ArcWorld®2000
SYSTEM MANUAL

Upon receipt of the product and prior to initial operation, read these instructions thoroughly, and retain for future reference.

Part Number: 183577-1CD
Revision: 3
Safety

Summary of Warning Information

This manual provides help for establishing safe conditions for operating the equipment. Specific considerations and precautions appear in this manual in the form of Dangers, Warnings, Cautions, and Notice.

Operate equipment per this instruction manual and any other information provided. If there are questions concerning the safe and proper operation of this equipment contact Customer Support.

Notes for Safe Operation

Read this manual carefully before installation, operation, maintenance, or inspection of the ArcWorld.

Classifications for Safe Operation in this manual are “DANGER,” “WARNING,” “CAUTION,” or “NOTICE.”

- **DANGER**: Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

- **WARNING**: Indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury.

- **CAUTION**: Indicates a hazardous situation, which if not avoided, could result in minor or moderate injury. It may also be used without the safety alert symbol as an alternative to “NOTICE”.

- **NOTICE**: NOTICE is the preferred signal word to address practices not related to personal injury. The safety alert symbol should not be used with this signal word. As an alternative to “NOTICE”, the word “CAUTION” without the safety alert symbol may be used to indicate a message not related to personal injury.
Even items described as “CAUTION” may result in a serious accident in some situations.

**WARNING**

- Read and understand this instruction manual thoroughly before installing and operating the ArcWorld.

  This instruction manual explains the installation, operation, maintenance, and inspection of the ArcWorld. Items not in this manual must be regarded as “prohibited” or “improper.”

  Not reading and understanding this instruction manual thoroughly may result in death or serious injury.

- Read Chapter 1 “Safety” of the Controller Instructions.

  Chapter 1 “Safety” of the Controller Instructions contains general information relating to safety and helps ensure correct and safe operation.

  Not reading and understanding Chapter 1 “Safety” of the Controller Instructions may result in death or serious injury.

- Do not remove motor or release brake of the Robot’s arm.

  Failure to follow this warning may result in death or serious injury from the unexpected turning of the Robot’s arm.
WARNING

• Before operating the ArcWorld, make sure servo power is OFF by pressing the EMERGENCY STOP buttons.

When servo power is OFF, the SERVO ON LED on the Programming Pendant is OFF.

Injury or damage to machinery may result if the emergency stop circuit cannot stop parts of the ArcWorld during an emergency. Do not use the ArcWorld if the EMERGENCY STOP buttons do not function.

Fig. : EMERGENCY STOP Button

• Once releasing the EMERGENCY STOP button, clear the cell of all items which could interfere with the operation of the ArcWorld. Then turn the servo power ON.

Injury may result from unintentional or unexpected Robot or Positioner motion.

Fig. : Release of EMERGENCY STOP

• Observe the following precautions when performing a teaching operation within the Robot’s and Positioner’s operating range:
  – Perform lockout by putting a lockout device on the safety fence when going into the enclosed area by the safety fence. In addition, the operator of the teaching operation must display a sign that operation is being performed so no other person closes the safety fence.
  – View the Robot and Positioner from the front whenever possible.
  – Always follow the predetermined operating procedure.
  – Always keep in mind emergency response measures against unexpected movement toward a person.
  – Ensure a safe place to retreat in case of emergency.

Failure to observe this instruction may cause improper or unintended movement of the Robot or Positioner, which may result in personal injury.

• Confirm that no person is present in the Robot's and Positioners operating range and the operator is in a safe location before:
  – Turning ON the Controller power
  – Moving the Robot or Positioner with the Programming Pendant.
  – Running the system in the check mode
  – Performing automatic operations

Personal injury may result if a person enters the Robots or Positioners operating range during operation. Immediately press an EMERGENCY STOP button whenever there is a problem.

• Read and understand the Explanation of the Warning Labels before operating the ArcWorld.
Safety
Notes for Safe Operation

WARNING

• Maintenance and inspection must be performed by specified personnel.
Failure to observe this caution may result in electric shock or injury.

• For disassembly or repair, contact Customer Support.

CAUTION

• Read and understand the Explanation of Warning Labels in the Controller instructions before operating the Robot.

• In some drawings in this manual, protective covers or shields are removed to show details. Make sure that all the covers or shields are installed in place before operating this product. The drawings and photos in this manual are representative examples and differences may exist between them and the delivered product.

YASKAWA is not responsible for incidents arising from unauthorized modification of its products. Unauthorized modification voids the product warranty.

• Perform the following inspection procedures prior to conducting Robot teaching. If problems are found, repair them immediately, and be sure that all other necessary processing has been performed.
  – Check for problems with Robot movement.
  – Check for damage to insulation and sheathing of external wires.

• Always return the Programming Pendant to the hook on the cabinet of the Controller after use.

• The Programming Pendant can be damaged if it is left in the Robot's or Positioner work area, on the floor, or near fixtures.
CAUTION

This Robot Cell has Collaborative Motion functionality:

Collaboration is a special type of operation between a person and Robot sharing a common workspace. The following are the guidelines for collaborative operation.

1. Used for pre-determined tasks.
2. Possible when all protective measures are active.
3. For Robots with features specifically designed for collaborative operation.
   • The integrator shall include in the information for use the safeguards and mode selection required for collaborative operation.

CAUTION

• Always return the Programming Pendant to the hook on the cabinet of the Controller after use.

The Programming Pendant can be damaged if it is left in the Robot's work area, on the floor, or near fixtures.

NOTICE

• The drawings and photos in this manual are representative examples and differences may exist between them and the delivered product.

• YASKAWA may modify this model without notice when necessary due to product improvements, modifications, or changes in specifications. If such modification is made, the manual number will also be revised.

• If your copy of the manual is damaged or lost, contact Customer Support to order a new copy. The representatives are listed on the back cover. Be sure to tell the representative the manual number listed on the front cover.

• To ensure safe and efficient operation at all times, be sure to follow all instructions, even if not designated as “DANGER”, “WARNING” or “CAUTION”.

• The integrator shall include in the information for use the safeguards and mode selection required for collaborative operation.
ArcWorld Explanation of Warning Labels

The following labels are attached to the ArcWorld. Always follow these warning labels.

*Fig. : ArcWorld Label Locations*

- **Robot Warning**
  
  Keep clear of moving parts when performing a teaching operation within the Robot's operating range. Failure to observe this instruction may result in personal injury.

- **Crush Warning**
  
  Keep clear of moving parts when performing a teaching operation within the Robot's operating range. Failure to observe this instruction may result in personal injury.
Arc Flash Warning

Do not open covers without appropriate personal protection equipment. Failure to observe this instruction may result in injury.

Collaborative Motion Label

Description
Collaboration is a special type of operation between a person and Robot sharing a common workspace. The following are the guidelines for collaborative operation.

Lockout and Tag-out Warning Label

Description
Use a device to ensure that the ArcWorld remain inoperable while repairs or adjustments are being made.
Safety
Product Identification Label

- High Voltage Label (Not Shown)

Description
This label lets know of hazardous voltage and there is a danger of getting an electrical shock.

Product Identification Label

Description
This label gives the Model and Serial Number of the ArcWorld. See Fig. : “ArcWorld Label Locations” for a reference of the location.
Programming, Operation, and Maintenance Safety

CAUTION

All operators, programmers, maintenance personnel, supervisors, and anyone working near the system must become familiar with the operation of this equipment.

Improper operation can result in personal injury and/or damage to the equipment. Only trained personnel familiar with the operation, manuals, electrical design, and equipment interconnections of this equipment should be permitted to program, or maintain the system. All personnel involved with the operation of the equipment must understand potential dangers of operation.

- Inspect the equipment to be sure no potentially hazardous conditions exist. Be sure the area is clean and free of water, oil, debris, etc.
- Be sure that all safeguards are in place. Check all safety equipment for proper operation. Repair or replace any non-functioning safety equipment immediately.
- Check the EMERGENCY STOP button on the operator station for proper operation before programming. The equipment must be in E-Stop mode whenever it is not in use.
- Back up all programs and jobs onto suitable media before program changes are made. To avoid loss of information, programs, or jobs, a backup must always be made before any service procedures are done and before any changes are made to options, accessories, or equipment.
- Any modifications to the Controller unit can cause severe personal injury or death, as well as damage to the ArcWorld. Do not make any modifications to the Controller. Making any changes without the written permission from YASKAWA will void the warranty.
- Some operations require standard passwords and some require special passwords.
- The equipment allows modifications to the software for maximum performance. Care must be taken when making modifications. All modifications made to the software will change the way the equipment operates and can cause severe personal injury or death, as well as damage parts of the system. Double check all modifications under every mode of operation to ensure that the changes have not created hazards or dangerous situations.
- This equipment has multiple sources of electrical supply. Electrical interconnections are made between the Controller and other equipment. Disconnect and lockout/tag-out all electrical circuits before making any modifications or connections.
- Do not perform any maintenance procedures before reading and understanding the proper procedures in the appropriate manual.
- Use proper replacement parts.
- Improper connections can damage the equipment. All connections must be made within the standard voltage and current ratings of the equipment.
Safeguarding Tips

CAUTION

All operators, programmers, maintenance personnel, supervisors, and anyone working near the system must become familiar with the operation of this equipment. All personnel involved with the operation of the equipment must understand potential dangers of operation. General safeguarding tips are as follows:

Improper operation can result in personal injury and/or damage to the equipment. Only trained personnel familiar with the operation of this equipment, the operator’s manuals, the system equipment, and options and accessories should be permitted to operate this equipment.

- Improper connections can damage the equipment. All connections must be made within the standard voltage and current ratings of the equipment.
- The system must be placed in E-Stop mode whenever it is not in use.
- In accordance with ANSI/RIA R15.06-2012, section 4.2.5, Sources of Energy, use lockout/tag-out procedures during equipment maintenance. Refer also to Section 1910.147 (29CFR, Part 1910), Occupational Safety and Health Standards for General Industry (OSHA).

Mechanical Safety Devices

CAUTION

The safe operation of this equipment is ultimately the user's responsibility. The conditions under which the equipment will be operated safely should be reviewed by the user. The user must be aware of the various national codes, ANSI/RIA R15.06-2012 safety standards, and other local codes that may pertain to the installation and use of this equipment.

Additional safety measures for personnel and equipment may be required depending on system installation, operation, and/or location. The following safety equipment is provided as standard:

Additional safety measures for personnel and equipment may be required depending on system installation, operation, and/or location. The following safety equipment is provided as standard:

- Safety barriers
- Door interlocks
- EMERGENCY STOP palm buttons located on operator station

Check all safety equipment frequently for proper operation. Repair or replace any non-functioning safety equipment immediately.
Maintenance Safety

**WARNING**

- Turn the power OFF, disconnect and lockout/tag-out all electrical circuits before making any modifications or connections.

Perform only the maintenance described in this manual. Maintenance other than specified in this manual should be performed only by YASKAWA-trained, qualified personnel.

National Safety Standard

We suggest that you obtain and review a copy of the ANSI/RIA National Safety Standard for Industrial Robots and Robot Systems (ANSI/RIA R15.06-2012). You can obtain this document from the Robotic Industries Association (RIA) at the following address:

Robotic Industries Association  
900 Victors Way  
P.O. Box 3724  
Ann Arbor, Michigan 48106  
TEL: (734) 994-6088  
FAX: (734) 994-3338  
www.roboticsonline.com

Ultimately, well-trained personnel are the best safeguard against accidents and damage that can result from improper operation of the equipment. The customer is responsible for providing adequately trained personnel to operate, program, and maintain the equipment.

**NEVER ALLOW UNTRAINED PERSONNEL TO OPERATE, PROGRAM, OR REPAIR THE EQUIPMENT!**

We recommend approved YASKAWA training courses for all personnel involved with the operation, programming, or repair of the equipment.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.
### Definition of Terms Used Often in This Manual

The ArcWorld usually consists of a Manipulator, Controller, Positioner, Programming Pendant, and supply cables.

In this manual, the equipment is designated as follows unless the instructions is for a specific piece of equipment:

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<th>Manual Designation</th>
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<td>ArcWorld</td>
</tr>
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<td>YRC1000 Controller</td>
<td>Controller</td>
</tr>
<tr>
<td>YRC1000 Programming Pendant</td>
<td>Programming Pendant</td>
</tr>
<tr>
<td>AR2010 Manipulator</td>
<td>Robot</td>
</tr>
<tr>
<td>Cable between the Robot and the Controller</td>
<td>Robot Cable</td>
</tr>
<tr>
<td>MH555, MH1655, MH3155</td>
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Descriptions of the Programming Pendant keys, buttons, and displays are as follows:

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<td>The keys which have characters printed on them are denoted with [ ]. ex. [ENTER]</td>
</tr>
<tr>
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<td>The keys which have a symbol printed on them are not denoted with [ ] but depicted with a small picture. ex. PAGE key</td>
</tr>
<tr>
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<td>“Axis Keys” and “Numeric Keys” are generic names for the keys for axis operation and number input.</td>
</tr>
<tr>
<td><strong>Numeric Keys</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Keys pressed</strong></td>
<td>When two keys are to be pressed simultaneously, the keys are shown with a “+” sign between them. ex. SHIFT key +COORD key</td>
</tr>
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<td>Three kinds of modes that can be selected by the mode key are denoted as follows: REMOTE, PLAY, or TEACH</td>
</tr>
<tr>
<td><strong>Button</strong></td>
<td>Three buttons on the upper side of the Programming Pendant are denoted as follows: HOLD button, START button, EMERGENCY STOP button</td>
</tr>
<tr>
<td><strong>Displays</strong></td>
<td>The menu displayed in the Programming Pendant is denoted with { }. ex. {JOB}</td>
</tr>
<tr>
<td><strong>PC Keyboard</strong></td>
<td>The name of the key is denoted ex. Ctrl key on the keyboard</td>
</tr>
</tbody>
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Registered Trademark

In this manual, names of companies, corporations, or products are trademarks, registered trademarks, or brand names for each company or corporation. The indications of © and ™ are omitted.

Customer Support Information

If assistance is needed with any aspect of the system, please contact Customer Support at the following 24-hour telephone number:

(937) 847-3200

Customer Support also has an e-mail address for routine technical inquiries, to contact Customer Support through e-mail use the following address:

technicalsupport@motoman.com

When using e-mail to contact Customer Support, please provide a detailed description of the issue, along with complete contact information. Please allow approximately 24 to 36 hours for a response to the inquiry.

DANGER

- Maintenance and inspection must be performed by specified personnel.
  Failure to observe this caution may result in electric shock or injury.

- For disassembly or repair, contact Customer Support.
- Do not remove the motor, and do not release the brake.
  Failure to observe these safety precautions may result in death or serious injury from unexpected turning of the Robot's arm.

NOTICE

Use e-mail for routine inquiries only. If there is an urgent or emergency need for service, replacement parts, or information, contact Customer Support at the telephone number shown above.
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1 Introduction

The ArcWorld is a fully integrated welding system that supports from wire to weld.

1.1 About This Document

This system manual provides a "first look" and overview of the complete ArcWorld. Read and understand this system manual before moving on to the more detailed documentation that is included with the ArcWorld. Although basic in content, the system manual is intended for personnel who have received operator training from YASKAWA and are familiar with the operation of this particular system. For more detailed information on any specific component or peripheral of the ArcWorld, review the full documentation package that is included (refer to section 1.5).

**NOTICE**

This manual documents a **standard** ArcWorld. If the system is custom or modified, use this manual in conjunction with the drawings, schematics, and part listings (Bill of Material) for the specific system. The drawings, schematics, and parts listing are included in the documentation package supplied with the ArcWorld.

This ArcWorld manual contains the following sections:

*Chapter 1 “Introduction”*
This section provides general information about the ArcWorld, a list of reference documents, and Customer Support contact information.

*Chapter 2 “Equipment Description”*
This section provides a description of the major components of the ArcWorld.

*Chapter 3 “Installation”*
This section provides installation procedures for the ArcWorld.

*Chapter 4 “Operation”*
This section provides an overview of ArcWorld operation, including start-up, loading, normal operations, fault recovery, and system shutdown.

*Chapter 5 “Maintenance”*
This section provides preventive maintenance requirements for certain components of the ArcWorld system.

*Chapter 6 “Alarms and Messages”*
This section contains information on alarms and ladders that are generated by the Controller ladder.
Chapter 7 “Spare Parts”
This section gives a list of recommended spare parts.

Appendix A
This Appendix includes a checklist for start-ups and after maintenance.

Appendix B
This Appendix is a glossary of definitions for words used in the industry.
1.2 System Overview

The ArcWorld provides a complete arc-welding solution in a standardized configuration (see Fig. 1.3). The system is designed around a Robot, a Controller, a welding power source, and two work stations, Station 1 and Station 2.

