FA Equipment for Beginners (Machinery Safety)

This course is intended for first time users to grasp an overview and understanding of the machinery safety and the safety measures to be taken for machinery.

L(NA)00261ENG

Introduction Purpose of the Course

This course is intended for first time users to understand the safety measures to be taken for machinery.
The course provides the basic knowledge, standards, regulations, and other information on machine safety.

Introduction Course Structure

The contents of this course are as follows.
We recommend that you start from Chapter 1.

Chapter 1 - Introduction

You will learn about the current situation of occupational accidents and the changes in the concept of safety in Japan.

Chapter 2 - What is "Safety"?

You will learn about the basic concept of safety.

Chapter 3 - Safety System

You will learn about the safety system.

Final Test

Passing grade: 60% or higher.

Introduction How to Use This e-Learning Tool

Go to the next page	>	Go to the next page.
Back to the previous page	<	Back to the previous page.
Move to the desired page	TOC	"Table of Contents" will be displayed, enabling you to navigate to the desired page.
Exit the learning	X	Exit the learning.

Cautions for Use

Safety precautions

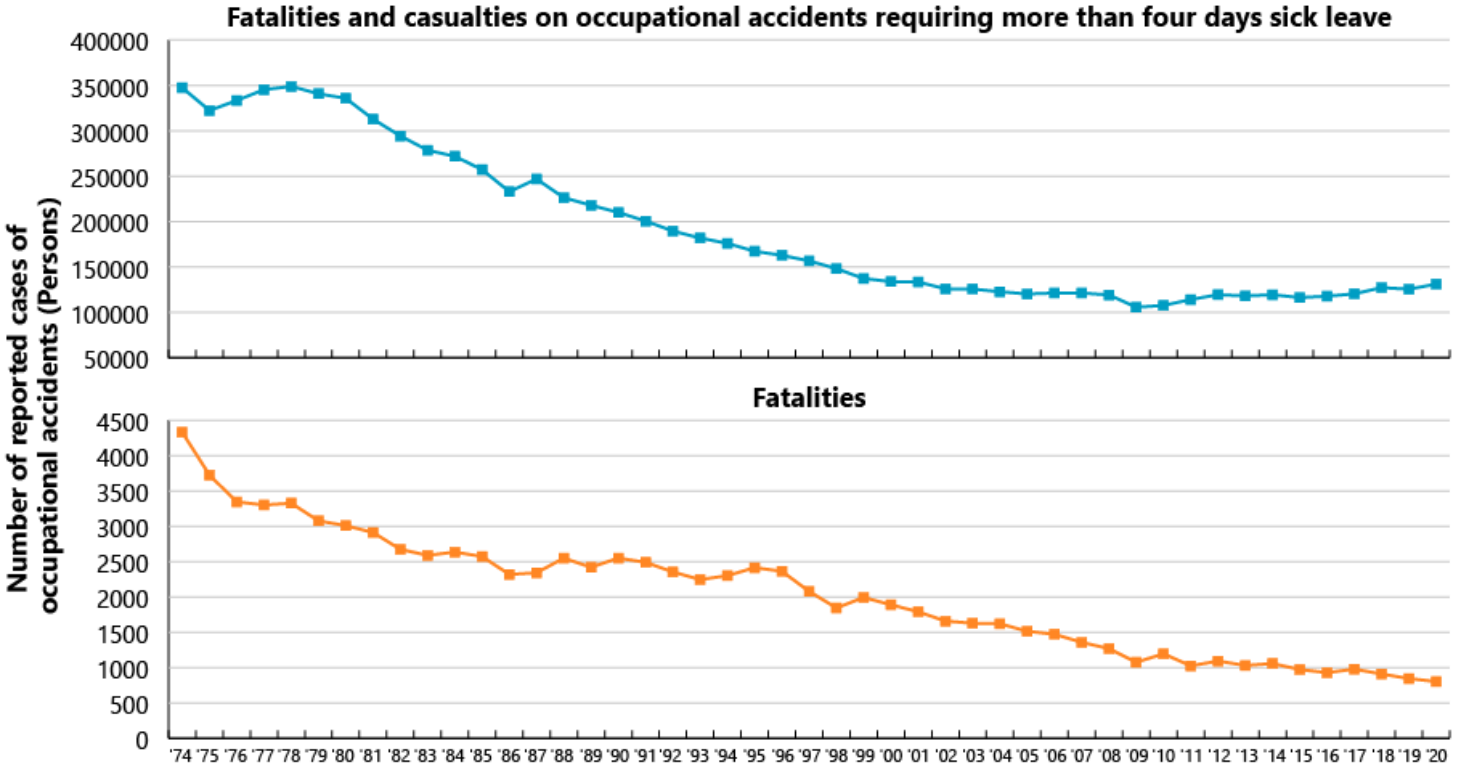
When you learn based on using actual products, please carefully read the safety precautions in the corresponding manuals.

Chapter 1 Introduction

First of all, let's learn about the current situation of occupational accidents and the changes in the concept of safety in Japan.

1.1 Current Situation of Occupational Accidents in Japan

The number of occupational accidents in Japan gradually decreased after peaking in the high economic growth period. However, the number has leveled off for the last several years.
As you can see in the graph below, the number of fatalities was 4330 in its peak. After that, the number gradually decreased and has remained around 1000 for the past decade.



Source: Ministry of Health, Labour and Welfare

1.2 Differences Between the Concept of Safety in Japan and the Concept of Safety in Europe

Japan has depended heavily on employee safety training including Kiken Yochi (hazard prediction) Training (KYT) to ensure safety. This concept of safety is different from that in Europe. The processes of designing and developing products are also different between Japan and Europe: Japan uses a bottom-up approach and Europe uses a top-down approach.
In Japan, however, the number of industrial accidents is not decreasing and the labor environment is changing. It is necessary to change the concept of safety from "Safety that depends on workers and training" to "Safety based on technology and design".

