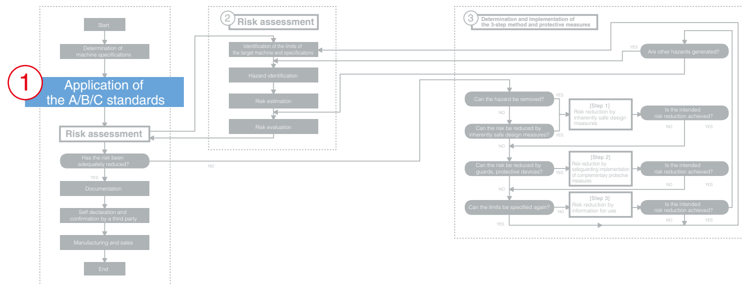
Type A standards This is a basic safety standard, comprising fundamental concepts, principles and requirements with regard to general safety aspects applicable to a wide range of products and systems.

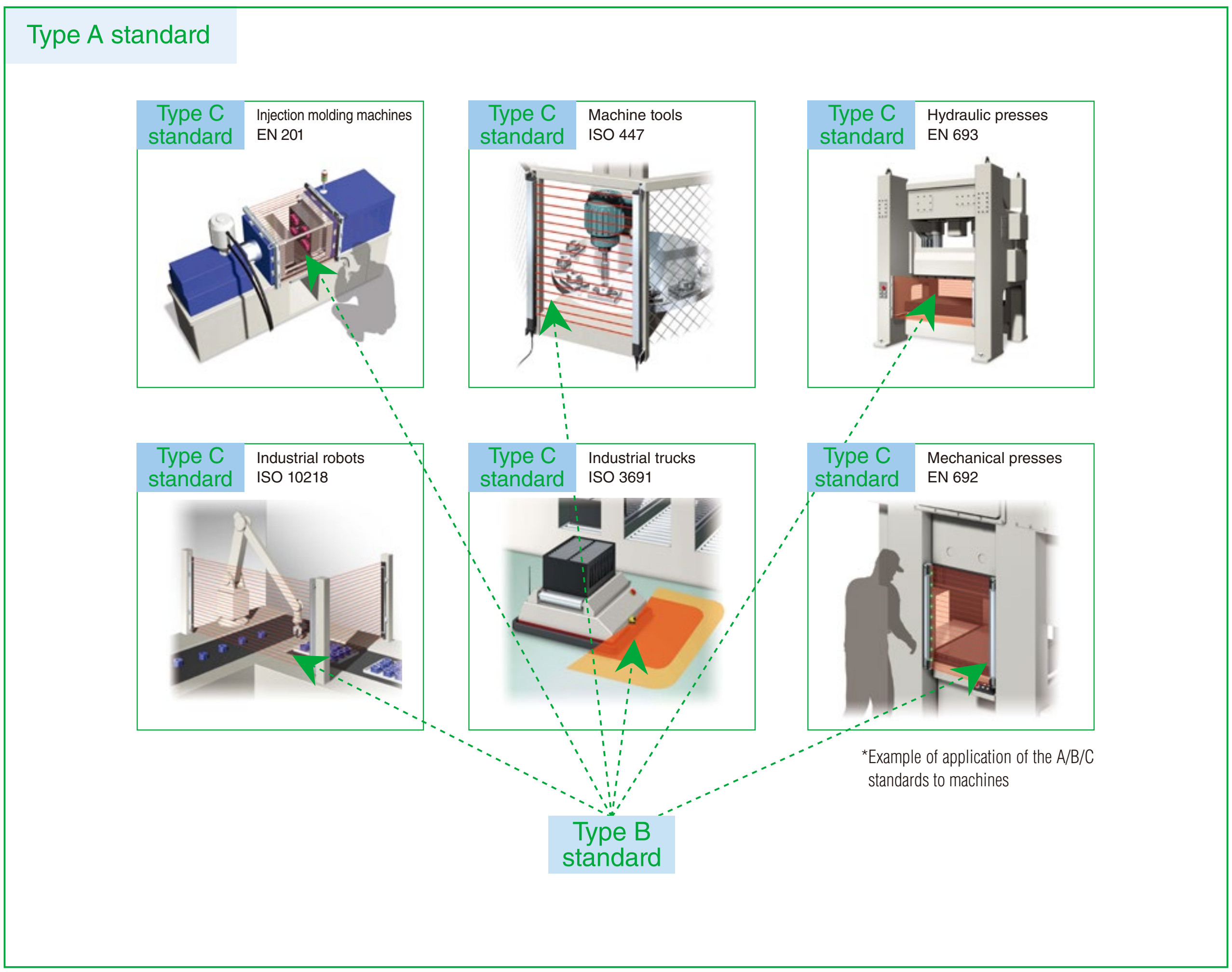
Type B standards This is a group safety standard, comprising safety aspects applicable to several products or systems, or a family of similar products or systems, making reference, as far as possible, to basic safety standards.

Type C standards This is a product safety standard, comprising safety aspects for a specific product or system, or a family of products or systems, making reference, as far as possible, to basic safety standards and group safety standards.

When determining the applicable safety standard, Type C standards must be applied to the machine if the Type C standard has already been established.
Type A or Type B standards would be applied if the Type C standard has not been established, or if the existing Type C standard is not sufficient for risk reduction.







*Example of application of the A/B/C standards to machines

04 Machine Design Process
Risk Assessment

Risk Assessment

The following flowchart shows the risk assessment process established by **ISO 12100**.

1 Determination of the limits of the machinery

Risk assessment begins with the determination of the limits of the machinery, taking into account all the phases of the machinery life. This means that the characteristics and performances of the machine or a series of machines in an integrated process, and the related people, environment, and products, should be identified in terms of the limits of machinery.

2 Hazard identification

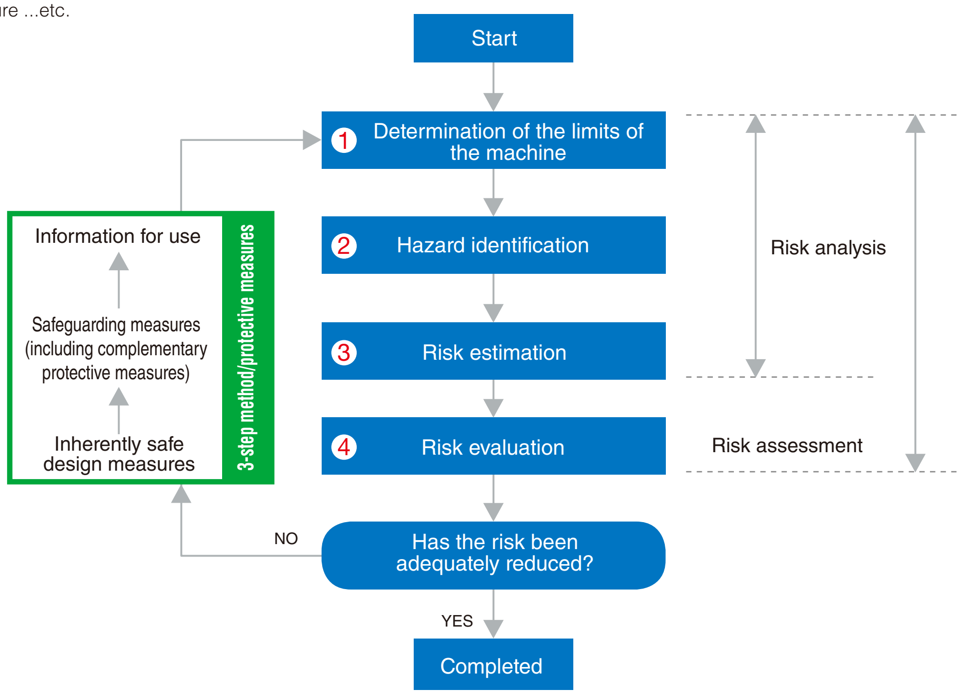
After determination of the limits of the machinery, the essential step in any risk assessment of the machinery is the systematic identification of reasonably foreseeable hazards (permanent hazards and those which can appear unexpectedly), hazardous situations and/or hazardous events during all phases of the machine life cycle.

3 Risk estimation

After hazard identification, risk estimation must be carried out for each hazardous situation by determining the elements of risk. When determining these elements, it is necessary to take into account the aspects, such as persons, duration of exposure, suitability of protective measure ...etc.

4 Risk evaluation

After risk estimation has been completed, risk evaluation must be carried out to determine if risk reduction is required.
If risk reduction is required, then appropriate protective measures must be selected and applied.



What are use limits?

Use limits include the intended use and the reasonably foreseeable misuse.

What are space limits?

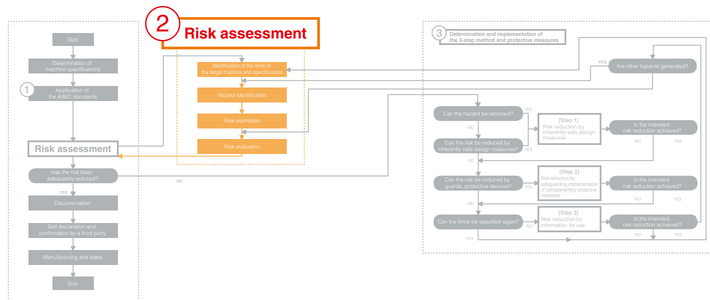
Space limits include the range of movement or human interaction such as the operator-machine interface.

What are time limits?

Time limits include the life limit of the machinery and/or of some of its components.

What is hazard identification?

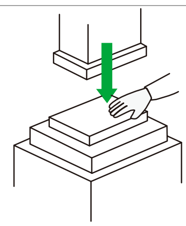
This is an identification of potential source of harm. The hazard either is permanently present during the intended use of the machine, or can appear unexpectedly.



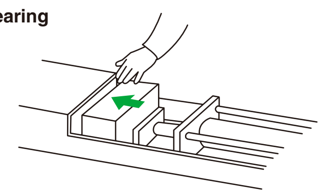
Hazard identification

▶ Mechanical hazards

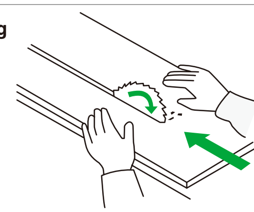
Crushing



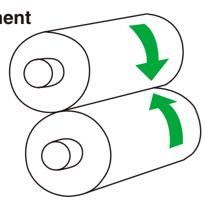
Shearing



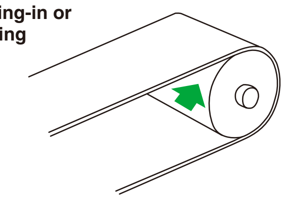
Cutting



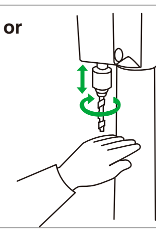
Entanglement



Drawing-in or trapping



Stabbing or puncture



▶ Other hazards

Electrical hazards, thermal hazards, noise hazards, vibration hazards, radiation hazards, material/substance hazards, ergonomic hazards, etc.

