A465 Robot Arm
User Guide

For use with a C500C Controller

UMI-33-465

CRS It's all about time

A465 Robot Arm User Guide

Rev.	Revision History	Date
001	Original Issue as A465 for C500C. Updated to CROS 1.16.	99-05
002	CSA revisions	99-12

P R E F A C E

About This Guide

This user guide accompanies the A465 robot arm**.** It contains general information, specifications, safety precautions, installation instructions, startup procedures, and basic operation instructions for the CRS Robotics A465 arm used with CRS Robotics C500C controller.

Who Uses This Guide

This installation guide is intended for those who have attended a CRS Robotics robot system training course. It is not intended as a self-teaching tool.

How to Use This Guide

Throughout this user's guide warnings are marked by a "!" symbol in the left margin. *Failure to comply with these warnings can result in system errors, memory loss, or damage to the robot and its surroundings*

This guide is task based and uses navigational aids to help you quickly find the topics and information you need. If a technical term is not familiar to you, refer to the Glossary.

This guide consists of the following chapters:

- **Introducing the A465 Arm** describes the main components of your A465 robot system.
- **Specifications** provides detailed technical specifications for the A465 arm.
- **Safety Precautions** describes essential procedures for the safe operation of your robot system.
- **Work Cell Design** explains how to design a safe work cell for the A465 arm.
- **Installation** describes how to install the A465 arm and connect it to other robot system components.
- **Commissioning the Robot System** lists the verification steps that must be performed to ensure safe operation of your robot system.
- **Basic Operation** explains how to home and move the arm.
- **Gripper Installation** describes how to install an optional servo or pneumatic gripper for use with the A465 arm.

For More Information

Additional information is available in the following documents

- *C500C Controller User Guide*
- *Application Development Guide*
- *RAPL-3 Language Reference Guide*

You can obtain copies of these documents, or other CRS Robotics literature, from the Customer Support Group.

Training

Training courses for POLARA administrators and system integrators are offered at our facility in Burlington, Ontario, Canada, or can be conducted at your facility. For additional information, contact the Training Department.

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Contents

CHAPTER 1

Introducing the A465 Arm

This chapter introduces you to the A465 arm and the main components of your A465 robot system. It covers the following topics:

- The A465 Arm
    - The A465 Robot System
- Optional Equipment
    - Hardware and Equipment
    - End Effectors
    - Hardware and Equipment
    - Software

The A465 Arm

The A465 arm is a robot arm designed for use with the CRS Robotics C500C controller. End-effectors such as servo grippers and other tools can be mounted in a flange on the end of the arm. The arm's articulated joints permit movement through six degrees of freedom in both Cartesian and precision frames of reference, providing a full range of motion within a predefined coordinate system.

Arm motion is controlled directly from a teach pendant or terminal. For more complex applications, programs written in the RAPL-3 programming language can be used to automate robot tasks.

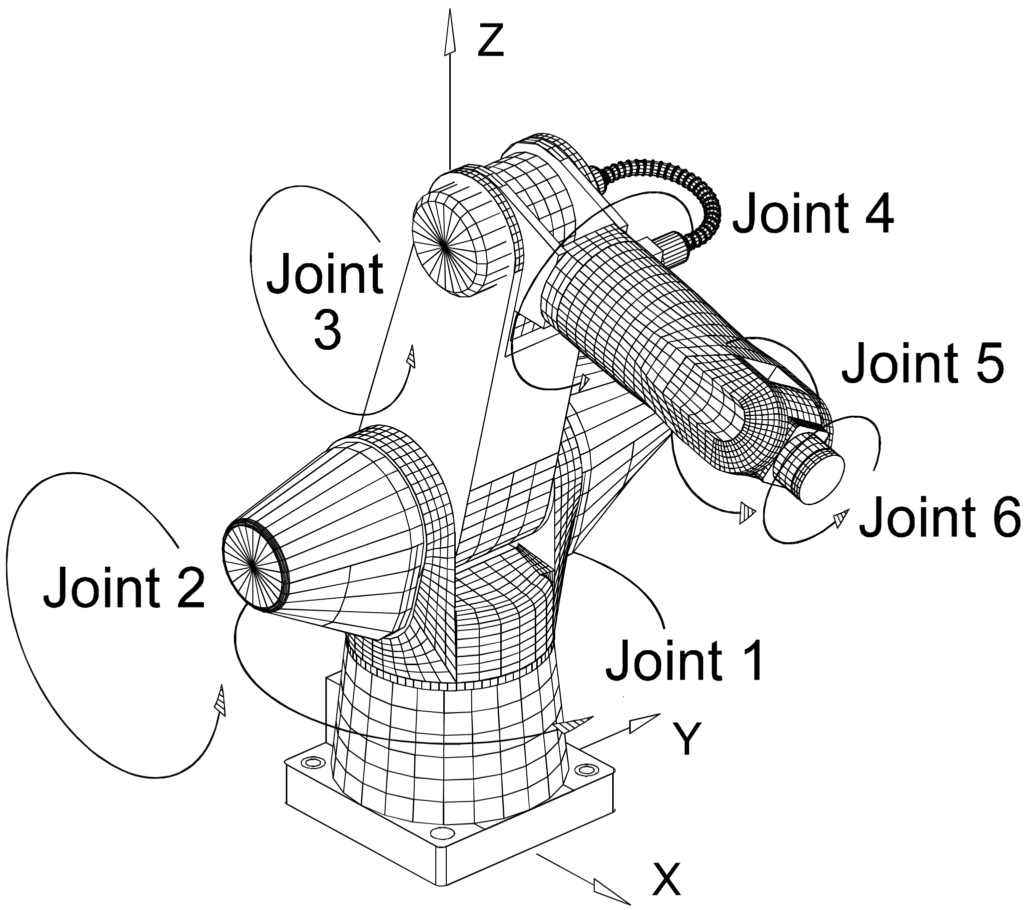


Figure 1: A465 articulated robot arm

The A465 Robot System

The A465 robot system consists of an A465 arm and a customized C500C controller running the CROS-500 operating system.

Optional Equipment

The following options are also available for use with A465 robot systems. Optional equipment can be ordered directly from your CRS Robotics distributor.

End Effectors

- Pneumatic Gripper and Adapter
- Servo Gripper and Adapter
- Microplate Fingers for Servo Gripper

Hardware and Equipment

- Teach Pendant
- Extra-Length Umbilical Cables
- Linear Track
- Force Sensor
- End Effector Custom Cabling
- Pressurized Suit for Harsh Environments
- General Purpose Input/Output Kit

Software

- Robcomm3 (RAPL-3 Program Development Environment and Interface to C500C)
- POLARA (Laboratory Automation Software)

CHAPTER 2

Specifications

This chapter provides detailed technical specifications for the following A465 parameters and components:

- Range of Motion, Dimensions, and Weight
- Reach
- Torque Ratings
- Joint Speeds and Acceleration Rates
- Payload
- Resolution
- Brakes
- Proximity Sensors
- Grippers

Range of Motion, Dimensions, and Weight

The arm's range of motion depends on the dimensions of each arm section (base, links, tool flange) and the extent of travel of each joint. These measurements determine the shape of the arm's workspace. See the following figures and tables.

Note: Dimensions involving a joint are measured to the joint axis.

Table 1: *Weight of the arm*

Weight (approx.)	lb	kg
Arm	67	32

Table 2: *Range of motion for each joint*

Joint	Axis	Range of Motion
Waist	1	+175° to –175°
Shoulder	2	+ 90° to – 90°
Elbow	3	+110° to –110°
Wrist rotate	4	+180° to –180°
Wrist pitch	5	+105° to –105°
Tool roll	6	+180° to –180°

Table 3: *Dimensions of A465 arm sections*

Section	Dimension	
	inch	mm
Base mounting surface to shoulder	13	30
Shoulder to elbow	12	305
Elbow to wrist pivot (joint 5)	13	330
Wrist pivot to tool flange surface	3	76

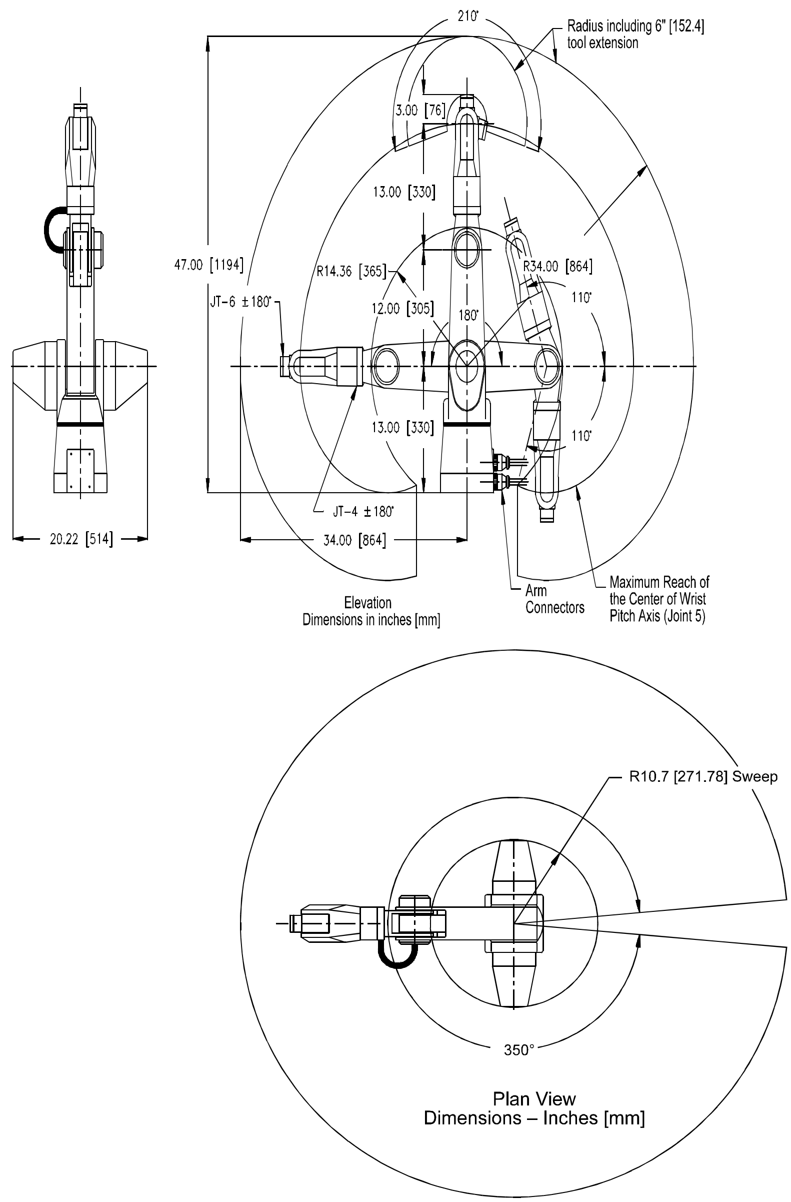


Figure 2: Range of motion and the dimensions of the sections of the A465 arm.

Reach

The maximum reach of the arm is calculated horizontally outward from the shoulder joint (axis 2) and vertically upward from the bottom of the base.

The arm can reach points below the level of the bottom of the base.

Table 4: *Maximum reach of the A465 arm*

Reach		inch	mm
Horizontal outward from the shoulder axis in the X-Y plane	to tool flange	28.00	711.2
	to finger platform of servo gripper	32.31	820.7
Vertical upwards along the Z axis	to tool flange	41.00	1041.0
	to finger platform of servo gripper	45.31	1150.87
Vertical downwards below the base level	to tool flange	3.00	76.2
	to finger platform of servo gripper	7.31	185.67

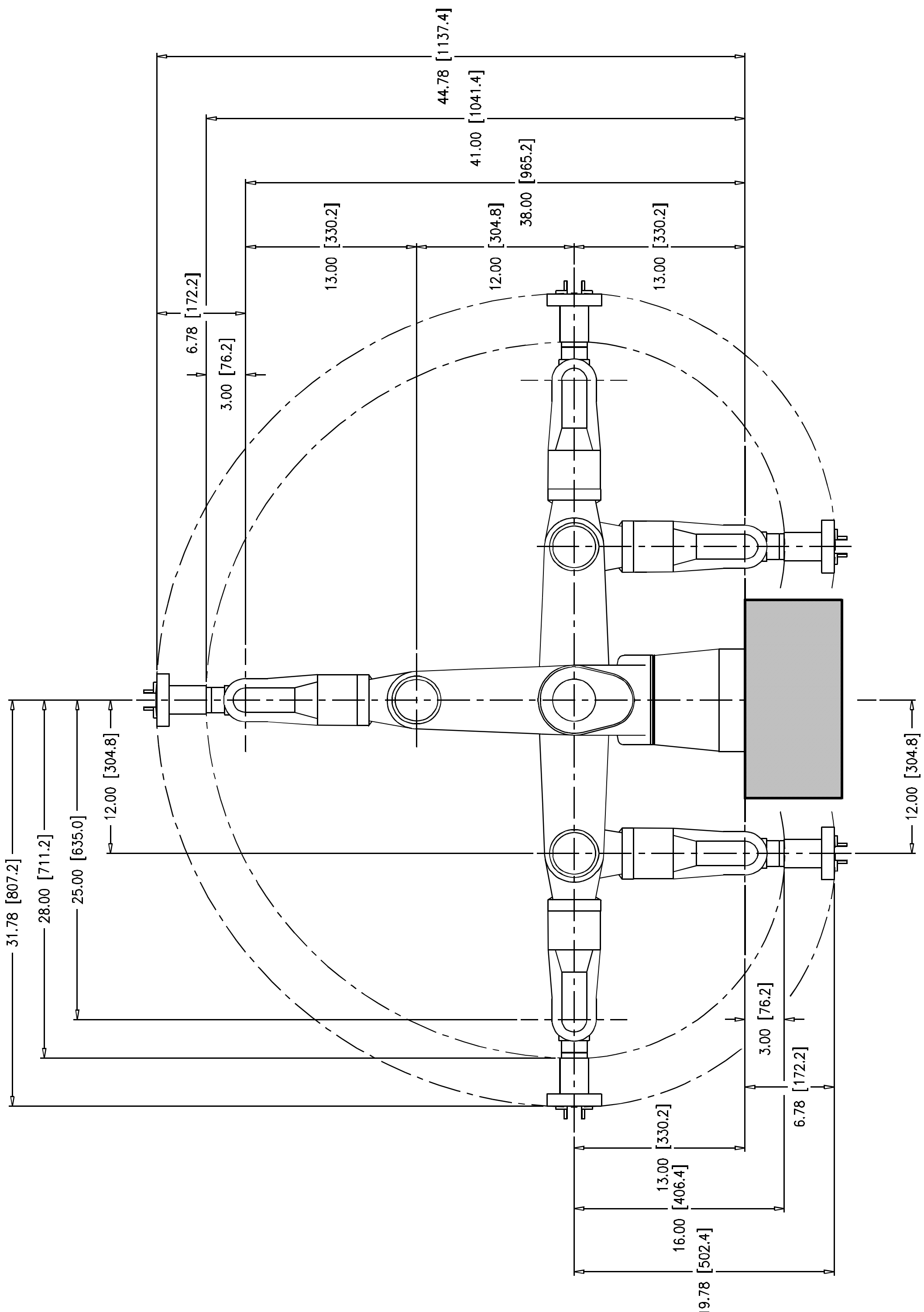


Figure 3: The maximum reach of the A465 arm horizontally from the waist and shoulder axes, and vertically above and below the base/mounting platform level. Dimensions to the tool flange and to the servo gripper finger platform are also shown.

