

JIS

JAPANESE INDUSTRIAL STANDARD

**Industrial robots —
Electrical equipment**

JIS B 8438—1991

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In the event of any doubt arising,
the original Standard in Japanese is to be final authority.

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Industrial robots - Electrical equipment

B 8438-1991

1. Scope

This Japanese Industrial Standard specifies electrical equipment for industrial robots of power supply voltage not exceeding 600 V a.c. and power supply frequency 50 to 60 Hz (hereafter referred to as robots) for the purpose of attainment of the following matters:

- (1) To ensure safety of the human body and the robot.
- (2) To minimize interruption of production due to failure of electrical equipment of robot.
- (3) To make the maintenance of robots easy.
- (4) To improve endurance of robots.

Remarks 1. The following Standards are cited in this Standard:

JIS B 0134-Glossary of Terms for Industrial Robots

JIS B 8434-Industrial Robots - Identification Symbols for Operator Controls

JIS C 0702-General Rules for Insulation Construction of Class II Electrical Appliances

JIS C 8305-Rigid Steel Conduits

JIS K 2241-Cutting Fluid

JIS P 3801-Filter Paper (for Chemical Analysis)

JIS Z 8801-Test Sieves

2. The units and numerical values in { } in this Standard are based on the traditional unit system and are given for informative references.

2. Definitions

For the purpose of this Standard, in addition to the terms specified in JIS B 0134, the following principal definitions shall apply:

- (1) electrical equipment The generic name of all the electrical machinery and apparatus which serve as a part of a robot. Electromagnetic machinery and apparatus, electronic devices, etc. are included.

- (2) electronic equipment The equipment mainly consisting of electronic components. For example, numerical control device, sequencer, servo-amplifier, etc.
- (3) controlgear The equipment in which machinery and apparatus for control, measurement, protection, adjustment, etc. are integrated and these machinery and apparatus are mutually connected mechanically and electrically.
- (4) control box The box which accommodates power supply disconnecting device, electromagnetic switches, relays, etc.
- (5) enclosure The generic name of covers provided for the purpose of protecting the human body from contact with the live parts and protecting the electrical equipment from external factors.
- (6) duct A structure of gutter or pipe shape which is used only for supporting and protecting wires.
- (7) conduit A rigid or flexible tubular duct made of metals or insulating materials.
- (8) live part⁽¹⁾ All the conductors and conductive parts on which the voltage is applied in the normal service state.

Note (1) The live part includes the neutral conductor and the conductive part connected thereto.

- (9) exposed conductive part The conductive part of electrical machinery and apparatus which is not the live part but may become alive at the time of failure and easily accessible by a man.
- (10) protective grounding wire The wire to be used for grounding by connecting the exposed conductive part to any one of the following parts:
 - (a) Other exposed conductive part
 - (b) Conductive part of a device other than electrical equipment
 - (c) Grounding electrode and grounding conductor
 - (d) Grounded live part (including neutral line)
- (11) protective circuit All of the protective grounding wire and conductive parts prepared for protection at a leakage fault.
- (12) power circuit The circuit which carries the power for such machinery and apparatus as motors and generators.
- (13) control circuit The circuit for running control and protection of robots,

- (14) signalling circuit The circuit for supplying signals to such components as display, indicator and alarm.
- (15) electronic component The component of electronic equipment. For example, resistors, capacitors, transistors and integrated circuits.
- (16) switch An apparatus which opens and closes the electric circuit.
- (17) power supply disconnecting device A switch which is operated manually or electrically to disconnect circuits for equipment or machine and apparatus from the power source.
- (18) control device Such devices as position detectors, operating switches, relays and magnetic valves which are used for control and operation of robots and are to be connected to the control circuit.
- (19) operating device Such devices as push button switches and selector switches used for manual control of robot running.
- (20) molded-case circuit-breaker An apparatus made by assembling a switching mechanism and a release in a case of insulating material having such functions that the electric line under the normal state can be opened and closed manually and the electric line is automatically interrupted at overload, short circuit, etc. without damage on itself.
- (21) overcurrent breaker An apparatus which has the function to break overcurrent and short-circuit current automatically such as a molded-case circuit-breaker, fuse and air circuit-breaker.
- (22) branched circuit A circuit which is branched from the main circuit and runs to the load via the branch overcurrent protective means.
- (23) electric line All or a part of the circuit which carries the current under normal service conditions.
- (24) (electrical) wire The generic name of insulated wires, bare wires, cords, cables, etc.
- (25) voltage to ground The voltage between the wire and the ground in an electric line of a grounding system, and the voltage between wires in an electric line of a non-grounding system.
- (26) marking The mark by means of symbols or letters for identification of the type of the component which is attached by the manufacturer of electrical component and electronic component.
- (27) servicing level The work plane on which the maintenance person stands at maintenance and repair of electrical equipment.
- (28) class II electrical appliance An appliance which employs throughout double insulation or reinforced insulation or the combination of double insulation and reinforced insulation and which is not grounded.
- (29) total insulation An insulation which covers the appliance entirely with insulating materials.

