



**MITSUBISHI
ELECTRIC**

MITSUBISHI ELECTRIC INDUSTRIAL ROBOT

SAFETY MANUAL

MITSUBISHI ELECTRIC CORPORATION

NOTE TO THE USER

1. AS FOR THE ASSURANCE OF SAFETY IN DESIGN AND CONSTRUCTION OF ROBOT SYSTEM, READ THIS MANUAL FIRST.
2. PLEASE MAKE SURE THAT THIS MANUAL IS DELIVERED TO END USERS FOR THEIR IMPLEMENTATION OF SAFETY.
3. DON'T USE ROBOTS IN A POTENTIALLY EXPLOSIVE ATMOSPHERE.

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Transportation Precaution

The United Nations' Recommendations on the Transport of Dangerous Goods must be observed for trans-border transportation of lithium batteries by air, sea, and land.

The lithium batteries (A6BAT and ER6) used in Mitsubishi industrial robots contain less than 1 g of lithium and are not classified as dangerous goods. However, if the quantity of lithium batteries exceeds 24 batteries for storage, etc., they will be classified as Class 9: Miscellaneous dangerous substances and articles. Shipping less than 24 batteries is recommended to avoid having to carry out transport safety measures as the customer's consignor. Note that some transportation companies may request an indication that the batteries are not dangerous goods be included on the invoice. For shipping requirement details, please contact your transportation company.

Waste Management

When disposing of this product, it is necessary to give consideration to the effective use of resources, waste handling and cleaning, and the collection and disposal of fluorocarbon. Please dispose of this product according to the waste management law of the country where it is used.

1. Effective Use of Resources

- (1) Please recycle the old product as much as possible.
- (2) For recycling purposes, we recommend disassembling this product into iron scrap and electrical parts, so that they can be sold to appropriate vendors.

2. Waste Handling and Cleaning

- (1) Please try to sell the old product for recycling in order to reduce the amount of waste material.
- (2) When disposing of this product, please do so according to the requirements of the appropriate industrial waste laws.

Disposing of batteries and used grease by the customer will cause environment contamination.

3. Collection and Disposal of Fluorocarbon

- (1) Handle the coolant inside the heat radiation fins used for heat dispersion in the power supply unit (converter unit) and the driving units (inverter unit, amplifier unit) appropriately, according to the designated fluorocarbon collection and disposal regulations.

The applicable products that use fluorocarbon are the following units built in the CR4, CR7, CR8 and CR9 controllers manufactured in or before 2002.

Unit model name	Charged coolant model name
MDS-B-CV-37 to 185	HCFC141b
MDS-B-V1-20 to 45	
MDS-B-V1-70 to 90	HCFC123
MDS-B-V2-2010 to 4535	

Note: The V1 model includes the V14 and V14L modes, and the V2 model includes the V24 model.

Robot System Safety Precautions

1. Be sure to install a safety barrier or enclosure around the robot to eliminate potential dangers in case an operator approached the robot carelessly.
2. Implement an interlock such that the door will not open even if an operator attempts to go through the barrier (within the safety area) while the robot is operating, or such that the servo power supply of the robot is turned off and peripheral devices are stopped automatically (the servo power supply is turned off) as soon as an operator opens the door. Connect the line of this interlock signal directly to the robot and peripheral devices without going through a secondary device such as a PLC. In case of our robots, the line should be connected to the emergency stop input terminal or door switch input terminal.
3. If a system is configured such that several robots are installed within the safety area, employ a design and structure where each robot and related devices can be operated independently of one another.
4. Robot systems should be designed so that the robot controller is installed outside the safety area.
5. Install a manual emergency stop switch at a location near the robot where it can be easily operated and connect it to the external emergency stop input terminal of the controller. (Use an always-closed B-contact type with structural lock function conforming to the IEC60204-1 specification.)
6. Configure the system so that the operational status of the robot (i.e. executing program operation, stopped, servo-on status, error status, etc.) can be verified easily from outside using visual status indicators, etc.
7. For the safety of all operators in the immediate vicinity, all errors should be accompanied by an audible alert as well as a visual signal.
8. Implement external means to manually shut down all power supplied to the robot system.
9. Be sure to configure the robot system so that it begins automatic operation on startup. Also, configure the system so that the robot does not resume automatic operation whenever the system is reset.
10. Be sure to ground the robot arm and controller to prevent electric shock and electrostatic discharge, improve noise resistance and minimize unnecessary electromagnetic irradiation.
11. If an operator must enter the area beyond the barrier (within the safety area) for the purpose of teaching and adjustment, etc. while the servo is turned on, a helmet must be worn. Perform the servo ON operation via the deadman switch in the teaching pendant under such conditions that the servo power supply can be turned off at any moment and there is enough space for the operator's body to avoid any potential danger.
12. When conducting team work, designate one responsible person, make sure gestures and commands used are thoroughly known and attend to mutual safety.
13. Be sure to indicate with hand and voice signals when turning the power supply on, operating electric wiring, and/or operating cranes and other heavy equipment so that everyone involved is alerted and dangerous situations can be avoided.

Sicherheitsmaßnahmen für das Robotersystem

1. Um den Roboter herum ist eine Sicherheitsbarriere oder Einfriedung anzubringen, damit bei unbedachter Annäherung an den Roboter potenzielle Gefahren ausgeschaltet werden.
2. Eine Sicherheitsverriegelung anbringen, die das Öffnen der Tür verhindert, wenn ein Bediener versucht, die Barriere (innerhalb des Sicherheitsbereichs) zu passieren, während der Roboter in Betrieb ist, oder durch die beim Öffnen der Tür die Servo-Stromversorgung des Roboters ausgeschaltet und Peripheriegeräte automatisch angehalten werden (die Servo-Stromversorgung ausgeschaltet wird). Die Leitung dieses Sicherheitsverriegelungssignals direkt an den Roboter und die Peripheriegeräte anschließen und nicht an ein Sekundärgerät (z.B. PLC). Bei unseren Robotern sollte die Leitung an das Eingangsterminal des Notausschalters oder Türschalters angeschlossen werden.
3. Falls die Konfiguration eines Systems mehrere Roboter im Sicherheitsbereich vorsieht, sollte bei Entwurf und Installation darauf geachtet werden, dass alle Roboter und entsprechenden Geräte unabhängig voneinander bedient werden können.
4. Robotersysteme sollten so installiert werden, dass sich der Roboter-Controller außerhalb des Sicherheitsbereichs befindet.
5. An einer leicht zugänglichen Stelle in Roboternähe einen manuellen Notausschalter anbringen und diesen mit dem externen Notausschaltungs-Eingangsterminal des Controllers verbinden. (Stets einen geschlossenen B-Kontakt mit struktureller Sperrfunktion gemäß IEC60204-1 verwenden.)
6. Das System so konfigurieren, dass der Betriebsstatus des Roboters (d.h. Ausführungsprogrammbetrieb, Stopstatus, Servo-Ein-Status, Fehlerstatus usw.) anhand von Sichtanzeigen usw. problemlos extern überprüft werden kann.
7. Zur Sicherheit des Bedienungspersonals in unmittelbarer Nähe des Roboters sollten alle Fehler durch Hör- und Sichtsignale angezeigt werden.
8. Externe Anlagen implementieren, die die manuelle Ausschaltung der Stromversorgung des Robotersystems ermöglichen.
9. Bei der Konfiguration des Robotersystems ist darauf zu achten, dass das System beim Hochfahren automatisch in Betrieb genommen wird. Zudem das System so konfigurieren, dass der Roboter beim Zurückstellen des Systems den Betrieb keinesfalls automatisch wieder aufnimmt.
10. Zur Vermeidung von Stromschlag und elektrostatischer Entladung, Verbesserung des Störwiderstands und Verhinderung unnötiger elektromagnetischer Abstrahlung ist auf ordnungsgemäße Erdung des Roboterarms und Controllers zu achten.
11. Falls es erforderlich wird, dass ein Bediener den Bereich hinter der Barriere (innerhalb des Sicherheitsbereichs) zu Schulungs- und Justierzwecken etc. bei eingeschalteter Servo-Versorgung betritt, ist ein Schutzhelm zu tragen. Bei der Teach-In-Programmierung den Servo-Ein-Betrieb so über den Totmannschalter durchführen, dass die Servo-Stromversorgung jederzeit ausgeschaltet werden kann und dass genügend Platz für den Körper des Bedieners besteht, um potenzielle Gefahren zu vermeiden.
12. Bei Teamarbeit einen Verantwortlichen bestimmen und sicherstellen, dass Handzeichen und Befehle eingehend bekannt und der gegenseitigen Sicherheit dienlich sind.
13. Mit Hand- und Rufsignalen auf das Einschalten der Stromversorgung und/oder Bedienungskräne und sonstiger schwerer Maschinen hinweisen, damit alle Betroffenen alarmiert sind und gefährliche Situationen vermieden werden können.