Safety that depends on workers and training (Japan)
Humans are the main cause of accidents.
It is possible to achieve safety by developing **management systems**, providing **training for workers**, and strengthening **regulations**.
In principle, it is possible to achieve safety **free of charge**.
Do not introduce **new technology** as measures for accidents that **should never happen**.
Focus on **frequency (number of accidents)**

Safety based on technology and design (Europe)
Prevention of accidents is a matter of **technology**.
It is inevitable that humans **make mistakes**. It is therefore impossible to ensure safety without **improving the technological capabilities**.
In principle, **costs** are involved in ensuring safety.
Work hard to reduce those accidents that **cannot be prevented**, leading to the creation of various **technologies and tools**.
Focus on **severity (significant accidents)**

1.3 How to Ensure Safety

How should we ensure safety in the workplace?
International safety standards were established based on the global concept of ensuring safety, assuming that humans make mistakes and machines fail.
Japan is now required to take action to ensure safety based on international safety standards.

Humans make mistakes.

Changes in employment styles

Increases in the number of part-time workers and foreign workers → **Safety must be ensured irrespective of experience in the operation.**

Changes in production methods

Low-volume high-variety production, diversification of market needs, more sophisticated and complicated machines → **Machinery itself must be designed safely and safety must be ensured regardless of human errors.**

Machines fail.

Machine design in accordance with international safety standards

Safe stop of a machine even if the safety device used fails → **Safety must be ensured during machine setup and maintenance.**

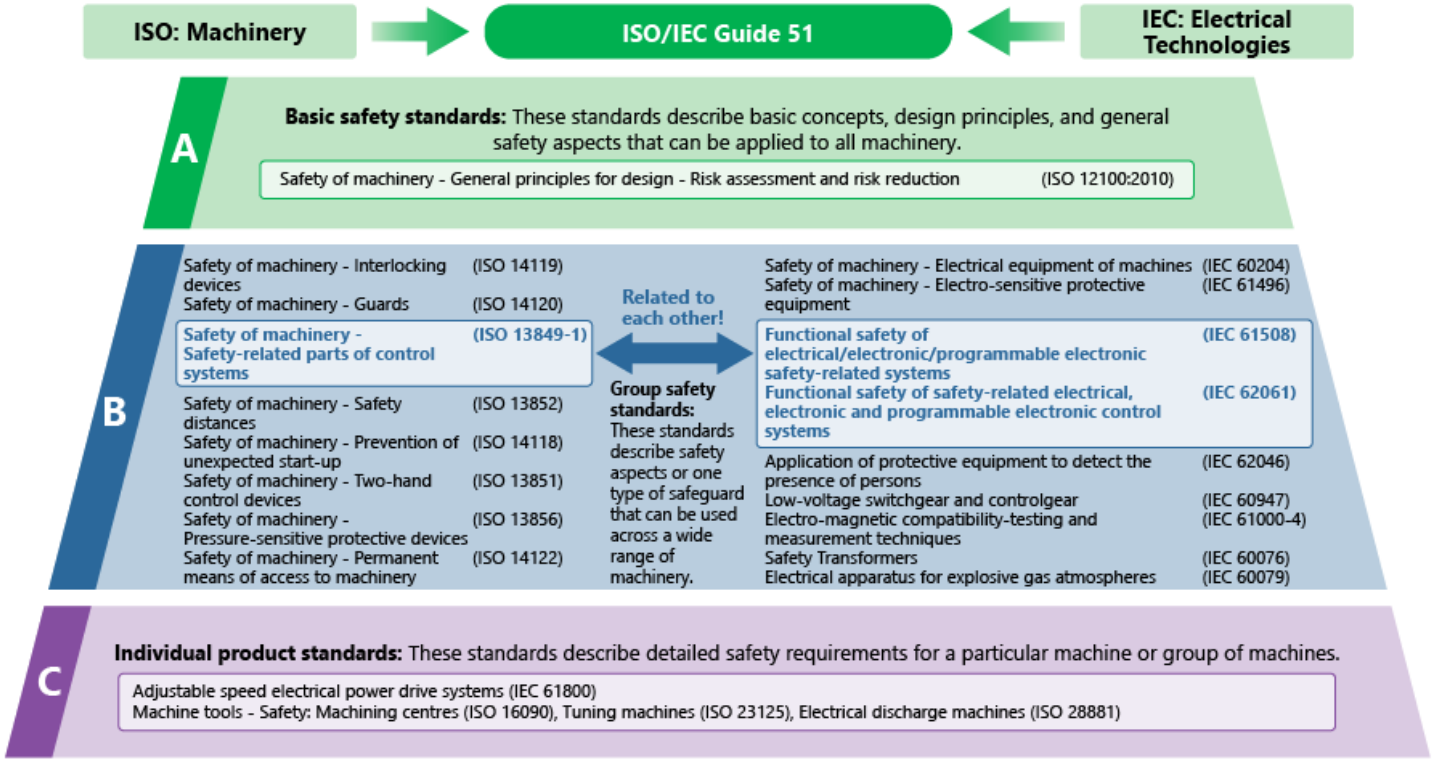
International safety standards

International safety standards systematically specify how to achieve the safety of machinery.

→ **Worldwide manufacturing industries must pay more attention to ensuring workplace safety.**
Machine design in accordance with international safety standards will be necessary in the future.

1.4 International Standards for Machinery Safety

International standards for machinery safety are hierarchically classified into three groups: basic safety standards (Type-A standards), group safety standards (Type-B standards), and individual product standards (Type-C standards).



* Data as of 2022. All standards are not listed.

1.5 Safety Standards in Japan

The compliance of Japanese Industrial Standards (JIS) to international safety standards is progressing. In addition, the global concept and measures of ensuring safety are incorporated into the Industrial Safety and Health Act.

Guidelines for Comprehensive Safety Standards of Machinery

(Announced in June 2001)

- The guidelines comply with **the international safety standard ISO 12100**. → ISO 12100 is incorporated into the Japanese Industrial Standards as JIS B 9700.

Amendment of the Industrial Safety and Health Act

- Transition to European safety design in 2006. The measures against press machines were mainly amended. **(Not only machine users but also manufacturers must be responsible for machine safety.)**
- The technical guidelines for securing safety for machinery through functional safety was established in 2016. **The safety integrity level (SIL) of IEC 61508 and the performance level (PL) of ISO 13849** are used to determine the requirements of safety functions.