3.1.2 Nameplate on control equipment A nameplate which indicates the specification given below shall be attached to each control equipment.

The rated current entered in the nameplate shall not be smaller than the total sum of rated currents of electrical machinery, apparatus and devices which operate at the same time in normal service conditions. If it is necessary to consider a power supply for more than the total sum of the rated currents due to the control system, the estimated current shall be taken as the rated current.

- (1) Manufacturer's name
- (2) Serial number or registered number
- (3) Rated voltage
- (4) Rated frequency and number of phases
- (5) Rated KVA or rated current

3.1.3 Marking of control device The control device shall bear the marking prescribed below.

In a device which employs a coil, the coil shall bear the following marking separately if the coil is detachable.

If the marking on apparatus is impossible due to small size, the specified items shall be indicated on the drawing or component list.

- (1) Manufacturer's name or trademark
- (2) Type of device or marking to identify the type
- (3) Operating voltage (frequency shall also be entered if a.c.)

3.1.4 Marking of replaceable components The replaceable components shall be marked by one of the following methods:

- (1) Letter symbols or graphical symbols.
- (2) Manufacturer's name or trademark and ratings, for all components other than the case of (1).

Remarks: The letter symbols and the graphical symbols shall be as specified in Annex 1 and Annex 2, respectively.

3.1.5 Marking of wires, apparatus and terminals The wires, apparatus, terminals, etc. shall be designated in a durable manner by using the marks identical to those in the drawings, for the convenience of maintenance, mounting, reassembling works or the like. However, if the said marking is difficult in electronic devices, such a case is an exception.

3.1.6 Marking of operating device All of the operating devices such as push-button switches and selector switches shall bear the marking denoting their functions by means of letters or symbols (item designation) (see JIS B 8434).

3.2 Instruction manual

3.2.1 General The instruction manual to be submitted to the user shall include necessary contents for installation, operation and maintenance of the electrical equipment.

It is desirable to attach an instruction manual to the control cabinet or the like.

3.2.2 Contents of instruction manual The instruction manual shall include the contents prescribed below. However, if the contents of (2), (4) and (6) can be easily understood from other parts of the instruction manual, such items may be omitted.

- (1) Installation work instruction
- (2) Interconnection diagram or interconnection table
- (3) Operation instruction
- (4) Programming instruction
- (5) Maintenance instruction
- (6) Detail list of wearing and spare parts

3.2.3 Form of instruction manual For referencing of the different documents, it is desired that each of the documents shall carry as a cross-reference the reference numbers of all the other documents belonging to one and the same electrical equipment, or all the documents shall be listed with reference number and title in a table of contents.

The size of instruction manual, and drawings attached thereto shall be prepared in A4 (210 x 297 mm) or A4 multiplied by an integer.

3.2.4 Content of particular instruction

- (1) Installation work instruction In the installation work instruction the contents given below which are necessary for the user to install a robot shall be stated.
 - (a) The position of power supply connection of the electrical equipment and the rated current of power supply or the minimum cross-section of wire.
 - (b) The space necessary for movement, maintenance, etc. of electrical equipment.

- (2) Interconnection diagram or interconnection table The interconnection diagram or interconnection table show the electrical connections between devices and between the electrical equipment and external devices, and the path of each wire shall be indicated if necessary.

If it is possible to operate the electrical equipment by the power supply of two or more kinds, the method of change over shall be practically indicated.

The terminals to be connected with the power supply and the protective grounding wire shall be indicated.

If necessary, the specification (number, cross-sectional area, kinds) and route of wires connecting the equipment and devices and the positions of grounding shall be clearly indicated.

- (3) Operation instruction The contents given below which are necessary for the user to operate the robot shall be indicated.
- (a) Explanation of functions of various operating switches, push buttons, key switches, etc.
 - (b) Explanation of display functions of various lamps, LEDs, etc.
 - (c) Explanation of the contents of displays, if such display devices as CRT and LCD are provided.
 - (d) Explanation of operations relating to closing and opening of the power supply.
 - (e) Explanation of operation relating to instruction of actuation.
 - (f) Explanation of operation relating to automatic running.
 - (g) Explanation of operation of the memory device to store various data if such a device is provided.
 - (h) If the actuation function changes due to various parameters, explanation of the functions.
 - (i) Explanation of functions of input-output signals for liberation of user.
 - (j) Explanation of function necessary for ensuring safety of user such as an emergency stop. The guidance necessary for ensuring safety on carrying out operation, installation and maintenance of robots shall be clearly stated or a safety manual in which the guidance is described shall be attached.
- (4) Maintenance instructions This instruction is a document in which matters relating to maintenance, adjustment, etc. are stated and shall include the explanation of the matters given below. It is recommended that the period of change of wearing parts is stated.

