Chapter 5. Operator's Guide

Contents

Introduction

This section introduces the reader to the manufacturing system and points out the major units and components with which a typical operator must be familiar. The reader should become familiar with the units and components identified in each illustration before proceeding.

This section primarily discusses the operation of a four-axis SCARA manipulator, but the concepts are easily applied to other configurations.

Major Units and Components

Each of these manufacturing systems contains:

- an IBM 7537 Industrial Computer / Motion Controller that serves as the controller for the manufacturing system, and

- a Servo Power Module that serves as the electrical interface between the controller and the manipulator.

These two major units are designed for mounting inside a standard 19-inch rack or other suitable enclosure.

The third major unit is either

- an IBM 7575 Manipulator, or

- an IBM 7576 Manipulator, or

- a non-IBM manipulator

The manipulator is actually the "working" unit of the manufacturing system. It carries on its tool shaft a gripper or some other customer-supplied tool that performs a task as it is moved. These units must be mounted securely to a sturdy base, usually a platform or a table alongside the production line.

Two other units in the manufacturing systems are the remote Manipulator Stop button and the pendant. The pendant is a hand-held key entry and display device. It is used primarily for the "teach" function, but it is also required for maintenance to retrieve error codes and select diagnostics. The pendant contains a 64-character display and a 32-button keypad, each button having its own indicator light.