Risk estimation & Risk evaluation

Example: Using a matrix

Example of an estimate with a severity value of "Serious" and a possibility value of "Comparatively high"

		Severity of injury or disease			
		Fatal	Serious	Medium	Slight
Possibility of injury or disease occurring	Extremely high	5	5	4	3
	Comparatively high	5	4	3	2
	Possible	4	3	2	1
	Low	4	3	1	1

Risk	Priority	
4 to 5	High	Risk reduction measures must be implemented immediately. Operations must be stopped until measures are implemented. Sufficient management resources must be brought in.
2 to 3	Medium	Risk reduction measures must be implemented promptly. It is desirable to avoid using the machine until the measures are implemented. Management resources must be brought in on a priority basis.
1	Low	Implement risk reduction measures if necessary.

What is risk estimation?

Risk estimation is defining likely severity of harm and probability of its occurrence.

What is risk evaluation?

Risk evaluation is judgment, on the basis of risk analysis, of whether the risk reduction objectives have been achieved.

04 Machine Design Process

3-step Method and Protective Measures

3-step Method and Protective Measures

What are protective measures?

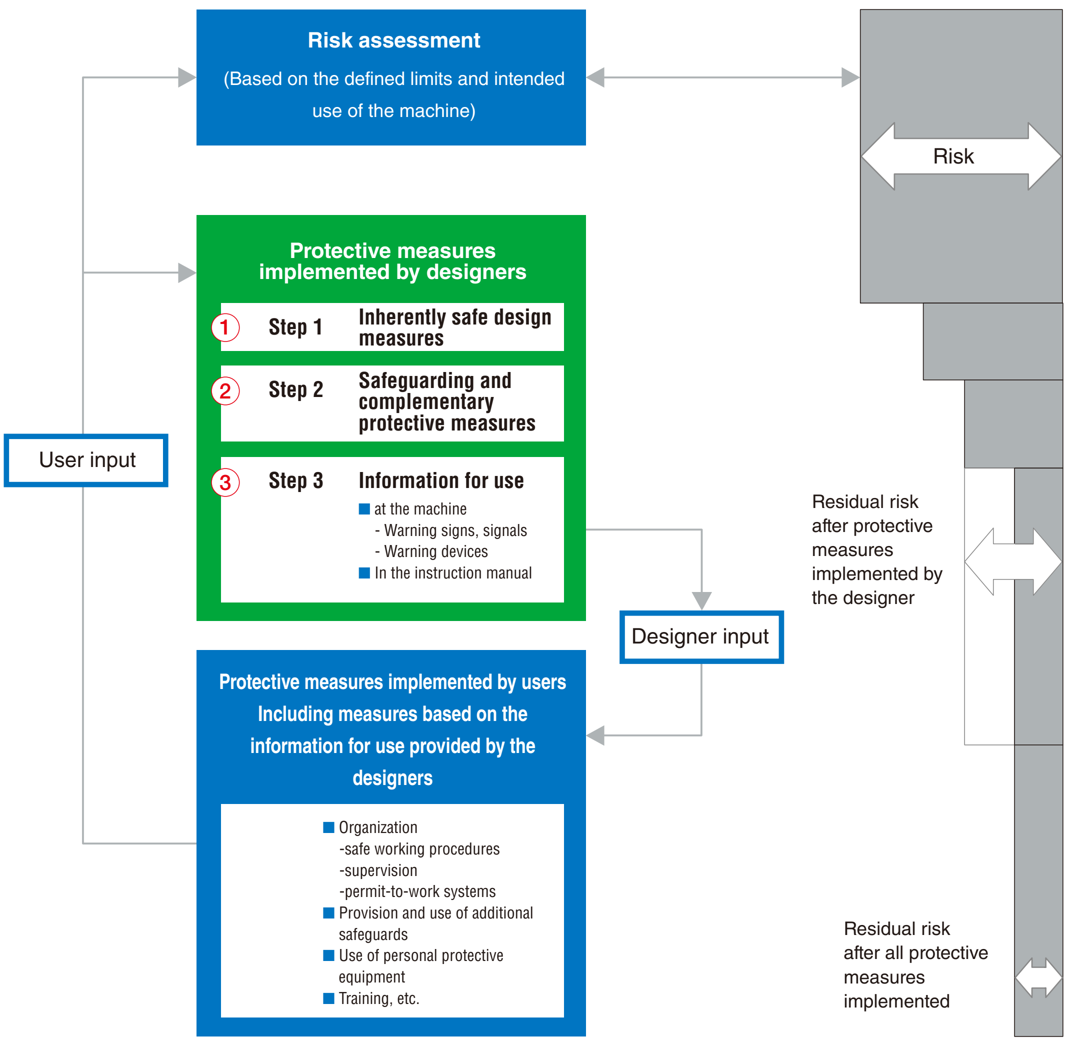
These are measures designed with the purpose of achieving risk reduction. Protective measures can be separated into two major groups: protective measures implemented by designers and protective measures implemented by users.

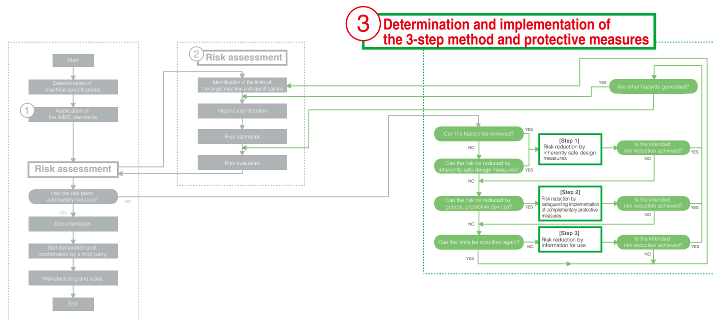
What is the 3-step method?

These are three methods implemented by designers and are classified as shown below.

1. **Inherently safe design measures**
2. **Safeguarding and complimentary protective measures**
3. **Information for use**

According to priority, these measures are ordered as 1, 2, and then 3. In other words, it is desirable to implement measures according to the following procedure, which is called the **3-step method and protective measures**.





Protective Measures, from ISO 12100:2010

The following definition applies.
Measure intended to achieve risk reduction, implemented
- by the designer (inherently safe design, safeguarding and complementary protective measures, information for use) and/or
- by the user (organization: safe working procedures, supervision, permit-to-work systems; provision and use of additional safeguards; use of personal protective equipment; training)

Inherently safe design measures, from ISO 12100:2010

The following definition applies.
Protective measure which either eliminates hazards or reduces the risks associated with hazards by changing the design or operating characteristics of the machine without the use of guards or protective devices

Safeguarding, from ISO 12100:2010

The following definition applies.
Protective measure using safeguards to protect persons from the hazards which cannot reasonably be eliminated or risks which cannot be sufficiently safe design measures

Complementary protective measures, from ISO 12100:2010

Protective measures which are neither inherently safe design measures, nor safeguarding (implementation of guards and/or protective devices), nor information for use, could have to be implemented as required by the intended use and the reasonably foreseeable misuse of the machine.

Information for use, from ISO 12100:2010

The following definition applies.
Protective measure consisting of communication links (for example, text, words, signs, signals, symbols, diagrams) used separately or in combination, to convey information to the user.

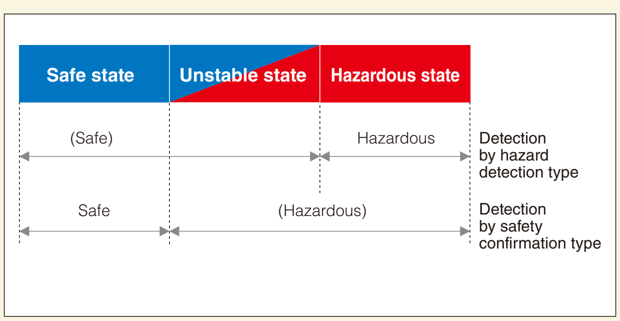
Residual risk, from ISO 12100:2010

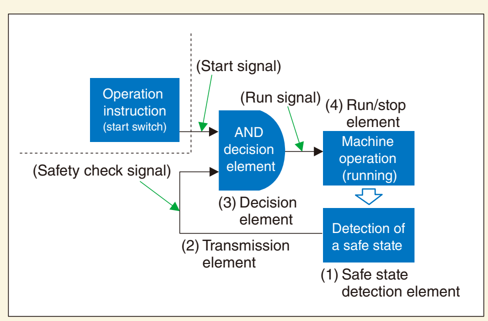
This is the risk remaining after protective measures have been implemented.
ISO 12100: 2010 distinguishes 1) the residual risk after protective measures have been implemented by the designer, and 2) the residual risk remaining after all protective measures have been implemented.

Column

Safety confirmation systems

These systems only permit the operation of a machine after safety has been confirmed. This is a method for constructing definite safety. In detail, it can be said the starting and running of machines is permitted by these systems only when they detect the absence of users in the operation range of the machine.