Ordinance on Industrial Safety and Health

- Article 24-13, requesting machine **manufacturers** to **notify users of the risk** of the machine, was added in 2012.
- Article 150-4 was amended in 2013 and the **collaborative workspace** where **an industrial robot and a human** can work together was clarified.
- A notification titled "**Training** on machinery safety for **design engineers and production technical managers**" was issued in 2014.

Japanese Industrial Standard corresponding to ISO 45001

- **ISO 45001** that specifies requirements for **occupational health and safety management systems** was published in 2018.
- **JIS Q 45100**, where requirements for health and safety activities specific to Japan were added to ISO 45001, was published in 2018.

Not only occupational safety but also machinery safety is incorporated into the law.

* Data as of 2022

1.6 Responsibility for Occupational Accidents

In Japan, when a worker is injured in a workplace, it has been considered that both the company and the worker are responsible for the accident.
Recently, however, occupational accidents are regarded as a corporate responsibility. Companies have an obligation to ensure the safety of their workers. Injured workers can file a lawsuit against their company, which may result in significant losses for the company.

Example: Press machine accident

1) The company thought that safety was ensured by providing safety training and Kiken Yochi (hazard prediction) Training (KYT) to workers.
2) A few days later, a machine operator got his hand crushed in the press machine while replacing the mold.

Past

The machine operator had to bear the responsibility for the accident.

Present

Accidents are regarded as a corporate responsibility. Companies have to ensure safety of their workers.

Leading to a lawsuit

- Compensation for injury
- Operation shutdown until safety measures are taken after an audit
- Facing difficulties in securing workers because of the news about the accident
- Pursuit of social responsibility

Significant losses

1.7 Advantages of the Standardization of Safety Standards

A user can clearly determine whether the ordered machine or equipment satisfies the requirements of safety standards by placing an order based on the in-house standards that comply with **international safety standards**. Both a user and a machine vendor can accumulate know-how on safety design, enabling the smooth configuration of safety systems.

User

- Placing an order based on **the in-house standards that comply with international safety standards**

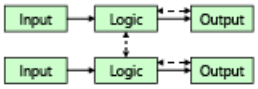
Whether the order satisfies the safety design can be checked.

- **Managing documents in a standardized format**
- Developing skills to check whether the ordered machine or equipment satisfies the safety requirements based on the in-house standards

Risks of the ordered machine or equipment can be shared with a machine vender.

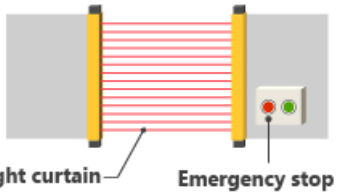
Machine vendor

- Implementing **safe design** based on **clear specifications**



Comment	Main power shutdown	Hazard 1	Hazard 2	Motor XX off
Emergency stop switch	✔	✔	✔	✔
Safety guard switch		✔	✔	✔
Safety light curtain			*	
Feedback 1	FB			
Reset button	Reset	Reset		
Feedback 2		FB		
Muting sensor 1			Muting1	
Muting sensor 2			Muting2	

- Designing machines and equipment **based on international safety standards**
- **Accumulating know-how** on **safety design**



1.8 Risk Assessment

A risk assessment is a systematic process of identifying, analyzing, and controlling potential hazards and risks in the workplace. Risk assessment methods include "numerical scoring", which adds the evaluation scores for each element and determines the risk level by the total score, and "risk graph", which uses a risk graph to estimate the risk from the performance level.

Numerical scoring method

Severity of harm + **Frequency of exposure to hazard** + **Possibility of avoiding harm** = **Risk level**

The severity of harm is evaluated.

Severity	Score	Description
1) Catastrophic	10	Death or permanent disabling injury
2) Serious	6	Major injury (requiring one month or more sick leave)
3) Moderate	3	Minor injury (requiring less than one month sick leave)
4) Minor	1	No injury or slight injury

How often a worker is exposed to hazard is evaluated.

Frequency	Score	Description
1) Frequent	4	Once a day
2) Often	2	Between once a week to once a month
3) Seldom	1	Once every 6 to 12 months

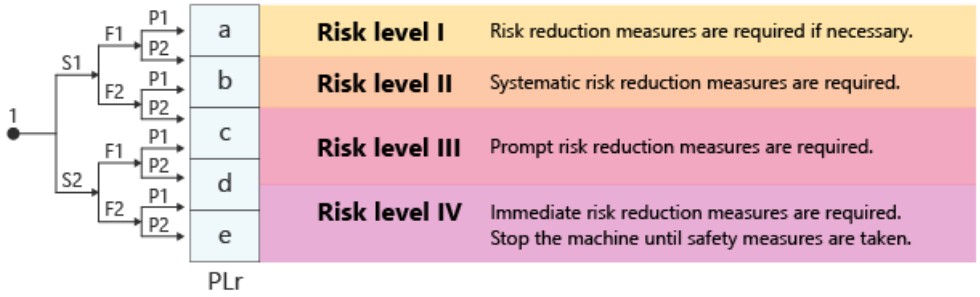
The possibility of avoiding harm is evaluated.

Possibility	Score	Description
1) Impossible	6	An accident may occur even if you pay the most attention.
2) Hardly possible	4	An accident may occur unless you pay more attention than usual.
3) Relatively possible	2	An accident may occur if you are careless.
4) Very likely possible	1	An accident may not occur under normal conditions.

The risk level is determined.

Risk level	Score	Approach to risk reduction
IV	12 to 20	Immediate risk reduction measures are required. Stop the machine until safety measures are taken.
III	9 to 11	Prompt risk reduction measures are required.
II	6 to 8	Systematic risk reduction measures are required.
I	5 or less	Risk reduction measures are required if necessary.

Risk graph method



1.9 Summary

The contents of this chapter are:

- Current Situation of Occupational Accidents in Japan
- Differences Between the Concept of Safety in Japan and the Concept of Safety in Europe
- How to Ensure Safety
- International Standards for Machinery Safety
- Safety Standards in Japan
- Responsibility for Occupational Accidents
- Advantages of the Standardization of Safety Standards
- Risk Assessment

Chapter 2 What is "Safety"?