로봇 시스템 안전 예방조치

1. 오퍼레이터가 무심코 로봇에 접근 할 경우에 빗어질 수 있는 위험상황을 제거하기 위해 로봇의 주변에 안전 장벽이나 울타리를 꼭 설치할 것.
2. 로봇이 가동 중일 때에는 오퍼레이터가 장벽을 (안전공간 내) 넘어가려고 할지라도 문이 열리지 않게할 인터록을 시행하던지, 아니면 오퍼레이터가 문을 여는 즉시 로봇의 서보 전원장치가 꺼지고 주변장치가 자동 정지 (서보 전원장치 꺼졌음) 되도록 시행할 것. 본 인터록 신호 선을 2차적인 장치인 PLC 등을 통하지 않고 직접 로봇 및 주변장치에 연결 할것. 우리 로봇일 경우, 선은 긴급정지 입력 터미널이나 문 스위치 입력 터미널에 연결되어야 함.
3. 로봇이 여러 대 안전공간 내에 설치되도록 시스템이 형성되어 있는 경우에는 각 로봇 및 관련장치가 각각 독자적으로 가동될 수 있는 디자인 및 구조를 고용할 것.
4. 로봇 시스템 디자인은 로봇 제어장치가 안전공간 밖에 설치되도록 고안되어야 한다.
5. 수동적 긴급정지 스위치는 로봇을 가동하기 쉬운 로봇 가까이 설치하고, 제어장치의 외부 긴급정지 입력 터미널에 연결 할 것 (IEC60204-1 사양에 준수하는 구조적 자물쇠 기능을 가진 항상 닫혀있는 B-접촉식을 사용 할 것.)
6. 로봇의 가동상태 (즉, 프로그램 가동 실시, 정지, 서보-ON 상태, 오류 상태, 등등.)가 밖에서 시각적 상태 지시기 등을 통하여 쉬이 확인될 수 있도록 시스템을 형성할 것.
7. 로봇에 인접해있는 모든 오퍼레이터의 안전을 위하여, 모든 오류는 귀에 들리는 경보 및 시각적 신호를 동반해야 한다.
8. 로봇 시스템의 모든 전원장치를 수동적으로 끌 수 있는 외부적 수단을 실행할 것.
9. 시동 시에는 반드시 자동으로 가동 되도록 로봇 시스템을 형성 할 것. 단, 시스템이 리셋 될 때에는 계속해서 자동가동이 되지 않도록 시스템을 형성 할 것.
10. 전기쇼크 및 방전 예방, 잡음저항 상 개선, 그리고 불필요한 전자석의 발광을 최소화하기 위해서 로봇의 팔과 제어장치를 반드시 접지 할 것.
11. 서보가 켜있을 때 교시 및 조절등의 목적으로 오퍼레이터가 장벽 내로 (안전공간 내) 들어가야만 할 경우에는 철모를 써야만한다. 서보 전원장치를 언제나 속히 끌수 있으며 오퍼레이터의 몸이 잠재적 위험을 회피할 수 있는 충분한 공간이 갖추어졌을 때는 교시 펜던트 내의 deadman 스위치로 서보 ON 작업을 할 것.
12. 팀 작업 시에는 책임자를 지명하며, 반드시 사용하는 몸짓 및 명령이 완전히 이해되도록 하여서 상호 안전에 주의 할 것.
13. 전원장치를 켤 때, 전기배선을 가동할 때, 그리고/또는 크레인 및 다른 중장비를 가동할 때에는 반드시 손과 음성으로 신호하여서 모든 관련 인이 경보를 받고 위험상황을 회피할 수 있도록 한다.

机器人系统安全预防措施

1. 务必在极器人四周安装安全围篱或保护圈，以防止操作员不小心接近 机器人而造成潜在伤害。
2. 装配互锁(interlock)，因此即使操作员试图在机器人操作期间穿越围篱(在安全区域内)，门也不会打开，或在操作员一打开门之后，机器人的伺服器电源系统将关闭，周边设施也会自动停止(伺服器电源系统已关闭)。将此互锁的信号线直接连接在机器人及其周边设施上，不需经过如PLC的第二个设施。以我们的机器人来说，此线应该要连接到紧急停止输入端子或者连接到门的开关输入端子。
3. 如果系统的配置是将若干机器人安装在安全区域之内，则必须使用另一种设计或结构，使每个机器人及其相关装置能够被分开独立操作。
4. 机器人系统的设计应将机器人控制器安装在安全区域之外。
5. 在机器人的附近安装一个手动的紧急停止开关，该地点必须要能方便操作并能连接到控制器的外部紧急停止输入端子。[使用符合IEC60204-1规定，具有结构锁功能的“永久关闭，B-接触型”(always-closed B-contact type)。]
6. 系统的配置必须要使机器人的操作状态(例如执行程序操作、停止、伺服器开启状态、错误状态等等)能够很容易地从外部利用目视的状态指示器加以确认。
7. 为了保障临近操作人员的安全，所有的错误必须要有发出声音的警告以及可看见的信号。
8. 在外部装设能以手动方式关闭机器人系统所有电源的装置。
9. 务必进行机器人系统配置，以便它在启动时能开始自动操作。此外，配置系统，使机器人在系统重设时不会回复自动操作。
10. 务必将机器人的手臂以及控制器接地，以防止电击以及静电放电的现象，并尽可能消除噪音，尽量减低不必要的电磁辐射。
11. 如果操作人员为了教学或调整等原因必须进入围篱内部(安全区域内)，当伺服器开启时，必须戴安全帽。必须在伺服器电源可随时停止，而且操作人员的身体有足够的活动空间避免遭遇潜在危险的情况下，经由教学指示条中的“无人开关”(deadman switch)来进行伺服器开启的操作。
12. 团队一起工作时，务必指派一位负责人员，确保每个人完全了解所使用的手势与命令并注意彼此的安全。
13. 开启电源、操作电线装配及(或)起重机，以及其它重装备的时候，务必利用手势与声音发出信号，使每一位参与人员都能保持警觉，避免危险情况的发生。

■Revision history

Date of Point	Instruction Manual No.	Revision Details
JUN.1999	BFP-A8006-*	First print
NOV.2000	BFP-A8006-*	Error in writing correction
OCT.2002	BFP-A8006-B	Error in writing correction
JAN.2004	BFP-A8006-C	Error in writing correction
MAY.2004	BFP-A8006-D	Robot System Safety Precautions was added.

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1. Preface

Nowadays, industrial robots have been widely introduced to many production lines and are estimated to increase more and more in the future. This is owing to many merits of industrial robots that conventional machines don't possess. Industrial robots, in place of human, can do elaborate jobs without saying. They can also continue to work in hazardous conditions for human without taking a rest.