Torque Ratings

This table shows the torque rating for each arm joint.

Table 5: *Continuous torque ratings for the A465 arm*

Joint	Axis	Torque	
		in-lb	N-m
Waist	1	350.0	39.50
Shoulder	2	590.0	66.08
Elbow	3	350.0	39.50
Wrist rotate	4	61.0	6.89
Wrist pitch	5	60.4	6.82
Tool roll	6	22.1	2.50

Joint Speeds and Acceleration Rates

The standard pick and place cycle is 1.2 seconds.

The following tables show the speed and acceleration rates for each arm joint.

Table 6: *Maximum speeds for A465 arm motion*

Motion	m/s
Compounded joint interpolated motions	4.35
Linear and path motions	1.02

Table 7: *Joint speeds at 100% program speed (RAPL 2.60)*

Joint	Axis	pulse/ms	Gear Reduction	Maximum Speed	
				rad/s	deg/s
Waist	1	50.0	100:1	3.14	180
Shoulder	2	50.0	100:1	3.14	180
Elbow	3	50.0	100:1	3.14	180
Wrist rotate	4	24.0	101:1	2.99	171
Wrist pitch	5	24.0	100:1	3.02	173
Tool roll	6	24.0	101:1	2.99	171

Table 8: *Default acceleration rates for A465 arm joints*

Joint	Axis	pulse/s²	rad/s²	deg/s²
Waist	1	2000	12.6	720
Shoulder	2	2000	12.6	720
Elbow	3	2000	12.6	720
Wrist rotate	4	2000	24.9	1430
Wrist pitch	5	2000	25.1	1430
Tool roll	6	2000	24.9	1430

Payload

Payload is the amount of mass (weight) carried by the arm and/or the amount of force the arm can exert on an object. This includes the mass of the end effector and any load that it carries.

Maximum and nominal payloads are determined for speeds and rates of acceleration that maintain rated precision. For rated precision, the arm travels at a reduced speed to carry the maximum payload, and the arm must carry a reduced payload to travel at maximum speed.

The maximum payload depends on the distance between the center of the tool flange surface and the center of gravity of the payload as shown in the payload derating tables and curves.

Table 9: *Payload rating at different speeds*

Payload	Speed	Mass
Maximum	80% speed or acceleration	3.0 kilograms
Nominal	100% speed or acceleration	2.0 kilograms

Table 10: *Axial distance from the tool flange surface*

Axial Distance		Mass	
inch	mm	lb	kg
2.0	51	6.61	3.00
2.3	58	6.61	3.00
4.0	102	5.00	2.27
6.0	152	3.89	1.76
8.0	203	3.18	1.44
10.0	254	2.69	1.22

Table 11: *Radial distance from the tool flange center*

Radial Distance		Mass	
inch	**mm**	**lb**	**kg**
2.0	51	6.61	3.00
4.0	102	3.25	1.47
6.0	152	2.17	0.98
8.0	203	1.63	0.74
10.0	254	1.30	0.59

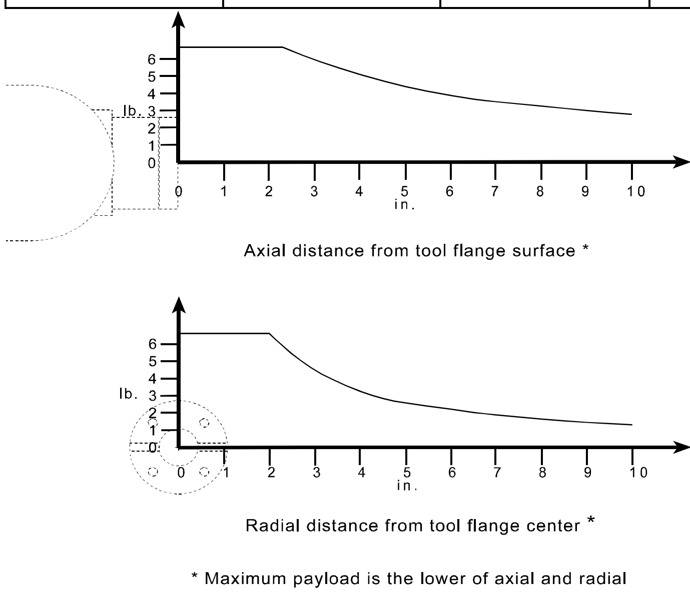


Figure 4: Decrease in payload according to distance from the center of gravity (Imperial units)

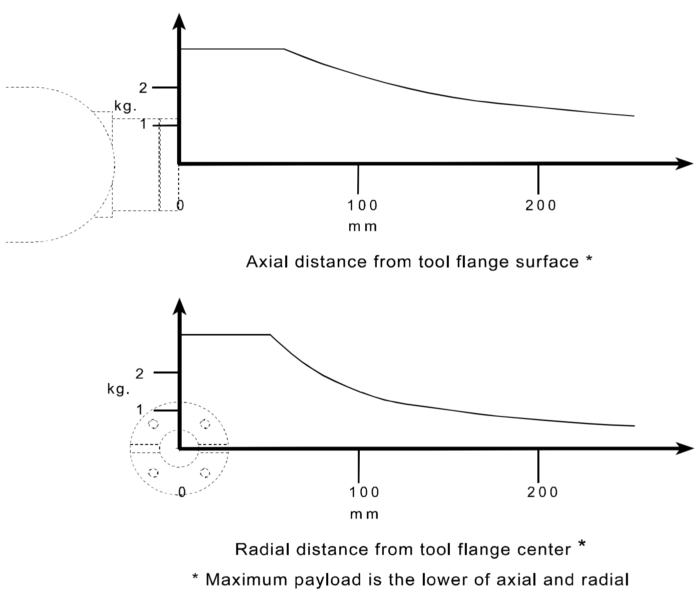


Figure 5: Decrease in payload according to distance from the center of gravity (Metric units)

Resolution

Resolution is the smallest increment of motion or distance that can be detected or controlled. Resolution depends on the distance between the center of the tool flange surface and the center of gravity of the payload as shown in the resolution derating tables and curves.

Table 12: *Resolution according to axial distance from the tool flange surface*

Axial Distance		Resolution	
inch	mm	inch	mm
0.0	0.0	0.0013	0.0330
2.0	51.0	0.0022	0.0559
4.0	102.0	0.0031	0.0787
6.0	152.0	0.0039	0.0991
8.0	203.0	0.0048	0.1219
10.0	254.0	0.0057	0.1448

Table 13: *Resolution according to radial distance from the tool flange center*

Radial Distance		Resolution	
inch	mm	inch	mm
0.0	0.0	0.0000	0.0000
2.0	51.0	0.0003	0.0076
4.0	102.0	0.0005	0.0127
6.0	152.0	0.0008	0.0203
8.0	203.0	0.0010	0.0254
10.0	254.0	0.0013	0.0330

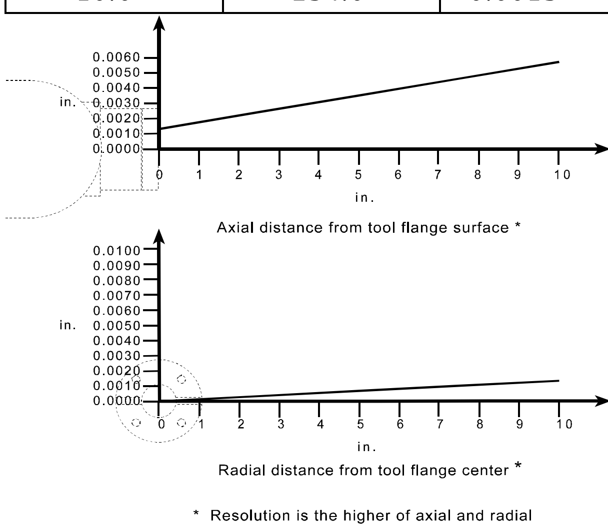


Figure 6: Decrease in resolution according to distance from the center of gravity (Imperial units)

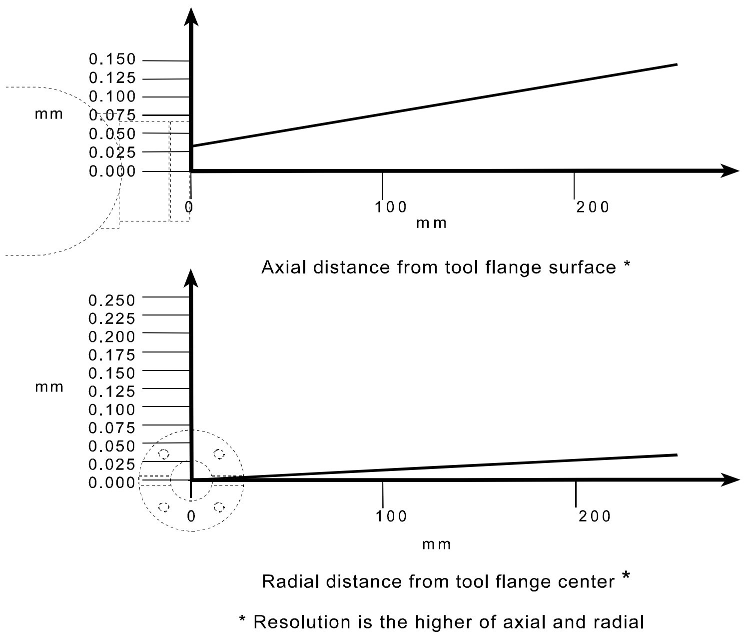


Figure 7: Decrease in resolution according to distance from the center of gravity (Metric units)

Repeatability

Repeatability is the ability to repeat the same motion or achieve the same points of location when presented with the same control signals. It can also be defined as the cycle-to-cycle error when trying to perform a specific task.

The A465 arm is capable of repeatable movements to within ± 0.002 inch (± 0.05 mm).

Brakes

Fail-safe brakes prevent the robot from moving under the influence of gravity or inertia when power is removed. Each brake consists of a spring-loaded clamp on a rotating disk. A 35 Volt DC signal energizes a magnetic solenoid which unloads the clamp.

Brakes are installed on joints 2 and 3.

Do not attempt to force or manually move joints when the brakes are engaged. *Moving or forcing joints while the fail-safe brake is engaged can cause damage to the A465 arm.*

Proximity Sensors

Each joint in the A465 arm contains a proximity sensor which is used by the controller to home the arm. Each joint also contains a cam or end-of-travel pin location which the proximity sensor uses to find its transition point.

Proximity sensors are not used to limit the positive or negative travel of any joint under normal operation. This is done by software limits.

Table 14: *Transition point locations for the A465 arm*

Axis	Joint	Transition Location
1	Waist	+ 175° (positive end of travel limit)
2	Shoulder	+ 10° (vertical is 0 degrees)
3	Elbow	– 60°
4	Wrist rotate	+ 180° (positive end of travel limit)
5	Wrist pitch	+ 25°
6	Tool roll	+ 180° (positive end of travel limit)

An arm in the calrdy position (links posed vertically upwards from the base) has all joints at 0 degrees.

Homing

When the robot is homed with the internal home command, the controller moves individual joints in sequence until the transition point has been found for each joint. The resolution of a proximity sensor by itself is not accurate enough for homing a joint. The controller uses the next zero pulse from the joint's encoder to accurately determine the arm position.

If obstacles within your work cell interfere with the regular homing sequence, a customized homing program may be devised instead. Customized homing is discussed further in the section entitled "Programming a Customized Homing Sequence" on page 37.

Grippers

Grippers are end effectors which enable the A465 robot system to grip or measure objects.

Warning! A465 robot systems equipped with a servo gripper lose power to the gripper and may drop their payload when the E-Stop is engaged. *Springs or other mechanisms can be added to the gripper fingers to ensure that the payload is not dropped.*

If servo grippers are used with your A465 system, you must design the gripper fingers to ensure that objects are not dropped when the fingers open. For more information on gripper installation and safety, see the section entitled "Gripper Installation" on page 71.

Custom-designed grippers and other end effectors are available from CRS.

Standard Grippers

Servo Gripper (SGRIP)

An electric, servo-controlled, parallel motion, two-finger gripper, capable of measuring objects between its fingers. Standard finger travel is 2.56 in. [65 mm] with programmable position and force.

Servo Gripper with Microplate Fingers (SEC-B0-645)

An electric servo-controlled, parallel motion, two-finger gripper, with fingers specially designed for handling laboratory microplates. Finger travel is 2.56 in. [65 mm] with programmable position and force.

Pneumatic Gripper (PGR112/3)

A two-jaw, double acting, air gripper with 3 in. [76.2 mm] long, angular motion, re-toolable fingers. Fingers can be machined to meet specific needs. Travel is 0.0 – 10.0 degrees per finger.

CHAPTER 3

Safety Precautions

This chapter describes the design of safeguards and other precautions for the safe use of the robot system and its work cell.

Danger! Design your robot work cell for safety. The robot is a potentially hazardous machine. *Injury to persons or damage to the robot, tooling, or other work cell components can occur from unsafe work cell design, robot installation, operation, or from system failure.*

This chapter contains the following sections:

- Robot Safety
- Emergency Stops (E-Stops)
- General Safeguards
- Power
- Power Failures
- Lock-out and Tag-out Procedures
- Environmental Requirements
- Robot Handling
- Operator Safety
- Safety and Operation Checks
- Working Within the Robot's Workspace

For more information on safe robot use and work cell design, refer to the following safety standards:

- ISO10218 (International Organization for Standardization)
- UL1740 (Underwriters Laboratories Inc.)
- ANSI/RIA15.06 (Robotic Industries Association)
- CAN/CSA-C22.2 No. Z434-94 (Canadian Standards Association)

Robot Safety

A robot is a potentially hazardous machine. Uncontrolled robot motion (robot runaway) and dropped payloads can result in serious damage to persons and equipment. System integrators and end-users must take responsibility for assessing risks and determining appropriate safety measures for the use and maintenance of the robot system.

Before installing or operating your A465 robot system, ensure that you are familiar with the safety procedures in this chapter and the following chapter, entitled “Work Cell Design”.

Safeguards and Safety Measures

Safeguards may include, but are not limited to: fixed barriers, interlock barriers, perimeter guarding, awareness barriers, and awareness signals.

Incorporate safety measures into your design to reduce the risk of hazards. Ensure that you:

- Use a diverse and redundant set of safety measures to provide an adequate level of safety.
- Design measures so that the activation of an interlock installed to prevent one hazard does not create a new hazard.
- Correctly install and operate the robot.

Prevent Personal Injury

Danger! Never enter or obstruct the workspace while the robot is in use. *The robot arm is capable of fast movement without warning. Install safeguards to prohibit access to the workspace when the robot is in use.*

Emergency Stops (E-Stops)

The emergency stop (E-Stop) circuit for the A465 robot is designed to immediately remove power from the arm when an E-Stop button is struck. During an E-Stop, fail-safe brakes on joints 2 and 3 are automatically engaged to prevent the arm from moving due to gravity or inertia. Power cannot be restored to the arm until the E-Stop button that triggered the emergency stop is manually reset.