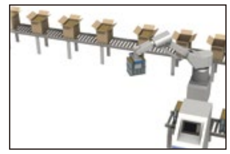


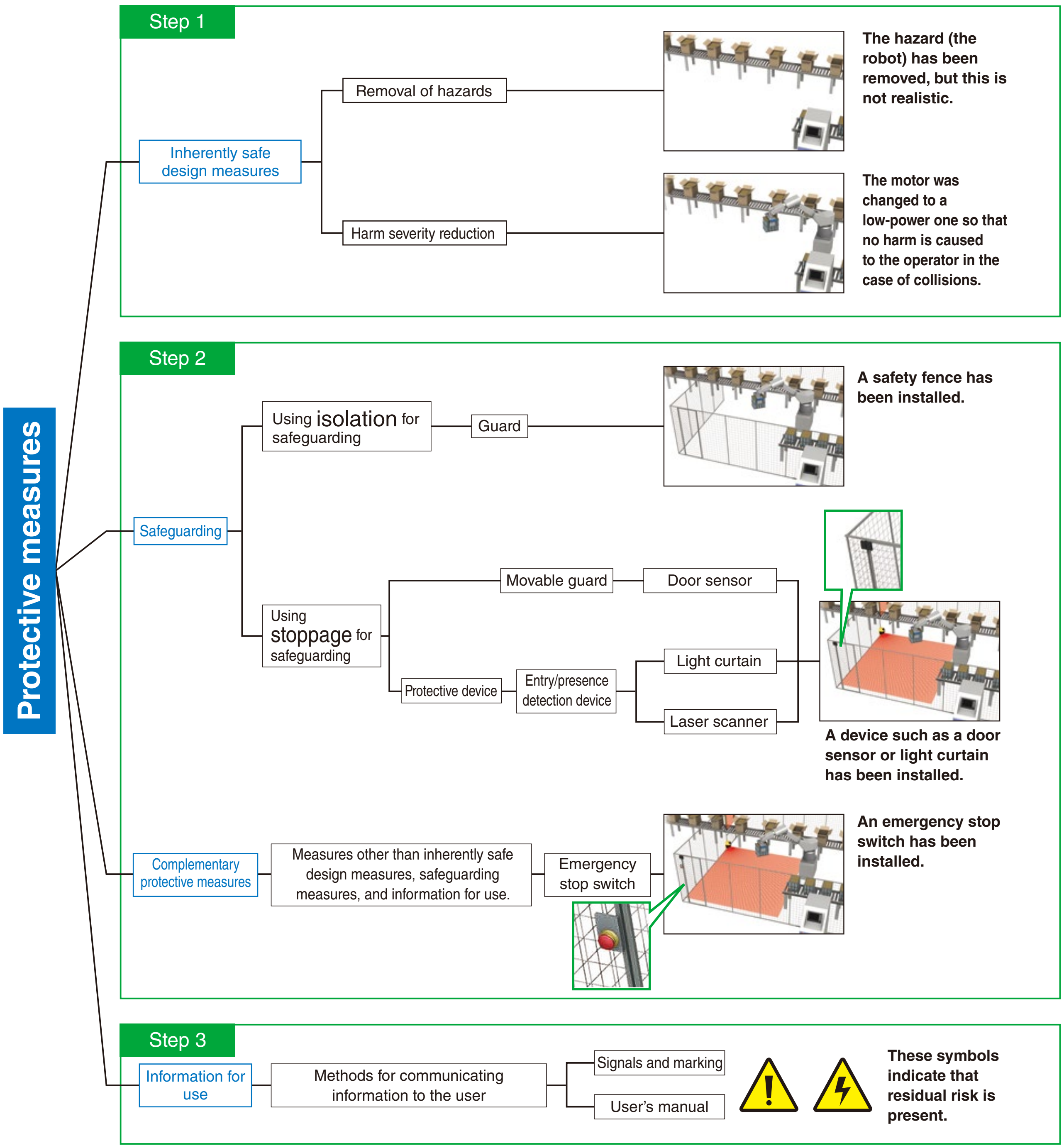


Example of Implementing the 3-step Method and Protective Measures

Example of Implementing the **3**-step Method and Protective Measures

Let's examine each step of the protective measures according to the risk assessment flowchart and the 3-step method and protective measures.





Step 1

The inherently safe design measures represent the first step, are the **only way to remove hazards**, and are the most effective way to reduce risk.

Step 2

The next measure is the implementation of safeguards. This measure is required when the **risks are not sufficiently reduced** by way of the inherently safe design measures. Safeguards are normally classified into two groups. Safeguarding by way of **isolation** and by way of **stopping**. For the former, guards (protective fences) are most commonly used. For the latter, light curtains or laser scanners are used as **one method**. **Complementary protective measures** (for example, emergency stop switches) are measures that differ from inherently safe design measures, safeguarding, and information for use and that are necessary due to risk existing because of the intended use and the reasonably foreseeable misuse of the machine. In the 3-step method, these measures are positioned in step 2 together with safeguarding. An example of these complementary protective measures is an **emergency stop device**.

Step 3

The last step is the provision of information for use. This is the final method and is required when risk cannot be removed or reduced by way of the inherently safe design measures, and safeguarding and complementary protective measures described above.

Intended use of machine

This is the use of the machine based on the information provided within the instructions for use.

Examples include the ways of using the machine as described in its user's manual or catalog (using the machine as intended by its designers).

Reasonably foreseeable misuse

This is the use of a machine in a way not intended by the designer, but which can result from readily predictable human behavior.

[Example 1] Using a machine with the door sensor disabled and the door opened in order to improve takt time.
[Example 2] Attempting to remove a component by inserting your hand into the drive part while the machine is operating.

Emergency stop

This is an emergency action that stops the processes or operation of the machine in dangerous situations. ISO 13850 defined the following two points.

- It must avert arising, or reduce existing, hazards to persons, damage to machinery or to work in progress.
- It must be initiated by a single human action.

05 ISO 13849-1 Revisions

Background of Revision

ISO 13849-1 (Safety of machinery — Safety-related parts of control systems — General principles for design), an international standard, was **revised** in 2006. As the background of the revision, semiconductor parts such as transistors and MOS-FETs have been put to use in the safety machinery that composes the safety-related parts of control systems, which represents a change in control methods from control by way of hard wiring to control by way of software. In the conventional way of thinking about categories, safety was determined according to system architectures (structures) that used mechanical safety devices and relays with forcibly guided contacts, so it could not be said that sufficient thought was given to safety attributable to the **reliability of parts**. Under these circumstances, attempts were made to regulate mechanical safety according to functions and reliability from around the year 2000. This way of thinking is called **"functional safety."** ISO 13849-1:2006 is a standard that revises ISO 13849-1:1999, which was based on the conventional standard EN 954-1, by adding details from IEC 61508 (IEC 62061), which defined functional safety. ISO 13849-1 was further revised in 2015.

EN 954-1
(ISO 13849-1:1999)
Category

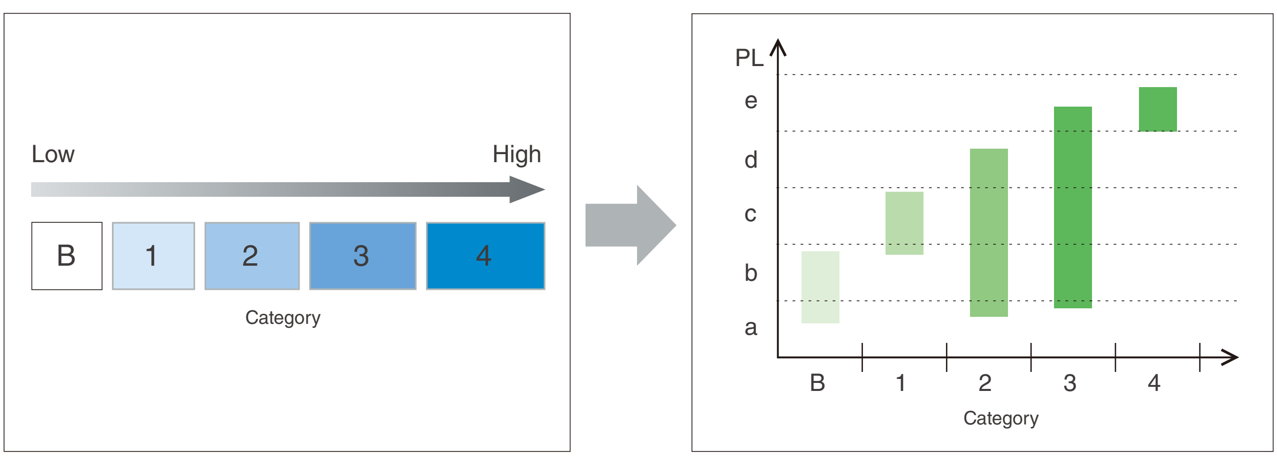
ISO 13849-1:2006
PL; Average probability of dangerous failure per hour

Functional safety of electrical/ electronic/programmable electronic safety-related systems IEC 61508/IEC 62061
SIL; Average frequency of a dangerous failure of the safety function

Overview of Revision

Safety "Category" was defined in ISO 13849-1: 1999. It is classification of the safety-related parts of a control system in respect of their resistance to faults and their subsequent behavior in the fault condition, and which is achieved by the structural arrangement of the parts and/or by their reliability.
Performance level (PL) was introduced in ISO 13849-1: 2006, which is quantitatively expressed as the reliability of safety-related parts of a control system, including diagnostic coverage or failure rate.

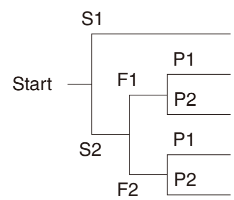
ISO 13849-1:1999 **ISO 13849-1:2006**



Reference: Requirements before Revisions

ISO 13849-1 specified the determination method of category and its requirements.

Symbol	Symbol details	Parameter	Short explanation on the parameter
S	Severity of injury	S1	Slight (normally reversible injury)
		S2	Serious (normally irreversible injury or death)
F	Frequency and/or exposure to the hazard	F1	Seldom-to-less-often and/or exposure time is short
		F2	Frequent-to-continuous and/or exposure time is long
P	Possibility of avoiding hazard or limiting harm	P1	Possible under specific conditions
		P2	Scarcely possible



Hazard Level	Category selection				
	B	1	2	3	4
I	△	○	◎	◎	◎
II	△	○	○	◎	◎
III	×	△	○	○	◎
IV	×	△	△	○	◎
V	×	△	△	△	○

◎ : Measures which can be over dimensioned for the relevant risk
○ : Preferred categories for reference points
△ : Possible categories which can require additional measures
× : Unacceptable categories

Category requirements defined by ISO 13849-1

Category	Summary of requirements	System behavior
B	SRP/CS and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled and combined in accordance with relevant standards so that they can withstand the expected influence. Basic safety principles shall be used.	The occurrence of a fault can lead to the loss of the safety function.
1	Requirements of B shall apply. Well-tried components and well-tried safety principles shall be used.*	The occurrence of a fault can lead to the loss of the safety function, but the probability of occurrence is lower than for category B.
2	Requirements of B and the use of well-tried safety principles shall apply. Safety function shall be checked at suitable intervals by the machine control system.	The occurrence of a fault can lead to the loss of the safety function between the checks. The loss of the safety function is detected by the check.
3	Requirements of B and the use of well-tried safety principles shall apply. Safety-related parts shall be designed, so that - a single fault in any of these parts does not lead to the loss of the safety function, and - whenever reasonably practicable, the single fault is detected.	When a single fault occurs, the safety function is always performed. Some, but not all, faults will be detected. Accumulation of undetected faults can lead to the loss of the safety function.
4	Requirements of B and the use of well-tried safety principles shall apply. Safety-related parts shall be designed so that - a single fault in any of these parts does not lead to a loss of the safety function, and - the single fault is detected at or before the next demand upon the safety function, but that if this detection is not possible, an accumulation of undetected faults shall not lead to the loss of the safety function.	When the faults occur, the safety function is always performed. Detection of accumulated faults reduces the probability of the loss of the safety function (high DC). The faults will be detected in time to prevent the loss of the safety function.

* Well-tried safety principles are, for example, 1) avoidance of certain faults (ex. avoidance short-circuit by separation), 2) reducing the probability of faults (ex. over-dimensioning or underrating of components), 3) by orientating the mode of fault (ex. by ensuring an open circuit in the event of fault), 4) detect faults very early, and 5) restrict the consequences of a fault (ex. earthing of the equipment).

06 PL (Performance Level)

PLr and PL (From ISO 13849-1:2006)

The performance level (PL) is a value used to define the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions.
On the other hand, the required performance level (PLr) is used in order to achieve the required risk reduction for each safety function.
Therefore, the performance level (PL) of safety-related parts of a control system must be equal to or higher than the required performance level (PLr).