On the contrary, industrial robots could act peculiar hazards against human if sufficient precautions were not provided. Industrial robots may give rise to hazards of injuring operators or damaging equipment.

We who have given created them must do our best to make them work safely to prevent such accidents. However, after they are shipped, safeguarding measures must be taken by the system integrators and/or the end users as well. This manual is intended to give general precautions and safeguarding to secure safety of all persons who are involved in the robots. Before introduction, installation, arrangement and so on of the robots, please read through this manual as well as the operation manual of the robot itself to be able to operate them safely and efficiently.

The fundamental idea of this manual bases on the following 'EC directive', 'International standard', and 'European norm', provisions of which are cited frequently through this manual. Refer to these documents if necessary.

- Machine directive : 89/392/EEC, 91/368/EEC
- ISO 10218 (1992) : Manipulating industrial robots - Safety
- EC 775 (1992) BS7228 Part6 (1992) : Recommendations for safety

Applicable Models

This manual is targeted for the following model series.

- A Series
- T Series

2. Fundamental concept of safety measures

This section explains the fundamental concept of safety that should be understood by all persons who use robots.

2.1 Purpose, application

We have developed industrial robots to contribute to economic activities, human health and safety by improving productivity, flexibility, and quality of manufacturing industry, as well as by securing safety in hazardous operation.

Therefore, we request users to understand our intention and never to make use of robots for purpose against above intention.

Typical applications of robots in manufacturing industry have included, for example, parts assembling, testing, machining, loading and unloading palletizing, sealer dispensing, painting, soldering brazing and deburring. In other applications such as education, and even amusements, robots are now being used.

However, applications of robots will not be limited to those above. If you make a use of a robot in a new application, particular attention should be paid in order to assess the risks on your own responsibility, because a different application may involve different hazards and different levels of risks. (e.g. handling of explosive or flammable material, harmful laser light beam, radioactive ray, poisonous chemicals, and biologically harmful microbe.)

2.2 Operating environments

The operating environments of a robot can affect its lifetime, function, performance, and safety. If the operating environments of a robot do not satisfy the following conditions, appropriate means should be taken to prevent the robot from being exposed to such undesirable conditions.

(1) Power supply

- (a) The line voltage must be within $\pm 10\%$ of the rating.
- (b) The duration period of an instantaneous power failure must be within 15 milliseconds.
- (c) The power supply must provide enough electricity needed at the maximum consumption.

–Recommendation

a larger transformer ; a stabilized power supply ; an UPS

(2) Electromagnetic noise

- (a) The surge voltage applied to a line must be less than 1000V, and its duration period must be within 1 μ s.
- (b) The robot must be isolated from a large-sized inverter, a high-frequency oscillator, a large-sized contactor, and a welding machine, where intense electromagnetic is generated.

–Recommendation

a noise-cut transformer ; a noise filter; reinforcement of ground lines and electromagnetic shields ; isolation by keeping away from noise sources ; reduction of noise level of emission.

(3) Static electricity

- (a) Where static electricity exceeding 4kV could be directly applied on the robot body or controller. Or where static electricity exceeding 8kV could be applied through airborne electrical discharge.

–Recommendation

prevention from storing static electricity ; discharging of static electricity

(4) Temperature, humidity

(a) The ambient temperature must be within the rated range. (between 0°C and 45°C for M series, between 0°C and 40°C for E series)

(b) The robot must be kept away from direct sunlight and any heat source.

(c) The relative humidity must be within the rated range. (between 45% and 85%, non-condensing)

–Recommendation

a local heating or cooling equipment ; a heat-resistant jacket ; isolation by keeping away from a heat source ;

NOTE: Countermeasure is needed against static electricity in low humidity and dewdrop in high humidity.

(5) Atmosphere

(a) No dust, no oil mist, and no corrosive gas must be contained in the atmosphere.

(b) No metal shavings and conductive material must be scattered.

(c) No combustible and explosive gas must be contained in the atmosphere.

–Recommendation

The oil mist proof types are recommended. Use the dust or an oil mist resistant jacket.

NOTE: Never use robots in a combustible or explosive atmosphere.

Install the controller in a shielded enclosure if used in a bad atmosphere, as the controller itself has openings for cooling.

(6) Liquid

(a) Water and other liquid must not splash a robot and a controller directly.

(b) Any portion of a robot and a controller must not be dipped in water and other liquid.

(7) Vibration

(a) The vibration and shock must be 3.5G at maximum during transportation.

(b) The vibration and shock must be 0.5G at maximum during normal use.

–Recommendation

Enforcement of rigid packing and shock absorbing.

(8) Radioactive ray

(a) The radioactive ray must not be more than a permitted level of ordinary person.

–Recommendation

isolation from and of a radioactive source

(9) Air pressure

(a) The height above sea level should not be more than 1000m. The robot can not work in vacuum.

–Recommendation

giving pressure to reach to 1 atmosphere

2.3 Safeguarding

2.3.1 Prevention of hazards in automatic operation

If the operation of an industrial robot can give rise to hazards of impact, trapping, or flying objects released by the gripper, methods for protection of person(s) must be taken using fixed guards or fences. (see figure 1) It is obvious that if an operator does not enter into a safeguarded space, no hazard of impact nor trapping will occur. Therefore, the separation of any person from any robot by creating a safeguarded space and a restricted space is one of the fundamental principles of safeguarding.

In other words, the principle prohibits a person from entering the safeguarded space during automatic operation. Further, the interlock must be installed so that the guard remains locked closed or opening the guard gives a stop instruction during automatic operation.

In addition to a guard and a fence, a presence sensing device that detects any intrusion into a space, or awareness means that provides a signal to persons of an approaching or present hazard may be used.