Warning! A465 robot systems equipped with a servo gripper lose power to the gripper and may drop their payload when the E-Stop is engaged. *Springs or other mechanisms can be added to the gripper fingers to ensure that the payload is not dropped.*

Pressing an E-Stop does not turn off power to the controller. Although the arm will not move, all processes not calling on robot commands continue to run. Robot programs may continue to run if structured error handling is included in the application.

With the exception of the live-man switch on the teach pendant, all E-Stop buttons are large red buttons on a yellow background.

The E-Stop circuit is connected to the following switches:

- E-Stop button on the front panel of the controller.
- E-Stop button on the front of the teach pendant.
- Live-man switch on the teach pendant.

You can also install additional E-Stop buttons if required. For more information on additional E-Stops, see the section entitled “Work Cell Design” in this guide.

General Safeguards

Additional safeguards can include, but are not limited to:

- **Physical barriers**, which are designed to prevent personnel from operating the arm from within the workspace of the robot system.
- **Presence sensor interlocks**, which automatically stop the arm when a door is opened or motion is detected within a certain perimeter.
- **Awareness signals**, which are audible or visible signals designed to alert personnel that they are approaching the robot and should move away before they trigger an automatic E-Stop circuit within the work cell boundaries.
- **Awareness barriers**, such as a length of yellow chain, which serves to alert personnel to the work cell boundaries without prohibiting access into the work cell.
- **Passive warnings**, such as markings on the floor or table top.
- **Beacon lights** which indicate when the robot system is powered on.
- **Training** to ensure that all personnel who program, operate, maintain, or repair the robot are adequately trained and demonstrate competence to perform their jobs safely.

Safety Regulations

In addition, your installation should comply with any applicable safety regulations or standards of your national or local jurisdiction.

Power

Grounding the System

Warning ! A potential difference between the arm and the controller can cause the umbilical cable to overheat and catch fire.

Ensure that the AC power supply is properly grounded. The incoming AC plug has three wires: hot, neutral, and chassis ground. All three wires must be used. Hot and neutral supply power to the system and the ground shields the controller from external noise and voltage potentials.

Grounding points must have an equal potential. For grounding instructions, see the section entitled “Grounding the Arm and Controller” on page 49of this guide.

Power Supply Requirements

Power supplied to the controller must be stable. If your power supply is unstable (has fluctuations in frequency or surges) install a regulating system in the power supply.

Do not exceed voltage fluctuations ±10% of the nominal voltage.

For variations in voltage only, install a regulating transformer. A more complete regulating system, such as a non-interruptible Power Supply (UPS), is recommended.

Note: Before entering within the robot’s workspace perform the checks and safety precautions as listed in “Safety and Operation Checks” on page 26.

Electromagnetic Interference

The C500C controller has been tested according to European EMC requirements and meets the industrial rating. The robot arm should not be exposed to excessive electrical noise and/or plasma (i.e. welding applications).

Electrostatic Discharge

Warning! Static electricity can damage the electronic components in the controller, arm and teach pendant. *Wear a grounded ESD wrist strap when working inside the controller.*

When handling electronic components or working inside the controller, you must wear an electrostatic discharge (ESD) wrist strap. Connect your ESD wrist strap to the controller chassis.

Electrically Live Objects

Do not allow anything electrically live to come into contact with the arm or controller.

Wiring

Do not damage the umbilical cables which carry power and signals between the controller and the arm. Protect the cables from damage or deterioration.

Do not exceed a bend radius of 10x cable diameter.

Do not apply pressure to any wiring, encoders on the ends of the motor shafts, or the elbow wiring conduit.

Power Failures

If a power failure occurs, the controller automatically removes arm power. This prevents the arm from moving when power is restored.

Servo Gripper Safety

Shutting off the power to the controller causes the gripper to release and open, potentially dropping a payload held in the gripper. If you are using a servo gripper in a situation where a dropped payload could be hazardous, take one of the following precautions:

- Add springs between the gripper fingers to maintain grip force. Verify that in the event of a power loss, the mechanical force exerted by the springs is sufficient to hold the object in place.
- Redesign the gripper fingers so that force is exerted from the inside of the object.

Restarting the Robot System

After a power failure, you must perform the following steps:

1. Restart the controller.
2. Reset and reconfigure the work cell.
3. Turn on arm power.
4. Home the robot.

Lock-out and Tag-out Procedures

CRS Procedures

The A465 robot arm receives power from the C500C controller. Power is supplied to the controller via a standard AC power cord with a NEMA style connector.

CRS recommends the following procedure to lock-out power to the controller:

1. Disconnect the AC power cord from the connector at the back of the controller.
2. Remove the fuses.
3. Remove the voltage selector.

Note: Without the AC power cord, fuses, or the voltage selector, the controller can not be powered.

CRS recommends the following procedure to tag-out the controller:

1. Create a tag marked **DO NOT POWER THE ROBOT!**
2. Hang the tag from the connector at the back of the controller.

OSHA Procedures

OSHA 1910-147 recommends an alternate lockout procedure where the AC power outlet supplying the controller has its circuit breaker locked-out at the main panel. Refer to OSHA 1910-147 Control of hazardous energy (Lockout/Tagout) for details concerning this approach.

Environmental Requirements

The A465 robot system has been designed and tested to meet the European Community EMC requirements pertaining to industrial, scientific, and medical (ISM) work environments, and the safety requirements prescribed by ISO 10218.

Indoor Use

The robot was designed for indoor applications only.

Temperature

Maintain the air temperature between 50-°F (10 °C) and 104-°F (40 °C).

Do not install the robot near heating or cooling units.

Do not expose the robot to temperatures below 50 °F (10 °C) or above 104 °F (40 °C) without a CRS-certified protective cover. Use a protective cover if temperatures fall above or below this range.

Humidity

Maintain the relative humidity below 50%, non-condensing.

Hazardous Environments

Do not expose the A465 robot system to corrosive liquids, flammable gases, or explosive dusts. Neither the arm nor the controller are rated for exposure to these harsh environments.

The controller electronics are more sensitive to corrosion than the arm. If the arm operates in a harsh environment, ensure that the controller is placed in a separate, controlled environment.

Use a CRS-certified protective cover to protect the robot arm from contaminated environments. Protecting the arm and controller from contaminants will lead to extended use.

Note: When using a protective cover, purge the air in the cover at regular intervals.

Ingress Protection

In general, do not expose the A465 robot system to an environment where exposure to solid objects and/or water is possible. The A465 arm is rated to IP40 for protection against solid objects and water when the chain in the underbody is oriented downward. When the chain in the underbody is oriented upwards, the rating drops to IP00.

In all cases, you should contact CRS before using the A465 system for applications requiring ingress protection.

Vibration and Shock

The robot has not been rated for operation in environments where it may be exposed to excessive vibration or impact.

Electromagnetic Interference

The A465 robot system should not be exposed to excessive electrical noise and/or plasma.

Robot Handling

The robot is a precision instrument and must be handled with care. The A465 robot arm weighs approximately 67 lb. (32 kg). At least two people should work together when lifting the arm.

Lifting and Transporting the A465 Arm

When lifting the arm, always grasp the robot under the cast aluminum base or under one of the machined aluminum arm links. Use a cart when transporting the arm, even over a short distance. The arm is not protected against excessive shock and can be damaged if it is dropped.

Warning! *Do not grasp the robot under the ABS-plastic motor covers on the sides, by the wrist or gripper, or by the elbow wiring conduit.*

The arm is most easily lifted from the ready position. To lift the arm:

1 While the robot system is still connected and powered on, place the arm in the ready position.

2 Press an E-Stop to remove arm power, shutdown the operating system, and turn off power at the controller's power switch.

3 Disconnect and unfasten the arm. With power removed, fail-safe brakes hold the joints firmly in place.

4 Place your shoulder under the outer link, and grasp the base with your hands, as shown in the figure below.

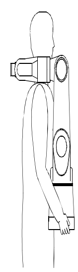


Figure 8: To lift the arm on and off a cart, shoulder it from the ready position.

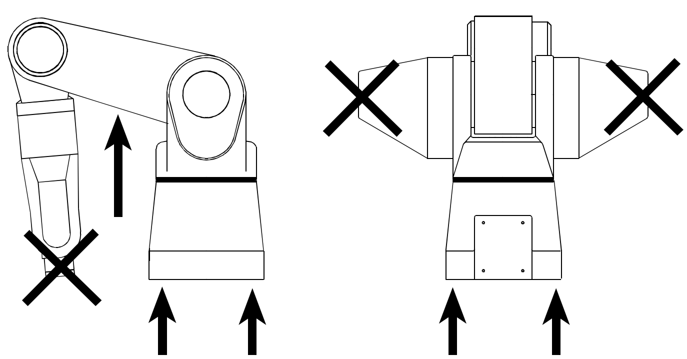


Figure 9: Always grasp the robot under the base or arm link.

Operator Safety

Operator Attitude towards the Robot

Maintain an attitude of respect for the robot as a potentially dangerous machine.

Operator Awareness of the Robot

When working near the robot, you must be aware of the arm's position and motion at all times.

- For occasional close approach to the workspace, have a second person observe the arm while within reach of an E-Stop.
- For continual close approach to the workspace, install precise presence-sensing devices interlocked to the E-Stop circuit.

Operator Position Near the Robot

Avoid any location that confines you between the arm and another object.

Operator Training

Ensure that personnel who program, operate, maintain, or repair the robot are adequately trained and demonstrate competence to perform their jobs safely. Attend a CRS training course for proper training.

Ensure that operators:

- Are familiar with the applicable safety precautions as stated in this chapter.
- Have a clear definition of their assigned task.
- Can identify the control devices and their functions used in performing their assigned task.
- Have designated methods of safeguarding, including safe work procedures from identified hazards.
- Test and ensure that the safeguards and interlocks function properly.

Emergency movement without drive power

The A465 robot arm does not have a brake release mechanism. In an emergency situation, the joints for this robot can be manually back driven.

Safety and Operation Checks

Ensure that you have followed all the safety instructions supplied within this manual.

BEFORE applying power to the arm, verify that:

- The robot is properly installed, mounted, and stable (refer to Chapter 4 “Installation” for mounting and installation procedures).
- Electrical connections are correct and that the power supplies (voltage, frequency and interference levels) are within the specified ranges (refer to page 20 for specified ranges).
- If you have modified your system, added hardware, software, or serviced your robot, recheck all the changes or additions.
- User memory is intact. Errors should not appear in your programs, location, or variable files.
- Safeguards are in place.
- The physical environment (humidity, atmospheric conditions, and temperature) is as specified.

AFTER applying arm power, verify that:

- The start, stop, and function keys on the teach pendant and controller front panel function as intended.
- E-Stops, safety stops, safeguards, and interlocks are functional.
- At reduced speed the robot operates properly and has the ability to handle the workpiece.
- Under normal operation, the robot functions properly and has the capability to perform its intended task at the rated speed and load.

Working Within the Robot's Workspace

Before entering within the robot's workspace perform the following checks and safety precautions:

1. Visually inspect the robot to determine if any conditions exist that can cause malfunctions or injury to persons.
2. If the teach pendant controls are used, test them to ensure that they function correctly. If any damage or malfunction is found in the teach pendant, complete the required repairs before allowing personnel to enter within the robot workspace.
3. While programming or teaching locations, the robot system must be under the sole control of the programmer.
   - When possible, program the robot with all personnel outside the safeguarded area.
   - When programming the robot and teaching locations within the safeguarded area, ensure that robot motion is reduced to at least 25% speed.
4. While servicing the robot arm, the robot system must be under the sole control of the service person.
   - Ensure that the robot is off-line. The arm must not be stopped in, or running, a program.
   - Ensure that the robot does not respond to any remote signals.
   - Ensure that all safeguards and E-Stops are functional.
   - Always remove power to the arm and controller before connecting or disconnecting cables.
   - Ensure that suspended safeguards are returned to their original effectiveness prior to initiating robot operation.
5. When power to the robot arm is not required, it should be turned off.

CHAPTER 4

Work Cell Design

This chapter explains some of the issues you must be aware of when designing the robot work cell. It contains the following sections:

- Physical Barriers
- Other Proximity Safeguards
- Installing a Beacon Light
- Additional E-Stops
- Controller Location
- Arm Location Within the Work cell
- Obstructions Within the Work cell

Physical Barriers

Physical safety barriers are designed to inhibit or prohibit access to the arm's workspace. Physical barriers include fixed barriers, interlock barriers, and perimeter guarding.

When installing physical barriers, ensure that the following criteria are met:

- Barriers must be beyond the total limit of the arm's possible workspace, even if the arm is programmed for only a portion of the total possible workspace.
- There must be sufficient clearance between the barriers and the total robot workspace (arm, gripper, and payload) to avoid trapping or crushing any object.

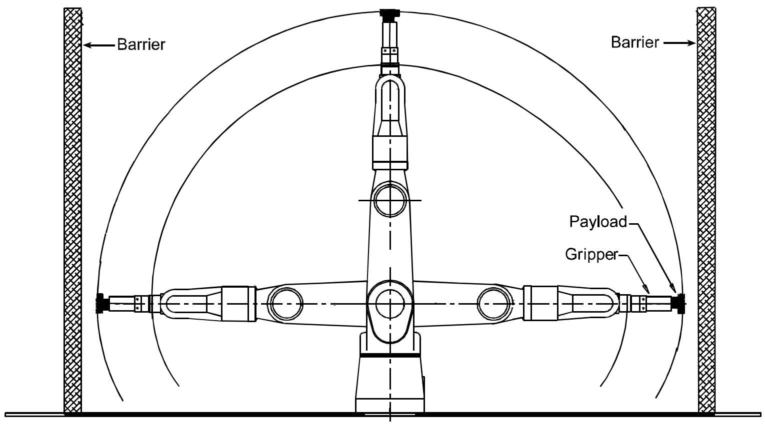


Figure 10: Barriers must be outside the total radius of the robot arm, gripper, and payload.
$\text{Radius}_{minimum}$= 28 in [711 mm] + $\text{Length}_{gripper}$ + $\text{Length}_{payload}$
$\text{Height}_{minimum}$ = 41 in [1041 mm] + $\text{Length}_{gripper}$ + $\text{Length}_{payload}$

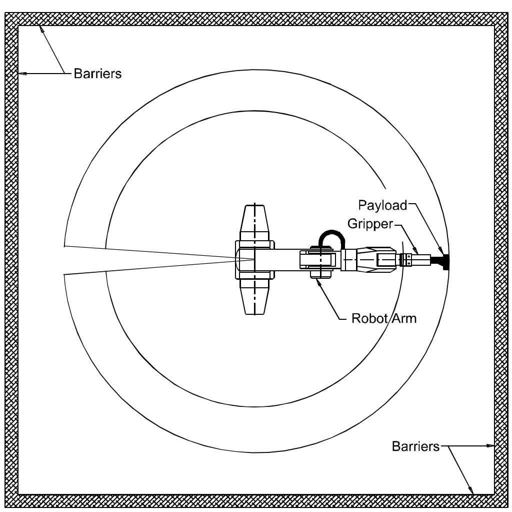


Figure 11: Barriers must be outside the total radius of the robot arm, gripper, and payload.