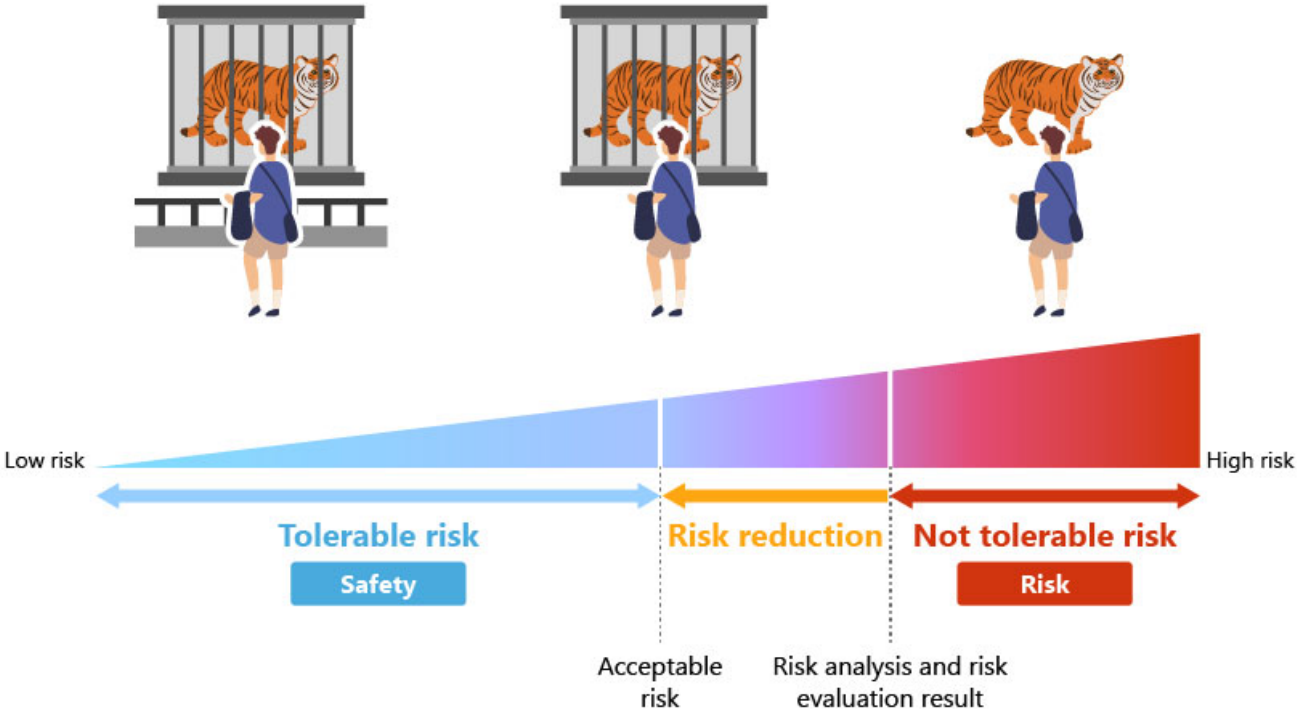
In this chapter, let's learn about the basic concept of safety.

2.1 What is "Safety"?

The international safety standard ISO/IEC Guide 51 defines the term "safety" as "freedom from risk which is not tolerable" and the term "risk" as a "combination of the probability of occurrence of harm and the severity of that harm". There are tolerable and not tolerable risks around us, and the definition of "safety" is determined how far we accept them as tolerable risks.

Definition in the international safety standard ISO/IEC Guide 51

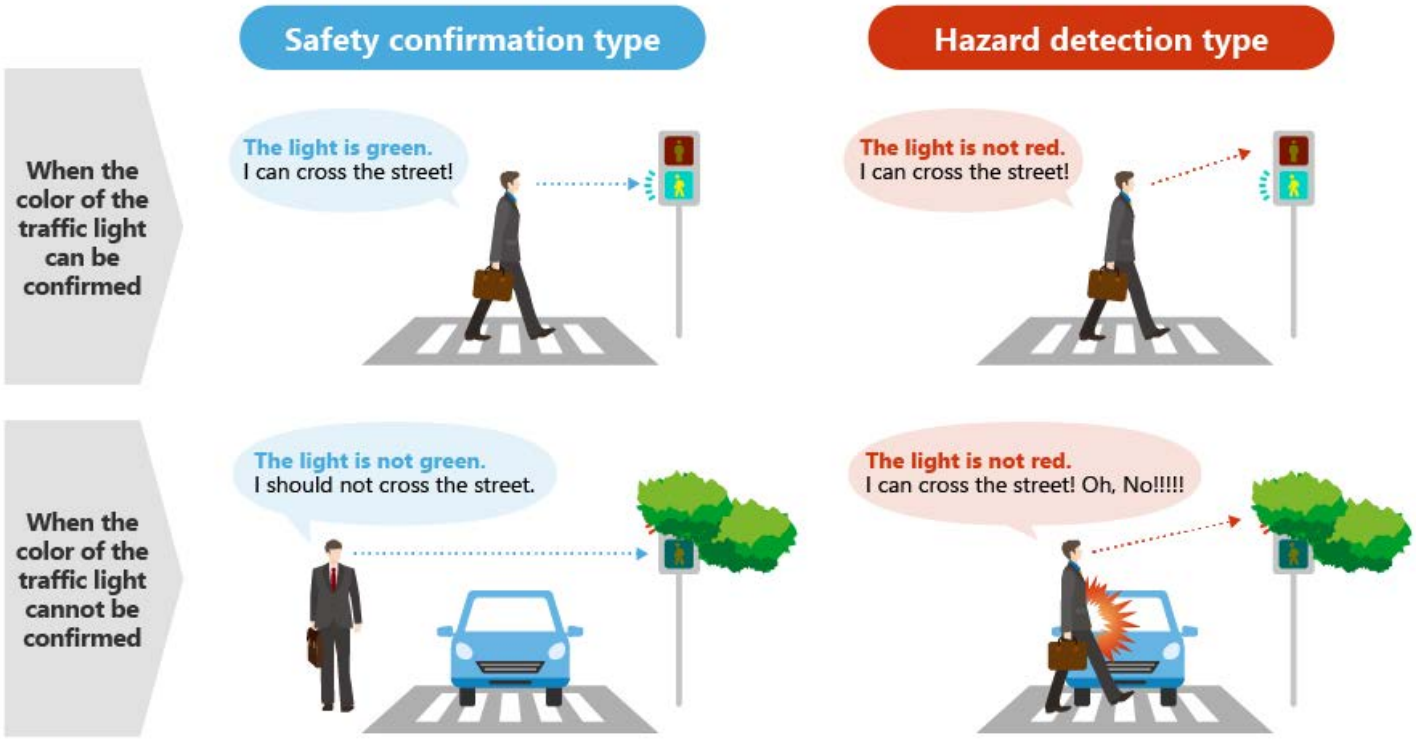
Safety = Freedom from risk which is not tolerable



* Zero risk can never be achieved.