- (a) Schedule of preventive maintenance
- (b) Information and its explanation necessary for change of parts
- (c) Explanation necessary for adjustment (arrangement drawing in the board is included)
- (5) Detail list of spare parts In the detail list of spare parts, the parts which are especially desired to be provided as spare parts shall be stated. For the spare parts stated in the maintenance instruction, information necessary for ordering the parts shall be stated in the detail list of spare parts.

4. General specification

4.1 Conditions of working, transportation and storage

4.1.1 Ambient temperature Electrical equipment shall operate under the ambient temperature prescribed below. If use at an ambient temperature other than this ambient temperature is expected the specification shall be separately agreed between the parties concerned with acceptance.

Ambient temperature: 0 to 40°C

Average temperature over a period of 24 h: 35°C or below

Remarks: The manufacturer of robots shall give the user such information that consideration is necessary if additional temperature rise resulting from the enclosure and heat generating body around the equipment is foreseen.

4.1.2 Altitude Electrical equipment shall operate normally at an altitude not exceeding 1000 m.

4.1.3 Atmospheric conditions Electrical equipment shall operate normally under atmospheric conditions with a relative humidity not exceeding 50 %⁽²⁾ at 40°C, and 90 % at 20°C without dewing. If higher humidities or abnormal amounts of dust, acids, corrosive gases, or salt are anticipated, a separate specification shall be agreed between the parties concerned with acceptance.

Note ⁽²⁾ Air with a relative humidity of 50 % at 40°C will produce dew if cooled to 28°C.

4.1.4 Transportation and storage Electrical equipment shall be capable of withstanding the conditions given below during transportation and storage. Suitable means shall be provided to prevent damage from humidity and from vibration. If necessary, a warning sign shall be attached to the enclosure.

Ambient temperature: -20 to 55°C

Provided, for short periods not exceeding 24 h: 70°C or below

4.1.5 Special specification In the case of special environmental conditions, the user shall notify the manufacturer such fact, and separate specifications shall be agreed upon.

4.2 Power supply Electrical equipment shall be designed for operation from the power supply voltage and frequency specified by the user. It shall operate correctly at voltages within $\pm 10\%$ from the nominal supply voltage and with frequency deviations up to $\pm 2\%$. Electronic equipment shall operate correctly under the conditions stated below.

Interlocks shall be provided to stop the associated operations if the electronic equipment may cause a maloperation due to instantaneous interruption of voltage and the maloperation may cause a problem on safety and continuous production.

- (1) Instantaneous voltage interruption of less than 10 milliseconds (ms) (power electronics equipment is excluded).
- (2) Voltage drop of less than 15 % of nominal supply voltage for a duration within 0.5 s.

4.3 Connection to power supply network The connection to power supply network shall be as follows:

- (1) It is recommended that the electrical equipment is connected to a single power supply as far as possible. If another voltage is necessary for the electronic equipment, electromagnetic clutches, etc. this voltage should, as far as possible, be supplied from such converting devices as transformers and rectifiers accommodated in the electrical equipment.
- (2) A neutral line (N) shall be used only with the agreement of the user. If it is used, this shall be clearly stated in the technical documentation such as the schematic diagram and interconnection diagram. There shall be no connection between the neutral line (N) and the protective circuit (PE) inside the electrical equipment.
- (3) Unless a plug is provided on robot side for connection to the power supply system, it is recommended to connect the wiring from the power source directly to the primary terminals of the supply disconnecting device. If this is not practical, wiring shall be made via terminals separately provided.

The main grounding terminal shall be provided in the vicinity of the power supply terminals.

If a neutral line is used, a separate insulated terminal shall be provided.

- (4) All terminals for the supply connection shall be clearly identified by the following symbols:

- (a) A.C. power supply: Phase 1 L 1
Phase 2 L 2
Phase 3 L 3
Neutral N
- (b) Protective grounding wire PE
- (c) Grounding E
- (d) Low noise (clean) grounding TE

5. Protection

5.1 Protection against electric shock The electrical equipment shall provide protection of persons against electric shock in normal service, at the time of current leak, or due to residual voltage, as given below.

- (1) Protection against electric shock in normal service This protection is the basic protection and intended to protect persons against dangers of direct contact with live parts. For each circuit or part, one of the following measures shall be employed, unless the protection of (3) is provided.

- (1.1) Protection by enclosures Live parts shall be located inside enclosures which comply with the relevant requirements of 7.2.

Opening an enclosure (doors, lids, covers, or the like) shall only be possible when one of the conditions (a), (b) and (c) given below is satisfied.

- (a) When use of key or tool is necessary This method is only allowed for access by the maintenance person⁽³⁾. Live parts inside the enclosure shall be protected by barriers⁽⁴⁾ so as to prevent unintentional contact with them when the doors are open.