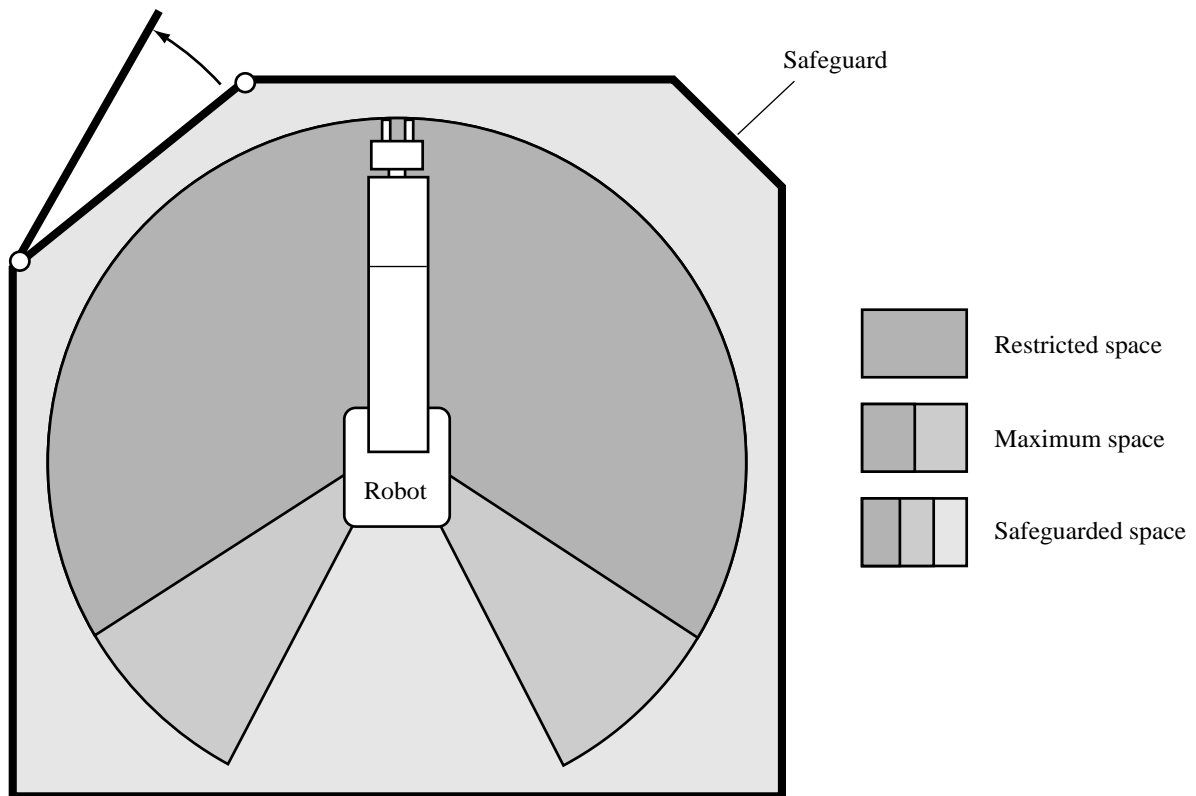


Fig. 1 Example of restricted space and safeguarded space

Definitions in above figure

- Limit region : Max. region limited with mechanical stoppers, etc.
- Max. region : Max. movement region of robot, including hand installed on end, etc.
- Safety protection region : Region protected with safety fence, including limit region

2.3.2 Safeguarding in programming

Some maintenance and programming personal are at times required to be within the restricted space while power is available to the machine actuators for teaching, program verification, maintenance, and trouble shooting.

On the other hand, it is recognized that operational characteristics of robots can be significantly different from those of other machines and equipment. Robots are capable of high energy movements through a large volume beyond the base of robots. The pattern and initiation of movement of the robot arm are difficult to predict and can vary because of variables in product and environmental conditions.

Therefore, the elimination of hazards or at least their reduction must be carried out during interventions in the safeguarded space while power is available to the machine actuators. Accordingly, a design of the robot system such as to allow the maximum number of tasks to be performed from outside the safeguarded space must be involved. However, if some task requires personnel to be within the safeguarded space, provision of compensatory means of safety must be taken instead of suspending safeguards.

If several robots are installed in a safeguarded space to constitute a certain system, each robot and device must be designed and installed so that each can be controlled independently.

An example of an interference mistake by the robot and peripheral device such as the workpiece, which may occur easily during teaching, is shown for reference in Fig. 2. Here, (A) is interference during movement with joint interpolation, (B) is interference caused by an incorrectly set movement destination position No., and (C) is interference caused by an incorrect hand grip open/close setting.

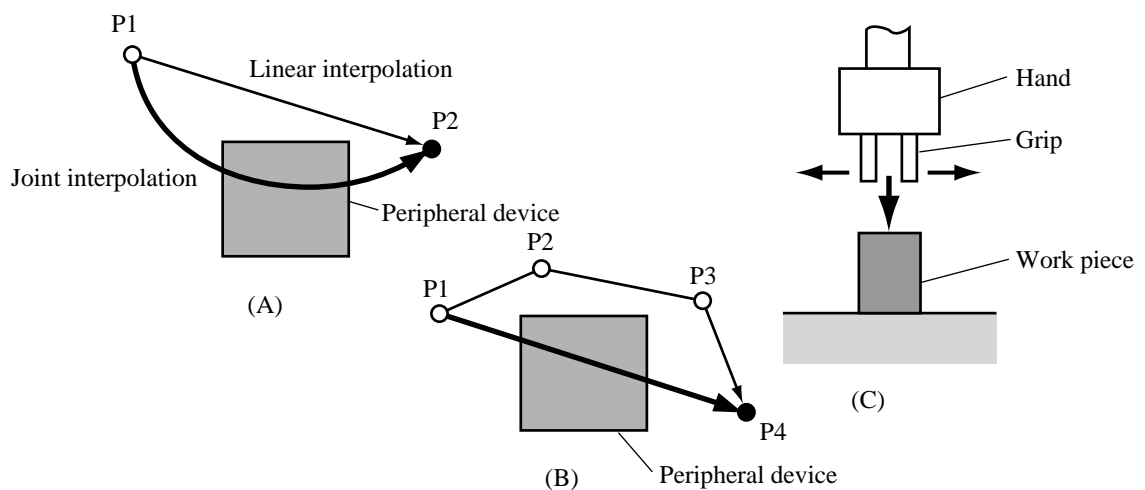


Fig.2 Example of work mistake during teaching

2.3.3 Safeguarding in maintenance and trouble shooting

When entering the safeguarded space for inspection, repair, cleaning, and maintenance, be sure to stop the robot and shut down the power supply with placing a lock and/or tag on the energy isolating device to prevent unwilling operation. When an intervention within the safeguarded space while power is available to the the robot is required, appropriate safe working procedures must be used to prevent a sudden motion of a robot and a careless operation of peron.

2.3.4 Verification of safety before starting operation

Prior to the use in nomal operation, ensure the proper operation of the robot and the robot system. If any damage or malfunction that may lead to an accident is found, required corrections must be completed and retesting must be performed.

Be sure that all system emergency stop devices remain functional.

3. Safety considerations in each operation

This section refers to the general precautions in each operation from unpacking to trouble shooting of robot system. Prior to the actual use of a robot, be sure to read relating items in the attached operation manual together with this safety manual.

3.1 Unpacking

- (1) The robot and the controller are packed separately in a corrugated cardboard for shipment. Be sure to obey the unpacking procedure indicated outside the corrugated cardboard.
- (2) When taking the robot out of shock absorbers, never hold resin covers. If you hold these covers, they may be damaged.
- (3) Keep the used corrugated cardboards and the used shock adsorbers for the secondary transportation in future.

3.2 Carrying

- (1) Confirm the weight on the rated nameplate before transporting the robot arm.
- (2) If the robot arm weighs 30kg or less, two workers must carry the robot while holding the unit at the bottom. If transportation handles are provided, use these handles when transporting. Always leave the robot arm arm fixing plate installed during the transportation work.
- (3) When transporting the robot arm, prepare even-length wires that can sufficiently withstand the robot weight. Pass these wires through the designated eye bolts, and suspend the robot with a crane. Always leave the robot arm arm fixing plate installed during the transportation work.
- (4) When putting the robot or the controller on an installing base or a pushcart, don't apply an excessive shock and an excessive vibration to the robot and the controller.
- (5) When transporting the robot after installed, be sure to release brakes of the robot arm and from the pose the same as the shipping pose. Don't carry or transport the robot with its arm extended.
- (6) When putting the robot on an installing base temporarily, fix the robot with one or more bolts to prevent from falling down.
- (7) When transporting the open cooling structure controller, as a general rule, two workers must insert their hands into the clearance at the bottom from the front side and back side. Make sure that excessive force is not applied on the switches, terminal block, connectors, or heat radiating fin, etc.
- (8) Many resin covers are used on the exterior surface of the robot. Never hold these parts and never apply forces to them. If you carry the the robot by holding these covers, that may cause hazards of damaging covers and eventually dropping the robot.
- (9) Before transporting the robot, the arm fixing plate must be installed.

3.3 Preparation of installation and operation

3.3.1 Robot arm, controller and control panel

- (1) When installing the robot arm, secure the area required for the work based on the layout design beforehand. At the same time, provide a sufficient clearance so that the robot's movable sections and periphery do not catch or collide. If the robot requires the origin to be set, make sure that there is no interference with the periphery in the origin setting posture.