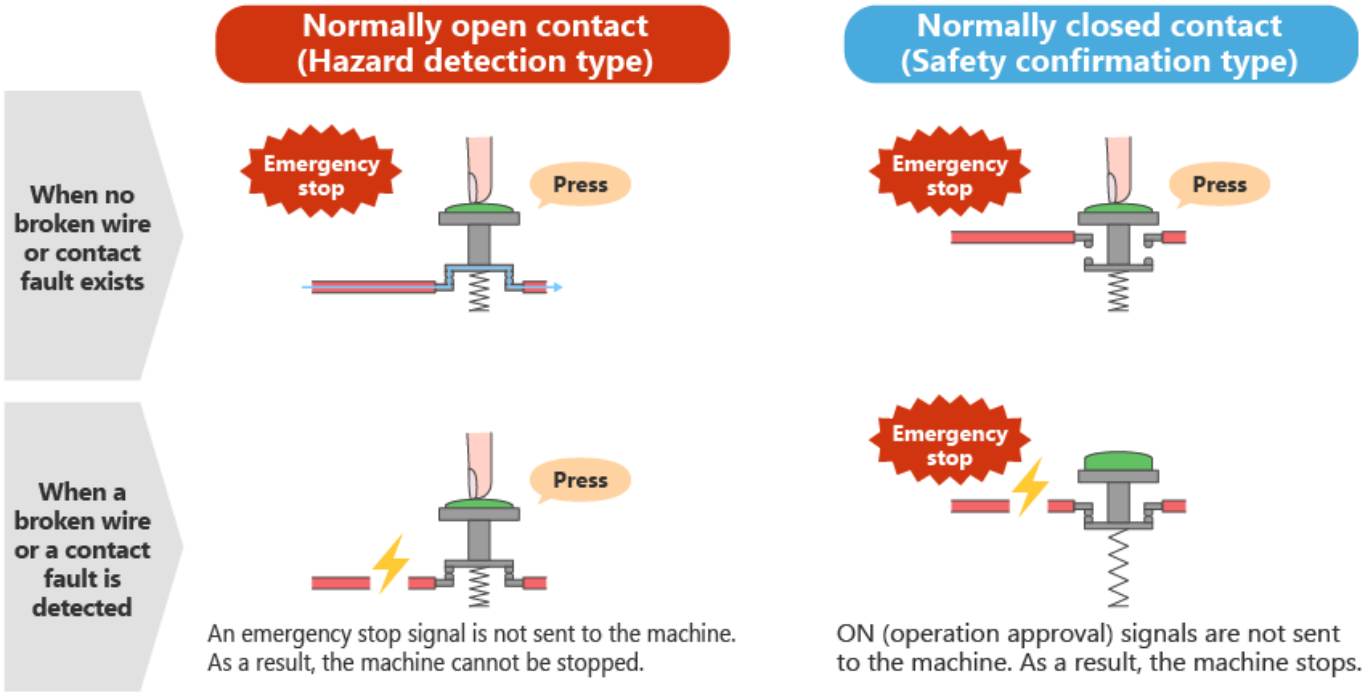
2.2 Difference Between Safety Confirmation Type and Hazard Detection Type

There are two types of safety concepts: safety confirmation type and hazard detection type.
In the example below, when the color of the traffic light cannot be confirmed, the judgment of a pedestrian will differ between the safety confirmation type and the hazard detection type.
The concept of machine safety requires that the machine operation shall be permitted only when safety is confirmed. We must adopt the safety confirmation type.



2.2 Difference Between Safety Confirmation Type and Hazard Detection Type

If a switch having a normally open contact (hazard detection type) is used as an emergency stop switch, an emergency stop signal is sent to stop the machine only while the switch is being pressed. In case of broken wires and contact faults, an emergency stop signal cannot be sent to the machine even when the switch is pressed in the event of an emergency.
On the other hand, if a switch having a normally closed contact (safety confirmation type) is used as an emergency stop switch, the machine stops as soon as ON (operation approval) signals are stopped (as soon as the switch is pressed).
The machine can be stopped even in case of broken wires and contact faults because it can no longer receive ON (operation approval) signals.
From a safety point of view, international safety standards require the use of normally closed contacts (safety confirmation type) for emergency stop switches so that the machine operates normally only when it receives ON (operation approval) signals.



2.3 Accident Cases and Safeguarding

In Section 2.1, you have learned the definition of safety: "freedom from risk which is not tolerable".
The following is an example of safety in industrial applications.
There are two conditions for an accident to occur: approaching the machine and touching the machine in operation.
To prevent accidents during machine operation, safeguarding ("isolation" and "stoppage") is important.
The safeguarding based on the isolation principle separates human workspace from machine workspace (hazard) with a safety device, such as a safety guard. The safeguarding based on the stoppage principle stops the operation of the machine (hazard) if a human enters the machine workspace during machine operation.

Isolation principle	Stoppage principle
Safeguarding with guards	Safeguarding with interlocking devices

* An interlocking device refers to a mechanical or electrical device that was designed to prevent machines from operating unless certain conditions are met, such as closing a guard for example.