Table 1-1: ArcWorld General Specifications

<table>
<thead>
<tr>
<th></th>
<th>ArcWorld 2000</th>
<th>ArcWorld 2200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controller</td>
<td>YRC1000</td>
<td></td>
</tr>
<tr>
<td>Robot</td>
<td>AR2010</td>
<td></td>
</tr>
<tr>
<td>Positioners</td>
<td>MH555, MH1655, or MH3155</td>
<td></td>
</tr>
<tr>
<td>Work Stations</td>
<td>one or two</td>
<td></td>
</tr>
<tr>
<td>Work Area/Envelope</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MH555</td>
<td>815mm</td>
<td></td>
</tr>
<tr>
<td>• MH1655</td>
<td>1000mm</td>
<td></td>
</tr>
<tr>
<td>• MH3155</td>
<td>1000mm</td>
<td></td>
</tr>
<tr>
<td>Positioner Motion (Main Axis)</td>
<td>±360</td>
<td></td>
</tr>
<tr>
<td>Payload Capacity Per Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MH555</td>
<td>555</td>
<td></td>
</tr>
<tr>
<td>• MH1655</td>
<td>1655</td>
<td></td>
</tr>
<tr>
<td>• MH3155</td>
<td>3155</td>
<td></td>
</tr>
<tr>
<td>Fencing</td>
<td>Heavy-gauge, wire-mesh or 14ga steel panels</td>
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</tr>
<tr>
<td>Riser Height</td>
<td>610mm</td>
<td></td>
</tr>
<tr>
<td>Access Door</td>
<td>Dual-channel Interlock</td>
<td></td>
</tr>
<tr>
<td>Light Curtain</td>
<td>Guarding Load Side / Operator</td>
<td></td>
</tr>
<tr>
<td>Approximate Weight of Controller Base Assembly</td>
<td>266.8kg</td>
<td>351.5kg</td>
</tr>
<tr>
<td>Approximate Weight of Positioner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• MH555</td>
<td>360.1kg</td>
<td></td>
</tr>
<tr>
<td>• MH1655</td>
<td>411.0kg</td>
<td></td>
</tr>
<tr>
<td>• MH3155</td>
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<td></td>
</tr>
<tr>
<td>Approximate Weight of Robot</td>
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<td></td>
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<td>Approximate Weight of Complete Assembly</td>
<td>CBA = Controller Base Assembly Poslb = Weight of Positioner #Man = Number of Robots Manlb = Weight of Robot</td>
<td></td>
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<tr>
<td>Dimensions of ArcWorld Cell Assembly</td>
<td>7509mm x 5697mm (1Robot, MHT55, 2M)</td>
<td>7498mm x 6680mm (2 Robots, MHT1655, 3M)</td>
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<tr>
<td>Dimensions of Controller Assembly</td>
<td>1150mm x 976mm</td>
<td>1950mm x 976mm</td>
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<tr>
<td>Input Voltages</td>
<td>480VAC without Transformer</td>
<td></td>
</tr>
<tr>
<td>External Axis Speed in TEACH Mode</td>
<td>250mm/sec</td>
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</tr>
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</table>
The ArcWorld features a total safety environment that meets or exceeds the requirements of the ANSI/RIA R15.06-2012 Robot Safety standard and is designed to safeguard both personnel and equipment. Heavy-gauge, wire-mesh safety fencing prevents unintended entry of personnel into the work cell while it is in operation. Arc curtains cover the wire-mesh fencing to decrease the amount of arc radiation that escapes the work cell during welding operations. A dual-channel interlocked access door at the back of the work cell provides convenient access to equipment while providing a safety interlock to disable all equipment should the access door be opened while the Robot(s) are active.

Safeguards for the system complement the systems operation while protecting people that will program, operate, and/or provide maintenance to the system. Possible pinch points and other hazards from the risk assessment process determined needed safeguards and interlocks. While the system design safeguards the support staff, it does not protect against misuse of the system. Misuse of the system includes, but is not limited to, climbing over/under barriers, climbing over/under interlocked doors, or disabling/bypassing of system interlocks.

During the install and commissioning process the end user must ensure tooling, and other equipment, do not cause additional hazards into the design. This evaluation ensures that the system will provide a safe and reliable operation. The Risk Assessment document should be reviewed for installation of the system and prior to operation. Any changes and additions to the system require a full review of the Risk Assessment document.
1.3 **System Layout**

The ArcWorlds consist of two main assemblies. These two main assemblies are the Robot Cell Assembly and the Controller Base assembly.

The system provides multiple configuration options for different application requirements. Several Robot options are available depending on applications and weld lengths. The Robot are mounted directly to the floor at the center of the cell for easy access to both stations.

The Positioners have a 3155kg capacities to comprise two work stations. Each Positioner is equipped with a MotoMount flexible fixture system, allowing the Positioners to be mounted directly to the floor. The Controller base assembly allows the Controller and welding power sources to share a common base outside the welding cell. The Functional Safety Unit (FSU) combined with the light curtains provide reliable safeguarding. All operator controls, including those on the Programming Pendant, Controller, welding power supply, and Operator Station, are accessible from outside the ArcWorld work cell.

### 1.3.1 Robot Cell Assembly

A standard Robot cell assembly includes:

- Two Operator Stations
- Positioner(s)
- Robot(s)
- Welding Equipment
  - Welding Torch (air-cooled)
  - Wire Feeder
  - Torch Mounts
- Safety Equipment
  - Heavy-gauge, wire-mesh safety fencing
  - Solid Panel (optional)
  - Arc curtains (covers the safety fencing)
  - Light Curtains System
  - Interlocked Work-Cell Access Door

---

**Fig. 1-1: Robot Cell Assembly**
1.3.2 Controller Base Assembly

The Controller Base Assembly includes:

- Top Hat and Interface
  - FSU Relay Board
  - Power Distribution Terminals
  - Eight port Ethernet Switch
  - Machine Safety Board
  - External Axis Connection(s)
  - Master Fuse Module
- Control Enclosure Assembly
- Controller
- Accessories/Air Panel
  - Pneumatic Filter/Regulator
  - Air Manifold
  - Valve Assemblies
  - Weld Accessories
  - 110V GFCI Receptacle (Optional)
- Welding Power Supply
- Transformer (Optional)

*Fig. 1-2: Controller Base Assembly*
1.3.3 Optional Equipment

The following optional equipment is available:

- **Slip Ring Kit: Air & I/O**
  This slip ring features 12 channel of discrete connections for customer use in a variety of scenarios. Each conductor can carry up to 10 amps of current.

- **Slip Ring Kit: EtherNet, I/O & Air:**
  This slip ring features both an EtherNet connection and six channels of discrete connections for customer use in a variety of scenarios. The EtherNet connection can be used for EtherNet/IP or other communication networks as appropriate - the cabling is shielded twisted pair when possible. Each discrete conductor can carry up to 10 amps of current.

- **Torch Cleaner**
  This stand-alone device uses a pneumatic motor with a reamer to clean the torch nozzle.

- **Wire Cutter**
  Automatically cuts welding wire to a desired length. A programmed path brings the welding wire into the cutter jaw. Using a Robot output signal, the pneumatic device will shear off the wire, leaving a clean edge at the programmed stick-out length. A specific length of wire is used for touch sensing on the Robot system.

- **Water-cooled Torch (with water circulator)**
  Reduces temperatures and prevents the system from overheating.

- **TouchSense™**
  The Touch Sensing function enables the Robot to find the welding joint.

- **ComArc™**
  Seam tracking functions by weaving the welding wire in the joint and sensing the current at each stroke of the weaving motion. If the detected current at each stroke is not the same, the Robot will correct its path in a direction required to make the current the same.

- **Digital Gas Flow Gauge**
  Provides a readout and diagnostic for the shield gas delivery to confirm if flow is present. This sends a digital signal to the Controller to trigger an alarm when detecting a low flow.

- **Beacon Light**
  Visual indicator of cell status and audible alert if alarm occurs. Colors indicate status conditions. Stack lights are in front of the cell for operator and plant personnel. Fence or post mounting is available for most cells and typically is located near the operator stations.

- **Tip Change Box**
  Service location for operators to address torch maintenance without entering the work-cell. Operator Station is integrated with all necessary Tip Change Request buttons and indicators.

- **Enabling Switch for Second Cell Occupant**
  Enabling switch with holster allows additional personnel to enter the work-cell when removing switch from holster.
1.3 System Layout

- **Wire Spool Mount**
  A bracket and cover to support cabling and mounting of a 30lb spool to the Robot. Also provided is conduit between the spool and wirefeeder.

- **Wire Delivery Kit for Bulk Wire**
  This kit includes brackets and conduit to attach to a customer provided bulk spool.

- **No Wire Sensor**
  Provides feedback from each wire conduit/delivery system when there is no wire present.

- **Exhaust Hoods**
  Ideal solution for capturing fumes before they can spread throughout a facility, and ensuring regulatory compliance.
  
  YASKAWA has worked with RoboVent to provide pre-engineered customized hoods that match each ArcWorld. Specific ventilation requirements require discussions with RoboVent.
1.4 Theory of Operation

The Controller "ArcWorld series of cells are designed for one or two Robots. The cells are available in two configurations:

• AW2000
• AW2200

The cell is designed for arc welding applications where the Robot(s), Controller(s) and welding power source(s) are located beside the cell. In the cell, the R2 Robot uses a full-size Controller cabinet. The DR2C configuration is such that if the Robot is needed to be redeployed, the Robot and Controllers can be separated for use in individual Robot applications.

Other items included with the cell are: A sliding door with safety interlock which allows access from the rear of the work cell. The Robots sit(s) on a 915mm riser(s). Mounting provisions are provided in the base for in cell torch cleaning station(s). The pedestal mount operator station is on front of the cell and is able to be relocated as desired based on cabling restrictions.
1 Introduction
1.4 Theory of Operation

1.4.1 System Teaching

**WARNING**

- Review the Risk Assessment prior to any interactions with the Work-Cell.

Failure to observe this warning can potentially be a hazardous situation which results in death or serious injury.

All systems are programmable by entering the interlocked work-cell access door or by viewing inside the cell from the exterior.

1. Place the selector switch on the Programming Pendant to TEACH.

**NOTICE**

Having the selector switch in the TEACH position limits all Robot and external axes speeds to 250 mm/sec and allows the position of the Interlocked Work-Cell Access Door to be open or closed.

**CAUTION**

- Avoid trip hazards (cable or other structures within the cell) while programming.

If not avoided injury can occur because the headstock Positioners are free to rotate as commanded from the Programming Pendant without regard to door status or light curtain violations.

2. Turn Robot servo motors on by pressing and holding the “Enable” button on the Programming Pendant.

3. Place selector switch on the Programming Pendant to PLAY when done with teaching.
1.4.2 System Operation

**WARNING**

- Check all programs, safety functions, and cell interactions before operating in an automatic operation.

Failure to observe this warning can potentially be a hazardous situation which results in death or serious injury.

The system can be placed into “AUTOMATIC OPERATION MODE” when the following conditions are met:

1. Complete path and logic programming.
2. Place the MODE switch on the Programming Pendant to “PLAY”.
4. Select the MASTER job on the Programming Pendant.
5. Now place the MODE switch to “REMOTE” so control can occur from either Operator Station.

**WARNING**

- Check all programs, safety functions, and cell interactions before operating in a continuous cycle.

Failure to observe this warning can potentially be a hazardous situation which results in death or serious injury.

6. From the “Main Menu” on the Programming Pendant select JOB then CYCLE.
7. Apply servo power using the [SERVO ON] button from any Operator Station.
8. Press the [START] button on either Operator Station to begin the INFORM job.

**NOTICE**

Once applying servo power and the job execution begins, then normal cell production can begin.

Normal cell production begins with the assumption that the Robots are in the home position. FSU Zones and Axis Range Limits ensure the Robot(s) operate in areas that are clear of human presence. This allows the Robots to stay within the “center” of the cell to access a torch cleaner or tip change station while either station is in use by the operator(s).

If a violation occurs with the station’s light curtain signal, the light curtains report this condition to the FSU and starts “AXIS SPEED MONITORING MODE” through the FSU. This prevents the headstock at that station from moving. If motion of the headstock is detected the entire system will go into an Emergency Stop condition and can be recovered after the source of the violation is addressed (possibly bad robotic programming). When a light curtain has been violated the “Light Curtain Reset” light will flash on
the associated operator station. If either Robot enters a station that is reporting a light curtain violation while in "PLAY MODE", the entire cell goes into an Emergency Stop condition. Recovery from the Emergency Stop condition can be done by clearing the Light Curtain (via manual reset) or changing to "TEACH MODE" and jogging the Robot(s) out of this station.

When the operator completes work in a station they will exit the station, and MAKE SURE all other operators and equipment are clear of the station, headstock, customer supplied tooling/fixture, and then press the [Light Curtain Reset] button to resume monitoring of the station by the light curtain. When the light curtain is clear the reset indicator stops flashing.

**NOTICE**

If a violation occurs with the station’s light curtain, the servos will remain on.

Pressing the [Cycle Start] button latches this station in for the queuing of work. The Robot(s) will approach this station immediately if no work is currently being performed. If work is occurring in the other station the Cycle Start Latched light will remain lit green and turns off when the cycle begins. Assuming there are no faults or issues during the production, the Robot(s) returns to a safe position once complete.

The MASTER job waits for Cycle Start inputs. It calls jobs based on the [CYCLE START CYCLE LATCHED] button being pressed and the state of the Thumb-wheel Switch dial/value. This job also controls the usage of the joystick jobs when the Robot(s) are not performing work at that station.

### 1.4.3 Key Safety Devices

#### 1.4.3.1 Controller with one or two Robots and FSU:

- Dual channel Programming Pendant EMERGENCY STOP
- Dual channel Programming Pendant “Enable” switch
- “TEACH/PLAY” mode input to FSU
  - Logic mapped from Machine Safety to FSU.
- Functional Safety Unit (FSU) - one per Robot
  - Limits Robot access as follows:
    - Complete perimeter access granted in TEACH mode.
    - Three axis limits are defined per Robot depending on light curtain status in PLAY mode.
      - Station 1 valid/allowed (light curtain 2 blocked)
      - Station 2 valid/allowed (light curtain 1 blocked)
      - Allowed in only “rear” of cell (light curtains 1 and 2 blocked.)
1.4 Theory of Operation

- Manages when the external axes in the system are in “Standstill Monitoring” based on the light curtain clear inputs
  - Station 1’s Positioner must be stationary if Station 1’s light curtain is blocked
  - Station 2’s Positioner must be stationary if Station 2’s light curtain is blocked

1.4.3.2 Safety Gate Interlock - tongue type: mechanical (qty 2):
  - Dual channel dry contact outputs

1.4.3.3 Operator Station per Workstation:
  - Red [ALARM / RESET] button - single channel with illumination
  - Green [SERVO ON] button - single channel with illumination
  - Red [ROBOT HOLD] button - single channel
  - 4 digit Thumb-wheel Switch - 8 wire (4 inputs, 4 outputs)
  - Green [CYCLE START CYCLE LATCHED] button - single channel with illumination
  - Green [START] button - single channel
  - Yellow [LIGHT CURTAIN RESET] button - single channel with illumination
  - Red EMERGENCY STOP button - dual channel with illumination
1.4.3.4 Safety Logic Implementation:

- **TEACH/PLAY Mode:**
  Disabling the FSU features function (files) can be difficult, especially when the Robot violates a defined Robot range or some other corrective action needs to be taken. Disabling the FSU functions requires the “Safety Mode” password to disable individual functions and then all of those functions have to be re-enabled before PLAY Mode production can begin. To eliminate these issues and expedite the steps to a remedy, PLAY mode status is a condition for many of the FSU files, thus changing to TEACH Mode will let a user quickly escape from the violating condition. **Putting the system in TEACH mode is often a first step to bypass or recover from many of the FSU’s monitoring functions.** The next thing to do is to move the Robot or barrier door into a condition that allows the cell to resume operation safely.

In TEACH mode, the Robot(s) are limited to motions with the cell. This perimeter definition is in a Range Limiting file to match the cell fencing.

**Fig. 1-3: Setting TEACH Mode in the Safety Logic Circuit Screen**
1 Introduction
1.4 Theory of Operation

- Functional Safety Unit: Safety Logic Implementation
  (1 Robot Zone shown):

**TEACH MODE**

In “TEACH MODE” a “R1 Teach Zone” has been established for the purpose of ensuring that the Robot remains within the confines of the work cell. Since “TEACH MODE” speeds are already limiting speed to 250mm/sec no additional safeguards will be taken. In “TEACH MODE”, “Axis Speed Monitoring” on either headstock will be disabled so that the programmer can jog and teach with the Positioners.

*Fig. 1-4: Teach Zone*

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*Fig. 1-5: Robot 1 - Axis Range Limit Files*

**Zone#1:** “R1 Safe/Center” → FSOUT#01

**Zone#2:** “R1 In Station 1” → FSOUT#02

**Zone#3:** “R1 In Station 2” → FSOUT#03

**Safety Logic Circuit Ext. Signal Allocation:**
(R1 only shown / R2 allocates 3 additional)
1 Introduction
1.4 Theory of Operation

**PLAY MODE**

In “PLAY MODE”, a combination of FSU-based Axis Range Limiting and “Axis Speed Monitoring” (Positioners) will ensure safe operation of the cell. The FSU-based “Axis Speed Monitor” function will be used to ensure that the appropriate headstock remains stationary in “PLAY MODE” anytime the light curtains at that station are violated. The Robot(s) are also restricted from entering the station until the light curtains at that station are reset. Any violations result in an E-Stop condition.

**Robot 1 - Robot Range Limit Files:**

Fig. 1-6: Robot Range Limits: One active zone that prevents the Robot from reaching beyond tooling or impacting the fence.

Fig. 1-7: Robot Range Settings: This zone is active all the time and prevents collisions in PLAY or TEACH mode. In PLAY mode, this zone also enforces light curtain stopping distances.

**NOTICE**

The values here are for reference only. They will change based on actual system configuration. Several variables control the data points: Robots (quantity and model variations) as well as Positioners model and station configuration.
1 Introduction
1.4 Theory of Operation

Station 1/2 - Axis Speed Monitor Files:

Fig. 1-8: Axis Speed Monitor Files Used (used for motion detection):
Always enabled:

![Diagram of Axis Speed Monitor Files](image1)

Fig. 1-9: Station#1 Axis Speed Monitor: When output signal goes “off” then motion is occurring.

![Diagram of Station#1 Axis Speed Monitor](image2)

**NOTICE**

If a dual Robot system the OUTPUT SIGNAL will use FS-OUT07 for this function.
Fig. 1-10: *Station#2 Axis Speed Monitor*: When output signal goes “off” then motion is occurring.

**NOTICE**

If a dual Robot system the OUTPUT SIGNAL will use FS-OUT08 for this function.
1 Introduction

1.4 Theory of Operation

In Case of a Two Robot system/AW2200 (FSU #2 Zone Configuration)

- All input signals come to FSU #2 to control activation of Robot 2’s limitation.