Performance Level (PL)	Average probability of Dangerous Failure per Hour (PFHd) 1/h
a	$\geq 10^{-5}$ to $< 10^{-4}$ (0.001% to 0.01%)
b	$\geq 3 \times 10^{-6}$ to $< 10^{-5}$ (0.0003% to 0.001%)
c	$\geq 10^{-6}$ to $< 3 \times 10^{-6}$ (0.0001% to 0.0003%)
d	$\geq 10^{-7}$ to $< 10^{-6}$ (0.00001% to 0.0001%)
e	$\geq 10^{-8}$ to $< 10^{-7}$ (0.000001% to 0.00001%)

Determination of Required Performance Level (PLr)

For each safety function to be carried out by a safety-related parts of a control system, the required performance level (PLr) must be determined, which is based on the following three parameters:

S Severity of injury

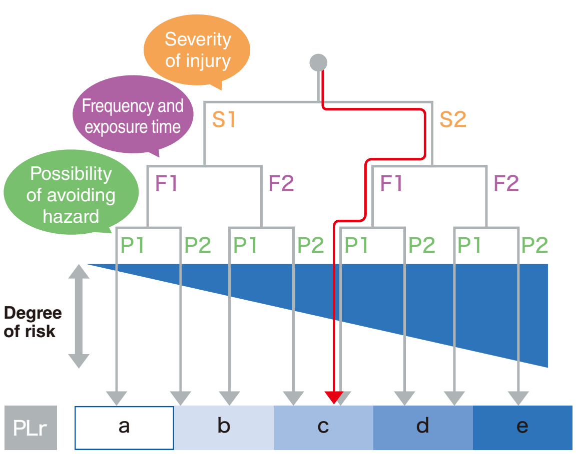
S1: Slight
S2: Serious
(such as irreversible injuries and death)

F Frequency and/or exposure to hazard

F1: Seldom-to-less-often and/or exposure time is short
F2: Frequent-to-continuous and/or exposure time is long

P Possibility of avoiding hazard or limiting harm

P1: Possible under specific conditions
P2: Scarcely possible



Evaluation example

The PLr is determined to be “c” for the following case.
Severity of injury: Serious (S2)
Frequency: Seldom (F1)
Possibility of avoiding: Possible (P1)

07 PL Parameters

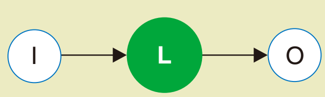
PL Parameters

For each safety-related part of the control system and/or the combination thereof that performs a safety function, the performance level (PL) must be determined (evaluated) by the estimation of the following principal aspects: 1) Category (Structure), 2) DC, 3) MTTFd, and 4) CCF.

PL

Parameter	Details	Level
Category	Category is the basic parameter used to achieve a specific PL. This states the required behavior of the safety-related parts of the control system in case of a fault. (See category description below for additional detail.)	B 1 2 3 4
DC	This is the diagnostic coverage of the safety-related control system. The value of the DC is given in four levels. (see page 22 for additional detail.)	High (≥99%) Medium (90% to 99%) Low (60% to 90%) None (<60%)
MTTFd	This is the mean time to dangerous failure of the whole or part of the safety-related system. The value of the MTTFd of each channel is given in three levels. (see page 22 for additional detail.)	High (30 to 100 years) Medium (10 to 30 years) Low (3 to 10 years)
CCF	This expresses the reliability of the whole safety-related control system in terms of foreseeable common cause failures. It is classified into two types: ≥65 points and <65 points. (see page 22 for additional detail.)	≥65 points <65 points

Category

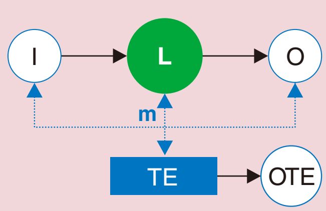


Designated architecture (structure) of categories B and 1

I: Input device (example: emergency stop switch)
L: Logic processing
O: Output device (example: relays with forcibly guided contacts)

* When a fault occurs on Category B and 1, it can lead to the loss of the safety function.

B	The safety-related parts of the control system must be designed in accordance with the relevant standards and using basic principles for the specific application to withstand the expected operating stresses, the influence of the processed material, and other relevant external influences.
1	In addition to the requirements of category B, safety-related parts of a control system have to be designed using well-tried components and well-tried safety principles.

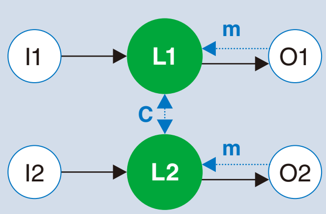


Designated architecture (structure) of category 2

m: Monitoring
TE: Test equipment
OTE: Output of test equipment

* When a fault occurs on Category 2 between checks, it can lead to the loss of the safety function.

2	In addition to the requirements of category B, the safety-related parts of a control system have to be designed so that their function(s) are checked at suitable intervals by the machine control system.



Designated architecture (structure) of categories 3 and 4

m: Monitoring
C: Cross monitoring

* When a single fault occurs on Category 3 device, the safety function is always performed (some but not all faults will be detected), but accumulation of undetected faults can lead to the loss of the safety function.
* In the case of Category 4, the lines for monitoring represent diagnostic coverage that is higher than in the designated architecture for category 3.

3	In addition to the requirements of category B, the safety-related parts of a control system have to be designed so that a single fault does not lead to the loss of the safety function. Whenever reasonably practicable, it has to be detected at or before the next demand upon the safety function.
4	In addition to the requirements of category B, the safety-related parts of a control system have to be designed such that a single fault does not lead to the loss of the safety function and it is detected at or before the next demand upon the safety function. If not possible, an accumulation of undetected faults does not have to lead to the loss of the safety function.

07 PL Parameters

DC (Diagnostic Coverage)

DC is a measure of the effectiveness of the diagnostics, which may be determined as the ratio between the failure rate of detected dangerous failures and the failure rate of total dangerous failures.
DC can exist for the whole or parts of a safety-related system.
The four denotations shown in the table to the right are provided in ISO 13849-1.

Denotation	Range
None	DC < 60%
Low	60% ≤ DC < 90%
Medium	90% ≤ DC < 99%
High	99% ≤ DC

MTTFd

MTTFd (Mean time to dangerous failure) is an expectation of the mean time to dangerous failure on the whole or part of a safety-related system.
The MTTFd is given for each channel, such as “I” (Input device), “L” (Logic), and “O” (output device).
The three denotations shown in the table to the right are provided in ISO 13849-1.

Denotation	MTTFd
Low	3 years ≤ MTTFd < 10 years
Medium	10 years ≤ MTTFd < 30 years
High	30 years ≤ MTTFd < 100 years

CCF

The CCF (Common Cause Failure) relates to the failure of different items, resulting from a single event, where the failures are not consequences of each other.
ISO 13849-1 provides a scoring process and quantification of measures against CCF. The total score must be 65 or better.

Determination of **PL**

(1) Category (five types: B, 1, 2, 3, and 4)
(2) DCavg (four types: high, medium, low, and none)
(3) MTTFd (three types: high, medium, and low)
(4) CCF (two types: ≥65 points and <65 points)

The following table can be used for determination of PL based on the above parameters.

Example: Category = 3, MTTFd = medium, DCavg = low, and CCF = ≥65 points

(1)Category		**B**	**1**	**2**	**2**	**3**	**3**	**4**
(2)DCavg		None	None	Low	Medium	Low	Medium	High
(3)MTTFd of each channel	Low	a	–	a	b	b	c	–
	Medium	b	–	b	c	c	d	–
	High	–	c	c	d	d	d	e
(4)CCF		None		≥65 points				

The PL is to be "c" according to the above example.

Column

Relationship between PL and SIL

IEC 61508-1 specifies the safety integrity level (SIL), which is similar to performance level (PL). The following table shows the relationship between these 2 concepts.

Relationship between PL and SIL (excerpt from ISO 13849-1:2006)

Probability of Dangerous Failure per Hour	PL	SIL (IEC 61508-1, high demand or continuous mode of operation)	Probability of Dangerous Failure per Hour (High demand or continuous mode of operation)
$\geq 10^{-5}$ and $<10^{-4}$	a	No correspondence	
$\geq 3 \times 10^{-6}$ and $<10^{-5}$	b	1	$\geq 10^{-6}$ and $<10^{-5}$
$\geq 10^{-6}$ and $<3 \times 10^{-6}$	c	1	$\geq 10^{-6}$ and $<10^{-5}$
$\geq 10^{-7}$ and $<10^{-6}$	d	2	$\geq 10^{-7}$ and $<10^{-6}$
$\geq 10^{-8}$ and $<10^{-7}$	e	3	$\geq 10^{-8}$ and $<10^{-7}$

08 ISO 14119 Revisions

Background of Revision

ISO 14119 is an international standard covering interlock devices such as door sensors. The standard was revised and reissued in 2013. Following the revision, the standard is now aligned with Europe's Machinery Directive. The Japanese standard JIS B 9710, issued in 2019, is also now aligned with the international standard.

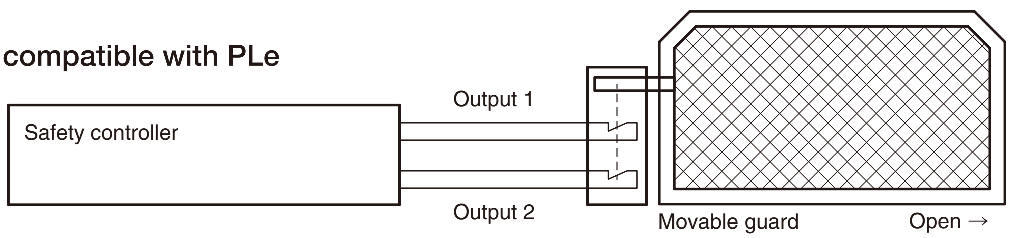
The most recent revision significantly changed the content of the standard. This section will discuss some of the newly introduced items, including content related to required performance levels (PLr) and the possibility of deactivation.

Door Sensor Selection and Required Performance Levels

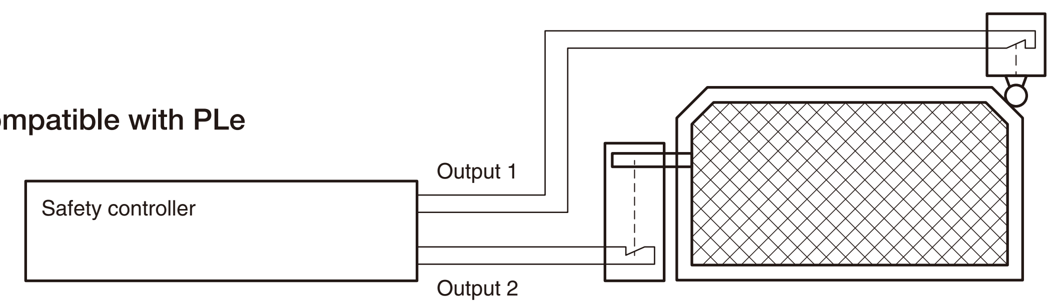
The most recent revision made it necessary to consider the required performance levels (PLr) or the SIL rating when selecting door sensors.
Especially when the PLr = e, safety functions must remain available even if the actuator breaks or is deformed due to excessive stress. One possible way to meet this requirement is to use two door sensors.