Study the following figures to familiarize yourself with the three major units and their components. The remote Manipulator Stop button and the pendant are illustrated and discussed in "Controls and Indicator Lights."
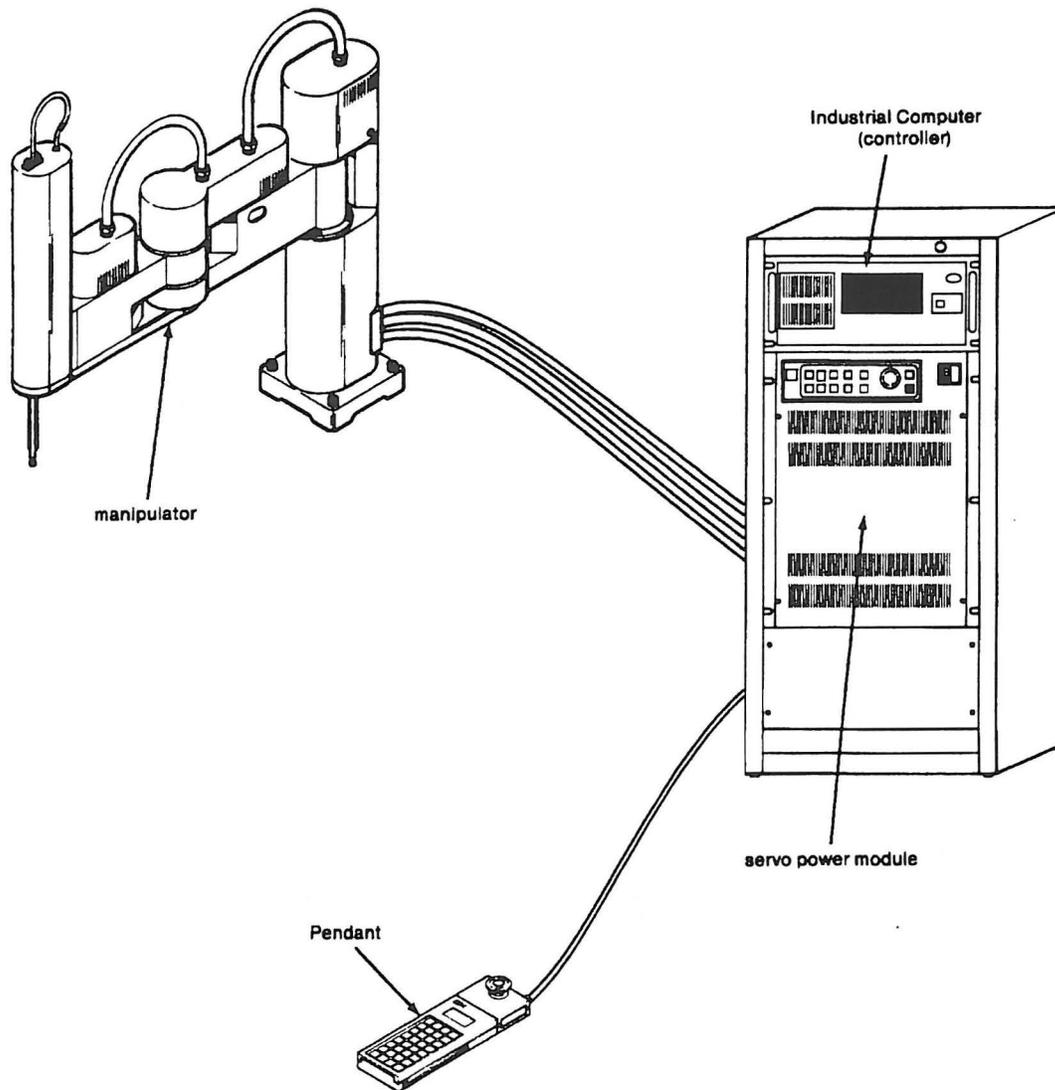
Figure 5-1. Manufacturing System Overview
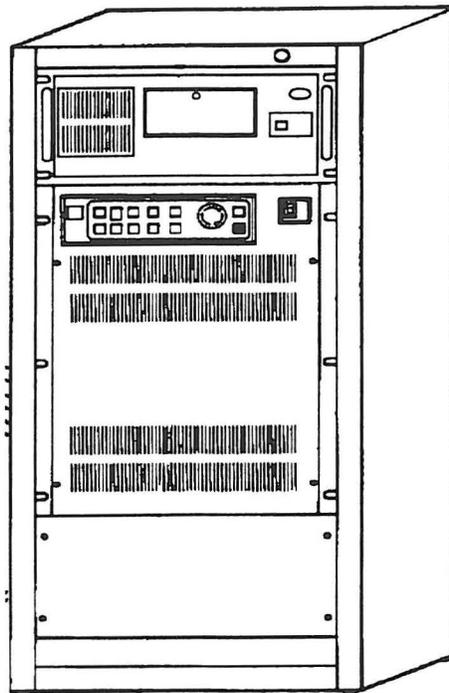
Figure   5-2. Controller and Servo Power Module Mounted in a 19-Inch Rack
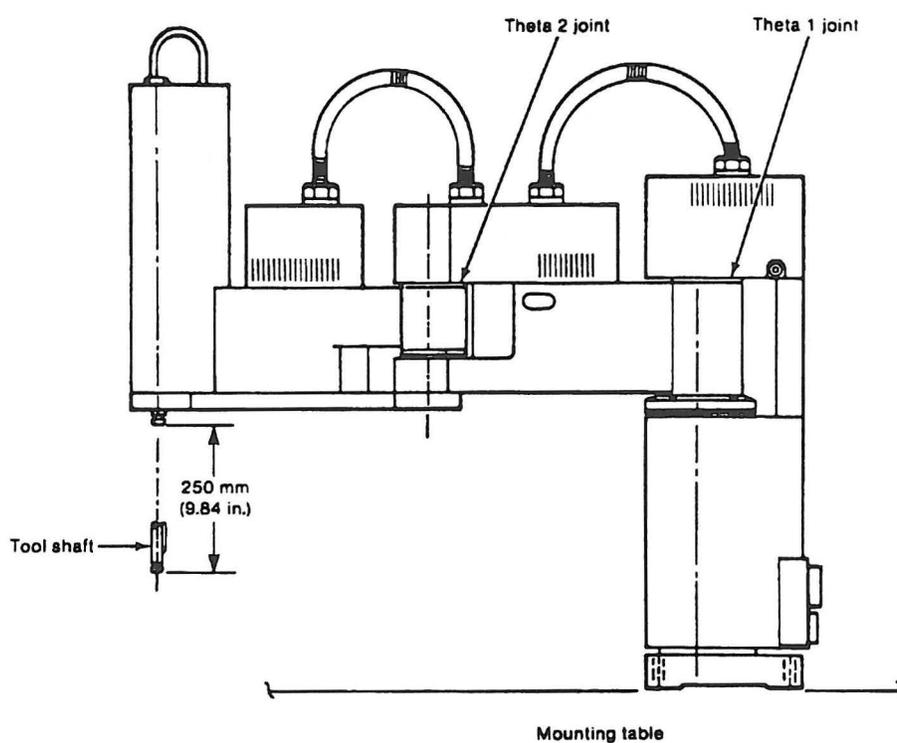
Figure 5-3. 7576 Manipulator