- Zone 4 - Same Function as R1/Zone 1. Center of cell, like Zone 1, same S-Axis values.

- Zone 5 - Same Function as R1/Zone 2. Same station access as Zone 2, negated S-Axis values due to Robot rotation 180 degrees.

- Zone 6 - Same Function as R1/Zone 3. Same station access as Zone 3, negated S-Axis values due to Robot rotation 180 degrees.

NOTICE

If there are any Robot orientation changes from a standard drawing layout, the S-axis values should be evaluated again.

Fig. 1-11: Safety Logic Circuit

- In Case of a Two Robot system/AW2200 (FSU #2 Zone Configuration)
- All input signals come to FSU #2 to control activation of Robot 2’s limitation.
- Zone 4 - Same Function as R1/Zone 1. Center of cell, like Zone 1, same S-Axis values.
- Zone 5 - Same Function as R1/Zone 2. Same station access as Zone 2, negated S-Axis values due to Robot rotation 180 degrees.
- Zone 6 - Same Function as R1/Zone 3. Same station access as Zone 3, negated S-Axis values due to Robot rotation 180 degrees.
1.5 Reference Documentation

For additional information on individual components of the ArcWorld 2000 system, refer to the following documentation that is included with the system:

- Motoman Lagging Supplement (P/N 186835-1CD)
- AR2010 Manipulator Manual (P/N 182442-1CD)
- AR2010 Manipulator Maintenance Manual (P/N 181847-1CD)
- MH3155 SIGMA-5 Positioner (P/N 171246-1CD)
- MH(T)-Series SIGMA-5 Positioner Manual (P/N 168961-1CD) (MH555 or MH1655)
- Brake Release Manual (P/N 179330-1CD)
- YRC1000 READ FIRST!! Safety Requirements (P/N 179526-1CD)
- YRC1000 Instructions (P/N 178642-1CD)
- YRC1000 General Operator’s Manual (P/N 178645-1CD)
- YRC1000 Maintenance Manual (P/N 178643-1CD)
- YRC1000 Alarm Codes Manual (P/N 178644-1CD)
- Operator’s Manual for Arc Welding (P/N 178646-1CD)
- Concurrent I/O Manual (P/N 178648-1CD)
- YRC1000 Independent/Coordinated Control Function Manual (P/N 178660-1CD)
- INFORM User’s Manual (P/N 178649-1CD)
- Functional Safety Board Operation Manual (P/N 165988-1CD)
- Vendor manuals for system components not manufactured by YASKAWA
## 1.6 Reference Table

The table below provides location(s) for various operations.

<table>
<thead>
<tr>
<th>Description</th>
<th>Manual/Chapter</th>
<th>Handling</th>
<th>Installation &amp; Commissioning</th>
<th>Start-up</th>
<th>System Information</th>
<th>Use of System</th>
<th>Maintenance</th>
<th>Decommissioning</th>
<th>Emergency Situations</th>
<th>Robot Specific Information</th>
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1.7 Customer Support Information

If assistance is needed with any aspect of the ArcWorld 2000 system, please contact Customer Support at the following 24-hour telephone number:

(937) 847-3200

For routine technical inquiries, Customer Support can be contacted at the following e-mail address:

techsupport@motoman.com

When using e-mail to contact Customer Support, please provide a detailed description of the issue, along with complete contact information. Please allow approximately 24 to 36 hours for a response to an inquiry.

NOTICE

Please use e-mail for routine inquiries only. If there is an urgent or emergency need for service, replacement parts, or information, contact Customer Support at the telephone number shown above.

Please have the following information ready before calling:

- System
  ArcWorld 2000 or ArcWorld 2200
- Manipulator (Robot)
  AR2010
- Positioner
  MH555, MH1655, or MH3155
- Primary Application
  Arc Welding
- Controller
  YRC1000
- Software Version
  Access this information on the Programming Pendant’s LCD display screen by selecting {MAIN MENU} - {SYSTEM INFO} - {VERSION}
- Robot Serial Number
  Located on the Robot data plate
- Robot Sales Order Number
  Located on the Controller data plate
# 1.8 Quick Start Guide

**WARNING**

Anyone working with the ArcWorlds is responsible for reading and understanding all included documents. This Quick Start Guide is just a basic outline of the setup of the ArcWorld.

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YRC1000 Operator's Mnl Sec 1.1.1
YRC1000 General Operator's Mnl Chap 3
YRC1000 Operator's Mnl Sec 1.1.1
YRC1000 General Operator's Mnl Chap 3
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YRC1000 General Operator's Mnl Chap 4
YRC1000 General Operator's Mnl Sec 4.3
ArcWorld 2000 System Mnl Sec 1.3.2, 2.3, & 4.2
2 Equipment Description

2.1 Robot Description

The ArcWorld 2000 system is available with a six-axis Robot. This Robot is specifically designed for arc-welding applications. The Robot has a payload capacity of 10kg and features a horizontal reach of 2010mm. The Robot features a relative positioning accuracy of ±0.08mm.

The Robots features an internal cabling design that provides high flexibility and streamlines the Robot profile, thus allowing access into confined spaces. The Robot’s B-axis (Pitch/Yaw) features an expanded range of motion that improves circumferential welding on cylindrical work pieces. The T-axis (Twist) can rotate the welding torch ±210 degrees without cable interference.

The Robot’s S-axis rotation is physically limited by stops located in the base of each Robot. For more information, refer to the Robot Manual that came with the ArcWorld documentation package (see section 1.5 “Reference Documentation” on page 1-20).

2.2 Controller

The Controller, shown in Fig. 2-1, features a Windows® CE Programming Pendant with a color touch screen, high-speed processing, built-in Ethernet, and robust PC architecture. The Controller easily handles multiple tasks and can control up to eight Robots (up to 72 axes, including Robots and external axes) and input/output (I/O) devices. Advanced Robot Motion (ARM) control provides high-performance path accuracy and vibration control.

The Controller coordinates the operation of the ArcWorld. It controls the Robot movement and welding power supply, processes input and output signals, and provides the signals to operate the welding system.

For more information on the Controller, refer to the Controller Manual that is included with the ArcWorld documentation package (see section 1.5).

Figure 2-1: Controller
2.2.1 Programming Pendant

The Programming Pendant (see Fig. 2-2) provides the primary means for programmer/operator interaction with the ArcWorld. The pendant features a Windows® CE operating system and displays information on a 640 X 480 pixels color LCD, touch-screen. The Programming Pendant also incorporates a SD card slot and USB port for program backups.

The Programming Pendant provides icon-driven system programming. It also features a menu-driven interface to simplify operator interaction with the Robots. Most operator controls are located on the Programming Pendant. This allows remote installation of the Controller. By using the Programming Pendant, the operator can teach the Robots motion; perform programming, editing, maintenance, and diagnostic functions; and enable or disable Operator Station control of the ArcWorld. For detailed information on the pendant’s programming keys, programming functions, and display functions, refer to the Controller Operator’s Manual for Arc Welding that is included with the ArcWorld documentation package (see section 1.5).

Figure 2-2: YRC1000 Programming Pendant
NOTICE

- The Programming Pendant’s LCD display goes dark after a few minutes of inactivity. Press any key to restore the screen.
- Placing the Programming Pendant’s Mode switch to REMOTE transfers control of the ArcWorld to the Operator Station.
- Refer to the Programming Pendant instructions for more details.
2.3 Operator Station

The Operator Station (see Fig. 2-3) is mounted on a panel between the two safety barrier doors. See Fig. 1.3 for the location of the Operator Stations in relation to the other components of the ArcWorld. The following paragraphs describe the controls on the Operator Stations.

**NOTICE**
Placing the Programming Pendant’s Mode Switch to REMOTE transfers control of the ArcWorld to the Operator Station.

Figura 2-3: Operator Station

### 2.3.1 Operator Station — ALARM/RESET
A red ALARM lamp illuminates to indicate that the Controller has encountered an alarm condition. Pressing the [ALARM/RESET] button clears a minor alarm or error condition.

### 2.3.2 Operator Station — SERVO ON
The green [SERVO ON] push button turns servo power ON if the Programming Pendant’s Mode Select Switch is set to REMOTE.

### 2.3.3 Operator Station — ROBOT HOLD
Pressing the red [ROBOT HOLD] button stops Robot operation and interrupts the job until the operator presses the green [START] button to resume operation. Operation resumes at the point in the program where the [ROBOT HOLD] state was initiated.
2.3.4 Operator Station — CYCLE START CYCLE LATCHED

**WARNING**

- The operation of the [CYCLE START CYCLE LATCHED] button depends on the structure of the Control Master job. Any alteration of the Control Master Job can cause injury to personnel or damage to equipment.

Pushing the green [CYCLE START CYCLE LATCHED] button initiates a cycle at the corresponding station if the Robot is in the HOME (Safe) position. If the [CYCLE START CYCLE LATCHED] push button is pressed while the Robot is still welding, or otherwise not in the HOME (Safe) position, the [CYCLE START CYCLE LATCHED] command is “latched” in (stored in) the Controller’s circuitry. When the Robot returns to the HOME (Safe) position, the “latched” [CYCLE START CYCLE LATCHED] command is automatically executed in the queued station. Circuitry in the Controller prevents the Positioner from continuously cycling should the operator depress and hold the CYCLE START CYCLE LATCHED] button.

2.3.5 Operator Station - Thumb-wheel

Thumb-wheel scrolls and selects the desired job.

2.3.6 Operator Station — START

Pressing the green [START] button starts the current, active job. The Programming Pendant’s Mode Select Switch must be set to REMOTE and servo power must be ON for the [START] button to function.

2.3.7 Operator Station — JOYSTICK CONTROL

The Home joystick controls Positioner rotation and user defined load positions. The Positioner has the ability to position the headstock ±360° in 2.5° increments for better part-loading and unloading ergonomics. This rotation of the headstock in 2.5° increments (also known as “jogging”) is accomplished with the JOYSTICK CONTROL.

2.3.8 Operator Station — LIGHT CURTAIN RESET

The [LIGHT CURTAIN RESET] button will flash after the light curtains are broken. The flashing indicates a manual reset is required and is done by pressing this button momentarily.

2.3.9 Operator Station — EMERGENCY STOP

Pressing the Operator Station’s EMERGENCY STOP button initiates an E-Stop condition. Refer to section 2.6.4 for information on the E-Stop condition and the procedures for recovering the ArcWorld from an E-Stop condition.
2.4 Positioner

The Positioner systems include a headstock drive assembly, tailstock column, and the MotoMount tool mounting system. Parts fixturing is mounted between the headstock and tailstock faceplates providing a highly versatile work area.

Refer to the Positioner manuals included (section 1.5 “Reference Documentation” on page 1-20) for MotoMount and technical details.

The ArcWorld system is capable of synchronized motion between various components depending on the job configuration. The Robot can be synchronized with the Positioner to work simultaneously with a rotating work piece. For additional information on this type of independent control and coordinated motion, refer to the Independent/Coordinated Control Function Manual that is included with the ArcWorld system documentation package section 1.5 “Reference Documentation” on page 1-20.

For additional Positioner information, including specifications, illustrated parts list, load capabilities, and dimensions, refer to the Positioner Manuals included with the ArcWorld documentation package.

**NOTICE**

- The customer shall supply all tooling and fixtures for the Positioner.
- It is recommended application of a corrosion/rust preventive compound for tooling and fixtures located in a high-humidity environment.
2.5 **Weld Station**

In a standard configuration, the ArcWorld system includes a welding power source, wire feeder, torch, and torch mount for each Robot.

Optional equipment may also be included with the ArcWorld system (refer to section 1.3.3 “Optional Equipment” on page 1-7).

2.5.1 **Welding Power Sources**

Various brands and types of welding power sources are available. The welding power source supplied with the ArcWorld depends on the customer’s specific application and preference. For specific information on the welding power source supplied with the ArcWorld, refer to the welding power source manual that is included with the system documentation package.

2.5.2 **Wire Feeder**

A welding wire feeder is mounted on the upper arm (U-Axis) of the Robot. An electronically controlled gas valve provides fast welding gas response time. Interchangeable feed rolls are used to accommodate different wire gauges and wire types. For additional information on how the wire feeder is mounted to the Robot’s upper arm, including allowable load and installation position, refer to the wire feeder documentation that is included with the ArcWorld documentation package.

2.5.3 **GMAW Torch**

The ArcWorld uses either an air-cooled or water-cooled robotic/automatic GMAW torch. These are heavy-duty torches designed for quick replacement and a minimum of Robot reprogramming. The GMAW torch is installed in a torch mount at the end of the Robot’s wrist flange. The torch mount can provide multi-dimensional impact (collision) detection to protect the Robot, torch, fixture, Positioner, and work piece from damage in the event of a collision. Any torch impact (collision) triggers an Emergency Stop condition (refer to section 4.3.2 “E-Stop Recovery” on page 4-9).

For applications that use the optional water-cooled torch, the ArcWorld includes a water circulator kit. For additional information on the torches that are supplied with the system, refer to the vendor documentation that is included with the documentation package.
2.6 Safety Features

The ArcWorld includes a total safety environment. Comply with all the safety instructions and precautions given throughout this manual. The safety equipment helps to ensure safe operation of the Robot work cell.

**NOTICE**

Users are responsible for determining that the safeguards provided with the ArcWorld are adequate for their plant conditions. Users must also ensure that all safeguards are maintained in working order.

2.6.1 Welding Arc Protection

One by-product of the welding arc is an intense level of ultraviolet light. The ultraviolet light radiates outwardly (equal strength in all directions) from the weld point whenever an arc is established. If not attenuated, the radiated ultraviolet light can present a health risk to personnel near the welding arc.

**WARNING**

- Never look directly at the welding arc without protective eye wear.
  - Although safety fence arc curtains block the radiation of ultraviolet light, never look directly at the welding arc without protective eye wear.

Not wearing protective eye wear can result in blindness.

The arc curtains filter (or "block") most of the ultraviolet light radiation that would otherwise escape the work cell. Just as the arc screen on the Positioner protects the operator from intense ultraviolet light, the arc curtains protect other personnel who are near the work cell.
2.6.2 Safety Fencing (Standard)

The heavy-gauge, welded wire safety fencing that is provided with the ArcWorld encloses the entire work cell. It forms a physical barrier that prevents personnel from entering the work cell during automatic operation.

2.6.2.1 Safety Fencing Based on Tooling Diameter

The cell is available with two fence configurations. One fence configuration is based on the full tooling diameter of the tooling (1300mm) and a second is based on a smaller or limited diameter tooling. A diagram which shows both is shown in Fig. 3-1(b "Plan View Side View" on page 3-4. When using the limited diameter tooling the fence span can be reduced due to the reduced stopping time of the Positioner. If the diameter of the tool is anywhere greater than 710mm, then the larger diameter fence solution must be used.

2.6.2.2 Safety Fencing (Option)

The cell can also be configured with solid panel fencing as an upgrade. This will block more of the ultraviolet light radiation that could escape from the work environment and also forms a physical barrier that prevents personnel from entering the work cell during automatic operation.
2.6.3 Safety Light Curtains

The safety light curtains work in conjunction with the Functional Safety Unit to help prevent serious injury to anyone entering a station safety zone while the Robot is working in that area. In PLAY mode, if the Robot is at station 1 and the operator steps into the station 1 safety zone, servo power is removed from the system and all Positioner motion stops. Servo power can be re-applied and operation resumed by pressing SERVO ON and START. Light curtains must be manually reset before operation can resume.

For additional information on the safety light curtain system, refer to the vendor documentation that is included with the ArcWorld system documentation package.

2.6.3.1 Additional Safety Light Curtains (Option)

Additional sets of light curtains can be integrated under the Positioner. These are mounted to the floor and monitor for conditions when operators use the system incorrectly. This prevents an operator from crouching down and going under the Positioner into the active Robot zone. These light curtains are muted during Positioner sweep so that tooling diameters are not impacted.

2.6.4 EMERGENCY STOP (E-Stop) Condition

E-Stop is a primary safety feature of the ArcWorld. A work-cell access door interlock, the safety light curtain system, Robot welding torch impact (collision) detection circuitry (refer to section 2.5.3), and EMERGENCY STOP buttons can trigger an E-Stop condition. An E-Stop condition immediately de-energizes the control system and activates the Robot emergency braking system (refer to section 2.6.6). The EMERGENCY STOP buttons are used for an intentional shutdown of the ArcWorld and are installed at the following locations:

- Programming Pendant
- Operator Stations

To resume operation after an E-Stop condition shutdown, the operator must clear and reset the action that caused the E-Stop condition (refer to section 4.3.2 “E-Stop Recovery” on page 4-9).

2.6.5 Programming Pendant’s ENABLE Switch

The ENABLE switch is part of the Programming Pendant and provides a safety feature that controls servo power while the system is in TEACH mode (see Fig. 2-2). When pressed in, this switch allows the operator to enable servo power. Should the operator release the switch or grasp it too tightly; however, servo power is immediately disabled, thus preventing further Robot movement. For detailed information about the operation of the ENABLE switch, refer to the Controller Operator’s Manual for Arc Welding that is included with the documentation package (see section 1.5 “Reference Documentation” on page 1-20).
2.6.6 Emergency Braking System

The Robot incorporates a braking system that protects personnel from injury and prevents equipment damage if servo power is removed. Upon loss of servo power, the brake system activates to hold all Robot axes in place. The brake system incorporates a feature that allows the operator to release the brake of a specific Robot axis, even if drive power is disabled. Brake release is accomplished with the Programming Pendant. Refer to the *Manual Brake Release* manual included with the documentation package (see section 1.5 “Reference Documentation” on page 1-20).

2.6.7 Interlocked Work-cell Access Door

The work-cell access door features a safety interlock (see Fig. 1.3 "System Layout" on page 1-5). Any attempt to open the access door while the Robots are in PLAY mode triggers an E-Stop condition (refer to section 2.6.4).
Two to three qualified technicians can install the ArcWorld in a reasonable amount of time. Always comply with all the safety instructions and precautions given throughout this manual.