2.4 Summary

The contents of this chapter are:

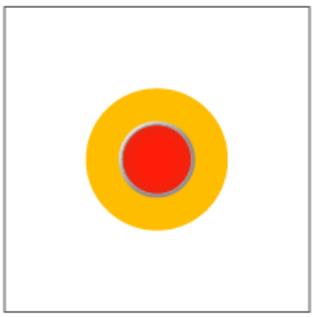
- What is "Safety"?
- Difference Between Safety Confirmation Type and Hazard Detection Type
- Accident Cases and Safeguarding

Chapter 3 Safety System

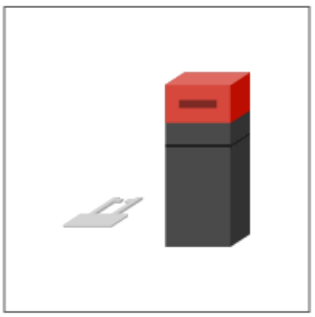
In this chapter, let's learn about the safety system.

3.1 Safety Devices (Safety Components)

Typical safety devices (safety components) for safeguarding are shown below.
Safety systems can be configured by using these safety devices (safety components) with a safety programmable controller.

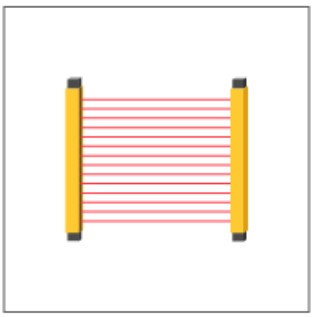


Emergency stop switch



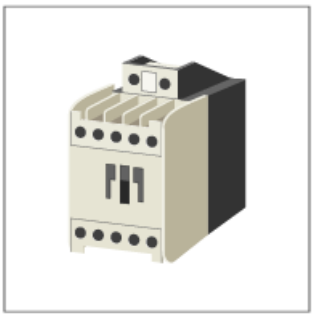
Safety guard switch

Enabling switch



Safety light curtain

Safety laser scanner



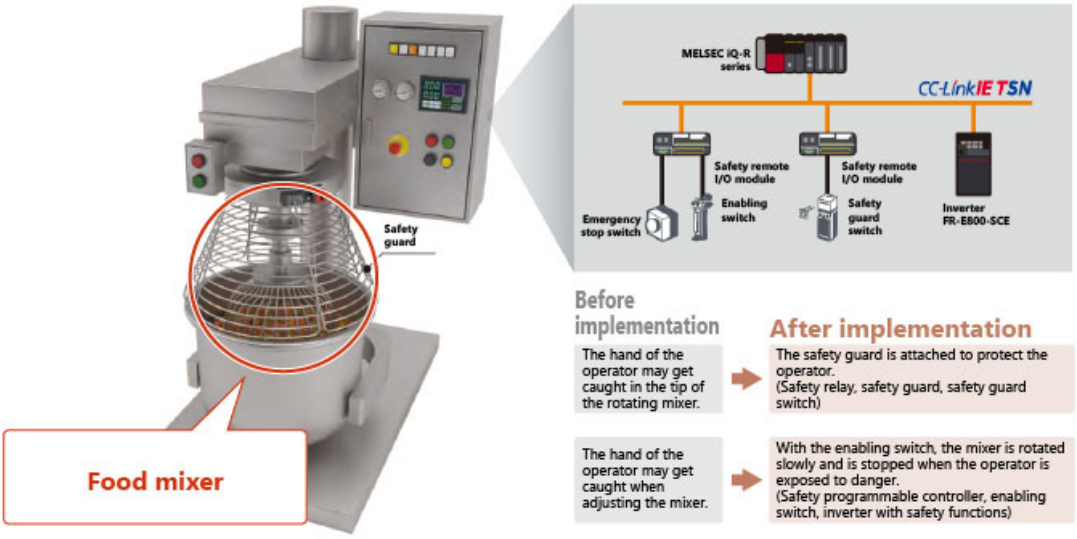
Electromagnetic contactor

Servo/inverter with safety functions

Robot with safety functions

3.2 Safety System Example

Let's take a look at how safety devices are actually used in a safety system.
The following is an example where a safety system is implemented to the food processing machine.



Before implementation	After implementation
The hand of the operator may get caught in the tip of the rotating mixer.	The safety guard is attached to protect the operator. (Safety relay, safety guard, safety guard switch)
The hand of the operator may get caught when adjusting the mixer.	With the enabling switch, the mixer is rotated slowly and is stopped when the operator is exposed to danger. (Safety programmable controller, enabling switch, inverter with safety functions)

3.2 Safety System Example

Safety Device 1: Safety Guard
There may be a case that the operator gets his hand caught in the rotating mixer when checking products or removing foreign matter.
After a safety system is implemented, the operator cannot enter his hand into the mixer while running.

Before implementation

After implementation

Safety Device 2: Enabling Switch

When a safety guard is not attached, a safety system is configured by using an enabling switch. The mixer rotates slowly only when the enabling switch is held down in the middle position.