$\text{Radius}_{minimum}$ = 28 in [711 mm] + $\text{Length}_{gripper}$ + $\text{Length}_{payload}$

Presence Sensor Interlocks

Presence sensor interlocks are used to automatically stop the arm when a door is opened or motion is detected within a certain perimeter.

Install presence-sensing safety interlocks at all points of access through physical barriers into the work cell. Interlocks should be integrated as part of the controller E-Stop circuit. For example, a door-mounted contact switch connected to the E-Stop circuit stops the arm when the door is opened and the contact broken, and it permits arm operation when the door is closed and contact is restored.

For further information on connecting devices via the E-Stop circuit, consult the C500C Controller User Guide.

Presence sensors include:

- Contacts on doors
- Light curtains
- Pressure-sensitive floor mats, etc.

Design and construct any presence-sensing device so that:

- When any component fails, the E-Stop circuit is interrupted.
- The presence-sensing envelope is far enough from the arm to stop arm motion before the intruder can reach the arm workspace.

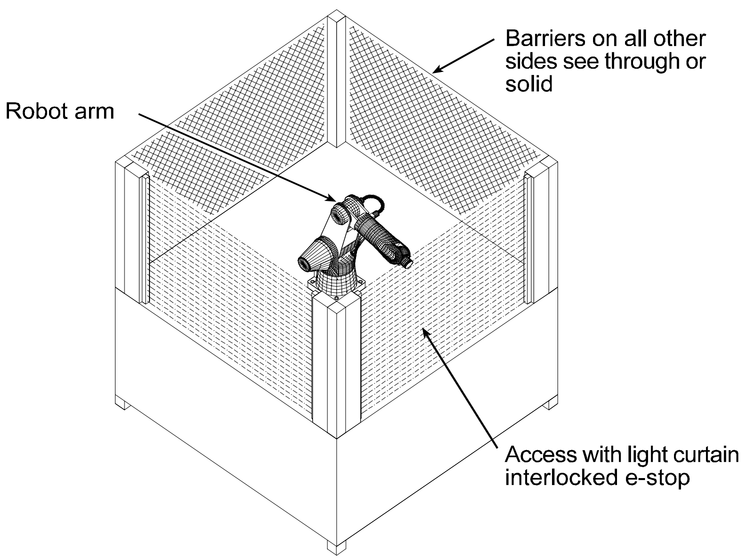


Figure 12: Example of barriers and interlocked light curtain.

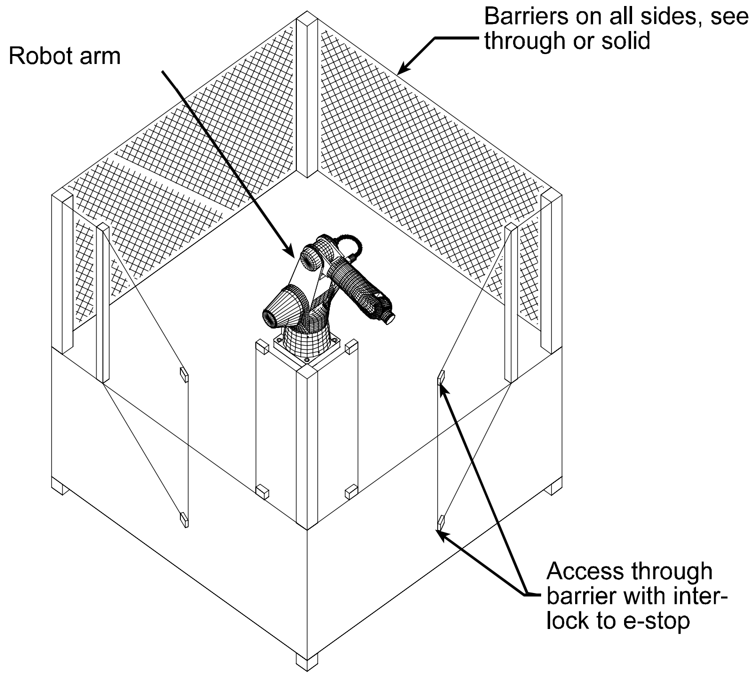


Figure 13: Example of barriers and interlocked contacts on doors.

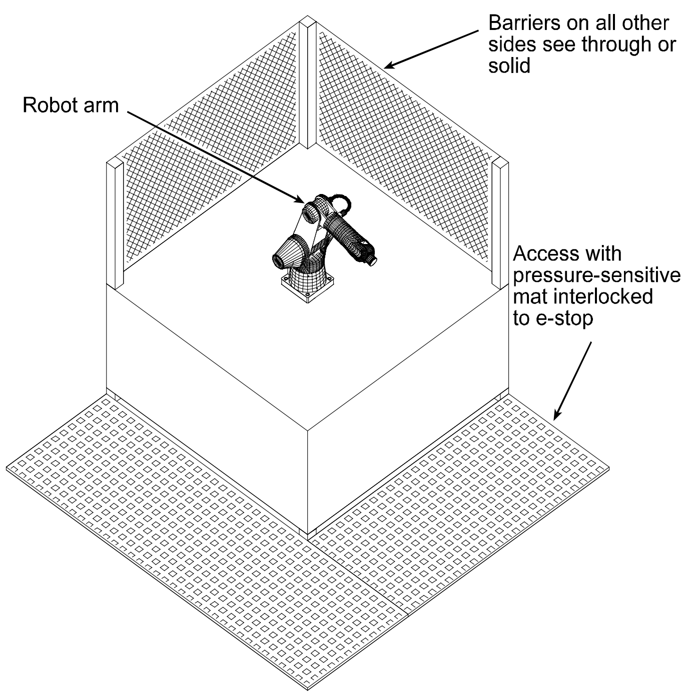


Figure 14: Example of barriers and interlocked pressure mats.

Other Proximity Safeguards

Your work cell should incorporate one or more of the following safeguards to prevent or minimize dangerous interactions within the workspace and ensure safe operation of the robot system.

Awareness signals

An awareness signal is an audio or visual alarm, such as a buzzer or light, activated by a sensor in a larger perimeter outside the inner, E-Stop-connected perimeter. The signal alerts the intruder to move away before triggering the E-Stop circuit.

Awareness barriers

An awareness barrier, such as a length of yellow chain, alerts personnel to the work cell boundaries without prohibiting access into the workspace.

Passive warnings

Passive warnings include markings on the floor or table top.

Beacon light

A yellow or amber indicator light which warns operators when the robot system is powered on.

Installing a Beacon Light

A beacon light must be installed as part of your work cell design. The beacon must be yellow or amber and must be visible from all approaches or points of entry. The beacon must be designed so as to light automatically whenever the robot system is powered on.

Warning! The beacon is only an awareness signal and should not be the sole indicator that the robot is capable of motion. *A lamp, when burned out, would indicate that the arm is not powered up when in reality it is powered up. To prevent this situation, CRS strongly recommends you properly interlock your work cell so that a lamp failure triggers a backup indicator. In addition, test and/or replace the lamp as part of your preventive maintenance schedule.*

CRS recommends that a 24V beacon or tower lamp be connected to the SYSIO connector on the back of the controller. The maximum voltage and current of the lamp for the SYSIO connector are 24V and 50mA, respectively.

Refer to the appropriate section in the C500C Controller User Guide for additional details about connecting to the SYSIO port.

Connecting the beacon light to the internal 24V supply

1. Place a jumper between pins 2 and 3.
2. Place a jumper between pins 24 and 25.
3. Connect the lamp or relay contact between pins 15 and 23 or 24.

Using an external 24V supply

1. Connect +24V supply to pin 3 or 4.
2. Connect the GND to pin 23 or 24.
3. Connect the lamp or relay contact between pins 15 and 23 or 24.

Additional E-Stops

To ensure safety, you should consider installing additional E-Stop buttons at the following locations:

- At or near the robot arm location.
- Within human reach of any approachable side of the robot arm work cell.

Design your work cell so that it conforms to the following requirements:

- All E-Stop buttons must be unobstructed.
- Personnel must be able to reach and activate the E-Stop without difficulty.
- All E-Stops must be outside the total safeguarded space of the robot arm, its gripper, and any payload.

Wiring and controller settings for custom E-Stops are discussed further in the C500C Controller user guide.

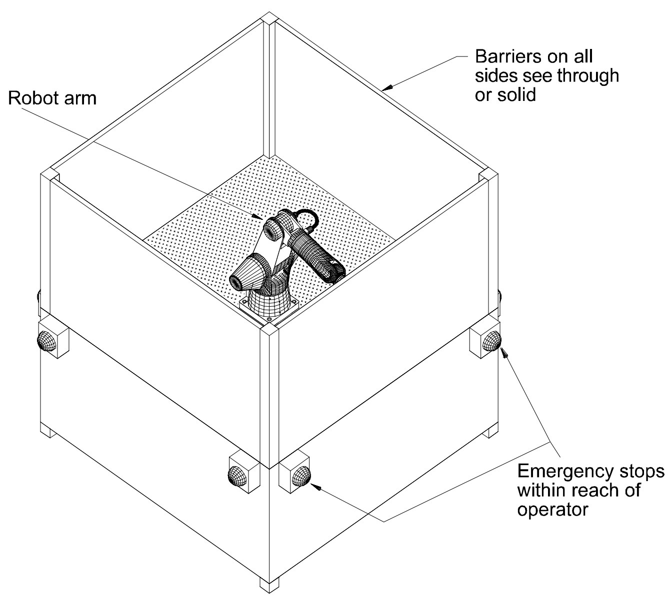


Figure 15: Typical barriers and remote E-Stop buttons.

Maximum Travel Distance and Stop Time

After an E-Stop is activated, the robot continues travelling a short distance. When designing your work cell and the location of E-Stops, you should keep this additional stopping distance in mind.

The maximum distance traveled and time taken for the A465 robot to come to a complete stop are shown below for both the automatic and teach modes of operation.

Table 15: Distance and time for an E-Stop in automatic mode

Joint	Time	Distance	Brake
1	1.8 sec	120º	
2	< 1 sec	10º	
3	< 1 sec	25º	
4	Varies with payload offset from tool flange		
5	Varies with payload offset from tool flange		
6	Varies with payload offset from tool flange		
7 (track)	< 1 sec	10 cm	
7 (track)	< 3 sec	21 cm	

Note: The maximum automatic mode time and distance for each joint was determined using a two kg payload.

Table 16: Distance and time for an E-Stop in teach mode

Joint	Time	Distance	Brake
1	< 0.5 sec	< 5º	
2	< 0.5 sec	< 5º	
3	< 0.5 sec	< 5º	
4	< 0.5 sec	< 5º	
5	< 0.5 sec	< 5º	
6	< 0.5 sec	< 5º	
7 (track)	< 1 sec	3 cm	
7 (track)	Not measured		

Note: The maximum teach mode time and distance for each joint was determined using a two kg payload.

Test Methodology

The figures shown in the above tables represent a worst case scenario. The tests were performed using the criteria shown below:

- Each joint was tested independently.
- The robot payload was a nominal payload.
- The robot speed was 100 percent for all joints.
- Online mode was enabled.
- Joint motion was selected such that gravity acted maximally on the joint.

Controller Location

For safety reasons, the C500C controller must be installed outside the work cell. This ensures that personnel operating the controller never enter the arm's workspace while the arm is powered up. It is important to plan for the location of the controller as part of your work cell design.

Arm Location Within the Work cell

The arm may be mounted on a table or pillar in an upright position or in an inverted position, suspended from overhead brackets. Whether upright or inverted, the arm should be firmly mounted on a supporting platform rigid enough to support the arm and withstand repulsion forces during acceleration and deceleration.

Warning! Do not install the arm on a wall or incline*. This places the arm joints under excessive stress. In case of a power failure, joint 1 does not contain a fail-safe brake and will fall due to gravity.*

Mounting the Arm in an Upright Position

When the arm is in the upright position, it is easier to obtain the maximum reach and may be easier to program, but its base occupies a portion of a table surface.

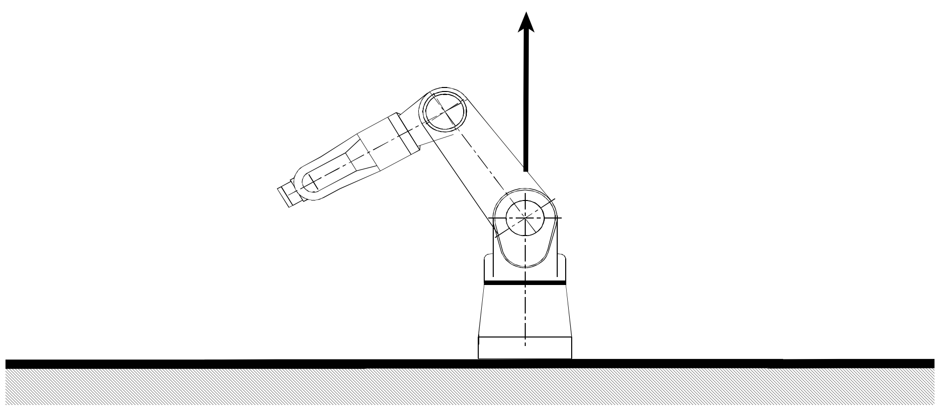


Figure 16: A465 arm in an upright position, on a table top or pillar.

Mounting the Arm in an Inverted Position

When the arm is in the inverted position, a greater portion of the table surface is available as workspace. However, maximum reach from the Z axis may be harder to obtain, and advanced programming may be required. A base offset must be defined. See the base() command. For more reach information refer to the tables and drawings in the sections entitled "Range of Motion, Dimensions, and Weight" and "Reach" on pages 6 and 8.

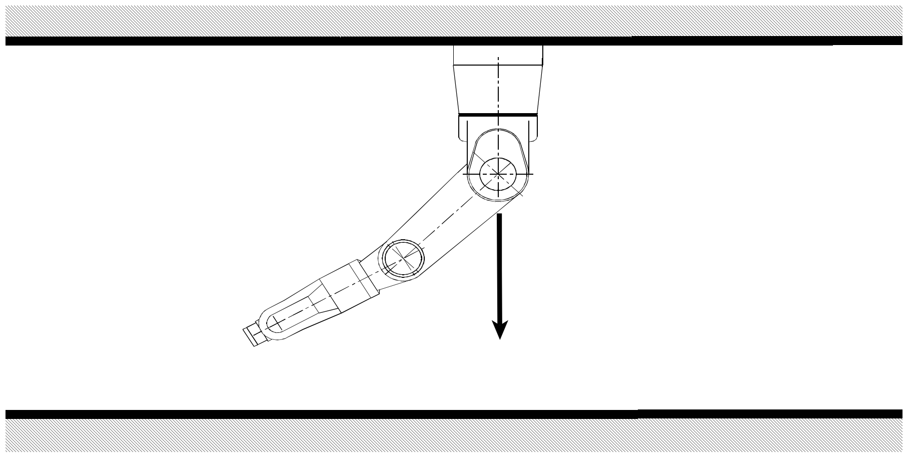


Figure 17: A465 arm in an inverted position, suspended from an overhead bracket.