The instructions given in this section are general guidelines for installing the ArcWorld system. Refer to the system drawings for more specific installation information.
3 Installation
3.1 Required Materials

3.1 Required Materials

All system components and most of the materials and fasteners needed for installation of the ArcWorld are included with shipment from the factory; however, the customer must supply some required items and installation tools (refer to section 3.1.1 and section 3.1.2).

3.1.1 Customer-supplied Items

• Shielding gas for the welding torches
• Local electrical service
• Earth ground wires for the Robots and Controller assembly
• Earth ground rods and/or buried copper sheeting (quantity and placement depth as required to achieve specified resistance-to-ground reading of 100 ohms or less)
• Chemical (optional) to increase conductivity of soil in the vicinity of the earth ground system
• Welding wire
• Clean, dry air supply (for torch tender or wire cutter options):
  – Flow Rate: 0.425m³/min (15cfm)
  – Pressure: 620kPa, gauge (90psi, gauge)
• Forklift
• Special anchor bolts and drill bits (refer to “Lagging Supplement” for suggested anchoring hardware)

3.1.2 Recommended List of Hand Tools and Equipment

• Safety Glasses
• Gloves (Leather, Heavy Duty)
• Socket Set (SAE and Metric)
• Phillips and Flat-Blade Screwdrivers
• Open-end Wrench (SAE and metric)
• Air-impact Gun (3/4-inch hex socket)
• Hammer Drill with Concrete Bits
• Face Shield
• Levels (short and long)
• Ratchet (3/4-inch hex socket)
• Hex key wrench sets (SAE and metric)
• Adjustable Wrenches (Large and Small)
• Hammers (dead-blow, steel, and non marring)
3.2 Site Preparation

CAUTION

• During installation planning, allow sufficient room for access to the work-cell door and system components that are exterior to the work cell.

Failure to observe this warning could result in injury to personnel during system operation and maintenance.

To prepare the site, proceed as follows:

1. Clear the floor space and overhead area needed for the ArcWorld (see Fig. 3-1(a) and Fig. 3-1(b)). Allow an additional 1.2m to 1.5m on all sides of the work cell to provide the clearances needed for installation.

2. Gather all customer-supplied items and required tools (refer to section 3.1).

NOTICE

ArcWorld dimension requirements are the same.
3 Installation
3.2 Site Preparation

Fig. 3-1(a): Plan View Overhead View

Fig. 3-1(b): Plan View Side View
3.3 Installation of ArcWorld

3.3.1 Installing ArcWorld in Location

See included system drawing package for the detailed ArcWorld layout.  
*Fig. 3-2: Cell Assembly*

The ArcWorld components are attached to wooden shipping skids at the factory, prior to shipment to the customer. The customer is responsible for inspecting the components for shipping damage.

**NOTICE**

If there is any equipment damage, notify the shipping contractor as soon as possible.
3.3 Installation of ArcWorld

1. Unbolt the components from the shipping skids using a 3/4-inch hex socket (see Fig. 3-3).

**Fig. 3-3: Typical Stabilizing Screw and Removal of A Shipping Lag Bolt**

**NOTE** – An air-powered tool is not required for removal of the shipping bolts, as these fasteners can be removed with ordinary hand tools. However, the air-powered tool does make quick work of the task.

TYPICAL WORK CELL COMPONENT

AIR IMPACT DRIVER WITH 3/8 INCH SOCKET (see NOTE)

STABILIZING SCREW (HOLLOW CORE)

SHIPPING BOLT (HIDDEN BY 3/8 INCH DRIVE SOCKET)

WOODEN SHIPPING PALLET

2. Move equipment in place according to system drawings.

3. Carefully remove protective plastic wrapping

4. Inspect each Robot for shipping damage.

**WARNING**

- Make sure lifting device is rated to handle at least:
  - 260kg for Robot
  - 1100kg for Positioner
  - 420kg for Controller Base Assembly

Not using a lifting device rated for the appropriate weights can result in death or serious injury.

**CAUTION**

- Make sure the foundation is rigid and strong enough to support the dynamic repulsion forces.
  - If the foundation surface is not level and even, grind the swell to flatten the surface.
  - The minimum thickness of the foundation is 150mm.

Not ensuring appropriate foundation can cause damage to flooring and equipment.
3.3 Installation of ArcWorld

5. Anchor each Robot securely in place (refer to “Lagging Supplement” for anchor suggestions).

6. Discard and recycle the shipping skids and other shipping material.

### 3.3.2 Door Latch Alignment

Adjust the location of the door latch as necessary to provide smooth operation of the door assembly. A #14 spanner bit is provided to loosen and adjust the location of the latch assembly. Shims can also be placed beneath the fence posts to make gross adjustments. See Fig. 3-4(a) through Fig. 3-4(c) for various latch adjustments.

**CAUTION**

- Wear protective eye wear during the anchoring process.

Failure to observe this CAUTION can result in eye injury.

**NOTICE**

Use the door interlock by attaching a lock to the door handle key for Lockout/tagout procedures.

*Fig. 3-4(a): Door Latch Alignment*
3 Installation

3.3 Installation of ArcWorld

**Fig. 3-4(b): Right Hand Sliding Configuration**

![Right Hand Sliding Configuration Diagram]

**Fig. 3-4(c): Left Hand Sliding Configuration**

![Left Hand Sliding Configuration Diagram]
3 Installation

3.3 Installation of ArcWorld

3.3.3 Installing the Arc Curtains

**CAUTION**

- Do not install the arc curtains until the cell walls are secure. Unsecured cell walls can fall and injure personnel and damage equipment.

1. Unfold each arc curtain and install one on the inside of each work-cell safety fence panel using the supplied plastic cable ties and the eyelets in each arc curtain (see Fig. 3-5.)

**NOTICE**

- The arc curtains are precut to match the work-cell fence panels. Each arc curtain bag contains documentation that includes the arc curtain dimensions. If necessary, these dimensions can be used to match the arc curtain to the correct work-cell fence panel.
- Make sure that there are no gaps between the arc curtains.

2. Install the work-cell door arc curtain on the inside of the door panel using the supplied plastic cable ties and the eyelets in the arc curtain (see Fig. 3-5.)

Fig. 3-5: Arc Curtain Installation on a Typical Safety Fence Panel

NOTE – Arc curtain is installed on the fence panel side that faces the INTERIOR of the robotic work cell.
3.4 Cable Connections

WARNING

• Ground resistance must be 100 Ω or less. Failure to observe this warning may result in fire and/or electric shock.

• Turn the primary power supply OFF, and put up a warning sign (ex. DO NOT TURN THE POWER ON) before wiring. Failure to observe this warning may result in electric shock and/or personal injury.

• Wiring must be performed by authorized or certified personnel. Failure to observe this caution may result in fire and/or electric shock.

• DO NOT cover the cable with heat insulating material and avoid multiple cabling when laying cables from the Robot to the Controller. Failure to observe this caution may result in burn caused by cable heat emission failure.

After components are level and securely in place, the cables should be unwrapped from around the equipment and laid out according to the cable diagram included in the system drawing package. Each cable connection is clearly identified for ease of installation.

NOTICE

A small gap exists between the bottom of the work-cell safety fence and the floor. This gap provides a passage for cables that run between the components outside the work cell and those inside the work cell.
### 3.4.1 Connecting Robot and Controller to Earth Ground

#### WARNING

- Do not use the ArcWorld unless specified components are connected to a low-resistance earth ground.

Operator injury or death, as well as equipment damage, can result from an inadequate or defective earth ground system.

- Do not connect the earth ground wire with the wires for the electric power source, welder, etc.
  - The low-resistance earth ground must be a “dedicated” ground that is a direct connection between a component and the earth ground point.

Operator injury or death, as well as equipment damage, can result from an inadequate or defective earth ground system.

#### 3.4.1.1 Installing Grounding Stake.

The customer shall supply all wires associated with the earth ground. The customer is responsible for establishing the correct gauge of all wires associated with the earth ground and maintaining an adequate earth ground (measured resistance of 100 ohms or less).

1. Treat soil with chemical that increases the soil conductivity in the vicinity of where the Grounding Stake will be located.
2. Drive the grounding stake at least 2.43m into the soil.
3. Check that the “low-resistance earth ground” has a resistance of 100 ohms or less (when measured directly between grounded equipment and the earth ground system). Be advised that specialized measuring equipment is usually required to get an accurate “resistance-to-ground” reading. Consult a specialist in this field, if required.

#### NOTICE

Multiple ground rods (bonded together) or even a bonded network of buried copper sheeting (plus conduction enhancing chemicals) may be required, depending on local soil conditions.
3.4.1.2 Connecting Robots to Earth Ground

1. Connect one end of an earth ground wire to the lug marked EARTH GROUND on the connector panel of Robot R1. See Fig. 3-6

Fig. 3-6: Grounding Method

2. Connect the other end of the earth ground wire to the low-resistance earth ground.

3.4.1.3 Connect the Controller assembly to the earth ground as follows:

1. Connect one end of an earth ground wire to the COMMON GROUND BUS BAR located inside the Controller.

2. Connect the other end of the earth ground wire to the low-resistance earth ground.
3.4.2 Connecting Robot Cables

Uses one cable to connect each Robot to the Controller. To connect the Robot Cables, proceed as follows:

**CAUTION**

- Do not use excessive force and make sure the cable connectors are correctly aligned with the mating connectors.

The connectors are a “multi-pin” type and are easily damaged if forced into position.

1. Unpack the Programming Pendant and plug its connector into the receptacle on the Controller.
2. Connect the 1BC connector of the Robot cable to the Robot.

![Fig. 3-7: Robot Cable](image)

Controller Side

![Diagram of controller side](image)

Robot Side

![Diagram of robot side](image)

3. Route the Robot Cable to the Controller connecting connector x11 to the Controller.
3.4.3 Connection to Local Electrical Service

WARNING

- Use a qualified, licensed electrician to connect the local electrical service connection to the ArcWorld.
  
  - Electrical and grounding connections must comply with the National Electrical Code (NEC), as well as all local electrical codes.

Indicates a potentially hazardous situation which, if not done, could result in death or serious injury to personnel.

NOTICE

The ArcWorld system is configured for three-phase 460/480V AC primary power. For additional information, refer to the electrical drawings and schematics that are included with the system documentation package (see section 1.5 “Reference Documentation” on page 1-20).

After all the system components have been properly installed and interconnected, connect local electrical service to the Controller and welding power source (refer to section 3.4.3.1 and section 3.4.3.2).

3.4.3.1 Controller

For detailed electrical service interconnect procedures for the Controller, refer to the Controller Manual and ArcWorld drawings and schematics that are included with the system documentation package (see section 1.5 “Reference Documentation” on page 1-20).

3.4.3.2 Welding Power Source

Refer to the welding power source documentation and ArcWorld drawings and schematics ensuring the pre-wiring of the welding power source.
3.5 Safety/Operation Check

Before installing the tooling and fixtures for the application, take a few minutes to perform the following safety/operation check:

1. Ensure that all shipping brackets and material are removed from the system.
2. Make sure the safety light curtains are aligned correctly. Refer to the Safety Light Curtain Documentation included with the ArcWorld.
3. Check the security and integrity of all cable connections.
4. Ensure that the work-cell sliding access door closes and the door interlock engages properly.
5. Verify the correct settings for the welding power source (refer to the welding power source documentation that is included with the ArcWorld).
6. Verify that local electrical service complies with the power requirements for the ArcWorld system.
7. Verify that local electrical service is correctly wired into the Controller assembly and the welding power source (refer to section 3.4.3).

8. Rotate the Power ON-OFF switch on the Controller to ON (see Fig. 2-1 "Controller" on page 2-1).

9. Set the power ON-OFF switch on the welding power source to ON.

10. Check for correct operation of all EMERGENCY STOP buttons (refer to section 2.6.4).

---

**CAUTION**

- Use a qualified, trained personnel who are familiar with the ArcWorld to perform the power-up sequence.

Not using someone who is qualified, trained and familiar with the ArcWorld can result in personal injury and equipment damage.

**NOTICE**

An electrical service disconnect box for the Controller shall be supplied (if desired) by the customer. It is not part of the ArcWorld shipment.

**WARNING**

- Make sure each EMERGENCY STOP button disables servo power when pressed.
  - Each EMERGENCY STOP button must immediately stop the Robot and Positioner movement when activated.

If the EMERGENCY STOP buttons do not work correctly serious injury or death can occur.
3 Installation
3.5 Safety/Operation Check

11. Check for correct operation of the system [HOLD] button on the Programming Pendant.

**NOTICE**

Refer to the following concerning [HOLD] buttons:

- *Operator's Manual for Arc Welding* for more information on the Programming Pendant’s HOLD button (see *section 1.5 “Reference Documentation” on page 1-20*).

- Robots Manual for more information concerning the Operators Station [HOLD] button (see *section 1.5 “Reference Documentation” on page 1-20*).

12. Check for correct operation of the work-cell access door safety interlock.

13. Remove power from the ArcWorld after completion of the Safety/Operation Check.
3 Installation
3.6 Installation of Tooling and Fixtures

Your ArcWorld is now ready for installation of the tooling and fixtures for your particular application. Personnel who are familiar with the operation of the ArcWorld should do the installation. After tooling installation, test the Positioner for correct operation. Refer to the Positioner manual for information on how to test that the Positioner is operating correctly (see section 1.5 “Reference Documentation” on page 1-20).

NOTICE

• An electrical service disconnect box for the Controller shall be supplied (if desired) by the customer. It is not part of the ArcWorld shipment.
• The customer supplies all tooling and fixtures for the Positioner.
• YASKAWA recommends applying a corrosion/rust preventive compound to the tooling and fixtures that are located in a high humidity environment.
This section provides a brief overview of the operating procedures and precautions for the ArcWorld. For more detailed operating information, refer to specific component manuals that are part of the documentation package (refer to section 1.5 “Reference Documentation” on page 1-20).

The ArcWorld is a fully integrated robotic GMAW welding cell. The Robot welds parts in Station 1 of the two-station system while the operator loads Station 2 with parts to be welded. When the Robot completes the welding program at Station 1, it returns to the HOME (Safe) position. The operator can then initiate a [CYCLE START CYCLE LATCHED] from the Operator Station for the new set of parts at Station 2. This moves the Robot to Station 2, and the welding processes continues. The operator moves into Station 1 and replaces the completed welded parts with parts for another welding cycle.

**NOTICE**

The customer supplies all tooling and fixtures for the Positioner.
4 Operation
4.1 Programming

The operation of this system is programming dependent. The following operating instructions are based on one possible configuration of this system. The system configuration and job structure may differ slightly from that presented here; however, basic operation will remain the same. For additional programming procedures and information, refer to the Controller documentation included with the ArcWorld system documentation package (see section 1.5 “Reference Documentation” on page 1-20).

Any changes made to the system configuration and/or job structure changes the operation of the system. YASKAWA recommends not modifying the original jobs and system configuration of the ArcWorld. If it is determined, a need to modify the original jobs and system configuration, make any modifications to a copy of the original. Keep the original as a backup. Do not modify the original. Modifications must be performed by trained and experienced personnel who are familiar with the operation of the ArcWorld. If there are any questions concerning the configuration of the system, please contact Customer Support (refer to section 1.7 “Customer Support Information” on page 1-24).

A major advantage of the ArcWorld system is its high degree of flexibility. The operator can fine tune the movement of both the Robots and Positioners according to the parts configuration. The Robots can be programmed to weld parts with the Positioner stationary, or the Robots and Positioners moving simultaneously. The Robot can be programmed to weld different seams on the same part and to move from part to part to continue welding.

With the Programming Pendant, the operator can develop a series of jobs for the Robot. You can program the Robots independently, the station axis independently, or the Robots and station axis together. You must select the axis combination when teaching the job initially. YASKAWA recommends programming the Robot(s) and station axis together to reduce the risk of interference.
4.2 Daily Operation

The procedures below represent the typical operating sequence from power-up to shutdown. The basic operating procedures may vary depending on the situation.

**CAUTION**

Collaboration is a special type of operation between a person and Robot sharing a common workspace. The following are the guidelines for collaborative operation.

- Used for pre-determined tasks.
- Possible when all protective measures are active.
- For Robots with features specifically designed for collaborative operation.

The integrator shall include information for the use of safeguards and mode selections required for collaborative operation.

- Perform the Start-up Procedure (see section 4.2.1.)
- Move Robot(s) to the HOME Position (see section 4.2.2.)
- Perform a Safety Circuit Check (see section 4.2.3.)
- Select the Control Master job (see section 4.2.4.)
- Perform an Operation Cycle (see section 4.2.5.)
- Perform the Shutdown procedure (see section 4.2.6.)
4.2 Daily Operation

4.2.1 Start-up Procedure

To start up the ArcWorld work cell from a power-off condition, proceed as follows:

1. If installed, switch the Controller electrical service disconnect box to ON.

2. Rotate the Controller’s power ON-OFF switch to ON (see Fig. 2-1 "Controller" on page 2-1).

3. Switch the welding power source electrical service disconnect box to ON (see Fig. 2-1 "Controller" on page 2-1).

4. Set the power ON-OFF switch on the welding power source to ON (the ON-OFF indicator lamp on the welding power source will illuminate).

5. Open the regulator valve for the welding gas supply.

6. Make sure that the work-cell access door is closed and operating properly and the door safety interlock is engaged.

7. Make sure that all EMERGENCY STOP buttons are released. EMERGENCY STOP buttons are installed at the following locations:
   • Programming Pendant
   • Operator Station

8. Select TEACH mode on the Programming Pendant.

9. Place the Robot in HOME position (refer to section 4.2.2).

4.2.2 Move Robot to the HOME Position

To move the Robot to the HOME position:

1. Select TEACH mode on the Programming Pendant.

2. Select {MAIN MENU} on the Programming Pendant’s touch screen.

3. Select {JOB} on the Programming Pendant’s touch screen (a job list appears on the screen).

4. Select {SELECT JOB} on the Programming Pendant’s touch screen (a job list appears on the screen).

5. Use the navigation cursor key to move the cursor to SAFE job and then press [SELECT] (the job appears on the display screen).