Manipulator Movement and Work Space

In order to perform the functions for which the manufacturing system can be programmed, the vertical shaft of the manipulator to which the working tool attaches moves through an area known as the "work space." This work space is slightly smaller than the manipulator arm clearance area.

Refer to the figure below as you read the following description of how the manipulator moves.
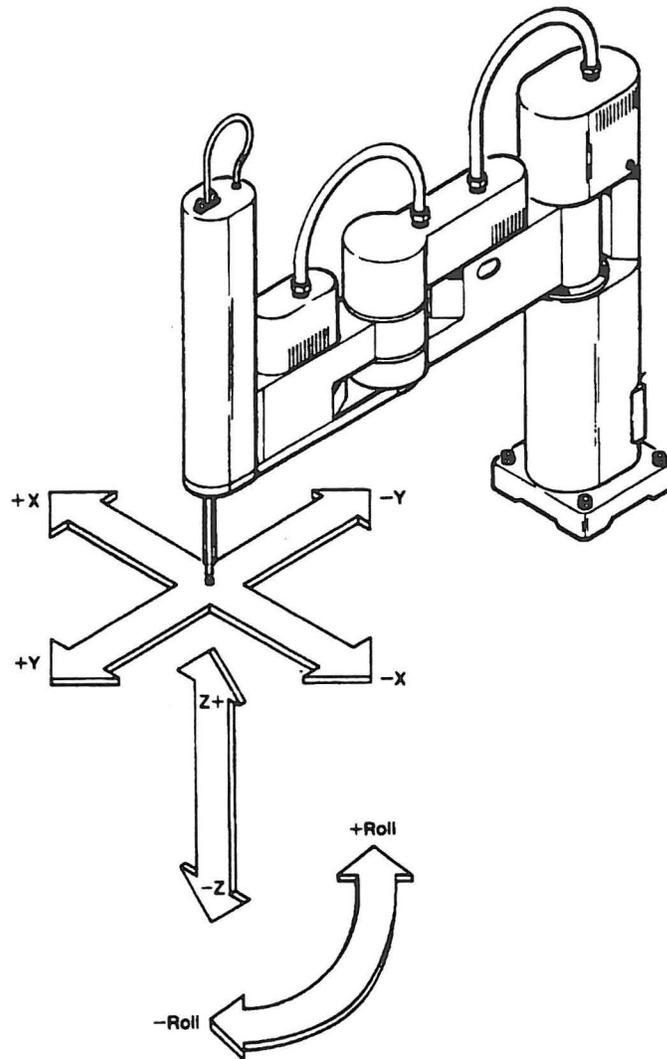
Figure 5-4. SCARA Manipulator Movement

The manipulator tool shaft moves horizontally on a jointed arm. This horizontal movement is defined as being in an X and Y plane.

The manipulator tool shaft also moves vertically on its own axis. This vertical movement is defined as being in the Z direction.

In addition to the horizontal movement (x and y) and vertical movement (z) that comprise the manipulator's "work space," the tool shaft rotates in both directions — that is, clockwise and counterclockwise. This movement is called "roll."