When using KEYENCE's GS Series, however, this requirement can be met using just one door sensor. The sensor's built-in self-diagnostics function makes this possible by ensuring safety functionality even in the event of actuator breakage or deformation.

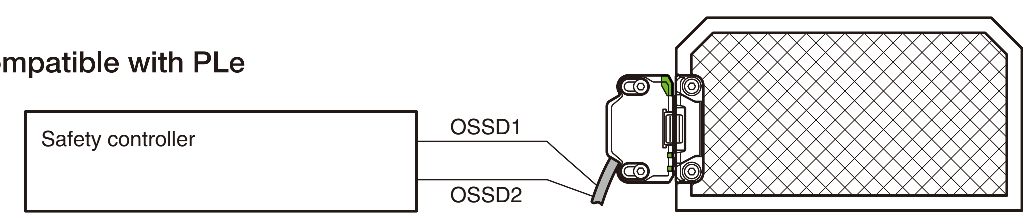
Not compatible with PLe



Compatible with PLe



Compatible with PLe



Minimizing defeat possibilities

Defeat is an action that makes door sensors inoperative or bypass them with the result that a machine is used in a manner not intended by the designer or without the necessary safety measures. The current revision requires machine builders to consider defeat possibilities and to take appropriate preventative measures.
The following introduces some examples of such preventative measures.

- **Prevention of accessibility to the door sensor main unit or actuator**
  Ex.: Mounting out of reach, physical obstruction or shielding
- **Prevention of substitute actuation of the door sensor by readily available objects**
  Ex.: Coding of actuators
- **Prevention of dismantling or de-positioning of the door sensor**
  Ex.: Using non-detachable fixing such as welding, gluing, one-way screws, riveting

The required preventative measures can be determined according to the type of door sensor. See the following table for more information.

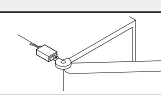
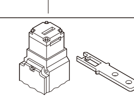
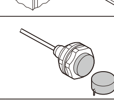
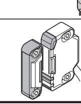
Table — Additional measures for preventing deactivation according to door sensor type

<table>
<tr><th rowspan="2">Principles and measures</th><th>Type</th><th>Type 1, Type 3[*1]</th><th colspan="2">Type 2, Type 4[*2]</th></tr>
<tr><th>Encoding</th><th>No</th><th>Low/medium</th><th>High</th></tr>
<tr><td colspan="2">Mounting out of reach</td><td rowspan="5">At least one required</td><td rowspan="4">At least one required</td><td></td></tr>
<tr><td colspan="2">Physical obstruction/Shielding</td><td></td></tr>
<tr><td colspan="2">Mounting in hidden position</td><td></td></tr>
<tr><td colspan="2">Status monitoring or cyclic testing</td><td></td></tr>
<tr><td colspan="2">Non-detachable mounting of door sensor main unit and actuator</td><td></td><td></td></tr>
<tr><td colspan="2">Non-detachable mounting of actuator</td><td></td><td>Required</td><td>Required</td></tr>
<tr><td colspan="2">Additional door sensor and checking for plausibility</td><td>Recommended (added)</td><td>Recommended (added)</td><td></td></tr>
</table>

*1 Does not include hinges.
*2 Does not include trapped key systems.

Reference: Door sensor types (Interlock devices, Type 1 to Type 4)

Under the current revision, interlock devices are categorized into the four types shown on the right. KEYENCE’s GS Series is a Type 4 interlock device. (The coding level can be switched low or high.)

	Switch/sensor operation	Coding	Examples
Type 1	Mechanical	No	• Rotary cams • Linear cams • Hinges 
Type 2	Mechanical	Yes (low to high)	• Tongue-shaped actuators • Trapped keys 
Type 3	Non-contact	No	Proximity switches (induction types, optical types, etc.) 
Type 4	Non-contact	Yes (low to high)	Coded sensors (magnetic types, optical types, etc.) 

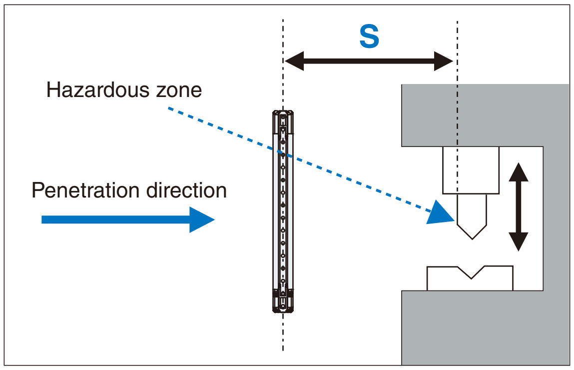
09 Light Curtain Installation and Safety Distance (Minimum Distance)

When installing a safety light curtain or other electrical detection protective device, refer to the **minimum required distances for stopping the machine prior to the body reaching the hazardous zone** when the body enters the detection zone. These distances are defined in standards such as ISO 13855.
When installing a light curtain, be sure to provide the safety distance (minimum distance) determined by sources such as the standards, regulations, and laws of the country or area in which the light curtain will be used.

Calculating the Safety Distance according to **ISO 13855**

Safety distance (S) = Approach speed of the body × response time + additional distance (which varies depending on the detection capability of the sensor)

Perpendicular direction of approach



Detection of the body

S = K × T + C	**40 < d ≤ 70**
	1.57" < d ≤ 2.76"

K = 1600 mm 62.99"/s (approach speed [assuming the walking speed of a person])
T = Maximum time required by the machine to stop + response time of the light curtain
C = 850 mm 33.46" (penetration distance [a value matching the standard length of a person's arm])

Detection of fingers and hands

S = K × T + 8(d - 14)	**d ≤ 40**
S = K × T + 8(d - 0.55")	**d ≤ 1.57"**

K = 2000 mm 78.74"/s (approach speed [assuming the penetration speed of a hand])
T = Maximum time required by the machine to stop + response time of the light curtain
d = Detection capability of the light curtain
Note: If S is greater than or equal to 500 mm 19.69", perform the calculation again with K equal to 1600 62.99". If the newly calculated result gives S less than or equal to 500 mm 19.69", set S to 500 mm 19.69".

Relationship between the Maximum Time Required by the Machine to Stop and the Safety Distance

The value T shown in the formula is formed by adding the following two parameters.
T = Maximum time required by the machine to stop + response time of the light curtain (ON → OFF)

> When K (penetration speed) = 2000 mm 78.74"/s
> For example, when using the GL-R08H light curtain (which has a response time of 0.0069 s)
> **S = 2000 mm 78.74"/s × (maximum time required by the machine to stop + 0.0069 s) + C**

As shown above, the maximum time required by the machine to stop is multiplied by the penetration speed (2000 mm 78.74"/s), so if the maximum time required by the machine to stop is increased by just 1 second, the safety distance is increased by (2000 mm 78.74"/s × 1 s = 2000 mm 78.74").
If the light curtain's response time is increased by 1 ms, the safety distance is increased by 2 mm 0.08".

Basic Calculation Examples

Perpendicular direction of approach: GL-R Series

Formula: S = K × T + C

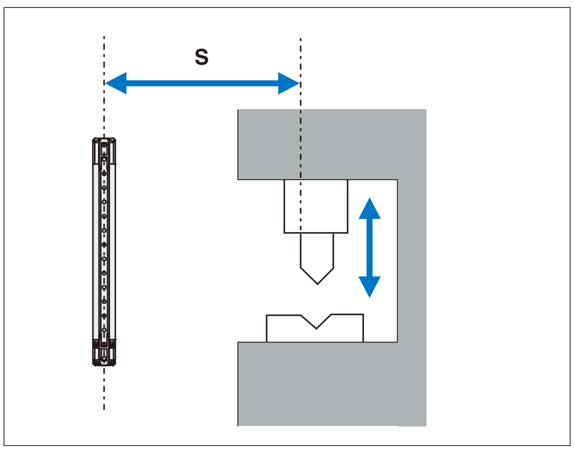
S: Minimum distance (mm inch; see the following figure) with S ≥ 100 mm 3.94"

K: Parameter extracted from the data based on the approach speed of the body (mm inch/s)

T: Overall system stop performance (s)
T = t1 (GL-R Series maximum response time) + t2 (maximum time required by the machine to stop)

C: Penetration distance (mm inch)
When d ≤ 40: 8 × (d - 14) with C ≥ 0   When d ≤ 1.57":8 × (d - 0.55") with C ≥ 0"
When 40 < d ≤ 70: 850   When 1.57" < d ≤ 2.76": 33.46"

d: Detection capability of the GL-R Series (mm inch)



Calculation Example (1)-1

When using the GL-R60H (detection capability d = 25 mm 0.98" and 60 beam axes)

Condition: Industrial application
K = 2000 mm 78.74"/s
t1 (GL-R60H response time) = 0.0157 s
t2 (maximum time required by the machine to stop) = 0.1 s
C = 8 × (25 - 14) = 88 mm   8 × (0.98" - 0.55") = 3.46"

S = K × T + C = 2000 × (0.0157 + 0.1) + 88 = 319.4 mm
S = K × T + C = 78.74" × (0.0157 + 0.1) + 3.46" = 12.57"

If S is greater than 500 mm 19.69", perform the calculation again with K equal to 1600 mm 62.99"/s.
If the newly calculated result gives S less than or equal to 500 19.69", set S to 500 19.69".