Notes ⁽³⁾ When other than maintenance person needs to have access, (for example replacement of fuses) either structure specified in (b) or (c) shall be employed.

- ⁽⁴⁾ The barrier to prevent electric shock is the one to prevent unintentional contact, and it may be ineffective for intentional contact.

- (b) When all power supplies inside enclosure are disconnected before the enclosure can be opened or due to opening of enclosure The door(s) shall be interlocked with a disconnect (for example the supply disconnecting device) so that the door(s) can only be opened, when the disconnect is open and so that the disconnect can only be closed when all doors are closed. However, the structure may allow release of this interlock by the maintenance person provided that on closing the door(s) the interlock is automatically restored.

- (c) When barrier, to prevent contact with live part is provided inside enclosure When barriers are provided to prevent contact with live parts, such construction is allowed that the doors can be opened without use of a key or tool or without disconnection of live parts for the purpose of replacement of lamps and fuses.

The barrier shall be so constructed that the removal of it requires a tool or that the removal disconnects the power supply automatically.

- (1.2) Protection by insulation of live parts Live parts shall be completely covered with insulation which can only be removed by destruction. Such insulation shall be capable of durably withstanding the mechanical, electrical and thermal stresses to which it may be subjected in service. Coating of paint or the similar treatment alone is considered to be insufficient for protection against electric shock.
- (2) Protection against electric shock in case of leak This protection is intended to prevent danger to persons in the event of an insulation failure between live parts and exposed conductive parts. For the electrical equipment, one of the measures specified below shall be employed, unless the protection of (3) is provided.
- (2.1) Protection by automatic disconnection of supply The automatic disconnection of supply is intended to prevent a touch voltage persisting for such time that a danger to persons could arise and shall consist of the following measures:
- (a) Connection of exposed conductive parts to the protective circuits [see the following (2.1.1) to (2.1.8)].
- (b) The user of automatic disconnection of supply shall provide a residual current operated circuit-breaker for each electric line which supplies power at a voltage exceeding 60 V. However, the manufacturers of robots are not responsible for installation of residual current operated circuit-breakers.
- (2.1.1) Protective circuit in general The protective circuit is composed of protective grounding conductor, enclosure, conductive structure of robot, etc. All the exposed conductive parts of electrical equipment and robots shall be connected with the terminal for protective grounding wire in accordance with (2.1.6).
- (2.1.2) Continuity of protective circuit The continuity of the protective circuit shall be ensured by effective connections i.e. by protective conductors or by direct structural interconnection.
- (a) The means for assembling the various metal parts may be considered as sufficient for ensuring continuity of the protective circuit, provided that the precautions taken achieve permanent good conductivity.

The connection means of protective conductors shall not have any additional function of fastening.

In the case of enclosures and conductors of aluminium or aluminium alloys, particular consideration shall be given to the danger of electrolytic corrosion.

- (b) When a part is removed for routine maintenance or any other reason, the protective circuit for the remaining parts shall not be interrupted.
- (c) Flexible metal conduits shall not be used as protective conductors unless specially designed and tested for that purpose. Flexible metal conduits and metal sheathed cables shall be connected with the protective circuit.
- (d) When removable or withdrawable parts of the electrical equipment are equipped with metal supporting surfaces, these surfaces are considered sufficient for ensuring continuity of the protective circuit, provided that the pressure exerted on them is sufficiently high.

Precautions shall be taken to achieve permanent good conductivity of the supporting surfaces.

- (e) If the electrical equipment can be withdrawn for setting or maintenance while current is passed, its exposed conductive parts shall be connected to the protective circuit by a protective conductor.
- (f) If circuits not in accordance with (2.3) are connected to devices attached to doors, covers, plates, etc., steps shall be taken to ensure continuity of the protective circuit. It is recommended that these parts are fitted with a protective conductor whose sectional area depends on the maximum sectional area of wire used for the apparatus attached.

The sliding contact, hinges protected against corrosion, or the like especially designed for this connection shall be considered satisfactory for the continuity of conductivity.

If no electrical equipment is attached to doors, covers, plates, etc. or if only circuits in accordance with (2.3) are connected, the usual metal hinges and fittings are allowed.

- (2.1.3) Exclusion of switching or interrupting devices from protective circuit The protective circuit shall not include switching or interrupting device (fuse, switch, etc.). However, a current detector is an exception.

When the protective circuit is opened for tests or measurements the circuit shall be so constructed that the opening and closing of such testing parts can only be done by the maintenance person using a tool.

- (2.1.4) Switching of protective circuit by plugs Where the continuity of the protective circuit is interrupted by means of connectors or plug-and-socket devices, the protective circuit shall be interrupted only after the other circuits have been interrupted and the continuity of the protective circuit shall be re-established before any other circuit is reconnected. However, this requirement does not apply to extra-low voltage circuits and ultra-low voltage circuits. This sub-clause is applicable to removable or withdrawable plug-in units.