Obstructions Within the Work cell

Keep the arm workspace clear of obstructions. If an obstruction cannot be removed, arm limits must be programmed to ensure that collisions do not occur within the work cell.

Programming a Customized Homing Sequence

If obstacles in your work cell interfere with the regular homing sequence, you will need to program a customized homing sequence for the arm's restricted workspace. Custom homing procedures written in RAPL-3 must include programmed limits to keep the arm clear of obstructions. As long as each joint is moved past its encoder at least once, joints can be homed in any order.

CHAPTER 5

Installation

This chapter covers installation of the A465 arm for use with a C500C controller. You can install the controller first or the arm first. Consult the C500C controller user guide for instructions on controller installation.

This chapter contains the following sections:

- Required Tools and Supplies
- Component Parts
- Preparing the Mounting Platform
- Unpacking the Arm
- Mounting the Arm on the Platform
- Connecting the Umbilical Cables
- Disconnecting Umbilical Cables
- Grounding the Arm and Controller

Required Tools and Supplies

The following tools and supplies are required.

Table 17: *Tools and equipment required to install the controller*

Procedure	Tools	Equipment
Designing a Work cell	—	—
Unpacking the Arm	• utility knife • hex key (5/16 in.)	—
Preparing a Mounting Platform	• machine tools to drill, tap, and ream	• Metal plate 30 Ksi [210 MPa]
Mounting the Arm	• hex key (5/16 in. or 6 mm)	• 4 cap screws • 2 dowel pins
Grounding the Arm	• small adjustable wrench (3/8 in., approx. 9.5 mm)	• # 12 gauge wire
Connecting the Umbilical Cables	• small Phillips screwdriver	—

Component Parts

Before installing the A465 arm, check that you have received all the components.

The robot system is generally packaged in two containers. If you have ordered options, the shipment may include more containers.

Options may include: gripper, teach pendant, arm user guide, controller user guide, software user guide(s) and diskette(s), cable extensions, and a GPIO termination block.

Table 18: *Container contents*

Container	Contents
Labeled "DESCRIPTION: ARM"	Arm Hex key (supplied with A465 or F3)
Labeled "DESCRIPTION: CTRL"	Controller Feedback cable Motor power cable Fuse kit with AC power cable Override plug
Labeled "DESCRIPTION: ARM"	Arm Hex key (supplied with A465 or F3)
Labeled "DESCRIPTION: CTRL"	Controller
Labeled "OPTIONS"	Feedback cable Motor power cable Fuse kit with AC power cable Override plug Options

Preparing the Mounting Platform

The arm must be firmly mounted on a supporting platform rigid enough to support the arm and withstand repulsion forces during acceleration and deceleration.

There are two methods of preparing a mounting platform:

- Fasten a metal plate to your supporting structure (bench, bracket, etc.) and mount the arm on that plate.
- Fasten the arm directly on a supporting structure.

If the arm will be regularly mounted and dismounted, use dowel pins to align the robot precisely. Dowel pins are also useful during installation after repair.

Before you begin

- Ensure that the arm's supporting structure (bench, bracket, etc.) is firmly fastened to the floor to prevent movement.
- If you are preparing a metal plate, the metal should have a minimum yield strength of 30 Ksi [210 MPa].

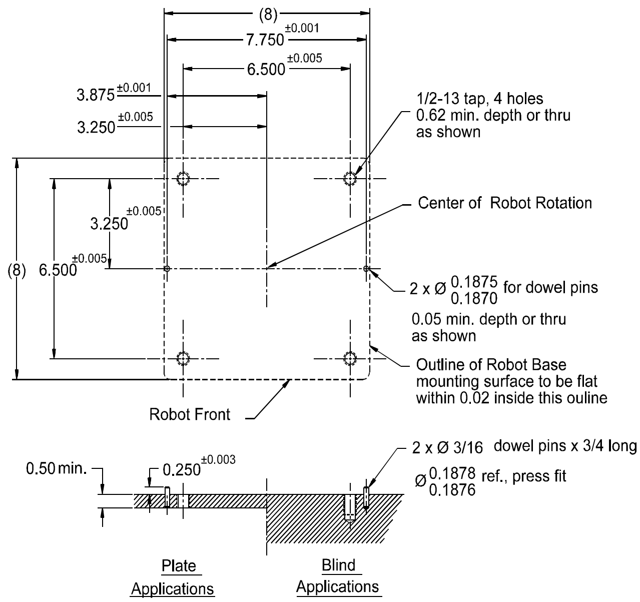
Note: The locations for metric and imperial dowel pins are different, as shown in the drawings. Both are in the sides of the base $^1/_2$ inch [12.7 mm] from each other.

Tools Required

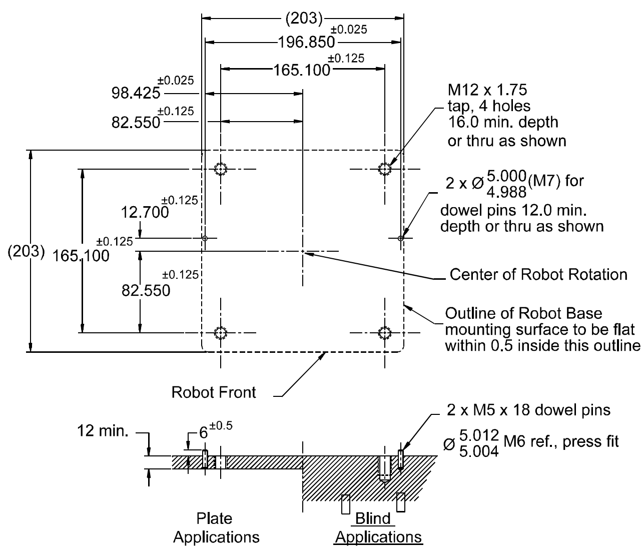
- Machine tools to drill, tap, and ream.

To prepare the mounting platform

1. Use the dimensions shown in the drawings on the next pages to prepare a mounting platform.
2. Drill and tap four holes for the threaded fasteners. Use either an Imperial ½ - 13 thread, or a metric M12 x 1.75 thread.
3. If you require dowel pins, drill and ream two holes for the dowel pins. The holes should be either $^3/_{16}$ inch (Imperial) or 5 mm (metric) in diameter.
4. If you prepared a plate, firmly fasten the plate to your bench, bracket, or similar supporting structure.



Robot Mounting Platform Requirements
- Imperial Fastener Version
- Dimensions in Inches



Robot Mounting Platform Requirements
- Metric Fastener Version
- Dimensions in Millimeters

Unpacking the Arm

***Warning! The A465 arm weighs approximately 67 lbs. (32 kg)**. You should be assisted by one or more persons when lifting the arm.*

To unpack the A465 arm, you need the following resources:

- Utility knife
- Two or three persons

Keep all packaging materials in case you need to move or ship the controller in the future.

To avoid damaging the arm, remove the arm from the shipping container according to the following instructions.

Opening the Shipping Container

1 Position the shipping container in front of you, shipping labels showing with the address label at your far left and the description label at the near right corner.

The back of the arm is now closest to you.

2 Slit open the tape on the top of the container, and open the flaps.

3 Remove the page with the serial numbers of the arm and controller and place it in a binder with this arm user guide.

4 Remove the $^{5}/_{16}$ in. hex (Allen) key from the top foam cushion.

5 Remove the top foam cushion and open the anti-static plastic to expose the A465 arm.

6 Using the long ball-point end of the $^{5}/_{16}$ in. hex key, remove the two $^{3}/_{8}$ in. cap screws that attach the robot arm base to the wooden shipping platform.

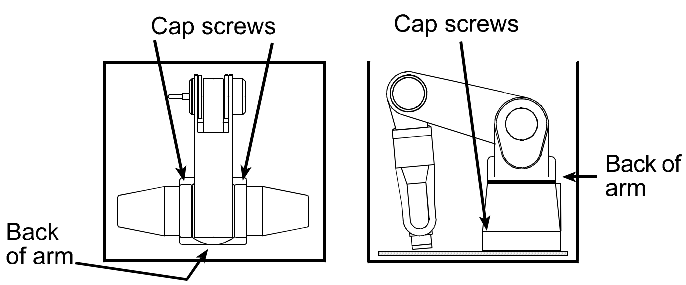


Figure 18:The two cap screws at the front of the base are indicated by arrows.

Note: The two cap screws are located at the front edge of the base, close to the center of the shipping container.

***Warning! Do not use the $^{3}/_{8}$ in. cap screws to mount the arm on its permanent platform.** Mounting requires $^{1}/_{2}$ inch or M12 cap screws.*

Protecting the Encoder

Warning! When moving the arm, take care not to damage the exposed encoder.

The encoder located at the base of the arm is a sensitive electronic component. When the arm is removed from the shipping platform, the encoder is exposed.

The encoder may be black, metal or plastic covered, approximately two inches [50 mm] in diameter, and recessed approximately $^{3}/_{16}$ inches [4 mm] from the mounting surface.

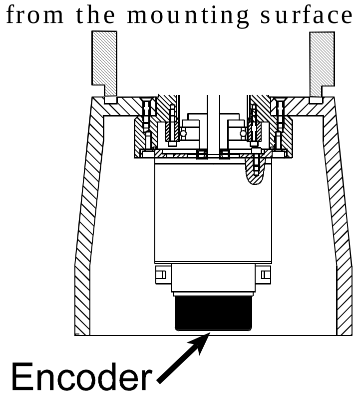


Figure 19: A cross-section of the open underside of the base showing the position of the encoder, at the center just above the base mounting level.

Ensure that the surface where you will place the arm base is clean and free of obstructions, including shipping screws, tools, and mounting hardware. The base of the robot arm is open on the underside and the encoder sits close to the bottom level of the base.

Lifting the Arm

If you need to move the arm any significant distance, use a cart to transport the arm. See Lifting and Transporting the A465 Arm on page 24 for a more detailed description of arm lifting procedures.

Warning! Lift safely to prevent injury*. The robot arm weighs approximately 67 lb. [32 kg].*

To lift the arm out of the shipping container:

1 Reach into the container and grasp the arm as shown below. If you need additional handholds, you can also grasp the arm under the outside edge of the cast aluminum base or under the machined aluminum link.

Warning! *Do not grasp the robot under the ABS-plastic motor covers on the sides, by the wrist or gripper, or by the elbow wiring conduit.*

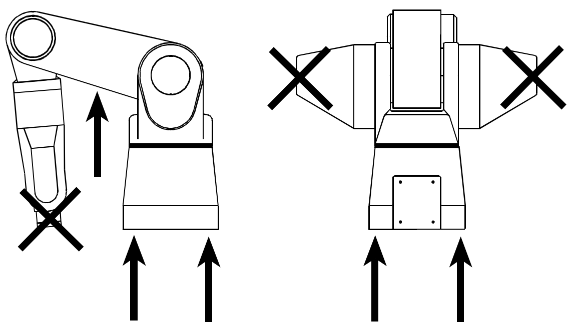


Figure 20: Grasp the arm where indicated by arrows, not by the motor covers or wrist.

2 Lift the robot arm out of the lower foam cushion and place it on a secure surface.

Storing the Packaging Materials

Keep all packaging materials in case you need to move or ship the arm in the future.

Important Documents

The serial numbers of the arm and the controller are listed on the page that you removed from the top of the container. Keep this information, as any future service provided by CRS will refer to these serial numbers. Store the Certificate of Compliance in a safe place.

Keep the Robot System Together

Your robot system consists of the A465 arm and controller listed on the shipping document. These were calibrated and burned-in at the factory as a complete system. Do not mix controllers and arms of different systems.

Mounting the Arm on the Platform

Tools Required

- Imperial $^{3}/_{8}$ in. hex (Allen) key or metric 10 mm hex (Allen) key
- Ensure that the mounting platform is clear of any obstructions. The encoder is exposed at the open underside of the base.

***Warning! Ensure that the mounting platform is clear of any obstructions**. The encoder is exposed at the underside of the base and can easily be damaged by small objects on the mounting surface.*

To Mount the Arm:

1 Lift the arm onto the mounting platform.

2 Fasten the arm to the platform using either:

- **a** Four $^{1}/_{2}$ – 13 UNC x 2.00 inch long, stainless steel 18-8, hex socket cap screws. (Imperial)
- **b** Four M12 x 1.75 x 50 mm long, stainless steel 18-8 (A2), hex socket cap screws. (Metric)

3 If desired, insert the dowel pins to precisely position the arm. Use either:

- **a** Two 0.1878/0.1876 diameter x 0.75 inch long, hardened steel precision ground dowel pins. (Imperial)
- **b** Two 5 mm diameter (M6 limits) x 18 mm long, hardened steel precision ground dowel pins. (Metric)

Note: Fasteners for mounting the A465 arm can also be ordered as a kit from CRS Robotics.

Connecting the Umbilical Cables

Two cables connect the robot arm to the controller: the feedback (or signal) cable with the 57 pin connector at each end and the motor power cable with the 24 socket connector at the controller end. Each cable has braided wire grounding straps at one or both ends that must be connected to the ground points of each robot.

You will need a small Philips screwdriver to connect the straps.

Warning! Do not attempt to use a cable with a damaged connector. This can result in robot runaway and potential injury!

Before You Begin

Before connecting the cables, take the following precautions:

- Ensure that the location for the cables is protected, and does not leave the cables exposed to possible damage.
- If the arm is not yet installed, only connect the cables to the controller.
- Ensure that the controller's main power switch is OFF.

Warning! Use only hand pressure to secure plastic connectors. *Using greater pressure with tools can damage the connectors.*

Connecting the Cables

For each cable, connect the grounding strap end into the controller. This end is labeled "controller end".

1 When making a connection, ensure that the connector key and keyhole are properly aligned. If they are not, you may damage the connector.

2 Rotate each cable in the connector keyhole until you feel a click, indicating that the connector is correctly locked in place.

Note: When turning the feedback cable (with the 57-pin connector), the last 10 degrees of rotation may require more force, as you compress the O-ring in the connector.

3 Route all umbilical cables, AC, I/O, and teach pendant cables away from high voltage sources such as: AC lines feeding other devices, AC or DC motors, heat, moving equipment, conveyors, etc.

4 Use the grounding screws to secure the cable grounding straps to the two grounding points at the back of the connector, and to the single grounding point at the base of the robot arm.

Warning! *Improper cable grounding can subject the encoder signals to external noise and result in loss of arm position*

5 Connect the other end of each cable to the base of the robot arm. There is only grounding strap to connect at the arm end.