6. Turn servo power ON by pressing [SERVO ON] and holding in the ENABLE switch.

7. Use the [FWD] button on the Programming Pendant to move the Robot to the HOME position.

8. Repeat step 5 through step 7 for additional Robots as required.

NOTICE

An electrical service disconnect box for the Controller shall be supplied (if desired) by the customer. It is not part of the ArcWorld system shipment.
4.2.3 Safety Circuit Check

Test each of the following safety circuit items daily for proper operation. If any of these items do not work as instructed, contact Customer Support (refer to section 1.7 “Customer Support Information” on page 1-24) before operating the cell.

4.2.3.1 Gate Interlock

Open gate interlock while Robot is in PLAY mode with servo power ON. Verify that servo power goes off.

4.2.3.2 EMERGENCY STOP Buttons

Press each EMERGENCY STOP button with the Robot in PLAY mode and servo power on. After pressing each button, verify that servo power goes off and the Programming Pendant reads “Robot is Stopped.”

4.2.4 Control Master Job

With the system powered up and in TEACH mode, call up the Master job:

1. Select {JOB} on the Programming Pendant’s touch screen.
2. Select {CTRL MASTER} on the Programming Pendant’s touch screen.
3. Press {SELECT} twice to activate the Master job.
4. Select PLAY mode on the Programming Pendant (job playback operation is enabled).
5. Press the [SERVO ON] button on the Programming Pendant.
6. Press the [START] button on the Programming Pendant (the Control Master job cycles, waiting for a Cycle Start input from the Operator Station).
7. Transfer control to the Operator Station by selecting REMOTE on the Programming Pendant’s Mode Select Switch.

The ArcWorld work cell is now ready for operation.
4.2 Daily Operation

4.2.5 Operation Cycle

The following is the typical sequence of operation for the ArcWorld work cell after start-up:

**CAUTION**

Collaboration is a special type of operation between a person and Robot sharing a common workspace. The following are the guidelines for collaborative operation.

- Used for pre-determined tasks.
- Possible when all protective measures are active.
- For Robots with features specifically designed for collaborative operation.

The integrator shall include information for the use of safeguards and mode selections required for collaborative operation.

1. The operator loads the fixture in Station 1 with the parts to be welded.
2. The operator steps out of the safety zone created by the safety light curtain system and moves to the Operator Station.
3. The operator presses the green [CYCLE START CYCLE LATCHED] button on the Operator Station.
4. The Robot(s) begin welding the parts.
5. While the Robot(s) are welding, the operator loads the operator side of station 2 with the next group of parts to be welded.
6. The operator again moves to the Operator Station and presses the green [CYCLE START CYCLE LATCHED] button (the Cycle Latched light illuminates). When the Robot(s) are finished welding at station 1, they return to Home position allowing the operator to process parts at station 1.
7. The operator moves back to the operator side of station 1 and unloads the completed, welded parts.

**NOTICE**

If the Robot is still welding at the opposite welding station when the CYCLE START CYCLE LATCHED button is pressed, the Robot will finish and then proceed to the other station automatically (see section 2.3.1).
4.2 Daily Operation

4.2.6 Shutdown

Use the following procedure to perform a normal shutdown of the ArcWorld:

1. Make sure that the Robot is in the HOME position.
2. Turn off the system servo power by pressing the [EMERGENCY STOP] button at the Operator Station or Programming Pendant.
3. Select TEACH mode on the Programming Pendant.
4. Rotate the Controller’s power ON-OFF switch to OFF. (See Fig. 2-1 "Controller" on page 2-1).
5. Set the welding power source’s power ON-OFF switch to OFF.
6. Close the regulator valve for the welding gas supply.
7. Switch the Controller disconnect box (if installed) to OFF.

**NOTICE**

An electrical service disconnect box for the Controller shall be supplied (if desired) by the customer. It is not part of the ArcWorld system shipment.

8. Switch the welding power source disconnect box to OFF. See Fig. 2-1 "Controller" on page 2-1.

The ArcWorld is now shut down.
4.3 System Recovery

When a system error or alarm occurs, it is required to clear the error or alarm to return the system to normal operation. The paragraphs below describe the different types of alarms and errors that might be encountered and how to clear them.

4.3.1 Alarms and Errors

Alarms and errors will stop the program. The three levels of alarms and errors are as follows:

• Error Messages
• Minor Alarms
• Major Alarms

For more detailed information on alarm and error recovery, refer to the Controller and Robot documentation that is included with the documentation package (see section 1.5 “Reference Documentation” on page 1-20). Cell specific alarms are available in chapter 6 “Alarms and Messages”.

4.3.1.1 Error Messages

Error messages are usually the result of simple, easily cleared operation errors. One example of this type of error is pressing the [START] button when the Robot is not in PLAY mode.

Clear errors of this type by pressing the [CANCEL] button on the Programming Pendant.

4.3.1.2 Minor Alarms

Minor alarms usually involve programming errors. Clear alarms of this type by pressing the [CANCEL] button on the Programming Pendant.

4.3.1.3 Major Alarms

Clear alarms of this type by cycling the Controller in accordance with the following steps:

1. Rotate the Controller power ON-OFF switch to OFF (see Fig. 2-1).
2. Allow the Controller power ON-OFF switch to remain in the OFF position for approximately ten seconds.
3. Rotate the Controller power ON-OFF switch back to ON.
4.3 System Recovery

4.3.2 E-Stop Recovery

4.3.2.1 An E-Stop condition is triggered by any of the following conditions:

- An EMERGENCY STOP button is activated.
- A work-cell access door is opened while the Robot is not in TEACH mode.
- The safety light curtain system is triggered while the Positioner is sweeping.
- A welding torch collision triggers a shock sensor output (refer to section 4.3.3).

4.3.2.2 If an E-Stop condition is triggered, restart the ArcWorld as follows:

1. To clear the E-Stop condition, perform any of the following actions that apply:
   - Release the activated EMERGENCY STOP push button
   - Close the work-cell access door
   - Clear the area in front of the Positioner that is protected by the safety light curtain system
   - Clear the shock sensor condition (refer to section 4.3.3)

2. Press the [SERVO ON] button on the Programming Pendant.

3. Select the REMOTE mode on the Programming Pendant’s Mode Select Switch to transfer control of the system to the Operator Station.

4. Press the green [CYCLE START CYCLE LATCHED] button on the Operator Station.

The ArcWorld is now ready to continue operation.

CAUTION

- Make sure to stand clear of the Positioner when restarting after an E-Stop condition.
  - If the Positioner is sweeping when an E-Stop condition occurs the Positioner will continue the sweep when the ArcWorld restarts.

Not following this Caution can cause injury when the ArcWorld restarts after an E-Stop condition.
4.3 System Recovery

4.3.3 Shock Sensor Recovery

Each Robot includes a gun mount. This mount is designed to protect the torch from damage in case of a crash (collision). A slight deflection of the torch activates a SHOCK SENSOR signal that triggers an E-Stop condition. To clear the E-Stop condition, you must override the shock sensor and move the affected Robot clear of the impact. To override the shock sensor, proceed as follows:

1. Press (MAIN MENU) on the Programming Pendant.
2. Use the Programming Pendant cursor key to select the (ROBOT) icon, then press [SELECT].
3. Use the Programming Pendant cursor key to select (OVERRUN-S.SENSOR), then press the [SELECT] key.
4. Select (RELEASE) to release the shock sensor.
5. Turn servo power ON by pressing and holding the Programming Pendant's ENABLE switch in the middle position while pressing the [SERVO ON/READY] push button.
6. Move the Robot clear of the impact position.

The ArcWorld is now ready to continue operation.

CAUTION

- Always reactivate the Shock Sensor before continuing system operation.
- The Robot can be damaged if the Shock Sensor Override Switch remains in the "Override" position.
4 Operation
4.3 System Recovery

4.3.4 Brake Release

The Robot brakes are designed to protect the Robot and other system components from damage in the event of things like a system or Robot failure, a loss of drive power, or any other occurrence that activates the brakes. It is then necessary to release the brakes on the Robot in order to move it. To release the brakes, proceed as follows:

**WARNING**

- Support the axis being released before proceeding.

Releasing brakes can cause a potentially hazardous situation which, could result in death or serious injury to personnel.

1. On the Programming Pendant, select TEACH mode and turn servo power OFF.
2. Select {ROBOT} on the Programming Pendant’s touch screen.
3. Select the {MANUAL BRAKE RELEASE} option. A Warning dialog box appears.
4. Select {YES} in the Warning dialog box.
5. Select the axis to be released using the cursor key.
5 Maintenance

Maintenance must be performed by authorized personnel who are familiar with the ArcWorld. Make sure to read and understand the documentation for a particular component before doing repairs, maintenance or preventive maintenance on that component. Make sure to understand the maintenance procedures, have the proper tools at hand, and comply with all the safety instructions and precautions given throughout this manual and follow all local and federal regulations.

The maintenance intervals given in Table 5-1 are recommendations only. Adjust the frequency and level of repair maintenance and preventive maintenance to suit the specific equipment schedules and shop environment.

For periodic maintenance procedures and schedules for the individual components of the ArcWorld, refer to the documentation that is included (refer to section 1.5).

---

**CAUTION**

- Use only YASKAWA-specified antifreeze if the system uses a water-cooled torch.

A typical automotive antifreeze contains additives that can clog the small cooling ports in the torch and damage sealing gaskets in the water circulator pump.

---

**Table 5-1: Periodic Maintenance**

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>COMPONENT</th>
<th>PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Water Circulator (optional)</td>
<td>Check level of coolant/antifreeze.</td>
</tr>
<tr>
<td></td>
<td>All safeguard items – work-cell door interlocks, EMERGENCY STOP buttons, safety light curtains, arc curtains, etc.</td>
<td>Check physical condition of each safeguard item and ensure that the safeguard item is working correctly.</td>
</tr>
<tr>
<td></td>
<td>Gas and Water Hoses</td>
<td>Inspect hoses for damage and replace as required.</td>
</tr>
</tbody>
</table>
### Table 5-1: Periodic Maintenance

<table>
<thead>
<tr>
<th>FREQUENCY</th>
<th>COMPONENT</th>
<th>PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly (or on condition)</td>
<td>ArcWorld</td>
<td>Remove accumulated dirt, grease, and debris from inside and outside the work cell.</td>
</tr>
<tr>
<td>Every Six Months (or on condition)</td>
<td>Spanner Plates</td>
<td>Check the integrity and security of anchor hardware in accordance with Hilti® documentation. Check the torque of hold-down nuts in accordance with Hilti® documentation (refer to Lagging Supplement).</td>
</tr>
<tr>
<td>As Required (check SISTEMA report for details)</td>
<td>Relays for Interface (Teach/Play) or optional Tooling Power</td>
<td>Replace relays with new parts based on expected lifetime. (Determine relays expected life and replace based on frequency of operation. They should be replaced at predetermined intervals to prevent system failures/shut-down in the future.)</td>
</tr>
</tbody>
</table>
6 Alarms and Messages

This section contains information on alarms and ladders that are generated by the Controller ladder. Cause and resolution of each alarm are presented to help with troubleshooting. For additional help contact Customer Support.

6.1 Alarms Based on Barrier Door Operation

Many of the alarm text below are for Station 1 (ST1). These alarms may also occur for Station 2, in that case the alarm text will show “ST2” instead of “ST1”.

Table 6-1: Barrier Door Alarms

<table>
<thead>
<tr>
<th>Alarm Text</th>
<th>Alarm Cause</th>
<th>Suggested Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST1 Barrier Fault Occurred</td>
<td>Some sort of alarm in the VFD Controller for this door</td>
<td>- Press corresponding general output to reset the VFD.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 1 = OUT #20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 2 = OUT #24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Some alarms can only be cleared by cycling power to the control drive. These are not typical.</td>
</tr>
<tr>
<td>ST1 Door Overtime Flt</td>
<td>Door was moving longer than 4.0 seconds. The total door cycle time is expected to be under 3.0 seconds.</td>
<td>Check for mechanical failure of the door, brake sticking, or failures in Raised or Lower switches.</td>
</tr>
<tr>
<td>ST1 Door Raised Not On</td>
<td>Door was moving up longer than 5 seconds and the &quot;Door Raised&quot; switch never engaged.</td>
<td>Investigate Door Raised proximity switch. Check for proper operation in Manual mode. Verify cabling.</td>
</tr>
<tr>
<td>ST1 Door Raised Not Off</td>
<td>Door was moving down longer than 5 seconds and the &quot;Door Raised&quot; switch stayed on.</td>
<td>Investigate Door Raise switch. Check for proper operation in Manual mode. Verify cabling.</td>
</tr>
<tr>
<td>ST1 Door Lowered Not On</td>
<td>Door was moving down longer than 5 seconds and the &quot;Door Lowered&quot; switch never engaged.</td>
<td>Investigate Door Lowered proximity switch. Check for proper operation in Manual mode. Verify cabling.</td>
</tr>
<tr>
<td>ST1 Door Lowered Not Off</td>
<td>Door was moving up longer than 5 seconds and the &quot;Door Lowered&quot; switch stayed on.</td>
<td>Investigate &quot;Door Lowered” switch. Check for proper operation in Manual mode. Verify cabling.</td>
</tr>
</tbody>
</table>
### 6.2 Alarms Based on Functional Safety Unit Conditions

**Table 6-2: Functional Safety Unit Alarms**

<table>
<thead>
<tr>
<th>Alarm Text</th>
<th>Alarm Cause</th>
<th>Suggested Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS CRITICAL FSU FUNCT DISABLED</td>
<td>The Functional Safety Unit has several files which need to be enabled to ensure safe operation of the cell. The Functional Safety Unit uses one the “Robot Range Limit” setting to control or limit the range of Robot motion based on several conditions. The “Axis Speed Monitor” function also monitors headstock monitor when the barrier doors are open.</td>
<td>In TEACH Mode - Robot Range Limit File #7 will be active, if someone changed the logic or other setting, this alarm could occur. Under normal operation this file is activated by Signal condition, which is a “TEACH/PLAY” mode input.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In PLAY Mode - with Station 1 barrier door closed (up) and Station 2 barrier door open (down), Robot Range Limit File #1 will be active, if someone changed the logic or other setting, this alarm could occur. Under normal operation this file is activated by the safety prox signals from each barrier door. If the safety prox is not activating properly this alarm may also occur falsely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In PLAY Mode - with Station 2 barrier door closed (up) and Station 1 barrier door open (down), Robot Range Limit File #2 will be active, if someone changed the logic or other setting, this alarm could occur. Under normal operation this file is activated by the safety prox signals from each barrier door. If the safety prox is not activating properly this alarm may also occur falsely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In PLAY Mode - with both barriers open (down), Robot Range Limit File #3 will be active, if someone changed the logic or other setting, this alarm could occur. Under normal operation this file is activate by the safety proximity signals from each barrier door. If the safety proximity is not activating properly this alarm may also occur falsely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In PLAY Mode - with both barriers closed (up), Robot Range Limit File #4 will be active, if someone changed the logic or other setting, this alarm could occur. Under normal operation this file is activated by the safety prox signals from each barrier door. If the safety prox is not activating properly this alarm may also occur falsely.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In PLAY Mode - Robot Range Limit File #5 and #6 must always be active, if someone changed the logic or other setting, this alarm could occur.</td>
</tr>
</tbody>
</table>

1 Reference cell drawings (183196-1 and 183197-1) and barrier drawings (182369-1 and 182369-2) for specific locations of each sensor.
### 6.3 Cell Messages

Table 6-3: Cell Messages

<table>
<thead>
<tr>
<th>Message Text</th>
<th>Message Cause</th>
<th>Suggested Resolutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROBOT RANGE FILE 1-6 DISABLED</td>
<td>After “SYS CRITICAL FSU” type alarm occurs, this message will follow, which helps point towards the specific feature to examine.</td>
<td>Check the menu: SAFETY FUNC. &gt; ROBOT RANGE LIMIT and verify that all Files 1 through 6 are setup per section 1.4.3.4</td>
</tr>
<tr>
<td>ROBOT RANGE FILE #7 DISABLED</td>
<td>After “SYS CRITICAL FSU” type alarm occurs, this message will follow, which helps point towards the specific feature to examine.</td>
<td>Check the menu: SAFETY FUNC. &gt; ROBOT RANGE LIMIT and verify that File 7 is setup per section 1.4.3.4</td>
</tr>
<tr>
<td>ANY SPEED MONITOR FILE DISABLED</td>
<td>After “SYS CRITICAL FSU” type alarm occurs, this message will follow, which helps point towards the specific feature to examine.</td>
<td>Check the menu: SAFETY FUNC. &gt; AXIS SPEED MONITOR and verify that Files 1 and 2 are setup per section 1.4.3.4</td>
</tr>
</tbody>
</table>
7  Spare Parts

7.1 Robot Spare Parts

Reference the supplied Robot Manual for spare part recommendations. See section 1.5 “Reference Documentation” on page 1-20.

7.2 Positioner Spare Parts

Reference the supplied Positioner Manual for spare part recommendations. See section 1.5 “Reference Documentation” on page 1-20.