Calculation Example (1)-2

When using the GL-R08L (detection capability d = 45 mm 1.77" and 8 beam axes)

Condition: Industrial application
K = 1600 mm 62.99"/s
t1 (GL-R08L response time) = 0.0069 s
t2 (maximum time required by the machine to stop) = 0.1 s
C = 850 mm 33.46"

S = K × T + C = 1600 × (0.0069 + 0.1) + 850 = 1021.04 mm
S = K × T + C = 62.99" × (0.0069 + 0.1) + 33.46" = 40.20"

Parallel direction of approach: GL-R Series

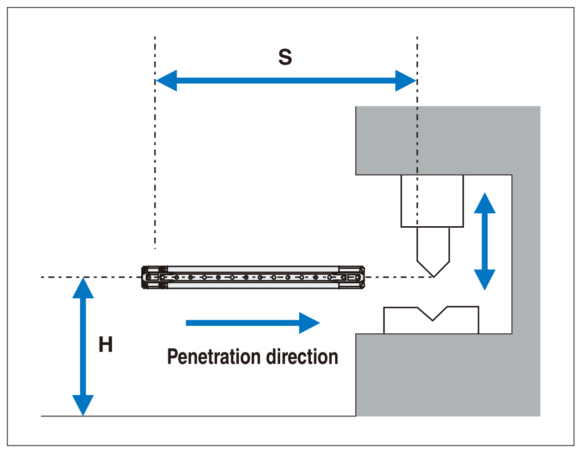
Formula: S = K × T + C

S: Minimum distance (mm inch; see the following figure)

K: Parameter extracted from the data based on the approach speed of the body (mm inch/s)

T: Overall system stop performance (s)
T = t1 (GL-R Series maximum response time) + t2 (maximum time required by the machine to stop)

C: Penetration distance (mm inch)
C = 1200 - 0.4H with C ≥ 850 mm   C = 47.24" - 0.4H with C ≥ 33.46"
H: Height of the detection zone above the reference plane (mm inch)
15 (d - 50) ≤ H ≤ 1000 with H ≥ 0   (d - 1.97") ≤ H ≤ 39.37" with H ≥ 0"



Calculation Example (2)-1

When using the GL-R30L (detection capability d = 45 mm 1.77" and 30 beam axes)

Condition: Industrial application
K = 1600 mm 62.99"/s
t1 (GL-R30L response time) = 0.0105 s
t2 (maximum time required by the machine to stop) = 0.1 s
H = 200 mm 7.87"

C = 1200 - 0.4 × 200 = 1120 mm
C = 47.24" - 0.4 × 7.87" = 44.09"

S = K × T + C = 1600 × (0.0105 + 0.1) + 1120 = 1296.8 mm
S = K × T + C = 62.99" × (0.0105 + 0.1) + 1120 = 51.06"

10 Light Curtain Installation and Safety Distance

Basic Calculation Example

Approaching the hazard by circumventing the top of the detection zone: GL-R Series

When it is not possible to prevent people from passing over the top of the detection zone in order to approach the hazardous zone, it is necessary to determine the height of the light curtain and the minimum distance S while keeping this issue in mind. You have to compare the S value calculated as shown below and the S value calculated under "Perpendicular Direction of Approach: GL-R Series" and set the larger value as the minimum distance S.

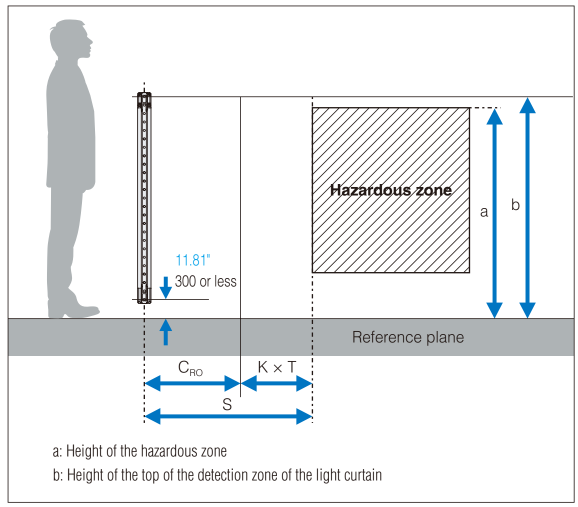
Formula: $S = K \times T + C_{RO}$

S: Minimum distance (mm inch; see the figure on the right) with $S \geq 100$ mm 3.94"

K: Parameter extracted from the data based on the approach speed of the body (mm inch/s)

K is determined according to the following table on the basis of S.

S (mm inch)	K (mm inch/s)
100 ≤ S ≤ 500 3.94" ≤ S ≤ 19.69"	2000 78.74"
500 < S 19.69" < S	1600 62.99"



C_{RO} is determined as shown in the following table according to the values a (height of the hazardous zone) and b (height of the top of the detection zone of the light curtain).

Hazardous zone height a	Height of the top of the detection zone of the light curtain (Height of the center of the top beam axis) b											
	900 35.43"	1000 39.37"	1100 43.31"	1200 47.24"	1300 51.18"	1400 55.12"	1600 62.99"	1800 70.87"	2000 78.74"	2200 86.61"	2400 94.49"	2600 102.36"
	Penetration distance into the hazardous zone C_{RO}											
2600 102.36"	0	0	0	0	0	0	0	0	0	0	0	0
2500 98.43"	400 15.75"	400 15.75"	350 13.78"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	250 9.84"	150 5.91"	100 3.94"	0
2400 94.49"	550 21.65"	550 21.65"	550 21.65"	500 19.69"	450 17.72"	450 17.72"	400 15.75"	400 15.75"	300 11.81"	250 9.84"	100 3.94"	0
2200 86.61"	800 31.50"	750 29.53"	750 29.53"	700 27.56"	650 25.59"	650 25.59"	600 23.62"	550 21.65"	400 15.75"	250 9.84"	0	0
2000 78.74"	950 37.40"	950 37.40"	850 33.46"	850 33.46"	800 31.50"	750 29.53"	700 27.56"	550 21.65"	400 15.75"	0	0	0
1800 70.87"	1100 43.31"	1100 43.31"	950 37.40"	950 37.40"	850 33.46"	800 31.50"	750 29.53"	550 21.65"	0	0	0	0
1600 62.99"	1150 45.28"	1150 45.28"	1100 43.31"	1000 39.37"	900 35.43"	850 33.46"	750 29.53"	450 17.72"	0	0	0	0
1400 55.12"	1200 47.24"	1200 47.24"	1100 43.31"	1000 39.37"	900 35.43"	850 33.46"	650 25.59"	0	0	0	0	0
1200 47.24"	1200 47.24"	1200 47.24"	1100 43.31"	1000 39.37"	850 33.46"	800 31.50"	0	0	0	0	0	0
1000 39.37"	1200 47.24"	1150 45.28"	1050 41.34"	950 37.40"	750 29.53"	700 27.56"	0	0	0	0	0	0
800 31.50"	1150 45.28"	1050 41.34"	950 37.40"	800 31.50"	500 19.69"	450 17.72"	0	0	0	0	0	0
600 23.62"	1050 41.34"	950 37.40"	750 29.53"	550 21.65"	0	0	0	0	0	0	0	0
400 15.75"	900 35.43"	700 27.56"	0	0	0	0	0	0	0	0	0	0
200 7.87"	600 23.62"	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

*1 Situations in which the height of the top of the detection zone is less than 900 mm 35.43" are not included because they cannot provide sufficient protection against circumvention and straddling.

*2 If the bottom of the detection zone is at a height of more than 300 mm 11.81" from the reference plane, sufficient protection cannot be provided against passing under the detection area to approach the hazard.

Calculation Example (3)-1

When using the GL-R60H
(detection capability d = 25 mm 0.98", 60 beam axes, and detection height of 1180 mm 46.46")

Condition: Industrial application

a (height of the hazardous zone) = 1400 mm 55.12"

b (height of the top of the detection zone of the light curtain) = 1180 + 300 = 1480 mm 46.46" + 11.81" = 58.27"

Hazardous zone height a	Height of the top of the detection zone of the light curtain (Height of the center of the top beam axis) b											
	900 35.43"	1000 39.37"	1100 43.31"	1200 47.24"	1300 51.18"	1400 55.12"	1600 62.99"	1800 70.87"	2000 78.74"	2200 86.61"	2400 94.49"	2600 102.36"
	Penetration distance into the hazardous zone C_{RO}											
2600 102.36"	0	0	0	0	0	0	0	0	0	0	0	0
2500 98.43"	400 15.75"	400 15.75"	350 13.78"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	250 9.84"	150 5.91"	100 3.94"	0
2400 94.49"	550 21.65"	550 21.65"	550 21.65"	500 19.69"	450 17.72"	450 17.72"	400 15.75"	400 15.75"	300 11.81"	250 9.84"	100 3.94"	0
2200 86.61"	800 31.50"	750 29.53"	750 29.53"	700 27.56"	650 25.59"	650 25.59"	600 23.62"	550 21.65"	400 15.75"	250 9.84"	0	0
2000 78.74"	950 37.40"	950 37.40"	850 33.46"	850 33.46"	800 31.50"	750 29.53"	700 27.56"	550 21.65"	400 15.75"	0	0	0
1800 70.87"	1100 43.31"	1100 43.31"	950 37.40"	950 37.40"	850 33.46"	800 31.50"	750 29.53"	550 21.65"	0	0	0	0
1600 62.99"	1150 45.28"	1150 45.28"	1100 43.31"	1000 39.37"	900 35.43"	850 33.46"	750 29.53"	450 17.72"	0	0	0	0
1400 55.12"	~~1200 47.24"~~	~~1200 47.24"~~	~~1100 43.31"~~	~~1000 39.37"~~	~~900 35.43"~~	850 33.46"	650 25.59"	0	0	0	0	0
1200 47.24"	1200 47.24"	1200 47.24"	1100 43.31"	1000 39.37"	850 33.46"	800 31.50"	0	0	0	0	0	0
1000 39.37"	1200 47.24"	1150 45.28"	1050 41.34"	950 37.40"	750 29.53"	700 27.56"	0	0	0	0	0	0
800 31.50"	1150 45.28"	1050 41.34"	950 37.40"	800 31.50"	500 19.69"	450 17.72"	0	0	0	0	0	0
600 23.62"	1050 41.34"	950 37.40"	750 29.53"	550 21.65"	0	0	0	0	0	0	0	0
400 15.75"	900 35.43"	700 27.56"	0	0	0	0	0	0	0	0	0	0
200 7.87"	600 23.62"	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

According to the above table, C_{RO} is 850 mm 33.46".

(Because b is 1480 mm 58.27", it is between 1400 55.12" and 1600 62.99". In this situation, use a b value of 1400 55.12".)

K = 1600 mm 62.99"/s

t1 (GL-R60H response time) = 0.0157 s

t2 (maximum time required by the machine to stop) = 0.1 s

$S = K \times T + C_{RO}$ = 1600 × (0.0157 + 0.1) + 850 = 1035.12 mm 62.99" × (0.0157 + 0.1) + 33.46" = 40.75"

(This is larger than the S value calculated under "Perpendicular Direction of Approach: GL-R Series.")