- (2) If the limitation of range of motion is required by the plan, please consult with us in advance. Only the range of J1 axis can be limited at some fixed points. Alternative method of limiting the range of motion may be provided only if they are designed, constructed, and installed to achieve the same level of safety as the mechanical stops. This may include using the limit switches according to IEC 204-1.
- (3) Install the controller and control panel starting device where the entry of operators in the safety protection region (inside the safety fence) can be confirmed from the operator control position.
- (4) If the working areas of robots overlap each other, provide interlock functions to prevent the robots from simultaneously entering their common area. (position detecting switches, etc.)
- (5) When the safeguarding methods are not in place prior to commissioning and functional testing, interim means of designating the restricted space must be in place before proceeding.
- (6) When it is intended that operators will perform manual operations associated with the robot, such as loading and unloading of parts, this must be taken into account in the arrangement of the robot system, either by providing loading devices so that the operator cannot access the hazardous area, or by providing appropriate safeguards for the manual activity.
- (7) Securely fasten the robot to the specified installing surface with four fastening bolts being careful to prevent deviation of the position. The installing base requires enough stiffness to withstand the weight of the robot and the reaction force.
- (8) Remove the arm fixing plate before operating the robot.
- (9) When using ceiling suspension or wall hanging installation methods, a jig allowing use of a standard lift, etc., is available from Mitsubishi. Please consult with your dealer for more information.
- (10) Install the controller outside the safety protection region (outside the safety fence). Install the controller's operation panel so that the operator can monitor the robot without facing his/her back to the robot, and at a height where the panel can be operated easily. (For maintenance workability, set the operation panel height at 0.6m or more.)
- (11) Install the controller on a level surface. Be sure not to prevent the heat fin from radiating heat and the fan from ventilating hot air. The ambient temperature of the controller must be within the rated range.
- (12) If the controller must be fixed to prevent dropping or movement, etc. from external vibration, always fix on the base surface. (Do not remove the rubber legs.)
- (13) When installing the robot, the controller and the peripheral equipment, take means of access into account to allow access in safety to all areas used for production, adjustment and maintenance operations.
- (14) Do not get on or hang from the robot.
- (15) Do not get on or place heavy objects on the controller.
- (16) Make sure that foreign matter does not enter the robot arm or controller. Entry of conductive matter such as screws or metal pieces, or the entry of flammable matter such as oil could lead to ruptures or damage, etc.

3.3.2 Cables

- (1) Tighten the connectors of the cables between the robot and the controller according to the instructions of the manual.
- (2) Don't pull or bend the cables with force. Protect the cables with ducts or covers if necessary.
- (3) When installing ducts or covers, means should be taken to prevent persons from stumbling, and caution signs should be indicated necessary.
- (4) Keep the robot machine cables and the external I/O cable away from other cables such as power cables and earth lines. Be sure that the external I/O cable is shielded.
- (5) Do not mistake the terminal connections. Failure to observe this could lead to ruptures or damage, etc.
- (6) Do not mistake the polarity (+, -). Failure to observe this could lead to ruptures or damage, etc.
- (7) When moving the robot on a slide rail, never use standard machine cables of the robot due to the poor resistance against bending. In this case, be sure to use flexible machine cables of the robot prepared as options.

- (8) Before connecting the power source line, be sure that the voltage of the power is within the rated range and the power switch of the controller is off. Then connect it to the correct portion.
- (9) Do not connect or disconnect the cables or connectors while the power is ON.

3.3.3 Hands

- (1) When using the optional motor-operated hand or the pneumatic hand, follow the instructions of the manual. Be sure that the total weight including workpieces is within the rated load.
- (2) If necessary, attach the specially machined picking tool to the end of the hand according to the shape of workpieces. Be sure that the tool has no sharp edges nor projections except functionally necessary portions.
- (3) When fixing a customer-made hand, be sure that the total weight including workpieces is within the rated load. Especially, when fixing an unbalanced hand, the rated torque of the wrist axes should also be taken into account.
- (4) When attaching a customer-made hand to the flange of the robot, fix it securely with specified bolts. Be sure that the hand has no sharp edges nor projections except functionally necessary portions, and provide covers and other protections as necessary.
- (5) If cables and hoses are connected to the hand, prevent cables and hoses from getting twisted round or damaged and from restricting the motion of the robot.
- (6) When using a pneumatic hand, supply clean air which pressure is within $0.7\text{MPa}\{7\text{kgf/cm}^2\}$ as the pressure higher than this may lead to a breakage of the internal pneumatic pipe in the robot arm.
- (7) If there is the possibility of a hand releasing a workpiece during motion thus causing a hazardous condition, necessary means should be taken for the gripping mechanism of the hand to prevent such hazards.
- (8) The hand must be designed and constructed so that power failure does not cause release of the load or result in a hazardous condition. To keep the opening or closing state of a pneumatic hand even when the electric power fails, make use of a double solenoid to control the hand.
- (9) Grasping a workpiece charged with static electricity could cause malfunctioning due to electrical-discharge through the hand and robot arm. Thus, always use an insulated structure for the hand and robot arm. When a charged workpiece is placed, the device on which it is placed could malfunction due to the electrical-discharge. Always structure the system so that the charged workpiece's charge is discharged with an appropriate electrical-discharge route.
- (10) Power for the confirmation sensor is supplied to the hand check cable enclosed with the robot (or optional). If the cable end cannot be treated sufficiently due to this, the end could contact the peripheral device or robot arm while the power is turned ON, and could lead to short circuit accidents. Thus, always treat the end when using the hand check cable.

3.3.4 Teaching pendant

- (1) Tighten the connector of the teaching pendant cable. Don't pull or bend the cable with force.
- (2) Determine the area where the teaching pendant is stored, and prevent the pendant from being carelessly dropped thus causing malfunction or damage.

3.3.5 Grounding

- (1) Be sure to ground the robot and the controller electrically according to the instructions of the manual. The grounding is indispensable to prevent electric shock, to reduce electrostatic charges, to improve electric noise resistance, and to reduce electromagnetic interference.
- (2) Use a wire of more than 2 mm² in cross section, and make its length as short as possible.
- (3) The robot and the controller should be grounded separately. Keep the ground points away from those of other large electric equipment.

3.3.6 Emergency stop

- (1) Install the manual emergency stop switch near the robot where it can be operated easily. Connect it to the external emergency stop terminal on the controller. (Always close B type contact, provided with a mechanical lock function. Complaint with IEC204-1 specifications.) When there are multiple installation places, install multiple switches. Refer to the instruction manual for the electrical specifications.
- (2) Install a switch on the safety protection devices, such as the safety fence door. Provide an interlock mechanism so that the robot will enter the emergency stop state if the switch is activated. (Example : The emergency stop state is entered when the safety fence door is opened during robot operation.)
- (3) In the case of the complex robot system designed to work together, emergency stop devices should stop not only the robot itself but also all relating equipment if its continued operation can be dangerous. In this case, for example, an emergency switch that has more than one contacts is desirable.

3.3.7 Safety stop

- (1) Install the stop switch near the robot where it can be operated easily. Connect it to the external input/output terminal on the controller. When there are multiple installation places, install multiple switches. Refer to the instruction manual for the electrical specifications.
- (2) Do not install the stop switch on the safety protection devices, such as the safety fence door. Install an emergency stop switch on the safety protection device.
- (3) Do not enter the safety protection region (inside the safety fence) in the stopped state.

3.3.8 Indicators

- (1) Pertinent information should be provided such as clearly indicating robot working modes and displaying the reason for unprogrammed robot stop. For this purpose, use the dedicated I/O bits of the controller. (e.g. run, wait, reset, error)
- (2) Where the risk may arise by a fault in the operation of unsupervised machinery, the machine must be equipped to give an appropriate acoustic or light signal as a warning.