7.3 ArcWorld Spare Parts

Each ArcWorld is supplied with interface panels that are mounted inside the enclosures. Recommended spare parts include:

<table>
<thead>
<tr>
<th>Component</th>
<th>YASKAWA Part Number</th>
<th>Recommended Quantity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Amp Fuse</td>
<td>180653-4</td>
<td>3</td>
<td>Pwr Dist. Enclosure, Controller</td>
</tr>
<tr>
<td>2 Amp Fuse</td>
<td>130295-7</td>
<td>3</td>
<td>Pwr Dist. Enclosure, 24VDC Pwr Supply</td>
</tr>
<tr>
<td>6.3 Amp Fuse</td>
<td>174327-3</td>
<td>2</td>
<td>Top Hat, Pwr/Enet Bd.</td>
</tr>
<tr>
<td>315 mA Fuse</td>
<td>174327-2</td>
<td>4</td>
<td>Top Hat, FSU Relay Bd (Expansion Safety)</td>
</tr>
<tr>
<td>2.5 Amp Fuse</td>
<td>174327-1</td>
<td>8</td>
<td>Top Hat, FSU Relay Bd (Expansion Safety), Op Station 1, Pwr/Enet Bd, Op Station 2, Pwr/Enet Bd</td>
</tr>
<tr>
<td>Coolant/Antifreeze</td>
<td>See welder manual or system bill of material</td>
<td>1</td>
<td>Water Circulation</td>
</tr>
</tbody>
</table>

When a part malfunctions, it is helpful to have replacement parts in stock for quick replacement. YASKAWA recommends the parts in the following sections be kept on hand.

WARNING

- Ensure that servo power is OFF and observe standard lockout/tagout practices before performing the following procedures.

Injury may result if servo power is not removed.
### Appendix A

#### A.1 Checklist

Since our customer is very important to us we include a checklist to use before start-ups and after maintenance for convenience and safety.

<table>
<thead>
<tr>
<th>BEFORE APPLYING POWER</th>
<th>Time/Date</th>
<th>Checked By</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>(Refer to System Drawings)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Mounting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Installation Section in all Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Connections, Controller Manual)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Ground</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Grounding in all Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Water</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Operation and Vendor Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Air</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Robot and Vendor Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Gas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Operation and Vendor Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Interlocks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Work Cells in all Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Limiting Devices/Software</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Limits in all Manuals)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Environment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Installation in Controller Manual)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Check Version</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(Refer to Confirmation of Software Version)</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Other Items to Check Before Applying Power**

*(Vendor or Integrator Supplied)*

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## Checklist

<table>
<thead>
<tr>
<th>Task</th>
<th>Time/Date</th>
<th>Checked By</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AFTER APPLYING POWER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Control Switches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Operator Station, Controller Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Axis Move and are Restricted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Basic Specifications, Robot Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check EMERGENCY STOP(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to EMERGENCY STOP in all Manual(s))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check External Power Disconnect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Turning OFF The Power Supply, Controller Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check TEACH Mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to TEACH Mode, Controller Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Playback Mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to PLAY Mode, Controller Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Location in Robot Manual)</td>
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<tr>
<td>Check Safeguards</td>
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</tr>
<tr>
<td>(Refer to Safeguards in all Manuals)</td>
<td></td>
<td></td>
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<tr>
<td>Check Manual Mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Manual Mode in Operations Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Check PLAY Mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Refer to Automatic Mode in Operations Manual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other Items to Check After Applying Power</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vendor or Integrator Supplied)</td>
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</table>
## Appendix A

A.1 Checklist

<table>
<thead>
<tr>
<th>DOCUMENTATION INCLUDED</th>
<th>Time/Date</th>
<th>Checked By</th>
</tr>
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<tr>
<td>System Drawings</td>
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<tr>
<td>Modifications Made to Original Protective Equipment</td>
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<tr>
<td>End Effector Load Analysis</td>
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<td></td>
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<tr>
<td>Instructions on Synchronized Motion</td>
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<td></td>
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<tr>
<td>(More than one piece of moving synchronized equipment)</td>
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<td></td>
</tr>
<tr>
<td>Programmed Limits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaborative Operation Declaration</td>
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<td></td>
</tr>
<tr>
<td>(Robot is suitable for integration that includes requirements met and types of operation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compliance Documents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ANSI, ISO, RIA, etc.)</td>
<td></td>
<td></td>
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<tr>
<td>Risk Assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Documents to Include (Vendor or Integrator Supplied)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vendor Manuals, Supplier Certifications, Compliance Documents, etc.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Appendix A

### A.1 Checklist

<table>
<thead>
<tr>
<th>Time/Date</th>
<th>Checked By</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARKINGS INCLUDED ON EQUIPMENT</td>
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<td>Business Name, Address, Info</td>
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<tr>
<td>Machinery Designation and Type</td>
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<tr>
<td>Year Built</td>
<td></td>
</tr>
<tr>
<td>Explosive Proof</td>
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</tr>
<tr>
<td><strong>Order Number (Serial Number)</strong></td>
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</tr>
<tr>
<td><strong>Other Markings on Equipment</strong></td>
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</tr>
<tr>
<td><em>(Vendor Machine Designation, Type, Serial No, Version, etc.)</em></td>
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</tr>
<tr>
<td><strong>OTHER ITEMS</strong></td>
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</tbody>
</table>
Appendix B

B.1 Glossary

3D Graphic Display Function
The 3D Graphic Display Function (this will be called 3D Display Function) is that, a 3D model of the Robot is displayed on the Programming Pendant window, and the current value of the Robot can be confirmed. By using the multi-window function, the job's teaching position displayed in the job content can also be confirmed on the 3D display window. When the functional safety function is valid, the functional safety range can also be displayed.

Absolute Data (ABSO Data)
Absolute Data (ABSO Data) is a correction factor for data that establishes an indicated value of zero when the Robot is at the predetermined Home (calibration position).

Accuracy
Accuracy is the measurement of the deviation between the command characteristic and the attained characteristic (R15.05-2), or the precision with which a computed or calculated Robot position can be attained. Accuracy is normally worse than the arm's repeatability. Accuracy is not constant over the workspace, due to the effect of link kinematics.

Active Compliant Robot
An active compliant Robot is one in which motion modification during the performance of a task is initiated by the control system. The induced motion modification is slight, but sufficient to facilitate the completion of a desired task.

Actual Position
The position or location of the tool control point. Note that this will not be exactly the same as the demand position, due to a multitude of unsensed errors, such as link deflection, transmission irregularity, tolerances in link lengths, etc.

Actuator
A power mechanism used to effect motion, or maintain position of the Robot (for example, a motor which converts electrical energy to effect motion of the Robot) (R15.07). The actuator responds to a signal received from the control system.
ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems
This standard provides guidelines for the manufacture and integration of Industrial Robots and Robot Systems with emphasis on their safe use, the importance of risk assessment and establishing personnel safety. This standard is a national adoption of the International Standards ISO 10218-1 and ISO 10218-2 for Industrial Robots and Robot Systems, and offers a global safety standard for the manufacture and integration of such systems.

ArcWorld
Robotic welding systems delivering flexible integrated robotics into the welding processes. ArcWorlds can be configured with multiple Robots, a heavy-duty Positioner or servo-controlled external axes for coordinated motion.

Arm
An interconnected set of links and powered joints comprising a Robot that supports and/or moves a wrist and hand or end-effector through space. The arm itself does not include the end-effector. See "Robot", "End-effector" and "Wrist".

Articulated Robot
A Robot with an arm that is broken into sections (links) by one or more joints. Each of the joints represents a degree of freedom in the Robot system and allows translation and rotary motion.

Articulation
Describes a jointed device, such as a jointed Robot. The joints provide rotation about a vertical axis, and elevation out of the horizontal plane. This allows a Robot to be capable of reaching into confined spaces.

Automatic Measurement Function
For optimal Robot motion, the mass properties of the end-effector should be specified. These properties can be derived from a CAD model of the tool. The Automatic Measurement Function is an alternative to a CAD model, and it uses the Robot arm itself to measure the tool properties. With this function, the user can register the load of tool, the position of the tools center of gravity and the moment of inertia at the center of gravity.

Automatic Mode
See "Play Mode".

Axis
A direction used to specify the Robot motion in a linear or rotary mode. (ISO 8373)

Axis Interference
The Axis Interference Area is a function that judges the current position of each axis and outputs a signal based on whether the current position is within a predefined range.
Base
The stable platform to which an industrial robotic arm is attached.

Base Coordinate System
The Base Coordinate System (sometimes referred to as World Coordinate System) defines a common reference point for a cell or application. This is useful when using multiple Robots or devices as positions defined in Base Coordinates will be the same for all Robots and devices.

Base Link
The stationary base structure of a Robot arm that supports the first joint.

Burn-in
Burn-In is a testing procedure where all components of the Robot are operated continuously for an extended period of time. This is done to test movement and movement programming of the Robot at early stages to avoid malfunctions after deployment.

Computer Aided Design (CAD)
Computer Aided Design (CAD). Computer graphic applications designed to allow engineering of objects (or parts), which are to be manufactured. A computer is used as a tool to design schematics and produce blueprints, which enable the accurate production of the object. The CAD system enables the three dimensional drawings of basic figures, exact sizing and placement of components, making lines of specified length, width, or angle, as well as satisfying varying geometric shapes. This system also allows the designer to test a simulated part under different stresses, loads, etc.

Carousel
A rotating platform that delivers objects to a Robot and serves as an object queuing system. This carousel delivers the objects, or work pieces, to the loading/unloading station of the Robot.

Cartesian Coordinates
Cartesian Coordinates is a type of coordinate system that specifies the location of a point in two dimensional space by a pair of numerical numbers, which further specify the distance to fixed axes that are perpendicular to each other. In simple terms, an XY graph represents a two dimensional Cartesian Coordinate System. When a point is specified in a three dimensional space (XYZ graph), it constitutes a three dimensional Cartesian coordinate system. A TCP position is specified in a Cartesian Coordinate.

Cartesian Robot
A Cartesian Robot is a Robot arm with prismatic joints, which allows movement along one or more of the three- axes in the X, Y, Z coordinate system.

Cartesian Topology
A topology, which uses prismatic joints throughout, normally arranged to be perpendicular to each other.
Cartesian-coordinate Robot
A Cartesian-coordinate Robot is a Robot whose arm degrees of freedom are defined by Cartesian Coordinates. This describes motions that are east-west, north-south and up-down, as well as rotary motions to change orientation.

Category 3 (Cat3)
Category 3 (Cat 3) means that the safety related parts of the control system will be designed so that:

• Single faults will not prevent the safety function from working correctly.
• Single faults will be detected at or before the next demand of the safety function.
• When a single fault does occur, a safe state shall be maintained until the detected fault is corrected.
• All reasonably foreseeable faults are detected.

Caution
Indicates a hazardous situation, which if not avoided, could result in minor or moderate injury. It may also be used without the safety alert symbol as an alternative to “NOTICE”.

Centrifugal Force
When a body rotates about an axis other than one at it's center of mass, it exerts an outward radial force called centrifugal force upon the axis, which restrains it from moving in a straight tangential line. To offset this force, the Robot must exert an opposing torque at the joint of rotation.

Circular Motion Type
A calculated path that the Robot executes, and is circular in shape.

Clamp
An end-effector which serves as a pneumatic hand that controls the grasping and releasing of an object. Tactile, and feed-back force sensors are used to manage the applied force to the object by the clamp. See "End-effector".

Clamping
The maximum permissible force acting on a body region, resulting from a Robot collision where the period of contact results in a plastic deformation of a person’s soft tissue.

Clamping Force
When contact can cause a body part(s) to be clamped.

Closed-loop
Control achieved by a Robot by means of feedback information. As a Robot is in action, its sensors continually communicate information to the Controller, which is used to further guide the Robot within the given task. Many sensors are used to feedback information about the Robot's placement, speed, torque, applied forces, as well as the placement of a targeted moving object, etc. See "Feedback".
Appendix B

Collaborative Robot
Term used to describe a robot system designed to operate in one or more of the four collaborative modes.

• "Safety Monitored Stop"
• "Hand Guiding"
• "Speed and Separation Monitoring"
• "Power and Force Limiting (PFL)"

Command Interpreter
A module or set of modules that determines what the received command means. The command is broken down into parts (parsed) and processed.

Command Position
The endpoint position of a Robot motion that the Controller is trying to achieve.

Compliance
Displacement of a Robot in response to a force or torque. A high compliance means the Robot moves a good bit when it is stressed. This is called spongy or springy. Low compliance would be a stiff system when stressed.

Compliant Robot
A Robot that performs tasks, with respect to external forces, by modifying its motions in a manner that minimizes those forces. The indicated or allowed motion is accomplished through lateral (horizontal), axial (vertical) or rotational compliance.

Configuration
The arrangement of links created by a particular set of joint positions on the Robot. Note that there may be several configurations resulting in the same endpoint position.

Contact Sensor
A device that detects the presence of an object or measures the amount of applied force or torque applied on the object through physical contact with it. Contact sensing can be used to determine location, identity, and orientation of work pieces.

Continuous Path
Describes the process where by a Robot is controlled over the entire path traversed, as opposed to a point-to-point method of traversal. This is used when the trajectory of the end-effector is most important to provide a smooth movement, such as in spray painting etc. See "Point-to-Point".

Control Algorithm
A monitor used to detect trajectory deviations in which sensors detect such deviations and torque applications are computed for the actuators.

Control Command
An instruction fed to the Robot by means of the human-to-machine input device. See Pendant (Teaching). This command is received by the Controller system and is interpreted. Then, the proper instruction is fed to the Robot's actuators, which enable it to react to the initial command. Many times, the command must be interpreted with the use of logic units and specific algorithms. See "Input Devices" and "Instruction Cycle".
Control Device
Any piece of control hardware providing a means for human intervention in the control of a Robot or robot system, such as an Emergency Stop button, a start button, or a selector switch. (R15.06)

Control Mode
The means by which instructions are communicated to the Robot.

Controllability
The property of a system by which an input signal can take the system from an initial state to a desired state along a predictable path within a predetermined period of time.

Controller
An information processing device whose inputs are both the desired and measured position, velocity or other pertinent variables in a process and whose outputs are drive signals to a controlling motor or actuator. (R15.02)

Controller System
The Robot control mechanism is usually a computer of some type, which is used to store data (both Robot and work environment), and store and execute programs, which operate the Robot. The Controller System contains the programs, data, algorithms; logic analysis, and various other processing activities, which enable it to perform. See "Robot".

Coordinate System or Frame
A Coordinate System (or Frame) defines a reference position and orientation from which a Robot position can be measured. All Robot positions are defined with reference to a Coordinate System. YASKAWA Robots utilize the following Coordinate Systems:

- "Base Coordinate System"
- "Robot Coordinate System"
- "User Coordinate System"
- "Cartesian Coordinates"

Central Processing Unit (CPU)
The Central Processing Unit (CPU) is the main circuit board and processor of the Controller System.

Cubic Interference Area
This area is a rectangular parallelepiped, which is parallel to the base coordinate, Robot coordinate or user coordinate. The Controller judges whether the current position of the Robot's TCP is inside or outside this area, and outputs this status as a signal.

Cycle
A single execution of a complete set of moves and functions contained within a robot program. (R15.05-2)

Cyclic Coordinate System
A coordinate system that defines the position of any point in terms of an angular dimension, a radial dimension and a height from a reference plane. These three dimensions specify a point on a cylinder.
Cyclo Drive
A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major (larger) axis.

Cylindrical Topology
A topology where the arm follows a radius of a horizontal circle, with a prismatic joint to raise or lower the circle. Not popular in industry.

Danger
Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. Safety Signs identified by the signal word DANGER should be used sparingly and only for those situations presenting the most serious hazards.

Dead Man Switch
Deprecated term. See "Enabling Device".

Degrees of Freedom
The number of independent directions or joints of the Robot (R15.07), which would allow the Robot to move its end effector through the required sequence of motions. For arbitrary positioning, six degrees of freedom are needed: three for position (left-right, forward-backward and up-down), and three for orientation (yaw, pitch and roll).

Direct-drive
Joint actuation, including no transmission elements (i.e., the link is bolted onto the output of the motor.)

Downtime
A period of time, in which, a Robot or production line is shut down, due to malfunction or failure. See "Uptime".

Drive
A speed (gear) reducer to convert high speed low torque to low speed high torque. See "Harmonic Drive", "Cyclo Drive" and "Rotary Vector Drive (RV)".

Drop Delivery
A method of introducing an object to the workplace by gravity. Usually, a chute or container is so placed that, when work on the part is finished, it will fall or drop into a chute or onto a conveyor with little or no transport by the Robot.

Dynamics
The study of motion, the forces that cause the motion and the forces due to motion. The dynamics of a Robot arm are very complicated as they result from the kinematical behavior of all masses within the arm's structure. The Robot arm kinematics are complicated in themselves.
Emergency Stop
The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the robot actuators, and causes all moving parts to stop. (R15.06)

Enable Switch
See "Enabling Device".

Enabling Device
A manually operated device which when continuously activated, permits motion. Releasing the device shall stop robot motion and motion of associated equipment that may present a hazard. (R15.06)

Encoder
A feedback device in the Robot arm that provides current position (and orientation of the arm) data to the Controller. A beam of light passes through a rotating code disk that contains a precise pattern of opaque and transparent segments on its surface. Light that is transmitted through the disk strikes photo-detectors, which convert the light pattern to electrical signals. See "Feedback", "Closed-loop" and "Feedback Sensor".

Envelope
Is the range of movement available. This range is determined by the length of a Robot's arm and the design of its axes. Each axis contributes its own range of motion.

EOAT
See "Gripper" or "End-effector".

End-effector
An accessory device or tool, specifically designed for attachment to the Robot wrist or tool mounting plate to enable the Robot to perform its intended task. (Examples may include: gripper, spot weld gun, arc weld gun, spray point gun or any other application tools.) (R15.06)

Endpoint
The nominal commanded position that a Robot will attempt to achieve at the end of a path of motion. The end of the distal link.

Error
The difference between the actual response of a Robot and a command issued.

Expandability
Being able to add resources to the system, such as memory, larger hard drive, new I/O card, etc.