Calculation Example (3)-2

When using the GL-R80H
(detection capability d = 25 mm 0.98", 80 beam axes, and detection height of 1580 mm 62.20")

Condition: Industrial application

a (height of the hazardous zone) = 1400 mm 55.12"

b (height of the top of the detection zone of the light curtain) = 1580 + 300 = 1880 mm 62.20" + 11.81" = 74.02"

Hazardous zone height a	Height of the top of the detection zone of the light curtain (Height of the center of the top beam axis) b											
	900 35.43"	1000 39.37"	1100 43.31"	1200 47.24"	1300 51.18"	1400 55.12"	1600 62.99"	1800 70.87"	2000 78.74"	2200 86.61"	2400 94.49"	2600 102.36"
	Penetration distance into the hazardous zone C_{RO}											
2600 102.36"	0	0	0	0	0	0	0	0	0	0	0	0
2500 98.43"	400 15.75"	400 15.75"	350 13.78"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	300 11.81"	250 9.84"	150 5.91"	100 3.94"	0
2400 94.49"	550 21.65"	550 21.65"	550 21.65"	500 19.69"	450 17.72"	450 17.72"	400 15.75"	400 15.75"	300 11.81"	250 9.84"	100 3.94"	0
2200 86.61"	800 31.50"	750 29.53"	750 29.53"	700 27.56"	650 25.59"	650 25.59"	600 23.62"	550 21.65"	400 15.75"	250 9.84"	0	0
2000 78.74"	950 37.40"	950 37.40"	850 33.46"	850 33.46"	800 31.50"	750 29.53"	700 27.56"	550 21.65"	400 15.75"	0	0	0
1800 70.87"	1100 43.31"	1100 43.31"	950 37.40"	950 37.40"	850 33.46"	800 31.50"	750 29.53"	550 21.65"	0	0	0	0
1600 62.99"	1150 45.28"	1150 45.28"	1100 43.31"	1000 39.37"	900 35.43"	850 33.46"	750 29.53"	450 17.72"	0	0	0	0
1400 55.12"	~~1200 47.24"~~	~~1200 47.24"~~	~~1100 43.31"~~	~~1000 39.37"~~	~~900 35.43"~~	~~850 33.46"~~	~~650 25.59"~~	0	0	0	0	0
1200 47.24"	1200 47.24"	1200 47.24"	1100 43.31"	1000 39.37"	850 33.46"	800 31.50"	0	0	0	0	0	0
1000 39.37"	1200 47.24"	1150 45.28"	1050 41.34"	950 37.40"	750 29.53"	700 27.56"	0	0	0	0	0	0
800 31.50"	1150 45.28"	1050 41.34"	950 37.40"	800 31.50"	500 19.69"	450 17.72"	0	0	0	0	0	0
600 23.62"	1050 41.34"	950 37.40"	750 29.53"	550 21.65"	0	0	0	0	0	0	0	0
400 15.75"	900 35.43"	700 27.56"	0	0	0	0	0	0	0	0	0	0
200 7.87"	600 23.62"	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

According to the above table, C_{RO} is 0 mm 0".

(Because b is 1880 mm 74.02", it is between 1800 70.87" and 2000 78.74". In this situation, use a b value of 1800 70.87".)

K = 2000 mm 78.74"/s

t1 (GL-R80H response time) = 0.0192 s

t2 (maximum time required by the machine to stop) = 0.1 s

$S = K \times T + C_{RO}$ = 2000 × (0.0192 + 0.1) + 0 = 238.4 mm 78.74" × (0.0192 + 0.1) + 0" = 9.39"

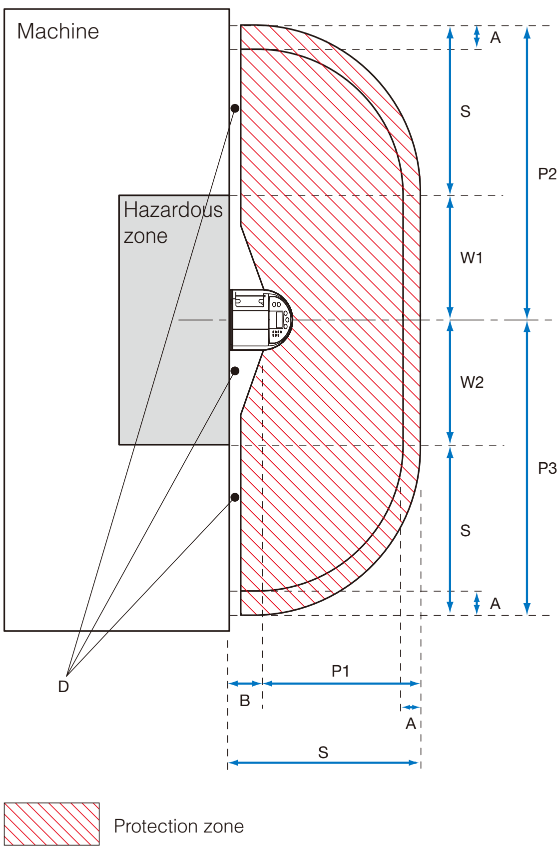
(This is smaller than the S value calculated under "Perpendicular Direction of Approach: GL-R Series.")

11 Laser Scanner Installation and Safety Distance

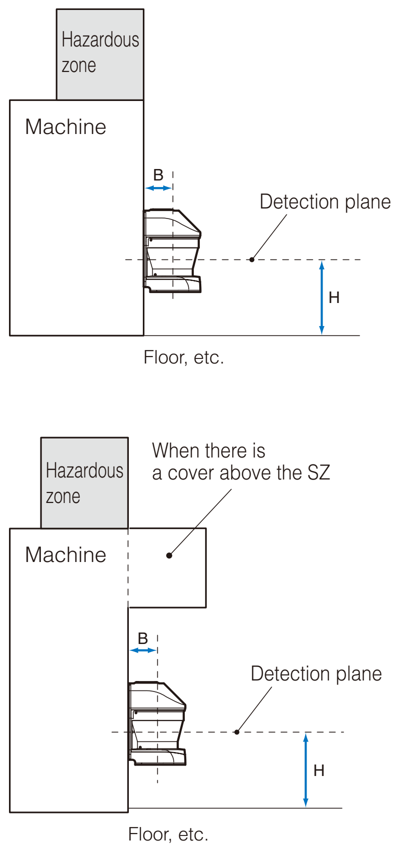
The protection zone must be configured so as to ensure the safety distance, which has been calculated according to the laws, regulations, and standards of the country or region in which the laser scanner (SZ) is installed as well as according to the specifications given in this document.

Example of Area Protection (Direction of Approach Parallel to the Protection Zone)

Top view of the machine



Side view of the machine



S = K × T + C + A (According to ISO 13855 and IEC 61496-3)

S: Safety distance (mm inch)

K: Approach speed of the body or parts of the body (mm inch/s)

T: Overall response time (t1 + t2; s)

t1: SZ response time (s)

t2: Maximum time required to stop the machine after receiving the OSSD signal from the SZ (s)

C: Distance that parts of the body approach the hazardous zone before penetrating the protection zone of the SZ (mm inch)

1200 - 0.4 × H (850 mm or higher) 47.24" - 0.4 × H (33.46" or higher)

H: Height of the detection plane above the floor or other reference plane (mm inch).

1000 ≥ H ≥ 15 × (d - 50) 39.37" ≥ H ≥ 0.59" × (d - 1.97")

d: SZ minimum detectable object size (mm inch)

A: Additional distance for the SZ protection zones (mm inch)

P1, P2, P3: Protection distances to be configured as the protection zones of the SZ

W1, W2: Width of the hazardous zone

B: Distance between the edge of the hazardous zone and the detection zone origin on the SZ

D: Unprotected space

⚠ Danger

- The unprotected space (D) between the protection zone and the protective structure must be less than the minimum detectable object size when the SZ is installed. The reason for this requirement is to prevent the machine operators from approaching into the hazardous zone through this space (D). Additional countermeasures for protection must be provided if there is a space (D) between the protection zone and the protective structure such that the minimum detectable object is not detected by the SZ.
- There is a risk of inadvertent undetected access beneath the detection plane (protection zone) if the height "H" of the detection plane (protection zone) is greater than 300 mm 11.81" (200 mm 7.87" for non-industrial applications).
  This factor must be taken into account when performing risk assessment prior to installing the SZ, and additional countermeasures must be taken if necessary.
- If you select the minimum detectable object size of 150 mm 5.91", "H" (the height of the detection plane) exceeds 1000 mm 39.37".
  You must select a minimum detectable object size of 70 mm 2.76" or less if you want to use the SZ for area protection (direction of approach parallel to the protection zone).

Example of Safety Distance Calculation

Safety Distance

S = K × T + C + A
= 1600 × 0.59 + 1080 + 100 = 2124 mm
62.99" × 0.59 + 42.52" + 3.94" = 83.62"

Protection Distances to Be Configured as the Protection Zones

P1 = S - B = 2065 mm 81.30"
P2 = S + W1 = 3124 mm 122.99"
P3 = S + W2 = 3124 mm 122.99"

K = 1600 mm 62.99"/s, approach speed of the body or parts of the body (constant)
T = t1 + t2 = 0.59, overall response time
t1 = 0.09 s, SZ response time (changeable)
t2 = 0.5 s, maximum time required to stop the machine after receiving the OSSD signal from the SZ
C = 1200 - 0.4 × H = 1080 mm 47.24" - 0.4 × H = 42.52"
H = 300 mm 11.81", height of the detection plane from the floor. This value must meet the following inequality: H ≥ 15 × (d - 50) H ≥ 15 × (d - 1.97").
d = 70 mm 2.76", minimum detectable object size (changeable)
A = 100 mm 3.94", additional distance for the SZ protection zones
B = 59 mm 2.32", distance between the edge of the hazardous zone and the detection zone origin on the SZ
W1 = W2 = 1000 mm 39.37", width of the hazardous zone

When setting the above protection zones, if there is a highly reflective background within 1.5 m 4.92' from the boundary of the protection zone, another 200 mm 7.87" must be added as additional safety distance to P1, P2, and P3.
We recommend that you mark the floor in order to indicate the specified protection zone.

12 Door Sensor Installation and Safety Distance

When installing a non-locking safety interlock such as the GS Series safety door sensor (non-contact type), the minimum distance for stopping dangerous machinery movements before a person reaches the hazardous zone after the door interlock is opened is defined by standards such as ISO 13855.
When installing an interlocking guard without guard locking, be sure to meet or exceed the safety distance (minimum distance) determined by the standards, regulations, and laws of the country or area in which the interlock guard will be used.