3.3.9 Isolation of power sources

- (1) Each robot system must have means to isolate each of its power sources by manual operation.
- (2) Isolation must be either visible (visible interruption of continuity in the power supply) or visibly ensured by permitting a check of the position of the operating control on the isolating unit, and it must be made clear which areas of the machine are isolated.
- (3) If necessary, means should be taken to lock the isolation device in the 'OFF' or 'OPEN' position to prevent careless operation.
- (4) When the power is shut down, the hand drops down more or less by itself because no brakes are installed in the wrist axes. If this may lead to a hazardous condition, the attitude of the wrist should turn down beforehand or the power should be shut down timely to prevent from hazardous condition.
- (5) When the power to the robot is shut off, the hand, etc., may drop slightly from the time that the power is shut off to when the brakes activate. If there is any risk of interference, etc., with the peripheral devices, set the robot to a posture where a hazardous state will not be created before shutting off the power.

3.3.10 Applying power

- (1) Before turning on the power supply, check that there is no person within the safeguarded space and that tools and other pieces are not left there.
- (2) Verify that the cables, hoses, and connectors are not damaged nor disconnected nor loose.
- (3) Verify that the workpiece and the peripheral equipment are positioned as specified. Also verify that applying power to peripheral equipment does not result in hazardous motion.
- (4) If some sequence in applying power to peripheral equipment may cause a hazardous condition, obey the safety sequence specified in advance. (The situation is the same as in the power shut down.)
- (5) After applying power, be sure to verify that emergency stop devices and other safeguards are functional.
- (6) Verify that each axis of the robot moves functionally by job operation and is restricted in motion as intended.
- (7) Do not open the cover or door of controller, after turning on the power supply.

3.4 Teaching and programming

- (1) Wherever possible, programming must be performed with all persons outside the safeguarded space. When it is necessary to perform programming with personal in side the safeguarded space, safe working procedures must be provided and observed. This includes the following items.
 - (a) Operation method and procedure, including authorization of operator and suspension procedure of safeguards
 - (b) Speed of jog operation (Automatic operation is for bidden.)
 - (c) Signaling method for several workers
 - (d) Measure for emergency
 - (e) Measure to prevent malfunction
- (2) Where the automatic operation can be initiated by the teaching pendant, never select the automatic mode in the safeguarded space.
- (3) When teaching inside the safety protection area (inside the safety fence), always secure the priority right for the robot control. (Always set the controller mode switch to "Teach", and set the teaching pendant "Enable/Disable" switch to "Enable".) Failure to so do could cause a very dangerous state as the robot could start with external commands.
- (4) The controller mode changeover switch has a key. When teaching, remove the key so that no one other than the teacher can change the mode.
- (5) Movement of other equipment in the safeguarded space which can present a hazard must either be prevented or under the sole control of the programmer.

When under control of the programmer, it must require deliberate action on the part of the programmer separate from the action to initiate robot motion.
- (6) Suppress any device movement that could cause a hazard in the safety protection area (inside the safety fence), or make sure that only the teaching operator can control the device.
- (7) Assign a monitor during the teaching work so that the robot operation can be stopped immediately if any abnormality occurs. Make sure that the operators, other than the teaching operator, inside the safety protection area (inside the safety fence) have a portable emergency stop switch.
- (8) Maintain sufficient illumination to produce an easy-to-work environment for the operstors.
- (9) Be sure to mark the operators to wear proper clothing, safety shoes and helmets.
- (10) As an emergency countermeasure during teaching, don't face your back toward the robot, and be sure to maintain a passage to shelter.
- (11) The programmer must return the suspended safeguards to their original effectiveness prior to initiating automatic operation of the robot system.
- (12) After completing the teaching work, validate and safety protection devices that were temporarily invalidated, and recovery the original function. (Example : Validate the door interlock of the safety fence, etc.)

3.5 Program verification

- (1) After teaching and programming, always confirm the operation with step operation before starting automatic operation.
- (2) When confirming the operation inside the safety protection area (inside the safety fence), follow the predetermined work procedures in the same manner as the teaching work.
- (3) When a peripheral device is to start in synchronization with the I/O signal from the robot during the confirmation, take special care to the operation. As with teaching operation, suppress any device movement that could cause a hazard in the safety protection area (inside the safety fence), or make sure that only the operator can control the device.
- (4) When starting a program in the middle, be sure to avoid collision between the robot and the peripheral equipment.
- (5) If a program is long-sized and intricate, print out the content of the program and examine it in advance. Sufficient understanding is required before verifying such a program.

3.6 Automatic operation

- (1) Before initiating the automatic operation, ensure that there are no exposed persons in the safeguarded space. If it is impossible, the control system must be designed and constructed so that an acoustic and/or visual warning signal is given whenever the machinery is about to start. The exposed person must have the time and the means to take rapid action to prevent the machinery from starting up. (e.g. installation of the emergency switches inside the safeguarded space)
- (2) Before initiating the automatic operation, ensure that all peripheral equipment is functional and there is no signals indicating malfunction.
- (3) Always start automatic operation outside the safety protection area (outside the safety fence). Even when resuming operation by resetting after stopping the robot with emergency stop, etc., during automatic operation, always start outside the safety protection area (outside the safety fence).
- (4) Before starting automatic operation, always confirm that the work details and selected program match. Use low-speed operation, when possible, until the first cycle ends. (Use the speed override change function.)
- (5) If any abnormality is observed in the robot or peripheral devices, stop the operation immediately. Note that if a new risk is posed due to the position where the robot is stopped, etc., take care to the timing for stopping the robot.
- (6) If the robot stops due to an unknown cause during automatic operation, avoid approaching the stopped robot. When the robot must be approached, input the emergency stop, or turn the main power off first. When turning the main power off, make sure that there will be no new risk caused.
- (7) When halting and resuming the program during automatic operation, make sure that there will be no new risk with the peripheral device when the program is started. (Adequacy of work start position, necessity of peripheral device initialization, etc.)
- (8) When the modification of the program is done during the suspension, be sure to verify the program at least one time before initiating the automatic operation.
- (9) When selecting a different operation speed with the speed override change function during automatic operation, make sure that there will be no new risk caused. (Risk from speed that is too fast, or too slow)
- (10) If a held workpiece or other object may fly out and cause a hazard by the centrifugal force during automatic operation or by the impact force of an emergency stop, suitable means must be taken to prevent such hazard.
- (11) When an emergency stop device is activated or the power is shut down, the hand drops down more or less by itself because no brakes are installed in the wrist axes. Also, when speed of the robot is fast, even the axis with a brake may not stop immediately because of its remaining power of speed. Prevent the hand from conflicting with peripheral equipment.

- (12) If the robot collides with a workpiece or the peripheral equipment at high speed due to e.g. a program error, then the workpiece, the peripheral equipment, the robot arm, and the reduction system of the robot may be considerably damaged. To avoid the hazardous condition caused by the collision, particular attention should be paid to assess the risks.