Before implementation

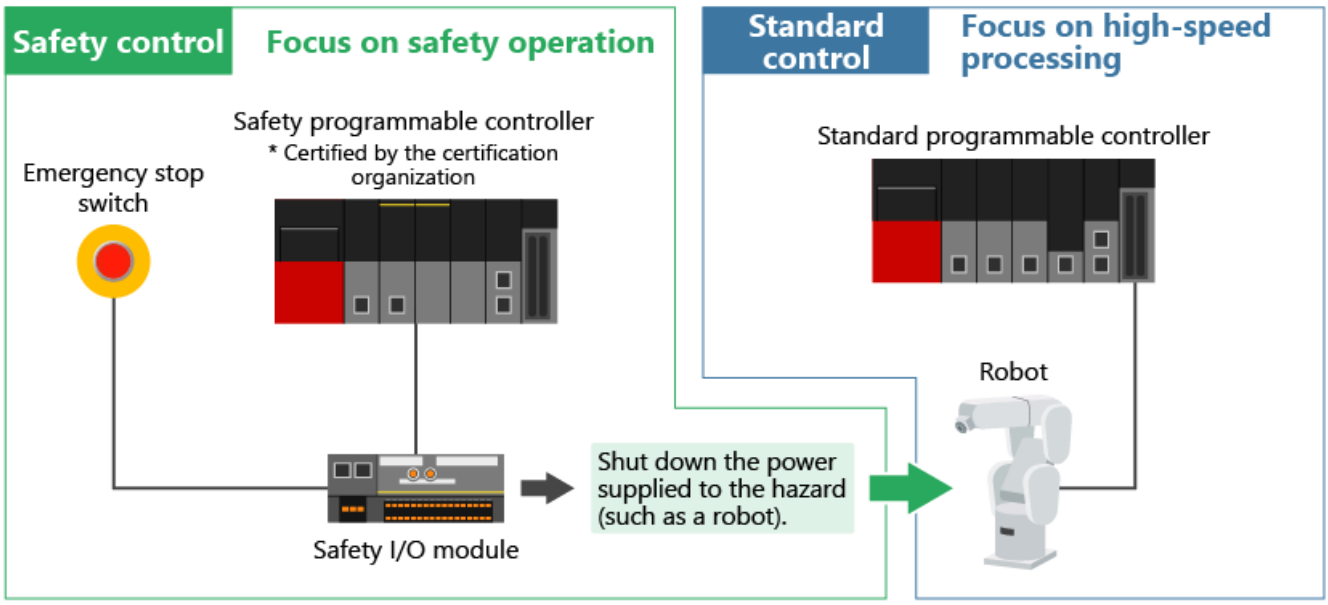
After implementation

[Point]

- In maintenance mode, the mixer rotates only when the enabling switch is held down in the middle position.
- The rotating speed in maintenance mode can be checked using the safety limited speed (SLS) function of the connected inverter, FR-E800-SCE.
  (The AC servo, MR-J5-G-RJ, has the same function.)

3.3 Overview of Safety Programmable Controllers

A safety programmable controller complies with the international safety standards (ISO 13849-1 and IEC 61508) and performs safety control together with safety devices connected, such as emergency stop switches and safety light curtains.
A safety programmable controller performs safety control, while a standard programmable controller performs standard control.
For example, in the system below, when a hazard is detected, the safety programmable controller shuts down the power supplied to the hazard (such as a robot) on the standard control side using a safety device connected.

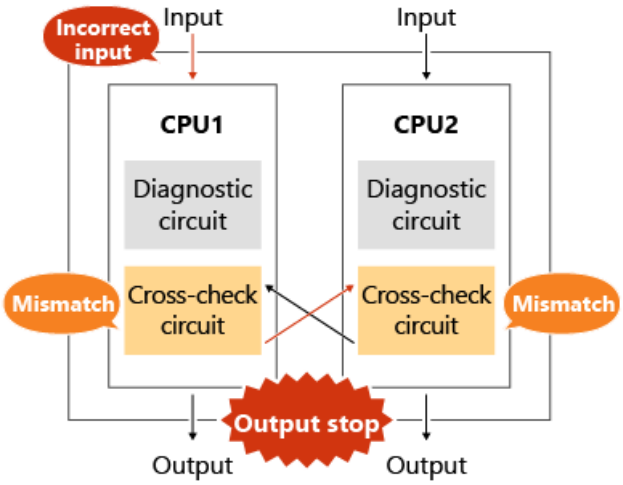


To satisfy the requirements for safety category 3 "A single fault in any of these parts does not lead to the loss of the safety function.", the Safety CPU has two CPUs internally and compares the operation results between the CPUs.
Only when the comparison results between the CPUs match, the operation result is output from the Safety CPU.
If the comparison results do not match due to incorrect input or CPU failure, the operation result will not be output.

◆ Input signal check processing in the Safety CPU

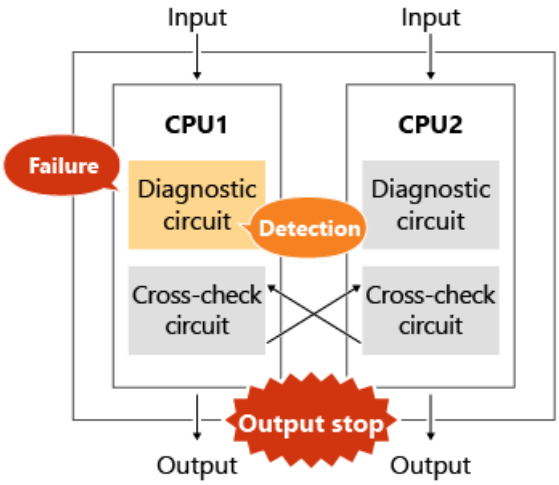
Incorrect input in one system

A data mismatch is detected in the cross-check circuit, and output is stopped.