Calculating the Safety Distance According to ISO 13855

Minimum distance (S) = Approach speed parameter (K) × Overall system stop time (T) + Intrusion distance (C)

$$S = K \times T + C$$

S: Safety distance (mm inch) <Minimum distance>
K: Parameter derived from data on approach speeds of the body or parts of the body (mm inch/s) <Approach speed parameter>
T: Time interval between the actuation of the sensing function and the termination of the hazardous machine function (seconds) <Overall system stop time>
C: Distance that a part of the body (usually a hand) can move past the safeguard towards the hazard zone prior to actuation of the safeguard (mm inch) <Penetration distance>

Basic Calculation Examples

Interlocking guards without guard locking — Safety distance against upper limb penetration

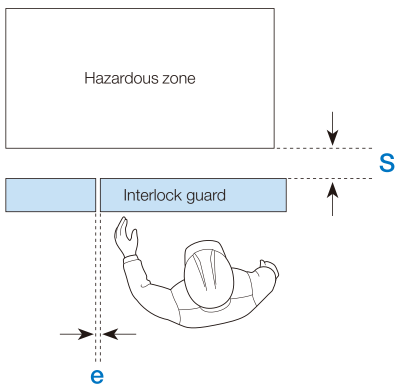
Formula: S = K × T + C

S: Distance from the hazardous zone to the edge of the non-locking interlock guard opening closest to the hazardous zone (mm inch)

K: 1600 (mm/sec) 62.99"/sec

T: Reaction time of the protective device t1 + Stopping time of the machine t2 - Opening time to open the guard t3 (seconds)

C: Safety distance to consider if it is possible to push fingers or a hand through the opening towards the hazard before a stop signal is generated (mm inch)
The safety distance "sr", found in the table on the following page, can be used as C.



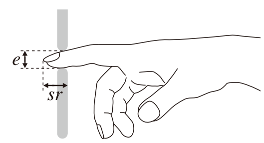
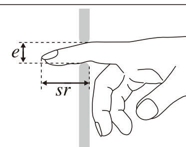
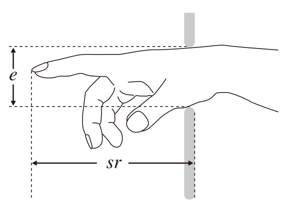
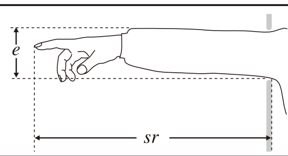
Calculation example **When using GS-11P5**

Condition: Industrial application
e (size of guard opening) = 18 mm 0.71"
K = 1600 mm 62.99"/sec
t1 (Response time of GS-11P5) = 20 ms
t2 (Stopping time of the machine) = 100 ms
t3 (Opening time to open the guard) = 100 ms
Because e = 18 mm 0.71", C = sr = 120 mm 4.72" according to the table on the page to the right.

S = K × T + C = 1600 × (0.02 + 0.1 - 0.1) + 120 = 32 + 120 = 152 mm
S = K × T + C = 62.99" × (0.02 + 0.1 - 0.1) + 4.72" = 1.26" + 4.72" = 5.98"

Reference If the safety distance is large, using an interlocking guard with guard locking such as certain GS Series devices (locking types) is recommended.

Safety Distance against Upper Limb Penetration <Excerpt from ISO 13857>

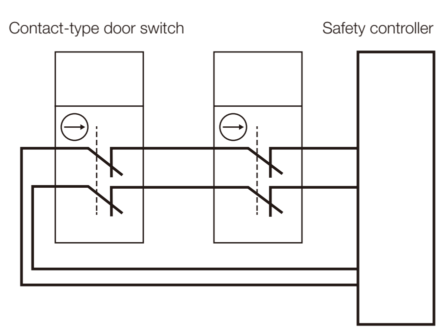
Part of body	Illustration	Opening (mm inch)	Safety distance to hazard, sr (mm inch) Slot opening	Square opening	Round opening
Fingertip		e ≤ 4 e ≤ 0.16"	≥ 2 ≥ 0.08"	≥ 2 ≥ 0.08"	≥ 2 ≥ 0.08"
		4 < e ≤ 6 0.16" < e ≤ 0.24"	≥ 10 ≥ 0.39"	≥ 5 ≥ 0.20"	≥ 5 ≥ 0.20"
Finger up to Knuckle joint		6 < e ≤ 8 0.24" < e ≤ 0.31"	≥ 20 ≥ 0.79"	≥ 15 ≥ 0.59"	≥ 5 ≥ 0.20"
		8 < e ≤ 10 0.31" < e ≤ 0.39"	≥ 80 ≥ 3.15"	≥ 25 ≥ 0.98"	≥ 20 ≥ 0.79"
Hand		10 < e ≤ 12 0.39" < e ≤ 0.47"	≥ 100 ≥ 3.94"	≥ 80 ≥ 3.15"	≥ 80 ≥ 3.15"
		12 < e ≤ 20 0.47" < e ≤ 0.79"	≥ 120 ≥ 4.88"	≥ 120 ≥ 4.88"	≥ 120 ≥ 4.88"
		20 < e ≤ 30 0.79" < e ≤ 1.18"	≥ 850*1 ≥ 33.46"*1	≥ 120 ≥ 4.88"	≥ 120 ≥ 4.88"
Arm to base of shoulder		30 < e ≤ 40 1.18" < e ≤ 1.57"	≥ 850 ≥ 33.46"	≥ 200 ≥ 7.87"	≥ 120 ≥ 4.88"
		40 < e ≤ 120 1.57" < e ≤ 4.72"	≥ 850 ≥ 33.46"	≥ 850 ≥ 33.46"	≥ 850 ≥ 33.46"

*1 If the width of the slot opening is 65 mm 2.56" or less, the thumb will act as a stop, and the safety distance may be reduced to ≥200 mm 7.87".

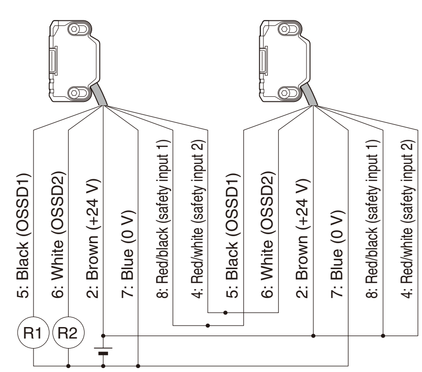
The dimensions of the opening, e, correspond to the sides of a square opening, the diameter of a round opening, and the narrowest dimension of a slot opening.
The above table is based on persons of 14 years of age and older.

Reference: Category/PL when installing two or more door sensors in series

When connecting multiple contact-type door switches in series, Category4/PLe may not be attainable. The ISO/TR 24119 technical report issued by ISO states that DC (Diagnostic Coverage) is limited to “None” when fault masking occurrences, such as multiple guards opening at the same time, are possible.
One way to ensure Category4/PLe is attainable, even when connecting switches in series, is to use an interlock device with a self-diagnosis function for internal circuitry and a monitored output (OSSD). The GS Series safety interlocks meet these requirements, ensuring the ability to maintain Category4/PLe even when connecting multiple units in series (up to 30 non-contact units or 25 locking units).



Not compatible with Category4/PLe



Compatible with Category4/PLe

13 Wiring Examples Using Safety Controllers for Different Categories

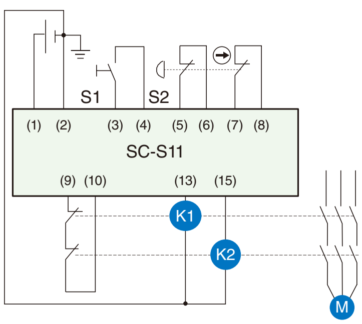
The following examples are from the composition of parts of safety-related control systems for machines in which the SC-S11 safety controller has been used.
If you are considering control circuits that actually use the SC-S11, be sure to thoroughly read the SC-S11 user's manual.

1 One emergency stop switch

Category: 4
Stop category: 0

Symbol explanations
S1: Reset input switch
S2: Emergency stop switch
K1, K2: Magnetic contactor, etc.
M: Three-phase motor

SC-S11 settings
Safety input mode setting: Contact output device connection
Interlock setting: Manual reset
EDM mode setting: EDM input enabled

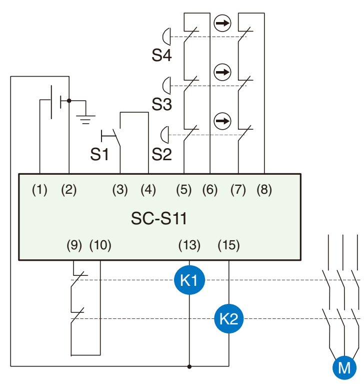


2 Three emergency stop switches

Category: 3
Stop category: 0

Symbol explanations
S1: Reset input switch
S2 to S4: Emergency stop switches
K1, K2: Magnetic contactor, etc.
M: Three-phase motor

SC-S11 settings
Safety input mode setting: Contact output device connection
Interlock setting: Manual reset
EDM mode setting: EDM input enabled

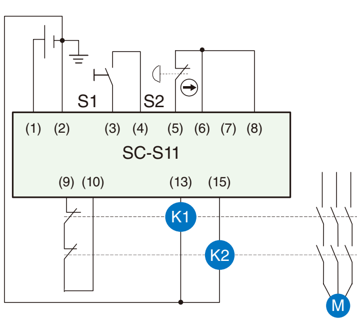


3 One emergency stop switch

Category: 2
Stop category: 0

Symbol explanations
S1: Reset input switch
S2: Emergency stop switch
K1, K2: Magnetic contactor, etc.
M: Three-phase motor

SC-S11 settings
Safety input mode setting: PNP output device connection
Interlock setting: Manual reset
EDM mode setting: EDM input enabled

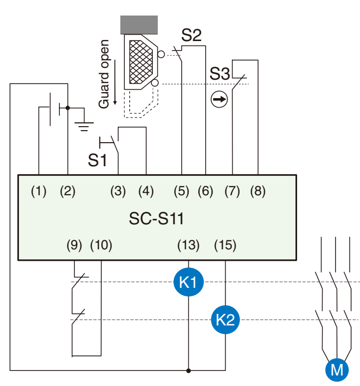


4 Limit switches for safety

Category: 4
Stop category: 0

Symbol explanations
S1: Reset input switch
S2: Limit switch for safety (N.O.)
S3: Limit switch for safety (N.C.)
K1, K2: Magnetic contactor, etc.
M: Three-phase motor

SC-S11 settings
Safety input mode setting: Contact output device connection
Interlock setting: Manual reset
EDM mode setting: EDM input enabled



MEMO

KEYENCE Safety Solutions

GC series
Safety Controller

GL-R series
Safety Light Curtains

SZ-V series
Safety Laser Scanner

GS series
Safety Interlock Switches
[Locking Type]

GS series
Safety Interlock Switches
[Non-Contact Type]

KEYENCE

CALL TOLL FREE — TO CONTACT YOUR LOCAL OFFICE **1-888-KEYENCE** 1-888-539-3623

www.keyence.com

SAFETY INFORMATION
Please read the instruction manual carefully in order to safely operate any KEYENCE product.

CONTACT YOUR NEAREST OFFICE FOR RELEASE STATUS

KEYENCE CORPORATION OF AMERICA
500 Park Boulevard, Suite 200, Itasca, IL 60143, U.S.A. **PHONE:** +1-201-930-0100 **E-mail:** keyence@keyence.com

KEYENCE CANADA INC.
E-mail: keyencecanada@keyence.com

KEYENCE MEXICO S.A. DE C.V.
E-mail: keyencemexico@keyence.com

KA11-1109

SafetySupportComp-KA-TG2-US 2110-1 611O36