Remarks: Metallic housings of connectors and plug-and-socket devices shall be connected to the protective circuit, except when using extra-low voltage circuit according to (2.3) or (3).

- (2.1.5) Cross-section of protective circuit The protective circuit shall be so designed that it is capable of withstanding the highest thermal and mechanical stresses that may be caused by ground-fault current which could flow in the protective circuit.

The sectional area of protective circuit shall be as given in Table 1.

In the case of using metals other than copper wires, it is permissible to use structural parts as the protective circuit if the equivalent sectional area relating to the resistance values satisfies the requirement of Table 1.

Table 1. Sectional area of protective copper wire

Rated current of fuse or overcurrent protective device protecting associated circuit (A)	Sectional area of protective copper wire (mm ²)
30 max.	2 min.
50 max.	3.5 min.
100 max.	5.5 min.
200 max.	14 min.

- (2.1.6) Terminal for external protective conductor The protective grounding conductor shall be connected to the terminal for the connection of the external protective conductor specified in 4.3 (3). The terminal shall be of a size as to enable the connection of external protective conductor with a sectional area given in Table 2, unless otherwise specified.

The terminal for external protective conductor shall be identified by one of the following methods:

- (a) Symbol: symbol of protective grounding terminal specified in Annex 2
- (b) Letters: PE
- (c) Color code: green/yellow (stripe)

Table 2. Sectional area of external protective conductor for determination of terminal size

Sectional area of phase conductor connected to the equipment	Sectional area of external protective conductor for which the terminal shall be determined
Less than 22 mm ²	Equal to that of the phase conductor
Not less than 22 mm ²	At least 50 % that of the phase conductor

(2.1.7) Manual actuators Manual actuators of electrical devices (e.g. knobs, handles and wheels) shall be either:

- (a) Made of insulating material or insulated from other conductive parts by means of supplementary insulation or reinforced insulation. This insulation shall at least be rated for the maximum voltage used in that part of the electrical equipment, where the actuator is mounted.
- (b) Electrically connected, in a secure and permanent manner, to the protective circuit.

It is preferred that parts of manual actuators which are normally grasped by the hand during operation comply with (a). Metal parts coated with paint, varnish, etc. can not be considered to comply with (a).

(2.1.8) Parts which need not be connected to protective circuit
It is not necessary to connect certain exposed conductive parts to the protective circuit if they are so mounted that they do not constitute a danger because one of the following reasons:

This provision applies to small parts such as screws, rivets and nameplates, on one hand and on the other hand to parts inside an enclosure, irrespective of their size, such as electromagnets of contactors or relays, iron cores of transformers and mechanical parts of devices.

- (a) They cannot be touched or grasped with the hand.
- (b) They are small in size (not exceeding 50 x 50 mm).
- (c) They are so located that contact with live parts or an insulation failure is impossible.

(2.2) Protection by use of class II electrical equipment or by equivalent insulation This protection is intended to prevent the appearance of dangerous voltage on the accessible parts though a fault in the basic insulation. One of the following measures shall be employed:

- (a) To use class II electrical devices or apparatus having double or reinforced insulation specified in JIS C 0702.
- (b) To use factory-built equipment having total insulation.
- (c) To apply supplementary or reinforced insulation to the electrical devices having the basic insulation only, in the process of installation, to achieve the same safety as the case of (a) or (b).

Remarks: In order to fulfill the safety measures envisaged by 6.2.2 and 6.2.3, it is recommended to connect the conductive (but not live) parts enclosed in insulating enclosures to the protective circuit.

- (2.3) Protection by use of functional extra-low voltage (FELV) This protection is intended to prevent the appearance of dangerous voltage on exposed conductive parts on the occurrence of fault in the insulation of the circuit.

The highest voltage in this circuit shall not exceed 50 V (r.m.s. value) a.c. or 120 V d.c. (including maximum ripple of 10 %).

In addition one of the following measures (a) or (b) shall be employed:

- (a) One side of the circuit or one side of the power supply to the circuit shall be connected to the protective circuit associated with the higher voltages used on the robot and to the related exposed conductive parts.
- (b) The source of power supply and all live parts and conductors of such circuits shall be separated or isolated from circuits with higher voltages by an insulation which is applicable to the maximum voltage used in the same part of the electrical equipment or on the same part of the machine (see 10.1.4).

Metallic covering such as screens and shielding shall be connected to the protective circuit of the higher voltages.

Plugs and socket-outlets used in the functional extra-low voltage circuit shall comply with the following:

- (c) Plugs of FELV circuit shall not be able to enter socket-outlets of other circuits.
- (d) Socket-outlets of FELV circuit shall not be able to receive plugs of other circuits.

- (3) Protection against electric shock both in normal service and in case of fault, by machine extra-low voltage (MELV) This protection is intended to protect persons against dangers of direct contact with live parts as well as against dangers of insulation failure between live parts and exposed conductive parts.