6 Check all connections to ensure that they are secure.

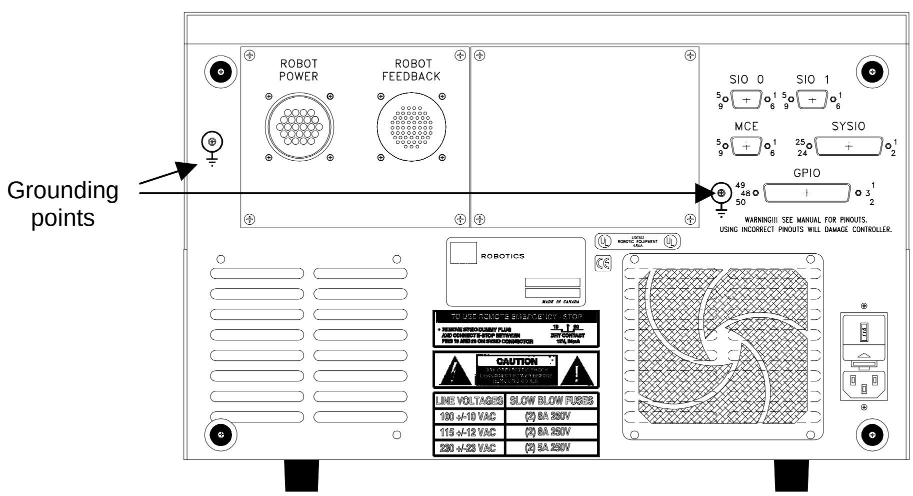


Figure 21: Controller rear panel for the C500C controller

Disconnecting Umbilical Cables

If you need to disconnect the umbilical cables, for example for service, follow this procedure.

To disconnect the umbilical cables:

1 Ensure the controller main power switch is OFF.

Warning! Turn off power before disconnecting the 57 pin feedback cable. *Uncontrolled arm motion due to a sudden interruption in power can result in injury.*

Warning! Do not drop or hit the connectors. *This can damage the connectors.*

2 At the controller, disconnect the grounding straps from the grounding point on the rear panel of the controller.

a Turn the locking ring counter-clockwise to release the connector.

b Pull the cable connector straight out from the controller connector.

3 At the arm, turn the locking ring counter-clockwise to release the connector and pull the cable connector straight out.

Grounding the Arm and Controller

To ensure proper operation of the robot system, the controller and the arm must be properly grounded by attaching grounding leads in the controller cables to ground points on the controller and the arm. Improper grounding can result in memory corruption, loss of arm position, and unreliable operation in some cases.

Warning ! A potential difference between the arm and the controller can cause the umbilical cables to overheat and catch fire.

The controller and the arm must be at the same potential. A difference in potential between the controller and the arm will produce a current in the umbilical cables. Although this current will not damage the controller, in extreme cases it could cause the umbilical cables to overheat and possibly catch fire.

Tools Required

- Small adjustable wrench ($^{3}/_{8}$ inch or 9.5 mm)
- Umbilical cable with a green/yellow #14 AWG wire c/w two round end connectors.

To Ground the Arm and Controller:

1 Ensure that the umbilical cables are connected between the arm and controller.

2 Unscrew the nut from the arm grounding stud.

Note: The arm grounding stud is located on the left side at the rear of the arm base, beside the umbilical cable connectors.

3 Connect the ring connector at the end of the green/yellow #14 AWG wire to the grounding stud.

4 Screw the nut back on the arm grounding stud.

5 Unscrew the fastener from the controller grounding point.

Note: Controller grounding points are located at the back of the controller housing, beside the umbilical cable connectors.

6 Connect the ring connector at the end of the green/yellow #14 AWG wire to the controller grounding point.

7 Screw the fastener back on the controller grounding point.

Next Steps

If you have not yet installed the controller, install the C500C controller before proceeding any further. Complete installation procedures for the controller are covered in the C500C Controller User Guide.

If you have installed both the arm and the controller, proceed to the next chapter, Commissioning the Arm, to test the functionality of your system and ensure proper operation of the arm.

CHAPTER 6

Commissioning the Robot System

Once the arm and controller are installed and properly connected, you must verify that the system is functioning correctly. This is referred to as commissioning your A465 robot system.

Commissioning involves the following steps that must be performed in order:

1. Checking the Arm and Controller Installation
2. Setting up a Terminal for Commissioning, or Setting up the Teach Pendant for Commissioning
3. Performing Safety Checks
4. Verifying Encoder Feedback
5. Checking All E-Stops
6. Moving the Arm Out of the Shipping Position
7. Checking the Live-man Switch

Once your system has been commissioned, it is operational and ready to be configured for use.

Checking the Arm and Controller Installation

To check for proper functioning of the arm and to move the arm out of the shipping position, the arm and controller components must be installed and ready to operate.

Verify the following:

- Arm is mounted and securely fastened.
- The controller is mounted outside the work cell.
- The arm and controller are properly grounded.
- The umbilical cables are connected and protected from damage.
- The fuses and voltage selector in the controller have been correctly installed and verified.
- The controller is connected in compliance with its stated power requirements.

Components Used to Commission the System

To check for proper functioning of the arm and to move the arm out of the shipping position, other robot system components must be installed and operating.

Table 19: *Tools required for commissioning*

Procedure	Required or Preferred Tool	Alternative Tool
Check Encoder Feedback	terminal	—
Check E-Stops	—	—
Move Out of Shipping Position	teach pendant	terminal
Check Live-man Switch	teach pendant	—

Setting up a Terminal for Commissioning

You can commission the system using a terminal with either CROS-500C or CROSnt.

Using a Terminal Running CROS-500C

The terminal must be connected to the controller via a straight-through cable (not a null modem cable). The cable should be connected from the RS-232 serial port on the computer to the port labeled *Console* on the front of the controller.

Terminal emulation software, such as Robcomm3, must already be installed on the computer.

To use a CROS-500C terminal to commission your system:

1. Start the software and open the terminal window.
2. Turn on the controller.
3. In the terminal window, run `\sbin\simsockd` in -rcv mode with compatible configuration from each simsockd.cfg file

Using a Terminal Running CROSnt

If you are running CROSnt, you can use a CROSnt terminal for commissioning your system.

The terminal must be connected via a SimSockD cable. The cable should be connected from the RS-232 serial port on the computer to the port labeled *Teach Pendant* on the front of the controller.

CROSnt must already be installed on the computer.

To use a CROSnt terminal to commission your system:

1. Start CROSnt and open the CROSnt Command Prompt window.
2. Turn on the controller.
3. In the CROSnt command prompt window, run `\sbin\simsockd` in -send mode with compatible configuration from each simsockd.cfg file.

Setting up the Teach Pendant for Commissioning

Setting Up the Teach Pendant For Normal Use

To use the teach pendant, you must first:

1. Connect the teach pendant to the port labeled Teach Pendant on the front of the controller. If there is an override plug in the connector, remove the plug and store it in a safe place.
2. Turn on the controller if it is not already on.

Using a Teach Pendant with a CROSnt system

Because the CROSnt terminal connects through the *Teach Pendant* port, systems with CROSnt do not normally use a teach pendant. If you have a system with CROSnt, and want to use the teach pendant, perform the following steps when using the teach pendant:

1. Disconnect the SimSockD cable from the teach pendant connection
2. Configure the teach pendant port (port 0 of CROS-500) to 19200 baud, using the system shell's `siocfg` command.
3. Connect the teach pendant to the port labeled *Teach Pendant* on the front panel of the controller.
4. If the teach pendant process (stpv3) is not already running on CROS-500C, started the teach pendant by typing **pendant** at the C500C prompt.

Performing Safety Checks

Follow the Safety Operation Checks on page 26 before operating the arm.

Verifying Encoder Feedback

This procedure verifies that position signals from the arm are being received by the controller.

To verify encoder feedback, you will need one of the following:

- A terminal emulator on a computer or a simple terminal.
- A Robcomm3 terminal window.
- A CROSnt command prompt (only available if you are running CROSnt).

To verify encoder feedback:

1 Turn on your computer or terminal. Depending on the tool that you are using, start Robcomm3 and open the terminal window, start a terminal emulator, or start CROSnt.

Warning! Do not turn on arm power until you have manually verified that all robot axes demonstrate feedback. *Failure to verify feedback can result in the arm running away uncontrolled when arm power is applied.*

2 Turn on the controller. **Do not power the arm.** The controller front panel display indicates “C500C CROS OK” and the terminal displays the >> prompt or the $ prompt.

3 If you have the >> prompt, go to the next step.
If you have the $ prompt, start ash by typing ash test.

4 If the teach pendant is connected and obtains control, transfer control from the teach pendant to the terminal. At the teach pendant, press Shift + ESC.

5 At the terminal prompt (>> or test>), type `w1` and press Enter. This command continuously displays the robot arm position as motor pulse counts.

6 **With arm power off**, manually verify feedback by pushing each axis gently in all directions of motion and observing the readout in your terminal window. The pulse count should increment (increase) and decrement (decrease) according to arm motion.

- The axis should display positive and negative feedback when moved back and forth.
- If the axis displays only positive or only negative feedback, re-check all umbilical connections to the robot.

7 Once you have verified feedback for all axes, press Ctrl+E. The regular terminal prompt returns.

You are now ready to check E-Stop functionality.

Checking All E-Stops

This procedure checks each E-Stop device to verify that it works. To do this, you must turn on arm power.

Warning! Do not turn on arm power if you have not performed the encoder verification in the previous step! *Failure to verify encoder feedback can result in the arm running away uncontrolled when arm power is applied.*

Note: Striking an E-Stop removes power from the servo gripper. Unless the gripper has been specifically designed to avoid this, pressing an E-Stop will cause the gripper to drop its payload.

1. Ensure that the controller is powered on and displays “C500C CROS OK”.
2. Re-set all the E-Stops to complete the E-Stop circuit. The E-Stop buttons on the controller and on the teach pendant are re-set by twisting until they spring out.
3. One at a time, test each E-Stop:
   - **a** Turn on arm power at the arm power switch, located near the upper right corner of the front panel. You should hear a series of clicks from the arm as the brakes release. The LED in the arm power switch should be continuously lit, indicating that arm power is on.
   - **b** Activate the E-Stop device: strike the E-Stop button, open the interlocked door, interrupt the light beam, step on the pressure-sensitive mat, etc.
   - **c** When you activate the E-Stop you should hear a series of clicks from the arm as the brakes engage. The LED in the arm power switch should not be lit, indicating that arm power is off. Check the LED.
   - **d** Re-set this E-Stop.
   - **e** Repeat steps a to d until all E-Stops are checked.

Schedule Regular Checking of E-Stops

Continue to check E-Stops and other safety measures throughout the operating life of the robot system. Establish a schedule of regular checks.

Moving the Arm Out of the Shipping Position

The arm is shipped with the arm positioned downward and the wrist almost level with the mounting surface.

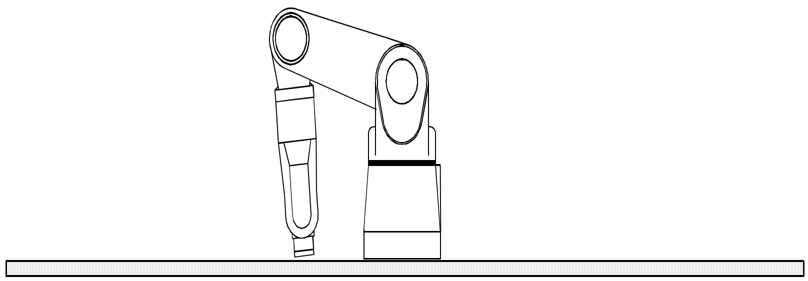


Figure 22: A465 arm shipping position. This is not a safe starting position.

Once mounted, you can use the teach pendant or other tool to carefully move the arm out of the shipping position and into a safe starting position.

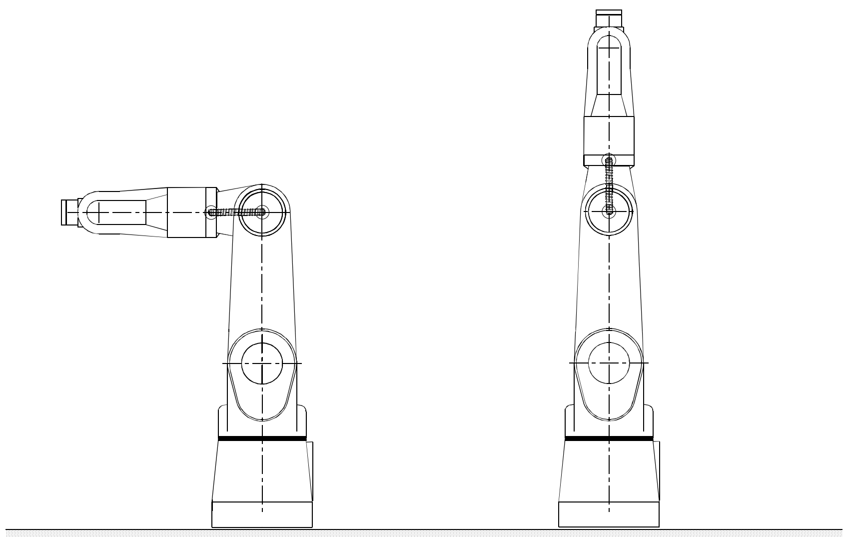


Figure 23: Safe starting positions for homing.

A safe starting position is any position where the arm links and tool flange are safely away from the mounting surface, base, cabling, and obstructions in the work cell. The two examples positions are safe starting positions.

You can move out of the shipping position by using the teach pendant or the terminal. It is safer to use the teach pendant.

Moving the Arm With the Teach Pendant

Before you begin, ensure that you have connected the teach pendant. The teach pendant (stpv3) process running must be running and must have control at the teach pendant. If not, open a terminal window and type **pendant** at the prompt.

To move out of the shipping position:

```
Application
```

```
test


1edit 2run
```

1 The teach pendant displays the Application screen with the application's name (test). Turn on arm power.

```
Application
test


1var       3motn
```

2 The bottom line of the screen indicates the selections. Press F1 (edit). This opens the Editing screen.

```
Manual Menu
       1%   VEL  JOINT
NOT HOMED
1home      3motn
```

3 Press F3 (motion). This opens the Manual Motion screen. The upper right corner displays the arm power status, "ON". Since the robot is not homed, only joint mode is available. Do NOT home the robot.

4 Squeeze the live-man switch.

- Adequate pressure, constantly applied, permits arm operation.
- No pressure, or excessive pressure, stops arm motion by shutting off arm power. To restore arm power, turn on arm power at the arm power switch.

5 As you squeeze the live-man switch, press the following axis keys to move each joint to a safe starting position. Move the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your work cell.

- Press **Ax2+** to raise up the arm at the shoulder.

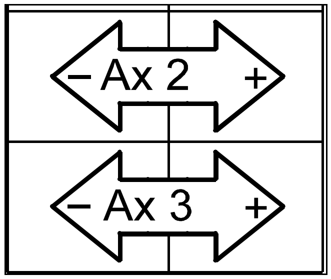


Figure 24: Teach pendant axis keys

- Press **Ax3+** to move out the outer link at the elbow.

Note: Move each joint a little distance at a time to prevent robot damage. Notice that some axes remain stationary.

6 When you are finished moving joints 2 and 3 with the axis keys, the arm should be in a safe starting position, as illustrated in the drawings on page 57.

Moving the Arm From a Terminal

Before you begin, ensure that you have one of the following:

- A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and have control of the robot at the terminal. (If not, at the teach pendant, press Shift + ESC to transfer control)
- The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port.

To move out of the shipping position:

1 Turn on arm power.

2 Set the speed to a very slow value by typing

```
speed 1
```

Warning! Be prepared to strike an E-Stop. *When you use a command from the terminal, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.*

3 Move joint 2 by 10 degrees by typing

```
joint 2, 10
```

4 Repeat this several times.

5 Move joint 3 by 10 degrees by typing

```
joint 3, 10
```

6 Repeat this. Continue moving the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your work cell.

7 When you are finished moving joints 2 and 3 with the joint command, the arm should be in a safe starting position, as illustrated on page 57.