External Force Limit
The threshold limit where the Robot moves to or retains position, even when external forces are applied (provided that forces do not exceed limits that would cause an error).
Feedback
The return of information from a Robot or sensor to the processor of the Robot to provide self-correcting control of the Robot. See "Feedback Control" and "Feedback Sensor".

Feedback Control
A type of system control obtained when information from a Robot or sensor is returned to the Controller in order to obtain a desired robot effect. See "Feedback", "Closed-loop" and "Feedback Sensor".

Feedback Sensor
A mechanism through which information from sensing devices is fed back to the control unit. The information is utilized in the subsequent direction of the robot's motion. See "Closed-loop" and "Feedback Control".

Flexibility
The ability of a robot to perform a variety of different tasks.

Force Feedback
A sensing technique using electrical signals to control a robot end-effector during the task of the end-effector. Information is fed from the force sensors of the end-effector to the control unit during the particular task to enable enhanced operation of the end-effector. See "Feedback", "Feedback Sensor" and "Force Sensor".

Force Sensor
A sensor capable of measuring the forces and torque exerted by a Robot and its wrist. Such sensors usually contain strain gauges. The sensor provides information needed for force feedback. See "Force Feedback".

Forward Kinematic Solution
The calculation required to find the endpoint position, given the joint positions. For most robot topologies this is easier than finding the inverse kinematic solution.

Forward Kinematics
Computational procedures which determine where the end-effector of a robot is located in space. The procedures use mathematical algorithms along with joint sensors to determine its location.

Frame
A coordinate system used to determine a position and orientation of an object in space, as well as the Robot's position within its model.

Functional Safety Unit (FSU)
The Functional Safety Unit (FSU) is a component of the Controller that provides programmable safety functions that enable collaborative operation of the robot. As these safety functions are programmable, the FSU allows the minimization of nearby overall equipment footprint, as well as human accessible areas. The FSU consists of two parallel Central Processing Units (CPUs) run concurrently, thereby providing dual channel checking. In addition, the FSU acquires robot position from its encoders independently from the motion control system of the Robot. Based on this feedback, the FSU monitors the Robot and tool's position, speed and posture.
Gantry
An adjustable hoisting machine that slides along a fixed platform or track, either raised or at ground level along the X, Y, Z axes.

Gantry Robot
A robot which has three degrees of freedom along the X, Y and Z coordinate system. Usually consists of a spooling system (used as a crane), which when reeled or unreeled provides the up and down motion along the Z axis. The spool can slide from left to right along a shaft which provides movement along the Z axis. The spool and shaft can move forward and back along tracks which provide movement along the Y axis. Usually used to position its end effector over a desired object and pick it up.

Gravity Loading
The force exerted downward, due to the weight of the Robot arm and/or the load at the end of the arm. The force creates an error with respect to position accuracy of the end effector. A compensating force can be computed and applied bringing the arm back to the desired position.

Gripper
An end effector that is designed for seizing and holding (ISO 8373) and "grips" or grabs an object. It is attached to the last link of the arm. It may hold an object using several different methods, such as: applying pressure between its "fingers", or may use magnetization or vacuum to hold the object, etc. See "End-effector".

Hand
A clamp or gripper used as an end-effector to grasp objects. See “End-effector”, and "Gripper".

Hand Guiding
Collaborative feature that allows an operator to hand guide the Robot to a desired position. This task can be achieved by utilizing additional external hardware mounted directly to the Robot or by a Robot specifically designed to support this feature. Both solutions will require elements of functional safety to be utilized. A risk assessment shall be used to determine if any additional safeguarding is necessary to mitigate risks within the robot system.

Harmonic Drive
Compact lightweight speed reducer that converts high speed low torque to low speed high torque. Usually found on the minor (smaller) axis.

Harness
Usually several wires, bundled together to deliver power and/or signal communications to/from devices. For example, the Robot motors are connected to the Controller through a wire harness.

Hazardous Motion
Unintended/unexpected robot motion that may cause injury.
Hold
A stopping of all movements of a robot during its sequence, in which some power is maintained on the robot. For example, program execution stops, however power to the servo motors remain on, if restarting is desired.

Home Position
A known and fixed location on the basic coordinate axis of the Robot where it comes to rest, or to an indicated zero position for each axis. This position is unique for each model of Robot. On Robot there are indicator marks that show the Home position for the respective axis.

IEC
International Electrotechnical Commission

Inductive Sensor
The class of proximity sensors, which has half of a ferrite core, whose coil is part of an oscillator circuit. When a metallic object enters this field, at some point, the object will absorb enough energy from the field to cause the oscillator to stop oscillating. This signifies that an object is present in a given proximity. See "Proximity Sensor".

Industrial Robot
A re-programmable multi-functional Robot designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks (R15.06). The principle components are: one or more arms that can move in several directions, a Robot, and a Controller that gives detailed movement instructions.

INFORM
The robot programming language for YASKAWA Robots. INFORM language allows the robot user to: instruct the robot to use its basic capabilities to fulfill a defined set of expectations and also to describe to the robot, through a definition of parameters and conditions, what the expectations are in some given situations or scenarios. In simple terms, the INFORM programming language allows the user to instruct the robot on what to do, when to do it, where to do it and how to do it.

Input Devices
A variety of devices, which allow a human to machine interface. This allows the human to program, control, and simulate the robot. Such devices include Programming Pendant, computer keyboards, a mouse, joy-sticks, push buttons, operator panel, operator pedestal etc.

Instruction
A line of programming code that causes action from the system Controller. See "Command Position".

Instruction Cycle
The time it takes for a Controller system's cycle to decode a command or instruction before it is executed. The Instruction Cycle must be analyzed very closely by robotic programmers to enable speedy and proper reaction to varying commands.
Integrate
To fit together different subsystems, such as robots and other automation devices, or at least different versions of subsystems in the same control shell.

Integrator
A company that provides value added services that results in creation of automation solutions by combining a robot and other automation and controls equipment to create an automation solution for end users.

Intelligent Robot
A robot that can be programmed to make performance choices contingent on sensory inputs with little or no help from human intervention. See "Robot".

Interference Area
Interference Area is a function that prevents interference between multiple Robots or the Robot and peripheral device. The areas can be set up to 64 areas. Three types of methods to use each interference area are as follows: Cubic Interference, Outside of Cubic Area and Axis Interference.

Interpolation
The method by which endpoint paths are created. In general, to specify a motion a few knot points are defined before all the intermediate positions between them are calculated by mathematical interpolation. The interpolation algorithm used therefore has a dramatic effect of the quality of motion.

ISO
International Organization for Standardization

ISO 10218-1 Robots and robotic devices — Safety requirements for industrial robots — Part 1: Robots
A robot specific safety specification that addresses manufacturer requirements, functionality, required safety performance, hazards, protective measures and documentation for the robot itself.

ISO 10218-2 Robots and robotic devices — Safety requirements for industrial robots — Part 2: Robot systems and integration
A companion document to ISO 10218-1. This safety specification provides guidance to both end users and robot integrators as it pertains to the safe design, Installation and commissioning of robot systems, as well as recommended procedures, safeguarding and information required for use.

ISO TS 15066(ANSI RIA 15.606): Robots and robotic devices - Collaborative robots
Provides detailed guidance not found in ISO 10218 parts 1 or 2 for the safe use of industrial robots operating collaboratively.

Jacobian matrix
The Jacobian matrix relates the rates of change of joint values with the rates of change of endpoint co-ordinates. Essentially it is a set of algorithm calculations that are processed to control the positioning of a robot.
JOB
JOB is the YASKAWA name for a Robot program created using YASKAWA's INFORM programming language. Typically, a JOB consists of instructions that tell the Controller what to do and data that the program uses when it is running.

Joint
A part of the Robot system, which allows a rotation and/or translational degree of freedom of a link of end-effector.

Joint Interpolated Motion
A method of coordinating the movement of the joints, such that all joints arrive at the desired location simultaneously. This method of servo control produces a predictable path regardless of speed and results in the fastest pick and place cycle time for a particular move.

Joint Motion Type
Also known as Point-to-Point Motion, Joint Motion Type is a method of path interpolation that commands the movement of the robot by moving each joint directly to the commanded position so that all axis arrive to the position at the same time. Although the path is predictable, it will not be linear.

Joint Space
a. Joint Space (or Joint Coordinates) is just a method of defining the position of the robot in terms of the value of each axis instead of as a TCP position. For example, the Home Position of a robot is often defined in Joint Space as each axis being at 0 degrees.
b. The set of joint positions.

Joints
The parts of the Robot arm which actually bend or move.

Kinematics
The relationship between the motion of the endpoint of a robot and the motion of the joints. For a Cartesian Robot this is a set of simple linear functions (linear tracks that may be arranged in X, Y, Z directions), for a revolute topology (joints that rotate) however, the kinematics are much more complicated involving complicated combinations of trigonometry functions. The kinematics of an arm is normally split into forward and inverse solutions.

Ladle Gripper
An end-effector, which acts as a scoop. It is commonly used to scoop up liquids, transfer it to a mold and pour the liquid into the mold. Common for handling molten metal under hazardous conditions. See "End-effector".
Laser
Acronym for Light Amplification by Stimulated Emission of Radiation. A device that produces a coherent monochromatic beam of light which is extremely narrow and focused but still within the visible light spectrum. This is commonly used as a non-contact sensor for robots. Robotic applications include: distance finding, identifying accurate locations, surface mapping, bar code scanning, cutting, welding etc.

Linear Interpolated Motion
Is a method of path interpolation that commands the movement of the robot by moving each joint in a coordinated motion so that all axis arrive to the position at the same time. The path of the Tool Control Point (TCP) is predictable and will be linear.

Linear Motion Type
Is a method of path interpolation that commands the movement of the robot by moving each joint in a coordinated motion so that all axis arrive to the position at the same time. The path of the Tool Control Point (TCP) is predictable and will be linear.

Link
A rigid part of a Robot, which connects adjacent joints.

Links
The static material, which connects the joints of an arm together. Thereby a kinematical chain is formed. In a human body, the links are the bones.

Load Cycle Time
A manufacturing or assembly line process term, which describes the complete time to unload the last work piece and load the next one.

Magnetic Detectors
Robot sensors that can sense the presence of ferromagnetic material. Solid-state detectors with appropriate amplification and processing can locate a metal object to a high degree of precision. See "Sensor".

Manipulator
A machine or robotic mechanism of which usually consists of a series of segments (jointed or sliding relative to one another) for the purpose of grasping and/or moving objects (pieces or tools), usually in several degrees of freedom. The control of the Robot may be by an operator, a programmable electronic Controller or any logic system (for example cam device, wired, etc.) (ISO 8373)
See "Arm", "Wrist" and "End-effector"

Manual Mode
See "Teach Mode".

Material Handling
The process by which an industrial robotic arm transfers materials from one place to another.
Material Processing Robot
A robot designed and programmed so that it can machine, cut, form or change the shape, function or properties of materials it handles between the time the materials are first grasped and the time they are released in a manufacturing process.

Mirror Shift Function
With the Mirror Shift Function, a job is converted to the job in which the path is symmetrical to that of the original job. This conversion can be performed for the specified coordinate among the X-Y, X-Z or Y-Z coordinate of the robot coordinates and the user coordinates. The Mirror Shift Function is classified into the following three: the Pulse Mirror Shift Function, the Robot Coordinates Mirror Shift Function and the User Coordinates Mirror Shift Function.

Mode Switch
As per safety standards, an industrial robot has three distinct modes of operation. These are TEACH (also called Manual) and PLAY (also called Automatic) and REMOTE. Switching between these modes is performed using a key switch on the Programming Pendant and is called Mode Switch.

Modularity
The property of flexibility built into a robot and control system by assembling separate units, which can be easily joined to or arranged with other parts or units.

Module
Self-contained component of a package. This component may contain sub-components known as sub-modules.

Motion Axis
The line defining the axis of motion either linear or rotary segment of a Robot.

Motor
See "Servo Motor".

Muting
While testing a robot program, the deactivation of any presence sensing safeguarding devices during the full robot cycle or a portion of the cycle.

Notice
NOTICE is the preferred signal word to address practices not related to personal injury. The safety alert symbol should not be used with this signal word. As an alternative to "NOTICE", the word "CAUTION" without the safety alert symbol may be used to indicate a message not related to personal injury.
Off-line Programming
A programming method where the task program is defined on devices or computers separate from the robot for later input of programming information to the robot. (ISO 8373)b. A means of programming a robot while the robot is functioning. This becomes important in manufacturing and assembly line production due to keeping productivity high while the robot is being programmed for other tasks.

Operator
The person designated to start, monitor and stop the intended productive operation of a robot or robot system. An operator may also interface with a robot for productive purposes. (R15.06)

Optical Encoder
A detection sensor, which measures linear or rotary motion by detecting the movement of markings past a fixed beam of light. This can be used to count revolutions, identify parts, etc.

Optical Proximity Sensors
Robot sensors which measure visible or invisible light reflected from an object to determine distance. Lasers are used for greater accuracy.

Orientation
The angle formed by the major axis of an object relative to a reference axis. It must be defined relative to a three dimensional coordinate system. Angular position of an object with respect to the robot's reference system. See "Roll", "Pitch" and "Yaw".

Palletizing
The process of stacking packages (i.e., boxes, bags, containers, etc.) in an organized fashion on a pallet.

PAM Function – Position Adjustment by Manual
Position Adjustment by Manual allows position adjustment by simple operations while observing the motion of the Robot, and without stopping the Robot. Positions can be adjusted in both teach mode and play mode.

Parallel Shift Function
Parallel Shift refers to the shifting of an object from a fixed position in such a way that all points within the object move an equal distance. In the model for Parallel Shift shown in the following, the shift value can be defined as the distance L (three dimensional coordinate displacement). The Parallel Shift Function is relevant to the actual operation of the Robot because it can be used to reduce the amount of work involved in teaching by shifting a taught path (or position). In the example in the figure below, the taught position A is shifted in increments of the distance L (this is actually a three dimensional XYZ displacement that can be recognized by the robot).

Path
The continuous locus of positions (or points in three dimensional space) traversed by the tool center point and described in a specified coordinate system. (R15.05-2)
Payload - Maximum
The maximum mass that the robot can manipulate at a specified speed, acceleration/deceleration, center of gravity location (offset), and repeatability under continuous operation over a specified working space. Maximum payload is specified in kilograms. (R15.05-2)

Pendant [Programming Pendant]
See "Programming Pendant"

Pendant Teaching
The mapping and recording of the position and orientation of a robot and/or Robot system as the robot is manually moved in increments from an initial state along a path to a final goal state. The position and orientation of each critical point (joints, robot base, etc.) is recorded and stored in a database for each taught position the robot passes through on its path toward its final goal. The robot may now repeat the path on its own by following the path stored in the database.

Performance Level d (PLd)
ISO Performance Level (PL) "d" means that the average probability of dangerous failure per hour of the safety related parts of the control system falls within $= 10^{-7}$ to $< 10^{-6}$. Additionally, other factors such as proper installation, maintenance and protection against environmental factors also apply. This is the minimum performance level specified in ISO 10218-2 section 5.2.2, unless a risk assessment would allow a lower value to be used.

Performance Level e (PLE)
ISO Performance Level (PL) "e" means that the average probability of dangerous failure per hour of the safety related parts of the control system falls within $= 10^{-8}$ to $< 10^{-7}$. Additionally, other factors such as proper installation, maintenance and protection against environmental factors also apply.

Pick and Place Cycle
The amount of time it takes for a Robot to pick up an object and place it in a desired location, then return to its rest position. This includes time during the acceleration and deceleration phases of a particular task. The robot movement is controlled from one point location in space to another in a Point-to-Point (PTP) motion system. Each point is programmed into the robot's control memory and then played back during the work cycle.

Pick-and-Place Task
A repetitive part transfer task composed of a picking action followed by a placing action.

Pinch Points
A pinch point is any point at which it is possible for a person or part of a person's body to be caught between moving parts of a machine, or between the moving and stationary parts of a machine, or between material and any part of the machine. A pinch point does not have to cause injury to a limb or body part, although it might cause injury – it only has to trap or pinch the person to prevent them from escaping or removing the trapped part from the pinch point.

Pitch
Rotation of the end-effector in a vertical plane around the end of the robot Robot arm. See "Roll" and "Yaw".
Appendix B

Play Mode
After a robot is programmed in Teach Mode, the Controller can be switched to Play Mode to execute the robot program. In Play Mode, the robot program is played back. This is the mode in which robots are used in production.

Playback Operation
Playback is the operation by which the taught job is played back. This function is used to decide where to resume the playback on the start operation after suspending the playback and moving the cursor or selecting other jobs. 0: Starts operation where the cursor is located in the job displayed at the moment. 1: The playback continuation window appears. Select “YES” and the playback resumes where the cursor has been located when the playback suspended. If “NO” is selected, the playback resumes where the cursor is located in the job displayed at the moment. Modes Switch on the Programming Pendant: PLAY – job is started up by [START] on the Programming Pendant and REMOTE job is started by a peripheral device (external start input).

Point-to-Point
Robot motion in which a limited number of points along a projected path of motion is specified. The Robot moves from point to point rather than a continuous smooth path.

Pose
Alternative term for robot configuration, which describes the linear and angular position. The linear position includes the azimuth, elevation and range of the object. The angular position includes the roll, pitch and yaw of the object. See “Roll”, “Pitch” and “Yaw”.

Position
The definition of an object’s location in 3D space, usually defined by a 3D coordinate system using X, Y and Z coordinates.

Position Level
The position level is the degree of approximation of the Robot to a taught position. The position level can be added to move instructions MOVJ (joint interpolation) and MOVL (linear interpolation). If the position level is not set, the precision depends on the operation speed. Setting an appropriate level moves the Robot in a path suitable to circumferential conditions and the workpiece.

Position Variables
Position Variables are used in a robot program (JOB) to define a location in 3D space, usually defined by a 3D coordinate system using X, Y and Z coordinates. As it is a variable, the value can change depending on conditions or on information passed to the JOB.