The circuit which satisfies all the following requirements may be exempted from protection against direct contact with live parts.

Although the circuits specified here fulfill the requirements for functional extra-low voltage circuit, the functional extra-low voltage circuits and the machine extra-low voltage circuits shall not be connected by means of plugs and socket-outlets.

- (3.1) The highest voltage in this circuit shall not exceed 25 V (r.m.s. value) a.c. or 60 V d.c. (including a maximum ripple of 10 %).
- (3.2) The maximum current which would flow in a connecting link between such live parts not protected against direct contact and exposed conductive parts shall not exceed 1 A if a.c. or 0.2 A if d.c.
- (3.3) Such live parts which are not protected against direct contact shall be fastened so that they can not move freely.
- Such parts shall have a shape that cannot be grasped by the hand.
- (3.4) The source of power supply, all live parts and conductors of such circuits shall be separated or isolated from circuits with higher voltages as specified in (2.3) and 10.1.4.
- (3.5) One side of the circuit or one point of the power supply to the circuit shall be connected to the protective circuit associated with the higher voltages than MELV as specified in (3) used on the robot and to the related exposed conductive parts.
- (3.6) Exposed conductive parts associated with such circuits shall be either separated or isolated from higher voltage circuits than PELV as specified in (2.3) (b) or connected to the protective circuit of the higher voltages.
- (3.7) Plugs and socket-outlets used in MELV circuit shall satisfy the following requirements:
- (a) Plugs of MELV circuit shall not be able to enter socket-outlets of other circuit.
- (b) Socket-outlets of MELV circuit shall not be able to receive plugs of other circuits.
- (3.8) Where such circuits are used as control or signalling circuits, they shall also fulfill the relevant requirements of 6.

- (4) Residual voltages If the equipment includes elements which may retain dangerous charges after it has been switched off [e.g. capacitors with a stored energy of exceeding 0.1 J (Joule)], it is recommended that the voltage is brought down to below 120 V (peak value) within 5 s with discharge resistors.

5.2 Short-circuit protection

5.2.1 General protection (Installation of overcurrent breaker) Unless otherwise specified by the user, the manufacturer of the electrical equipment is not responsible for providing short-circuit protection at the point of entry of the main supply cables to the electrical equipment. Usually this protection is provided at the origin of the main supply cables.

The manufacturer of the electrical equipment shall state on the installation instruction the data necessary for choosing the type, the characteristics and the rated or setting current of this short-circuit protective device [see 3.2.4 (1) and 5.2.3].

The short-circuit protective device shall not trip within the maximum starting time of the motors same as the overload protective device.

If the short-circuit protective device is provided with means for instantaneous interruption, its current setting shall be at least 110 % of the sum of the peak currents of all motors and devices liable to be started or operated simultaneously.

5.2.2 Protection of circuits and branches All live conductors shall be protected against short circuits by protective devices suitably chosen in accordance with 5.2.3. Devices for detection and for disconnection of short-circuit current shall be inserted in all live conductors. However, where a neutral conductor is used [see 4.3 (2)], which is directly connected to the ground and if the sectional area of the neutral conductor is at least equal to that of the associated phase conductors, no short-circuit current detection nor disconnection is necessary in the neutral conductor (N).

Protective grounding conductors (PE) shall not contain devices for current detection nor for disconnection [see 5.1 (2)(2.1.3)].

One protective device may protect several branched circuits against short-circuit.

- (1) Protection by fuses or molded-case circuit-breakers Fuses which are readily obtained by the user shall be selected.

The interrupting capacity shall be at least equal to the prospective short-circuit current at the place of installation.

A lower interrupting capacity is permitted if another protective device having the necessary breaking capacity is installed on the supply side. In this case the instantaneous tripping current setting of the protective device on the supply side shall be set to a value not exceeding 80 % of the current which can safely be interrupted by the protective device on the load side.

- (2) Protection by relays Protection by instantaneous overcurrent relays in branched circuits acting on a protective device having a sufficient interrupting capacity is admissible as a short-circuit protective device. The protective device may either interrupt one or several circuits or branched circuits.

This disconnecting device may be the general protective device or the emergency stopping device (see 5.6).

5.2.3 Rating and setting of short-circuit protective devices The rated current of fuses or the setting current of other short-circuit protective devices shall be selected as low as possible, but shall be capable of withstanding transient currents such as starting currents of the motor and rush currents of the transformer.

The rated or the setting current of a short-circuit protective device is determined by the smallest sectional area of the conductors to be protected by that device. The short-circuit protective device shall be so selected that it operates before the conductor reaches the dangerous temperature due to the short-circuit current.

- Remarks 1. The sectional area of the insulated wire shall be determined in accordance with 9.3.
2. The short-circuit protective devices shall be chosen not only to protect the conductors, but also to take into account the needs of co-ordination with the other electrical devices. The short-circuit protection of electronic devices shall be as specified by the manufacturer.