3.7 Maintenance

- (1) Where possible, maintenance of the robot and peripheral equipment should be performed from outside the safeguarded space.
- (2) When operations from outside the safety protection area (outside the safety fence) are not possible and the fence must be entered, as a general rule, turn the power off first. At this time, make sure that no new risk will be caused by turning the power off.
- (3) When work must be carried out inside the safety protection area (inside the safety fence) without turning the power off, always secure the priority right for the robot control. (Always set the controller mode switch to "Teach", and set the teaching pendant "Enable/Disable" switch to "Enable".) Failure to do so could cause a very dangerous state as the robot could start with external commands.
- (4) If the stored energy may cause a hazardous condition after shutting down the power, means must be provided for the controlled release of stored energy.
This energy source may be in the form of (but not limited to) fluid pressure accumulators, capacitors, springs, counter balances, and flywheels.
Appropriate label must be affixed to each stored energy source.
- (5) Do not open the controller door or cover immediately after turning the power off. Wait for the time given in the controller and instruction manual before opening the door or cover.
- (6) Be sure to place working notices on the power supply and start switches to prevent a third person from operating them carelessly. If necessary, provide a watchman to operate the emergency stop device immediately when the robot operators unexpectedly.
- (7) Securely carry out daily and periodic inspections referring to the operation manual. Regarding to the maintenance of the robot system, observe the inspection and maintenance program of the robot system manufacturer. If a skilled operation is needed for the robot itself, consult with our service shop.
- (8) When maintaining the controller, check the normal operation of the internal cooling fan by e.g. examining the air flow.
- (9) When the brakes are released, the robot will drop with its own weight, so make sure that there are no operators in the robot's movable range. If there is any risk of interference, etc., with the peripheral devices, set the robot to a posture where a hazardous state will not be created before releasing the brakes.
- (10) A small amount of lubricating grease may ooze out of the robot arm. If the surrounding environment could be contaminated from this grease dropping, check for grease oozing during the periodic inspection. If any grease is oozing out, wipe it off before it contaminates the surrounding environment.
- (11) For maintenance, provide a sufficient space of working and sufficient illumination to produce an easy-to-work environment for operators.
- (12) Don't modify the robot or use any unspecified parts. Be sure to prevent modifying any safety devices.
- (13) When turning on the power after completing the maintenance, ensure that the restoration of the power does not result in hazardous condition.
- (14) After completing the maintenance, the suspended safeguards must be returned to their original effectiveness.
(e.g. interlocking guards must be functional.)
- (15) Do not carry out a megger test (insulation resistance test) during the inspections.
- (16) Do not short-circuit, charge, heat, incinerate or disassemble the battery.

3.8 Trouble shooting

- (1) As with maintenance, consider whether the priority of the work can be set as (1) work outside the safety protection region (outside the safety fence), (2) work inside the safety protection region (inside the safety fence) with the power turned off, (3) work inside the safety protection region (inside the safety fence) with automatic operation canceled. If work must be carried out inside the safety protection region (inside the safety fence) always set the controller mode switch to "Teach" and set the teaching pendant "Enable/Disable" switch to "Enable".
- (2) Be sure to place working notices on the power supply and start switches to prevent a third person from operating them carelessly. If necessary, provide a watchman to operate the emergency stop device immediately when the robot operates unexpectedly.
- (3) If an alarm occurs on the robot, first check the alarm number or error mode which is useful for trouble shooting. Record this information and refer to the corresponding pages of the manual.
- (4) If the content of trouble shooting exceeds the range of the user, consult with our service shop as far as the robot is concerned with the trouble.

3.9 Modifications

- (1) Avoid modifications based on user-judgements, and use of maintenance parts other than those designated. Never modify the sections related to safety, such as the emergency stop.
- (2) Faults caused by modifications made by the user will not be covered by the warranty.

3.10 Disposal

- (1) Treat this unit as general industrial waste.
- (2) Do not disassemble the parts.
- (3) Dispose of batteries according to local laws.
- (4) Contact the Mitsubishi Service Dept. for collection of used grease. Disposal of used grease by the user will pollute the environment.

4.Safeguarding

Safeguarding includes the use of safeguards such as interlocking guards, awareness means in addition to the safeguards, and safe working procedures to reduce the possibility of injury while performing an assigned task. Here, the guidance on safeguards and awareness means are provided for customers to check their safeguarding.

4.1 Safeguard

- (1) Fixed guards must be installed outside the maximum space of the robot.
- (2) Fixed guards must be constructed to withstand foreseeable operational and environmental forces.
- (3) Set the fixed guard to prevent entry into the safety protection region (inside the safety fence) from entrances other than those provided with an interlock device or presence detection device. (So that an operator cannot climb over, go under or get over the fence.)
- (4) Fixed guards must be permanently fixed in position and only be removable with the aid of a tool.
- (5) Fixed guards must be free of sharp edges and projections and must not themselves be a hazard.
- (6) The interlocking guards should be designed so that interlock prevents the robot system from automatic operation until the guard is closed. The closure of the guard is a deliberate action at the control station.
- (7) The interlocking guard with guard locking should be designed so that the guard remains locked closed until the risk of injury from the hazard has passed or that opening the guard while the robot system is working gives a stop or emergency stop instruction. Where the hazard cannot be eliminated immediately by power interruption, the interlocking system must need to include a guard locking and/or a braking system.
- (8) When the operator's entire body can enter the safety protection region (inside the safety fence) from the door with interlock, install a device so that the door cannot be closed unintentionally.
- (9) The interruption, re-establishment after an interruption of fluctuation in whatever manner of the power supply to the safeguards must not lead to a dangerous situation.
- (10) Guards and protection devices must cause minimum obstruction to the view of the production process.
- (11) Guards and protection devices must enable essential work to be carried out on installation and/or replacement of tools and also for maintenance by restricting access only to the area where the work has to be done, if possible without the guard or protection device having to be dismantled.
- (12) Reestablishing the interlocked gate or presence sensing device field must not in itself restart automatic operation.
- (13) a presence sensing device must be installed and arranged so that persons cannot enter and reach into a hazardous area without activating the device or cannot reach the restricted space before the hazardous conditions have ceased.
- (14) Barriers used in conjunction with the presence sensing device may be required to prevent persons from bypassing the device.
- (15) The operation of presence sensing device must not be adversely affected by any of the environmental conditions for which the system was intended.
- (16) Resumption of robot motion must require the removal of the sensing field interruption. This must not be the control to restart automatic operation.
- (17) Where laser ray equipment or other harmful ray equipment is used, guards and protection devices must prevent any accidental radiation as well as reflection and diffusion that may damage health.

4.2 Awareness means

- (1) An awareness barrier must be constructed and installed so as to prevent inadvertent entry into the restricted space.
- (2) An awareness signal device must be constructed and located such that it must provide a recognizable audible or visual to persons of an approaching or present hazard.
- (3) When awareness signals in the form of light are used to warn of hazards in the restricted space, sufficient devices must be used and located so that the lights can be seen by all persons in the proximity of the space.
- (4) Audible awareness devices must have a distinctive sound of greater intensity than the ambient noise level.

5. System documentation

The robot system documentation to be supplied by the robot system manufacturer shall contain the documents of all the components included in the system with their identification *e.g. robot, associated equipment, safeguards(. It shall also as a minimum include the following:

- (1) a clear, comprehensive description of the robot system and its installation including mounting and connection to external power sources;
- (2) a description of foreseeable hazardous conditions and how to avoid them;
- (3) a description *including interconnecting diagrams(of the safeguards, interacting function, and interlocking of guards with hazardous conditions particularly with interacting installation;
- (4) any further instructions for use specific to the system.

6. Training

Personnel who perform maintenance or repairs on robot or robot systems must be trained in the procedures necessary to perform safely the required tasks.




Therefore, the user must have an inspection and maintenance program and ensure those personnel are adequately trained and demonstrate competence to perform their include, but is not limited to, the following:

- (1) a review of applicable standard safety procedures and the safety recommendations of the robot manufacturer(s) and the robot system designers;
- (2) a clear definition of assigned tasks and responsibility of each person;
- (3) identification and explanation of all control devices and their functions used in performing the assigned task;
- (4) identification of the hazards associated with the assigned task;
- (5) the designated method(s) of safeguarding including the safe working procedures from the identified hazards;
- (6) the method for testing or otherwise ensuring the proper functioning of the safeguards and interlocks.

7. Degree of danger and damage, and indications

Warning labels, corresponding to the degree of danger and damage (refer to Table 2) are attached to the robot arm and controller. Fully understand the meaning of the warning label, and take special care when handling. Do not remove, modify or contaminate the warning labels.

Table 2 Degree of danger and damage, and indications

Level	Degree of danger and damage	Caution prompting symbol and signal term
DANGER	When there is a great risk that the operator could be subject to fatalities or serious injuries ⁽¹⁾ if handling is mistaken.	 DANGER
WARNING	When the operator could be subject to fatalities or serious injuries ⁽¹⁾ if handling is mistaken.	 WARNING
CAUTION	When the operator could be subject to injuries ⁽²⁾ or when only physical damage ⁽³⁾ could occur if handling is mistaken.	 CAUTION

Note (1) Serious injury refers to injuries with after effects such as blindness, injury, burns (high temperature, low temperature), electric shocks, bone fracture, and poisoning, and to injuries requiring hospitalization or long-term medical treatment.