Checking the Live-man Switch

If you are using a teach pendant, use this procedure to verify that the teach pendant live-man switch is working.

Note: You must hold the live-man switch with reasonable but not excessive force while you press an axis key for the duration of a robot move. Too little or too much force on the live-man switch breaks the E-Stop circuit and removes arm power.

Before you begin, ensure that the teach pendant is connected and displays a motion screen. If you do not have a motion screen:

- Ensure that the teach pendant has control. You can give control to the pendant by typing pendant at the ash prompt.
- If the teach pendant has control but is displaying some other screen, press ESC until you return to the Application screen. Press F1 (edit), then press F3 (motion).

1 While holding the live-man switch and pressing an axis key during a robot move, release the live-man switch.

  a After releasing the live-man switch you should hear a series of clicks as the arm brakes engage. At the same time, arm power is shut off. Check that the LED in the arm power switch is not lit.

  b Restore arm power by pressing the arm power switch on the front panel of the controller.

2 While holding the live-man switch and pressing an axis key during a robot move, squeeze the live-man switch tightly.

  a After tightly squeezing the live-man switch you should hear a series of clicks as the arm brakes engage. At the same time, arm power is shut off. Check that the LED in the arm power switch is not lit.

  b Restore arm power by pressing the arm power switch on the front panel of the controller.

3 Without applying any pressure to the live-man switch, press an axis key. The arm should not move.

CHAPTER 7

Basic Operation

This chapter describes how to perform the following basic procedures:

- Homing the Arm
- Moving With The Teach Pendant Axis Keys
- Moving by Limping One Joint at a Time

The A465 is designed for stand-alone operation after homing. Stand-alone operation does not require operator intervention. RAPL-3 programs specially written for your particular application move the robot to the predefined locations.

Homing the Arm

The A465 arm must be homed before you can teach locations or run any robot application.

Why The Arm Is Homed

When power to the controller is off, the arm position data in the controller's memory is lost. As a result, whenever the controller is powered on, the controller does not know the position of the arm.

The "homing" procedure moves the arm to a mechanically determined position which is then retained in the controller memory. Homing slowly moves each axis in sequence until its proximity sensor is detected and the zero pulse of its encoder is found. Afterward, during any motion, the encoders continually send position counts to the controller. Using these counts, the controller knows any position of the arm relative to the home position.

Homing Procedure

This manual describes homing the arm from the teach pendant and from the terminal.

To home the arm, you must:

1 Move to a safe starting position for homing

2 Issue the home command

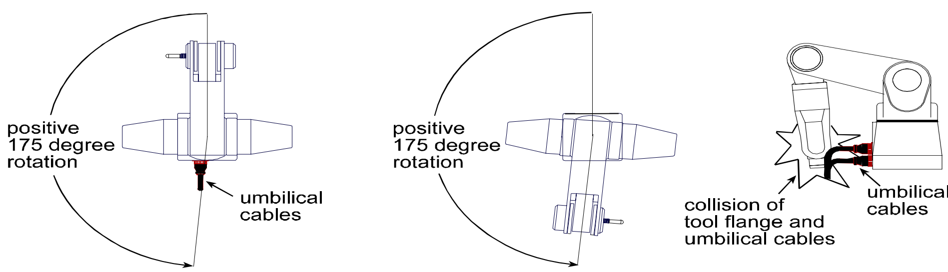


Figure 25: Home the arm from a safe starting position. Homing first rotates joint 1 (the waist joint) to the end of its travel (+175°). Homing from the shipping position can cause the tool flange to hit the umbilical cables.

Moving to a Safe Starting Position

If the arm is already in a safe starting position, bypass this procedure and go to the next procedure, Issue the Home Command, on page 65

Before you begin, ensure that the arm's work cell is free of obstruction.

You can move to a safe starting position by using the teach pendant or the terminal. It is safer to use the teach pendant.

Using the Teach Pendant

Before you begin, ensure that you have connected the teach pendant. The teach pendant (stpv3) process running must be running and must have control at the teach pendant. If not, open a terminal window and type **pendant** at the prompt.

To move to a safe homing position with the teach pendant, follow these steps.

```
Application
test

1edit 2run
```

1 The teach pendant displays the Application screen with the application name (test). Turn on arm power.

```
Application
test

1var        3motn
```

2 The bottom line of the screen indicates the selections. Press F1 (edit). This opens the Editing screen.

3 Press F3 (motion). This opens the Manual Motion screen.

```
Manual Menu          ON
       1%   VEL  JOINT

           3motn 4mode
```

4 Squeeze the live-man switch. Adequate pressure, constantly applied, permits arm operation. No pressure, or excessive pressure, stops arm motion by shutting off arm power. To restore arm power, turn on arm power at the arm power switch.

5 As you squeeze the live-man switch, press the axis keys to move each joint to a safe starting position. Move the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your work cell.

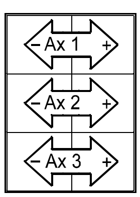


Figure 26: Teach pendant axis keys

6 When you are finished moving joints with the axis keys, the arm should be in a safe starting position, such as in the drawings on page 57.

Using the Terminal

Before you begin, ensure that you have one of the following:

- A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and have control of the robot at the terminal. (If not, at the teach pendant, press Shift + ESC to transfer control)
- The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port.

To move to a safe starting position:

1. Turn on arm power.
2. Set the speed to a slow value by typing

   `speed 10`

Warning! Be prepared to strike an E-Stop. *When you use a command from the terminal, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.*

3. Move joints with the joint command. For example, type

   `joint 2, 10`

   `joint 1, –5`

4. Continue moving the joints until the arm links and tool flange are safely away from the mounting surface, base, cabling, and any elements in your work cell.
5. When you are finished moving, the arm should be in a safe starting position, such as in the drawings on page 59.

Issuing the Home Command

Once the robot is in a safe starting position you can home the arm by using the teach pendant or the terminal.

Warning! Do not home the arm from the shipping position or other unsafe position. *Homing from the shipping position can cause the tool flange to hit the umbilical cables. Homing from some other positions may cause your gripper to collide with equipment in your work cell.*

Axes

The home command homes all arm axes and the track axis, if there is one. It does not home any carousel axes. These must be homed separately.

Homing Objective

When you have homed the arm, you will place it in the ready position to check that it homed successfully. You will use the markers indicated in the diagram.

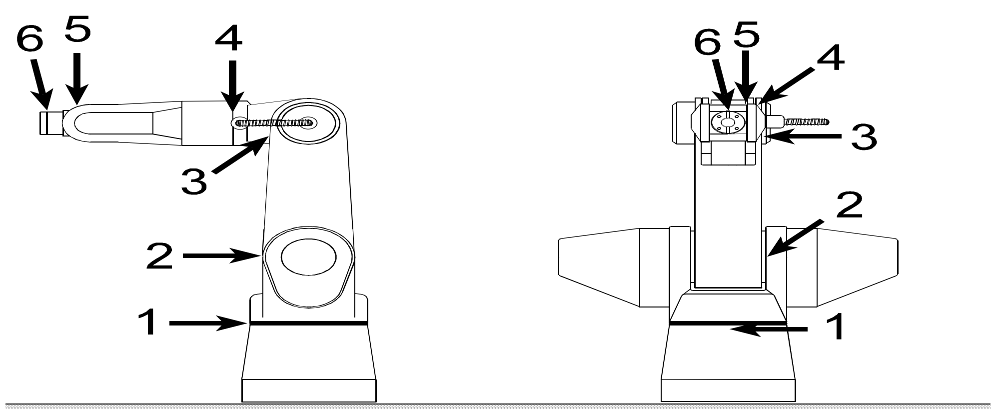


Figure 27: The location of the markers with the arm in the ready position.

You can home the arm by using the teach pendant or the terminal. It is safer to use the teach pendant. Systems with CROSnt may have to use the terminal.

Using the Teach Pendant

Before you begin, ensure that you have connected the teach pendant. The teach pendant (stpv3) process running must be running and must have control at the teach pendant. If not, open a terminal window and type **pendant** at the prompt.

To use home the arm with the teach pendant, follow these steps.

1 From the Main Menu, press F2 for motion.

```
003:Confirm
start robot HOMING
procedure
1no   2yes
```

2 Press the HOME key or F1 on the teach pendant's keypad. A confirmation screen displays.

3 Press the live-man switch to enable arm motion.

4 Press F2 (yes) to confirm and start the homing sequence. Maintain light pressure on the live-man switch for the duration of the homing sequence. Each joint rotates individually in sequence from joint 1 to joint 6. When arm motion stops, the homing sequence is complete.

```
005:Manual  Homed



1motn 2mode 3loc 4here
```

5 Release the live-man switch. Check that the teach pendant LCD displays the message "Homed" and that the amber LED of the Home switch on the front panel of the controller is on.

6 Press the READY key on the keypad. Maintain light pressure on the live-man switch for the duration of the READY sequence. When the arm stops it is in the READY position.

7 Visually inspect each marker. The pointers should point toward each other. The location of each marker is shown in the drawing on page 65.

- If the arm did not home correctly, repeat the procedure.
- If the arm refuses to home correctly for three consecutive attempts, contact you distributor or CRS Robotics.

Using the Terminal

Before you begin, ensure that you have one of the following:

- A terminal emulator or the terminal window of Robcomm3 communicating through the front panel console port and have control of the robot at the terminal. (If not, at the teach pendant, press Shift + ESC to transfer control)
- The Command Prompt window of CROSnt communicating through the SimSockD cable in the teach pendant's port.

Warning! Be prepared to strike an E-Stop. *When you use a command from the terminal, the robot attempts to move to the commanded position, without knowing if it is safe to do so. Use the proper joint number and distance value to avoid a collision.*

To home the arm:

1. Type `home`, press Enter, and at the prompt, type Y (yes).

   Each joint rotates individually in sequence from joint 1 to 6 and the amber LED of the Home switch flashes. When arm motion stops and the LED is lit continuously, the homing sequence is complete.

2. Type ready and press Enter. The arm moves to the ready position.
3. Visually inspect each marker. The pointers should point toward each other, refer to page 65 for the location of each marker.
   - If the arm did not home correctly, repeat the procedure.
   - If the arm refuses to home correctly for three consecutive attempts, contact your distributor.

Moving With The Teach Pendant Axis Keys

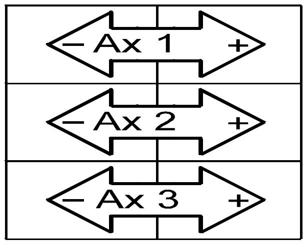


Figure 28: Teach pendant axis keys. On the teach pendant, there is a negative (–) key and a positive (+) key for each axis. "Ax1" for axis 1 (the waist joint), etc.

When moving initially with the teach pendant, you are moving in joint mode. In joint mode, when you press an axis key, one joint moves. Each axis has two keys, one for motion in the positive direction, and one for motion in the negative direction.

1 Squeeze the live-man switch and press an axis key.

2 To determine the movement of each axis, use the following table:

Table 20: *Movement of A465 Axes*

Joint	Axis	Key	Negative (–)	Positive (+)
Waist	1	Ax1	Rotates arm	Rotates arm
			(right-hand rule, vertical axis upward)	
Shoulder	2	Ax2	Lowers arm	Raises arm
Elbow	3	Ax3	Lowers outer link	Raises outer link
Wrist Rotate	4	Ax4	Rotates wrist	Rotates wrist
			(right-hand rule, axis outward)	
Wrist Pitch	5	Ax5	Pitches wrist down	Pitches wrist up
Tool roll	6	Ax6	Rolls tool	Rolls tool
			(right-hand rule, axis outward)	

Moving by Limping One Joint at a Time

"Limping" a joint disengages the servo control to the motor and makes the joint go limp. After you limp the joint, you can position the link by hand. After you position the link, you can "unlimp" the joint, which re-establishes servo control and holds the link in its new position.

Before you begin:

- Ensure that the teach pendant is connected to the controller.
- You will be working within the robot's workspace, observe the safety and operation checks on page 27 "Working Within the Robot's Workspace".

1 Power ON at the main controller switch. The teach pendant displays the Main Menu screen.

```
001:Main Menu
    Not Homed


1manu  2edit  3run
```

```
Manual  NOTHmd
 VEL  JOINT
 10%
1motn 2mode 3loc 4here
```

2 Turn ON arm power. The teach pendant displays the status message "ON".

3 Press F1 (Manual) to change to the Manual screen.

4 Press F1 repeatedly until LIMP displays.

```
005:Manual  NOTHmd    ON
 LIMP JOINT


1motn 2mode 3loc 4here
```

5 Press the joint's positive (+) axis key.

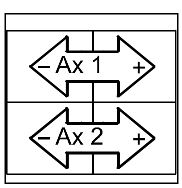


Figure 29: Teach pendant axis keys. In limp mode, a positive (+) key limps a joint and the negative (–) axis key unlimps the joint. "Ax 1" for axis 1 (the waist joint), "Ax2" for axis 2 (the shoulder joint), etc.

- For joints 1, 4, 5, and 6, the joint limps immediately.
- For joints 2, or 3, you must confirm limping.
  - **a** Check that the link is supported.

Warning! Support the link. *Limping will release the joint. The link will fall due to gravity. Failure to support the link can result in damage to the arm, tooling, or work pieces.*

```
039:Confirm:          ON
 Limp robot axis?
 Axis 3: Elbow?
 1no   2yes
```

b Press F2 for Yes. The joint limps.

```
039:Confirm:          ON
 Limp robot axis?
 Axis 2: Shoulder?
 1no   2yes
```

6 Move the link by hand.

Warning! Be careful when entering the robot arm workspace. Even though the joint is limp, arm power is ON. *Hold the arm near the wrist to move the joint by hand.*

Caution! Do not move the joint too forcefully. *The harmonic drive is back-drivable. This allows you to rotate the joints and have that motion transferred back through the drives to the motors. Excessive force, when positioning the arm by hand, may over-stress the drives.*

7 Press the joint's negative (–) axis key. The servo engages and holds the joint in position.

CHAPTER 8

Gripper Installation

This chapter describes how to install a servo or pneumatic gripper. It contains the following sections:

- Attaching the Adapter and Gripper
- Connecting the Cable or Hose
- Enabling and Testing the Gripper

To install a gripper, the arm must be moved out of the shipping position and fitted with a tool flange adapter. The gripper attaches to the tool flange adapter.

Attaching the Adapter and Gripper

Procedure:

Attaching a gripper requires the sequence of four procedures.

1. Identify the adapter parts
2. Attach the wrist plate adapter to the wrist tool flange
3. Attach the gripper plate adapter to the gripper
4. Attach the adapter plates together

You need:

- $^{5}/_{32}$ inch hex key
- $^{3}/_{32}$ inch ball point hex key
- (4) 10-24 x ¼ inch hex socket cap screws (supplied)
- (4) 10-24 x $^{3}/_{8}$ inch hex socket cap screws (supplied)
- (4) 8-32 x ¼ inch button head screws (supplied)

Before you begin:

For best access to the tool flange, use the teach pendant or issue joint commands to place the arm in the Ready position and rotate joint 1 so the flange is toward you.