5.2.4 Short-circuit protection of conductors in front of robot protective device If the conductors (with a smaller sectional area) connecting a supply circuit (with a larger sectional area) with the short-circuit protective devices of branched circuits are complying with the requirements given below, no short-circuit protection is necessary.

- (1) The sectional area of smaller conductors is at least equal to that required for the conductors after these protective devices in their run.
- (2) The length of the thinner conductor is not more than 3 m.
- (3) The thinner conductors are protected against external influences by an enclosure or a duct.
- (4) The thinner conductors are not placed close to combustible material.

5.3 Protection of motors The protection of motors shall be as follows:

- (1) An overload protective device shall be provided. However, if the rated output is not exceeding 0.2 kW, such motors are excluded.

- (2) Protection by a thermal detector built-in the motor is recommended, under such service environment that the cooling effect of motor is not sufficient.

5.4 No-voltage protection Where automatic restarting of a robot after interruption and restoration of the power supply may cause risk to the operator or damage to the robot or the work, an appropriate no-voltage protection shall be employed.

5.5 Undervoltage protection Where voltage drop might cause malfunctioning of the robot with consequential danger to the operator or damage to the robot or the work, an appropriate undervoltage protection shall be employed.

5.6 Emergency stopping and supply disconnecting device If both functions are achieved by interruption of one and the same circuit, an apparatus which satisfies all the requirements of both 5.6.2 and 5.6.3 may be used.

5.6.1 The electrical equipment of robots shall have the following two functions:

- (1) Function to stop the robot body as quickly as possible in case of emergency.
- (2) Function to disconnect all the devices from the power supply network.

5.6.2 Emergency stopping device

5.6.2.1 The emergency stopping device shall be a device which can quickly stop the robot to avoid accidents to the operator, robot and peripheral equipment, and shall employ one of the methods stated below.

The interruption command signal shall be transmitted directly or by interruption of the control circuit normally energized.

Further it is recommended to use a device which facilitates a quick stop (e.g. mechanical brake) as emergency stop function.

- (1) Installation of emergency stop switch which can open and close the power circuit of the robot manually or by electrical operation.
- (2) Such configuration of circuits that all the electromagnetic contactors or the like belonging to circuits considered as dangerous can be opened by a command.

5.6.2.2 Electrical performance of emergency stopping device
The electrical performance of emergency stopping device shall be as follows:

- (1) The emergency stop switch of 5.6.2.1 (1) shall be capable of breaking the maximum overload current (the total sum of the locked-rotor current of a motor of the largest capacity plus the sum of the normal running currents of all other equipment) of the robot.

- (2) The device in the control circuits of 5.6.2.1 (2) shall be capable of breaking the current flowing in the control circuits completely. If the interrupting device (e.g. molded-case circuit-breakers contactors) of the emergency stopping device of 5.6.2.1 (1) or 5.6.2.1 (2) have a sufficient breaking capacity, the device may serve as protection against overload and/or short-circuit.

5.6.2.3 Function of emergency stopping device The operation of the emergency stopping device shall not endanger the operator or the robot.

5.6.2.4 Construction and arrangement of emergency stopping device Actuators for emergency stopping device shall be located in a manner to be readily visible and quickly reached by the operator from his working and operating positions.

The actuator shall not reset unless manual resetting (electrical system is allowed) is done. If there are two or more working or operating stations or other critical places, an actuator shall be reached from each of such places or an actuator shall be provided at each place.

All actuators for emergency stopping device shall be colored red.

The surface on which actuators of emergency stopping device of handle or push-button type shall be colored yellow.

If there are several actuators for emergency stopping device, it shall only be possible to restart the robot after all actuators have been reset.

The actuator shall consist of the following:

- (1) Handle type device
- (2) Push-button of mushroom head type
- (3) (a) cord(s) extended along the working area (which initiates the emergency stop when pulled and when disrupted)
- (4) (a) stop rail(s) or pedal(s) (without mechanical guard)
- (5) Other device suitable for the purpose

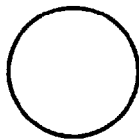
5.6.3 Power supply disconnecting device The power supply disconnecting device shall comply with the following requirements:

- (1) The device shall be capable of manually disconnecting all the electric equipment of the robot from the power supply.
- (2) If there are two or more power supplies, a separate power supply disconnecting device shall be provided for each power supply. Where possible danger or damage may be caused by operating one power supply disconnecting device only, an appropriate interlocking function shall be given to the control circuit or the power supply disconnecting device.