Note (2) Injury refers to injuries, burns and electric shocks that do not require hospitalization or long-term treatment.

Note (3) Physical damage refers to extended damage to buildings, peripheral devices or workpieces.

A. Examples of safety protection device configuration

A-1. Safety protection device configuration methods

A-1-1. Stop functions

The following three methods are available for the stopping methods, a basic means of safety protection.

Emergency stop	The robot's drive power is directly shut off and the robot immediately stopped by the relay wire circuit "opening" operation (B contact) without passing through software or IC (Integrated Circuit.) An excessive force may be applied on the robot during high-speed operation.
Deadman stop	If the Enable/Disable switch on the teaching box is set to Enable, when the switch is released, the robot's drive power is directly shut off and the robot immediately stopped by the relay wire circuit "opening" operation (B contact) without passing through software or IC (Integrated Circuit.) An excessive force may be applied on the robot during high-speed operation.
Servo OFF	The input signal is judged by the software, the motor power is shut off, and the motor stopped. During operation, the motor will decelerate to a stop before the servo is turned OFF, so it may take some time before the stopping is completed.

The other stop functions(emergency stop, temporary stop, etc.) are used to judge the input signal by the software and stop the operation. These are used to confirm the operation status, etc., but since the power is not shut off, these do not act as stop functions for safety protection.

A-1-2. Safety protection functions

Safety speed limiter	This sets the high-speed operation speed with the operation panel, etc. This function limits the speed to a safe speed.
Exclusive starting control	This prohibits the start command from a source other than the device being used.

The following functions can be used for the safety protection devices.

The following functions are also available as safety protection assembled in the product. These functions are already assembled in the teaching box, and will function as safety protection functions without special consideration.

- (1) Hold to run This function starts operation only when the key, etc., is pressed. Operation stops when released.
- (2) Double key pressing This function validates the commands only when two keys are pressed simultaneously.

A-1-3. Safety protection measures

Measures for safety protection using the above stop functions and safety protection functions are indicated below, together with the correspondence to Occupational Safety and Health Laws.

Measure A : Servo OFF

Measure B : State in which emergency stop can be applied immediately (teaching pendant emergency stop, emergency stop switch inside fence, etc.)

Measure C : Safety speed limiter, exclusive starting control (teaching pendant enable, manual mode, etc.)

Movable range	Operation status	Drive source shut off	Measures	Corresponding Provisions
Outside	During automatic operation	Not shut off	Signaling of operation start Provision of fences and enclosures	Article 104 Article 150, Clause 4
Inside	During teaching, etc.	Shut off Measure A	Indication that work is in progress	Article 150, Clause 3.
		Not shut off	Measures to stop operation immediately, etc. Measure B and Measure C	Article 150, Clause 3, etc.
	During inspections, etc.	Shut off Measure A	Indication that work is in progress with operation stopped, etc. Indication that work is in progress	Article 150, Clause 5.
		Not shut off	Measures to stop operation immediately, etc. Measure B and Measure C?	Article 150, Clause 5, etc.

A-2. Examples of safety protection device configuration

An example of the safety protection device configuration is shown below.

Example of safety protection device configuration

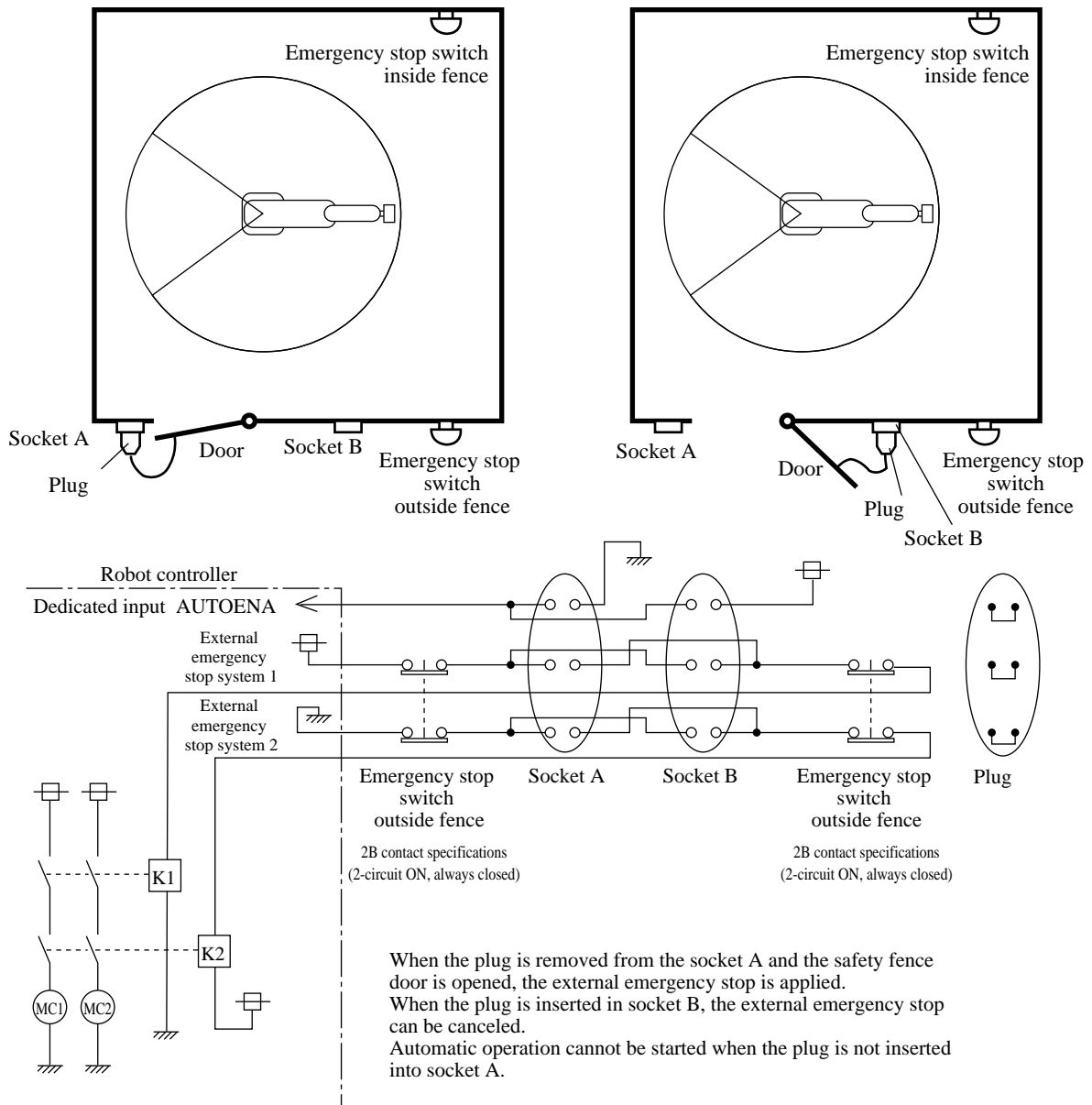


Fig. A-1 Example of safety measures

Although not indicated in the drawing, confirmation signals are prepared for each function in the signals output from the robot, such as the "In emergency stop" that is output when an emergency stop is applied. Create a safe configuration by providing interlocks and displays with these signals.

Input signals that are used for recovery after the safety protection device functions and the power is shut off are prepared. These include the "alarm reset" input signal and "servo ON" input signal. By considering the recovery method beforehand, the robot can be operated efficiently.