Ensure the flange is in its vertical position. Joint 5 and 6 homing markers should point towards each other.

Safety Precautions: Refer to the section entitled "Servo Gripper Safety" on page 21before proceeding with the installation of the gripper.

Warning! Ensure that arm power is OFF when entering the arm's workspace. *Refer to and follow the operation and safety instructions in the section entitled "Working Within the Robot's Workspace" on page 27.*

Note: Each step uses a different size cap screw. Ensure that you use the correct size cap screw for each attachment.

Identifying Adapter Parts

Before installing either a pneumatic or servo gripper, you must first attach a tool flange adapter. The adapter has two parts.

- **Wrist plate:** the thicker plate, approximately 1/4 in. [6 mm] thick at its outside diameter, attaches to the wrist tool flange.

- **Gripper plate:** the thinner plate, approximately 1/12 in. [2 mm] thick at its outside diameter, attaches to the gripper.

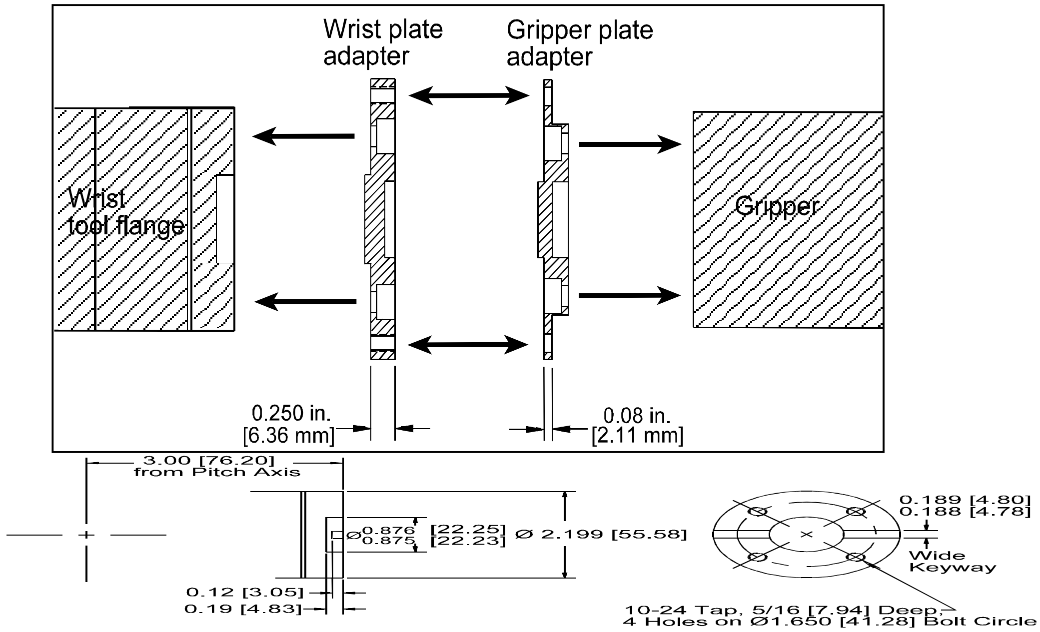


Figure 30: Mounting dimensions of the tool flange for the gripper in inches [mm].

Attaching the Wrist Plate Adapter to the Tool Flange

1. Place the wrist plate on the wrist tool flange, inserting the raised pilot of the plate into the depressed pilot of the wrist's tool flange. The counter-bores for the screws face outward. If configured with a key, insert the key and align the keyways.

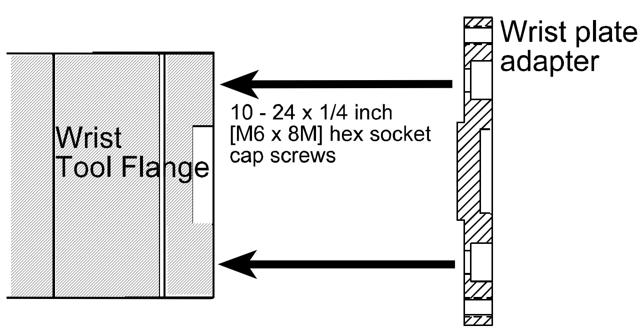


Figure 31: Attaching the wrist plate adapter to the tool flange

2. Fasten with four 10–24 x 1/4 in. hex socket cap screws, tightening the screws with a 5/32 in. hex key.

Attaching the Gripper Plate Adapter to the Gripper

1 Place the gripper plate on the gripper with the depressed pilot of the adapter towards the flat surface of the gripper. The counter-bores for the cap screws face outward.

2 If two or more holes in the gripper plate become obstructed by the gripper body, insert the 8–32 x 1/4 button head screws in the obstructed holes prior to mounting the plate to the gripper (refer to the “trapped screw” drawing on the next page).

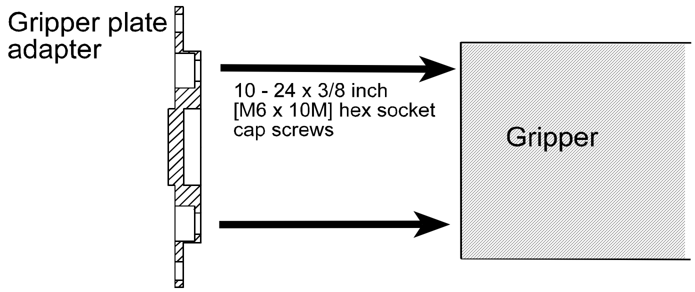


Figure 32: Attaching the gripper plate adapter

3 Fasten with four 10-24 x 3/8 in. hex socket cap screws, tightening the screws with a 5/32 in. hex key.

Attaching the Two Adapter Plates Together

1 Attach the adapter plates together, inserting the raised pilot of the gripper plate into the depressed pilot of the wrist plate. Avoid twisting or straining the gripper cable, connectors, hoses, or fittings.

2 Align the holes for the cap screws.

3 Fasten with four 8–32 x 1/4 in. hex button cap screws, tightening the screws with a 3/32 in. hex key.

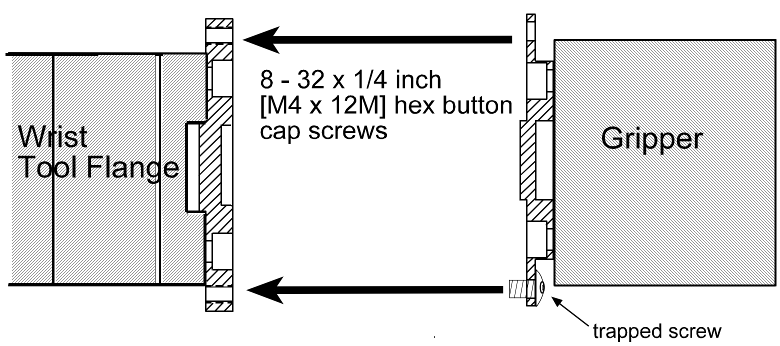


Figure 33: Attaching the wrist tool flange and gripper adapter plates together

Note: Use the 3/32 ball pointed end of the hex key to fasten screws that may be trapped between the gripper and the gripper plate.

Connecting the Cable or Hose

The electrical connector is located on the upper side of the arm's outer link.

The pneumatic connector is located on the lower side of the outer link, approximately 3 1/4 in. [80 mm] behind the wrist axis.

Servo Gripper

To connect the servo gripper cable:

1. Line up the white dot marker on the gripper cable connector with the white dot marker on the arm connector.
2. Push the cable connector onto the arm connector until it clicks. The outer collar is spring loaded.

To disconnect the servo gripper:

1. Pull back the spring loaded outer collar.
2. Pull out the cable connector from the arm connector.

For information on specifications, testing, operating, maintenance, troubleshooting, and repair, see the Servo Gripper User Guide.

Pneumatic Gripper

The pneumatic gripper is supplied with two $^{1}/_{16}$ in. [1.6 mm] barbed fittings.

Caution! Design your pneumatic tooling so that, during a power failure, safe gripping is maintained.

To connect the pneumatic gripper:

1 Screw a barbed fitting into each of the two air ports of the pneumatic connector on the lower side of the link.

2 At the arm end of the gripper’s air hose, separate the two air hoses for approximately one inch [25 mm] of length.

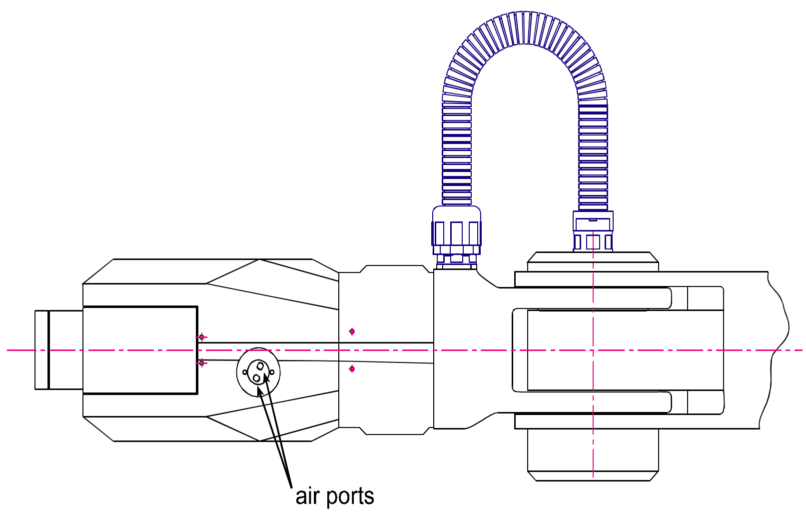


Figure 34: The two air ports for the pneumatic gripper.

3 Push one hose onto one barbed fitting and the other hose onto the other fitting.

4 Connect the workshop air supply to the 1/8 NPT air port at the rear of the robot base. Use only **dry, clean, filtered, non-lubricated** air at a maximum of 100 psi [6.89 kPa or 6.89 Bar].

Enabling and Testing the Gripper

Enabling

To enable the gripper, use the `/diag/setup` command or the `gtype` command to choose the type of gripper (air or servo). Refer to the RAPL-3 Language Reference Guide for further details.

Testing

Test the operation of the gripper as follows:

1 At the teach pendant, press the **GRIP** key, then press **GRIP CLOSE** and **GRIP OPEN**.

2 Check that `OPEN` opens the gripper and `CLOSE` closes the gripper.

Air Ports

There are two air ports located on the underside of the arm.

- Pressing the OPEN key or issuing the RAPL-3 command open initiates air flow from the port closest to the wrist joint.
- Pressing the CLOSE key or issuing the close command initiates air flow from the port furthest from the wrist joint.
- If the operation of the gripper is reversed (OPEN closes the gripper and CLOSE opens the gripper), reverse the connections of the two hoses with the two barbed fittings.

Glossary

Arm
The mechanical, task-performing part of a robot, directed by the controller. An arm consists of a sequentially connected set of links and joints having one end, the base, attached to a platform, the other end outfitted with a tool which performs work. The joints are powered and capable of moving the links and the tool to various locations and orientations.

Awareness Signal
An audio or visual alarm device, such as a buzzer or a light, activated by a sensing device, which makes aware the nearness of a person to the robot arm work cell or workspace.

Axis (X, Y, or Z)
A reference line of a coordinate system. In a Cartesian coordinate system, the three axes (X, Y, Z) meet at right angles, with X and Y defining a horizontal plane and Z defining the vertical dimension. Any point in the arm's workspace, i.e. any location of the gripper or tool, can be identified by this system.

Axis of Motion
A line which passes through any of an arm's joints about which a link or similar section rotates.

Controller
The computerized device that controls the arm. It receives input, processes data, sends control signals to the arm, and receives feedback from the arm. During the running of a robot application, the controller executes a robot software program.

Degree of Freedom (DOF)
The types of independent motions in which the arm can move its end effector (gripper, tool), as defined by the axes of motion. For example, the A465 has six degrees of freedom and can move to coordinates specified by X, Y, Z, Yaw, Pitch, and Roll.

Emergency Stop (E-stop)
A method that overrides robot controls, removes arm power, and stops movement of the robot arm.

Encoder
A precision device attached to each motor shaft which converts the movement of a joint to a signal for processing by the controller.

End Effector
A work-performing device attached to the tool flange for the robot's task, such as a gripper, dispenser, buffing wheel, or spray head.

Gripper
An end effector designed to grasp or hold.

Harmonic Drive

A type of precision mechanical transmission. This device joins a motor and a joint providing smooth motion, high torque, and low backlash. A harmonic drive contains three components: circular spline, flexspline, and wave generator. The circular spline is a rigid ring with internal teeth which engage the external teeth of the flexspline. The flexspline is a non-rigid, thin cylindrical cup with external teeth on a slightly smaller pitch diameter than the circular spline. The wave generator is a thin raced ball bearing assembly fitted onto an elliptical plug serving as a high efficiency torque converter.

Interlock

A safety device connected to a machine which prevents the machine from doing anything unless the device's integrity is maintained or restored. For example, a door-mounted contact switch connected to the robot system by the e-stop circuit which breaks contact and stops the arm when the door is opened, and permits arm operation only when the door is closed and contact is restored.

Joint

A part of an arm connecting two links and containing an axis of rotation that provides a degree of freedom.

Limping

A method of moving the arm by disengaging the servos which normally hold the joints in place. A limped joint can be moved by hand.

Link

A rigid part of a robot arm between two neighboring joints.

Payload

The amount of mass (weight) carried by the arm and/or the amount of force the arm can exert on an object.

Pitch

See Yaw, Pitch, Roll.

Range of Motion

The extent of travel of a link or of an arm. This is dependent on the limits of rotational motion of the joints and the lengths of the links.

RAPL (Robot Automation Programming Language)

An automation-oriented language of commands used for robot applications and communication.

Reach

The maximum distance that the arm can extend the tool flange or gripper. Reach defines the work envelope.

Repeatability

The ability of the arm to repeat the same motion or achieve the same points when presented with the same control signals. Also, the cycle-to-cycle error of the robot system when trying to perform a specific task.

Resolution

The smallest increment of motion or distance that can be detected or controlled.

Roll

See Yaw, Pitch, Roll.

Safeguard Device

A safeguard is a device designed to protect persons from a hazardous point or area. Safeguard devices include but are not limited to: fixed barriers, interlock barriers, perimeter guarding, awareness barriers, and awareness signals.

Teach Pendant

A hand-held robot control terminal having a keypad and LCD display. It provides a means to move the robot, teach locations, and run robot programs. It is connected by its cable to the robot controller.

Umbilical Cables

Cables which connect the controller and the arm. The motor power cable carries power to the motors. The feedback cable carries feedback from the encoders and servo gripper, as well as power for the encoders, servo gripper, brake release, and air solenoid control.

Work Cell

A station composed of the arm, the apparatus integrated with the arm (material handling, reagents, sensors, etc.), and the arm workspace.

Work Envelope

The outer boundary of the workspace. The limit of the arm’s reach.

Workspace

The space or volume consisting of all points that the robot arm can reach. The outer boundary of the workspace is the work envelope.

Yaw, Pitch, Roll

The orientation of the wrist is defined by three angles: yaw (orientation about the Z axis), pitch (orientation about the Y axis) and roll (orientation about the X axis). The right-hand rule applies in determining the direction of these angles.

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