- (3) The power supply disconnecting device shall be one of the following:
- (a) A switch-disconnector having sufficient make-break capability
 - (b) A disconnector having a special auxiliary contact which causes the contactors to break the load before the opening of main contacts of the disconnector
 - (c) Molded-case circuit-breaker
- (4) If a power supply disconnecting device so placed as to be readily accessible to the operator, the breaking capacity of the apparatus specified in (a) or (c) of (3) shall be capable of interrupting the maximum overload current of the robot the same as the emergency stopping device.
- (5) The power supply disconnecting device shall satisfy the following requirements:
- (a) The device shall have stable OFF position and ON position, and each of them shall be indicated by the symbols of Fig. 2.

Fig. 2

OFF indication



ON indication



- (b) The gaps can be verified on all the contacts at OFF position or the position indicator cannot indicate OFF until adequate breaking distance is achieved between the contacts.
 - (c) The disconnector shall be equipped with an external operating handle. If the disconnector does not serve also as an emergency stopping device, its external handle shall not be red. Black or gray is recommended.
 - (d) The disconnector shall have a function for opening all the load circuits except the neutral conductors.
- (6) The circuits stated below may be connected to the primary side of the power supply disconnecting device.

If voltages remain in certain circuits connected to the primary side of the disconnector, such fact shall be stated in the maintenance instruction and indicated on the warning label placed in proximity to the power supply disconnecting device. It is recommended that such circuits are provided with their own disconnecting device.

- (a) Power supply circuits for lightening needed during maintenance or repair.
 - (b) Socket-outlet circuits for the exclusive connection of repair and maintenance tools like hand drills.
 - (c) Undervoltage tripping circuits
 - (d) Control circuits specified in (8)
- (7) All the exposed parts which are still live after opening the power supply disconnecting device, shall be separately covered, in order to prevent electric shock. Such covers shall be marked with the warning sign specified in 3.1.1. However, for circuits which fulfill the requirements of 5.1 (2.3) this item does not apply.
- (8) It is recommended to use orange for the color of conductors in interlock circuits which are supplied from outside, and which remain live when the power supply disconnecting device is open, to distinguish them from other circuits. If there is an appropriate warning label, item (7) does not apply to these circuits.

5.7 Protection against maloperation

5.7.1 Adequate measures shall be employed to avoid dangers due to maloperation of electrical equipment. It is recommended to employ one or more of the measures stated below and other measures at once.

- (1) Mechanical safety precaution on the machine
- (2) Proper interlocking of electrical circuits controlling mechanical movement
- (3) Additional circuits providing safety function
- (4) Double checking circuit

5.7.2 Where relays are used in safety circuits, if maloperation of the relay may result in loss of safety effect, two such relays shall be used so that the safety of the circuit is ensured even if one of them fails.

5.7.3 Circuits assuring safety functions shall, in case of a failure, fall to a safe state.

5.8 Electromagnetic and electrostatic interferences As for the electromagnetic and electrostatic interferences, the following matters shall be taken into consideration:

- (1) The disturbance wave generated by the electronic equipment itself shall be minimized as practicable.
- (2) Undesirable effects of electrostatic and electromagnetic interferences shall be avoided by use of appropriate filters and time-delay elements, adequate choice of power supply, suitable wiring method, etc.

(3) It is recommended to employ, at least, the measures given below to reduce electromagnetic interferences:

- (a) Reference potential circuit or common connections The reference potential point or common point of each unit is connected to a point and the point is grounded with a conductor of large section.
- (b) Frame connections Each frame of equipment is connected to a common point. Braided conductors of large sectional area are used between movable parts and enclosures. The connection to the frame to be as short as possible.
- (c) Transmission of signals Electrostatic screens, electromagnetic shields, twisted conductors and appropriate arrangement of cables (crossing cable runs at a possible larger angle) to ensure that the signal wiring is not affected by interference from control or power cables.
- (d) Separation of equipment Sensitive equipment (units working with pulses and/or at low level) is separated and/or shielded from switching equipment such as electromagnetic relays thyristors, etc.

6. Control and signalling circuits

6.1 Control and signalling circuit supplies and protection

6.1.1 Control and signalling circuit transformers It is recommended that transformers are used exclusively as the power supply for control and signalling circuits. However, such cases that the circuit has five or less electromagnetic coils (contactors, relays, valves, etc.) or the circuit is for a simple robot having no control device or instrument outside its control cabinet, are exceptions.

Such transformers shall be insulated transformers and shall be connected to the load side of power supply disconnecting device. It is recommended that the primary side of the transformer is not connected to the neutral line.

6.1.2 Several transformers If there are several transformers, their primary sides shall be so connected that their secondary side voltages are in the same phase.

6.1.3 Overcurrent protection As for the overcurrent protection, the following matters shall be taken into consideration:

- (1) Control and signalling circuits directly connected to the power supply or circuits in the primary side of control and signalling transformers shall be protected against short circuit in accordance with 5.2.2 and 5.2.3.

Remarks: When choosing these protective devices, devices of such construction that the auxiliary contacts do not weld in case of short circuit shall be employed.