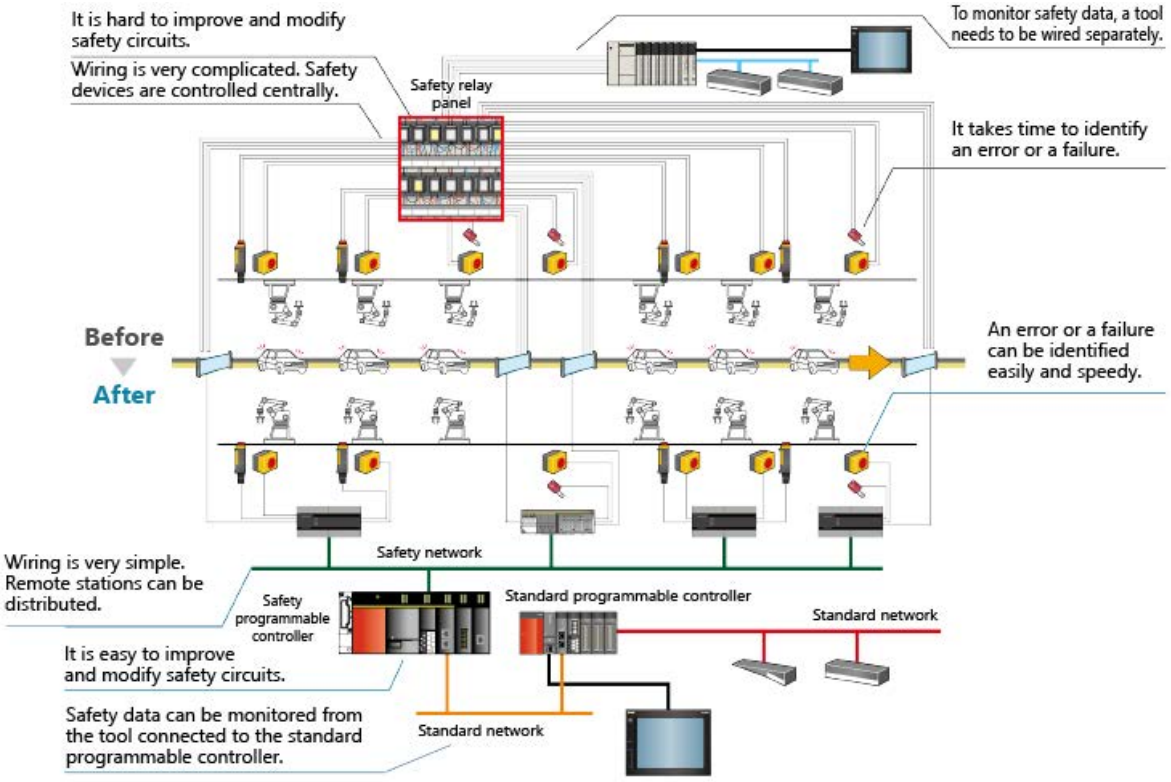
Failure in one system

A failure is detected in the diagnostic circuit, and output is stopped.



3.5 Safety Communications (Safety Network Technology)

The safety network technology, which incorporates the concept of IEC 61508* for functional safety, is standardized in IEC 61784-3*.
IEC 61784-3 also defines the safety function response time, communication errors, and remedial measures to implement the requirements of IEC 61508.
* Data as of 2022



3.6 Summary

The contents of this chapter are:

- Safety Devices (Safety Components)
- Safety System Example
- Overview of Safety Programmable Controllers
- Basic Architecture of Safety Programmable Controllers
- Safety Communications (Safety Network Technology)

* Configuration of a safety system requires the judgment of qualified personnel such as safety assessors and experts such as safety consultants.

Test Final Test

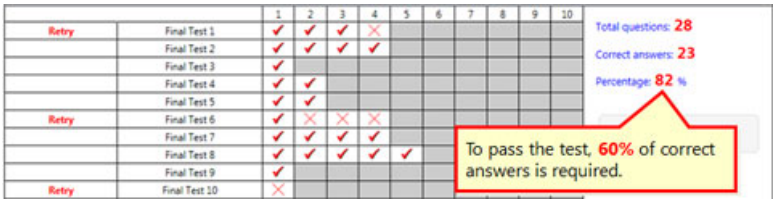
Now that you have completed all of the lessons of the FA Equipment for Beginners (Machinery Safety) course, you are ready to take the final test. If you are unclear on any of the topics covered, please take this opportunity to review those topics.

There are a total of 5 questions (13 items) in this Final Test.

You can take the final test as many times as you like.

Score results

The number of correct answers, the number of questions, the percentage of correct answers, and the pass/fail result will appear on the score page.



Test **Final Test 1**

The following figure shows the differences between the concept of safety in Japan and the concept of safety in Europe. Fill in the blanks with appropriate terms.

Q1 Humans

Q2 a matter of technology

Q3 number

Q4 severity

Safety that depends on workers and training (Japan)	Safety based on technology and design (Europe)
[Q1] are the main cause of accidents.	Prevention of accidents is [Q2].
It is possible to achieve safety by developing management systems, providing training for workers, and strengthening regulations.	It is inevitable that humans make mistakes. It is therefore impossible to ensure safety without improving the technological capabilities.
In principle, it is possible to achieve safety free of charge.	In principle, costs are involved in ensuring safety.
Do not introduce new technology as measures for accidents that should never happen.	Work hard to reduce those accidents that cannot be prevented, leading to the creation of various technologies and tools.
Focus on the [Q3] of accidents 	Focus on the [Q4] of accidents 

[+]

Test **Final Test 2**

The following statement describes international standards for machinery safety. Fill in the blanks with appropriate terms.

International standards for machinery safety are hierarchically classified into three groups: **(Q1)** (Type-A standards), **(Q2)** (Type-B standards), and **(Q3)** (Type-C standards).

Q1 basic safety standards

Q2 group safety standards

Q3 individual product standards

Test **Final Test 3**

The following statements describe what "safety" is. Fill in the blanks with appropriate terms.

The international safety standard ISO/IEC Guide 51 defines the term "safety" as " **(Q1)** " and the term "risk" as a "combination of the **(Q2)** and the severity of that harm". There are tolerable and not tolerable risks around us, and the definition of "safety" is determined how far we accept them as tolerable risks.

Q1 freedom from risk which is not tolerable

Q2 probability of occurrence of harm

Test **Final Test 4**

The following sentences describe the safety confirmation type and the hazard detection type. Fill in the blanks with appropriate terms.

If a **(Q1)** switch is used as an emergency stop switch, emergency stop signals are sent to stop the machine only while the switch is being pressed. In case of broken wires and contact faults, emergency stop signals cannot be sent to the machine even when the switch is pressed in the event of an emergency.

Q1 hazard detection type

Q2 safety confirmation type

Test **Final Test 5**

The following statements describe "safeguarding". Fill in the blanks with appropriate terms.

There are two conditions for an accident to occur: approaching the machine and touching the machine in operation. To prevent accidents during machine operation, safeguarding is important.

Two principles apply. The safeguarding based on the **(Q1)** principle separates human workspace from machine workspace (hazard) with a fixed guard. The safeguarding based on the **(Q2)** principle stops the operation of the

Q1 isolation

Q2 stoppage

Test Test Score

You have completed the Final Test. Your results are as follows.
To end the Final Test, proceed to the next page.

		1	2	3	4	5	6	7	8	9	10
	Final Test 1	✓	✓	✓	✓						
	Final Test 2	✓	✓	✓							
	Final Test 3	✓	✓								
	Final Test 4	✓	✓								
	Final Test 5	✓	✓								

Total questions: 13

Correct answers: 13

Percentage: 100 %

Clear

You have completed the FA Equipment for Beginners (Machinery Safety) course.

Thank you for taking this course.

We hope you enjoyed the lessons and the information you acquired in this course will be useful in the future.

You can review the course as many times as you want.

Review

Close