Power and Force Limiting (PFL)
Collaborative feature that allows both the operator and robot to work in proximity to one another by ensuring the robot will slow down and stop before a contact situation occurs. In order for this feature to be safely implemented, functional safety and additional detection hardware must be used. A risk assessment shall be used determine if any additional safeguarding is necessary to mitigate risks within the robot system.
Presence-sensing Safeguarding Device
A device designed, constructed and installed to create a sensing field to detect an intrusion into such field by people, robots or objects. See “Sensor”.

Programmable Logical Controller (PLC)
A solid-state control system, which has a user programmable memory for storage of instructions to implement specific functions such as: I/O control logic, timing, counting arithmetic and data manipulation. A PLC consists of a central processor, input/output interface, memory and programming device, which typically uses relay equivalent symbols. The PLC is purposely designed as an industrial control system, which may perform functions equivalent to a relay panel or a wired solid-state logic control system, and may be integrated into the robot control system.

Programmable Robot
A feature that allows a robot to be instructed to perform a sequence of steps and then to perform this sequence in a repetitive manner. It can then be reprogrammed to perform a different sequence of steps if desired.

Programming Pendant
A hand-held input device, linked to the control system with which a robot can be programmed or moved. (ISO 8373) This enables the human operator to stand in the most favorable position to observe, control and record the desired movements in the robot's memory.

Proximity Sensor
A non-contact sensing device used to sense when objects are a short distance away, and it can determine the distance of the object. Several types include: radio frequency, magnetic bridge, ultrasonic and photoelectric. Commonly used for: high speed counting, sensing metal objects, level control, reading coding marks and limit switches. See “Inductive Sensor”.

Pulse Coordinates
YASKAWA robots define robot joint axes position in degrees for revolute joints. Pulse is also another way to specify robot joint position, and it does so in robot motor encoder pulse counts.

Quality Assurance (QA)
Describes the methods, policies and procedures necessary to conduct quality assurance testing during design, manufacturing and deliver phases of creating, reprogramming, or maintaining robots.

Quasi-static Clamping
A type of contact between a person and part of a robot system where the body part can be clamped between the moving part of the robot system & another fixed or moving part of the robot cell.

Range of Motion
The full movement potential of the robot.
Reach
The volume of space (envelope), which a robot's end-effector can reach in at least one orientation.

Real-time System
A computer system in which the computer is required to perform its tasks within the time restraints of some process simultaneously with the system it is assisting. The computer processes system data (input) from the sensors for the purpose of monitoring and computing system control parameters (outputs) required for the correct operation of a system or process. The computer is required to do its work fast enough to keep pace with an operator interacting with it through a terminal device (such as a screen or keyboard). The operator interacting with the computer has access, retrieval and storage capability through a database management system. System access allows the operator to intervene and alter the system's operation.

Record-playback Robot
A Robot for which the critical points along desired trajectories are stored in sequence by recording the actual values of the joint-position encoders of the robot as it is moved under operational control. To perform the task, these points are played back to the robot's servo-system. See "Servo-system".

Rectangular-Coordinate Robot
A robot whose Robot arm moves in linear motions along a set of Cartesian or rectangular axis in X, Y and Z directions. The shape of the work envelope forms a rectangular figure. See "Work Envelope".

Reliability
The probability or percentage of time that a device will function without failure over a specified time period or amount of usage (R15.02). Also called: the robot's uptime or the Mean Time Between Failure (MTBF).

Remanufacture
To upgrade or modify robots to the revised specifications of the manufacturer. (R15.06)

Remote Mode
Remote Mode is a type of Play Mode where the automatic execution of robot program is initiated from an external device (not the Programming Pendant). During this mode, the use of the Programming Pendant is disabled.

Repeatability
A measure of how close an arm can repeatedly obtain a taught position. For instance: once a Robot is manually placed in a particular location and this location is resolved by the robot, the repeatability specifies how accurately the Robot can return to that exact location. The degree of resolution within the robot control system determines the repeatability. In general, an arm's repeatability can never be better than its resolution. See "Teach" and "Accuracy".
Resolution
The amount of robot joint motion required for the position sensing to change by one count. Although the resolution of each joint feedback sensor is normally constant, the resolution of the endpoint in world coordinates is not constant for revolute arms, due to the non-linearity of the arm's kinematics.

Revolute Joint
The joints of a robot, which are capable of rotary motion.

Risk Assessment
The process of evaluating the intended use of a machine or system for foreseeable hazards and then determining the level of risk involved for the tasks identified.

Risk Mitigation
A secondary step in the risk assessment process that involves reducing the level of risk for the identified tasks, by applying risk reduction measures in order to eliminate or mitigate the hazards.

Robot
A re-programmable, multi-functional Robot designed to move material, parts, tools or specified devices through variable programmed motions for the performance of a variety of tasks. Common elements which make up a robot are: Controller, Robot and end-effector. See "Manipulator", "Controller" and "End-effector".

Robot Coordinate System
The Robot Coordinate System is defined in the base axis of a Robot, and points in the Robot Coordinate System will be relative to the base of the robot. Note that by default the Base Coordinate System and Robot Coordinate System are the same.

Robot Integrator
See "Integrator".

Robot Programming Language
An interface between a human user and a robot, which relates human commands to the robot.

Robot Range Limit Monitoring
Monitors the Robot arm or its tool to be in the designated safety area

Robot Simulation
A method for emulating and predicting the behavior and the operation of a robotic system based on the model (i.e., computer graphics) of the physical system. (R15.07)

Roll
Rotation of the robot end effector in a plane perpendicular to the end of the Robot arm. See "Pitch" and "Yaw".

Rotary Joint
A joint which twists, swings or bends about an axis.
Appendix B

Rotary Vector Drive (RV)
A brand name for a speed reduction device that converts high speed low torque to low speed high torque, usually used on the major (larger) axis. See "Cyclo Drive" and "Harmonic Drive".

Rotational Motion
A joint which twists, swings or bends about an axis. An example of this is the elbow of a human arm.

S

Safeguard
A barrier guard, device or safety procedure designed for the protection of personnel. (R15.06)

Safety Integrity Level
Safety Integrity Level (SIL) is IEC's method for determining the performance level of a safety system. SIL 2 corresponds to ISO Performance Level “d”, and SIL 3 corresponds to ISO Performance Level “e”. ISO 10218 allows for the use of either.

Safety Logic Circuit
The safety logic circuit monitors safety critical external devices such as the light curtains and FSU generated signals. The safety logic circuit is programmed via an intuitive user interface that is supported on the YASKAWA Programming Pendant. It enables to set up the logical operations, such as stopping the Robot or outputting a signal if the servos are on.

Safety Monitored Stop
Collaborative feature designed to allow safe human-robot interaction. Only when robot motion ceases can the human safety enter the collaborative workspace. Servos can remain energized in accordance with a category 2 stop in accordance with ISO 10218-1:2011, 5.4. A risk assessment shall be used to determine if any additional safeguarding is necessary to mitigate risks within the robot system.

SCARA Robot
A cylindrical robot, having two parallel rotary joints (horizontally articulated) and provides compliance in one selected plane. (ISO 8373)

Second Home Position
Apart from the “home position” of the Robot, the second home position can be set up as a check point for absolute data. The initial value of the second home position is the home position (where all axes are at pulse 0). The second home position can be changed.

Security Mode
Levels of operator modes on YASKAWA Controllers, include: Operation Mode, Edit Mode, Management Mode, Safety Mode and One Time Management mode.
Sensor
Instruments used as input devices for robots, which enable it to determine aspects regarding the robot's environment, as well as the robot's own positioning. Sensors respond to physical stimuli (such as heat, light, sound, pressure, magnetism and motion), and they transmit the resulting signal or data for providing a measurement, operating a control or both. (R15.06)

Sensory Feedback
Variable data measured by sensors and relayed to the Controller in a Closed-loop System. If the Controller receives feedback that lies outside an acceptable range, then an error has occurred. The Controller sends an error signal to the robot. The robot makes the necessary adjustments in accordance with the error signal.

Servo Control
The process by which the control system of the robot checks if the attained pose of the Robot corresponds to the pose specified by the motion planning with required performance and safety criteria. (ISO 8373)

Servo Motor
An electrical power mechanism used to effect motion or maintains position of the Robot (for example, a motor which converts electrical energy to effect motion of the Robot) (R15.07). The motor responds to a signal received from the control system and often incorporates an encoder to provide feedback to the control loop.

Servo Pack
An alternating, current electrical power mechanism that is controlled through logic to convert electrical supply power that is in a sine wave form to a Pulse Width Modulated (PWM) square form, delivered to the motors for motor control: speed, direction, acceleration, deceleration and braking control.

Servo-controlled Robot
The control of a robot through the use of a Closed-loop Servo-system, in which the position of the robot axis is measured by feedback devices and is stored in the Controller's memory. See Closed-loop System and Servo-system.

Servo-system
A system in which the Controller issues commands to the motors, the motors drive the arm, and an encoder sensor measures the motor rotary motions and signals the amount of the motion back to the Controller. This process is continued many times per second until the arm is repositioned to the point requested. See "Servo-controlled Robot"

Shock Detection Function
Shock detection is a function supported by the Controller that reduces the impact of a Robot collision by stopping the Robot without any external sensor when the tool or the Robot collide with a peripheral device.

Shoulder
The first or second axis of a robot is sometimes referred to as a shoulder axis as it somewhat resembles a human shoulder. This is often used in describing humanoid or dual-arm systems such as the YASKAWA Motoman® SDA10D.
Simulation
A graphical computer program that represents the robot and its environment, which emulates the robot's behavior during a simulated run of the robot. This is used to determine a robot's behavior in certain situations, before actually commanding the robot to perform such tasks. Simulation items to consider are: the 3D modeling of the environment, kinematics emulation, path-planning emulation and simulation of sensors. See "Sensor", "Forward Kinematics" and "Robot".

Singularity
A configuration where two joints of the robot arm become co-axial (aligned along a common axis). In a singular configuration, smooth path following is normally impossible and the robot may lose control. The term originates from the behavior of the Jacobian matrix, which becomes singular (i.e., has no inverse) in these configurations.

SlipRing
Discrete connections for customer to use in a variety of scenarios.

SLURBT
SLURBT are terms that describe each axis of the Robot for convenience. The definition of each value is as follows:
- S – Swing or Swivel
- L – Lower Arm
- U – Upper Arm
- R – Rotate
- B – Bend
- T – Twist

Softlimit Setting Function
The Softlimit Setting Function is a function to set the axis travel limit range of the Robot motion in software.

Speed and Separation Monitoring
Collaborative feature that allows both the operator and robot to work in proximity to one another by ensuring the robot will slow down and stop before a contact situation occurs. In order for this feature to be safely implemented, functional safety and additional detection hardware must be used. A risk assessment shall be used to determine if any additional safeguarding is necessary to mitigate risks within the robot system.

Spline
A smooth, continuous function used to approximate a set of functions that are uniquely defined on a set of sub-intervals. The approximating function and the set of functions being approximated intersect at a sufficient number of points to insure a high degree of accuracy in the approximation. The purpose for the smooth function is to allow a Robot to complete a task without jerky motion.

Spline Motion Type
A calculated path that the robot executes—that may be parabolic in shape. A spline motion may also accomplish a free form curve with mixtures of circular and parabolic shapes.
Appendix B

Standstill Monitoring
Using the Axis Speed Monitor function will activate an emergency stop condition if a motion occurs.

Stop Position Monitoring
See “Standstill Monitoring”

System Integrator
See “Integrator”

Teach
To program a Robot arm by manually guiding it through a series of motions and recording the position in the Controller memory for playback.

Teach Lock
While the Teach Lock is set, the mode of operation is tied to the Teach Mode and the machines cannot be played back using either [START] or external input. For safety purposes, always set the mode switch to “TEACH” before beginning to teach.

Teach Mode
A Controller mode in which a Robot is programmed by manually guiding it through a series of motions and recording the position in the Controller memory for playback. Industrial robots that do not have an active Power and Force Limiting Function require the use of a Three Position Enabling Device in Teach Mode.

Teach Pendant
See “Programming Pendant”

Teaching Window
Teaching Window is a user interface screen on the Programming Pendant. This window contains the JOB CONTENT window and teaching is conducted within this window. The JOB CONTENT window contains the following items: line numbers, cursor, instructions, additional items, comments, etc.

Through-beam
An object detection system used within a robot’s imaging sensor system. A finely focused beam of light is mounted at one end and a detector at the other. When the beam of light is broken, an object is sensed.

Time Measuring Function
Time measuring function measures the execution time for the specified section in the job or the signal output time of the specified signal.

Tool
A term used loosely to define a working apparatus mounted to the end of the robot arm, such as a hand, gripper, welding torch, screw driver, etc. See “Arm”, “Gripper” and “End-effector”.

ArcWorld 2000
Tool & arm Interference
In a system with one Controller and multiple Robots, the Tool & Arm Interference Check Function can be used to detect possible interference to avoid collision during operation. The following three patterns can be checked:

- Arm against arm
- Arm against tool
- Tool against tool

Tool against tool
Interference is checked by using a cylinder that is slightly larger than the arm or tool. A sphere is placed on both ends of the cylinder. If the cylinder and spheres of one Robot have any contact with those of the other while moving, the Robots stop because interference was detected.

Tool Center Point (TCP)
The Tool Center Point (TCP) defines the tip of the current tool as defined relative to the tool flange. For example, for a welding robot, the TCP will generally be defined at the tip of the welding gun. After defining and configuring the TCP, the robot motion will be defined relative to this frame (i.e., rotation in the Rx direction would cause rotation around the X-axis and positions will be taught in this frame).

Tool Control Point
See "Tool Center Point (TCP)"

Tool Coordinates
When the tool attached to the robot moves, so does its tool coordinate system in reference to a fixed coordinate system, for example, world coordinates. In general, the tool coordinates do not align with the world XYZ coordinates.

Tool Frame
A coordinate system attached to the end-effector of a robot (relative to the base frame).

Touch Sensor
Sensing device, sometimes used with the robot's hand or gripper, which senses physical contact with an object, thus giving the robot an artificial sense of touch. The sensors respond to contact forces that arise between themselves and solid objects.

Trajectory Generation (Calculation)
The computation of motion functions that allow the movement of joints in a smooth controlled manner.

Transducer
A device that converts energy from one form to another. Generally, a device that converts an input signal into an output signal of a different form. It can also be thought of as a device which converts static signals detected in the environment (such as pressure) into an electrical signal that is sent to a robot's control system.
Appendix B

U

Uptime
A period of time in which a robot or production line is operating or available to operate, as opposed to downtime.

User Coordinate Setting
User coordinates are defined by three points that have been taught to the Robot through axis operations. These three defining points are ORG, XX, and XY, as shown in the diagram below. These three points of positional data are registered in a user coordinate file. ORG is the home position, and XX is a point on the X-axis. XY is a point on the Y-axis side of the user coordinates that has been taught, and the directions of Y- and Z-axes are determined by point XY.

User Coordinate System
The User Coordinate System is any reference point that a user has defined for their application. This is often attached to an object such as a pallet and allows a user to teach points relative to this object. For example, a set of position could be taught relative to a User Coordinate System attached to a pallet and then easily transferred to a different User Coordinate System on another pallet. This allows for positions to be reused efficiently. See also, "User Coordinate Setting".

V

Vacuum Cup Hand
An end-effector for a robot arm which is used to grasp light to moderate weight objects, using suction, for manipulation. Such objects may include glass, plastic; etc. Commonly used because of its virtues of reduced object slide slipping while within the grasp of the vacuum cup. See "End-effector".

Vision Guided
Control system where the trajectory of the robot is altered in response to input from a vision system.

Vision Sensor
A sensor that identifies the shape, location, orientation, or dimensions of an object through visual feedback, such as a television camera.
Warning
Indicates a potentially hazardous situation which, if not avoided, will result in death or serious injury. Hazards identified by the signal word WARNING present a lesser degree of risk of injury or death than those identified by the signal word DANGER.

Work Envelope
The set of all points which a Robot can reach without intrusion. Sometimes the shape of the work space, and the position of the Robot itself can restrict the work envelope.

Work Envelope (Space)
The volume of space within which the robot can perform given tasks.

Work Home Position
The Work Home Position is a reference point for Robot operations. It prevents interference with peripheral device by ensuring that the Robot is always within a set range as a precondition for operations such as starting the line. The Robot can be moved to the set Work Home Position by operation from the Programming Pendant, or by signal input from an external device. When the Robot is in the vicinity of the Work Home Position, the Work Home Position signal turns ON.

Work Piece
Any part which is being worked, refined or manufactured prior to its becoming a finished product.

Workspace
The volume of space within which the robot can perform given tasks.

World Coordinates
A reference coordinate system in which the Robot arm moves in linear motions along a set of Cartesian or rectangular axes in X, Y, and Z directions. The shape of the work envelope forms a rectangular figure. See "Rectangular-Coordinate Robot".

World Model
A three dimensional representation of the robot's work environment, including objects and their position and orientation in this environment, which is stored in robot memory. As objects are sensed within the environment the Controller system continually updates the World Model. Robots use this World Model to aid in determining its actions in order to complete given tasks.

Wrist
A set of rotary joints between the arm and the robot end-effector that allow the end-effector to be oriented to the work-piece. In most cases the wrist can have degrees of freedom which enable it to grasp an object with roll, pitch, and yaw orientation. See "Arm", "End-effector", "Roll", "Pitch", "Yaw" and "Work Piece".

Wrist [Secondary Axis]
An interconnected set of links and powered joints between the arm and end-effector, which supports, positions and orientates the end effector. (ISO 8373)
**X**

**Y**

**Yaw**
Rotation of the end-effector in a horizontal plane around the end of the Robot arm. Side to side motion at an axis. See "Roll" and "Pitch".

**Z**