The position of the tool shaft must be oriented relative to a pre-defined reference position called "home."

Below, a similar diagram is shown for a Cartesian Coordinate Robot (CCR).
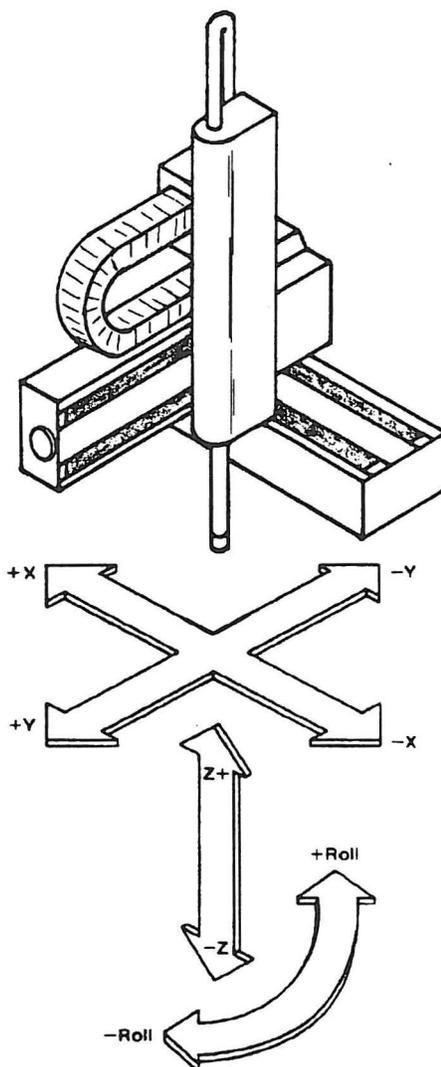
Figure 5-5. CCR Manipulator Movement

Controls and Indicator Lights

This chapter familiarizes the reader with the controls and indicator lights of the manufacturing system. It explains what each control and indicator light is for and when it is used.

7537 Controls and Indicator Lights
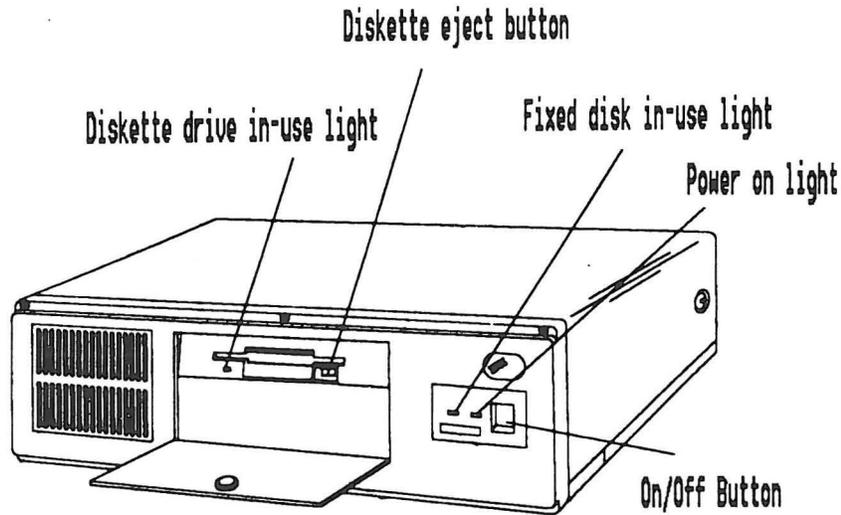
Figure 5-6. 7537 Controls and Indicator Lights

Button/Light	Description of Function
ON/OFF button	This button turns on and turns off power to the 7537.
Power on light	This light indicates when power is on to the 7537.
Fixed disk in-use light	This light indicates when the optional fixed disk drive is in use.
Diskette drive in-use light	This light indicates when the diskette drive is in use.
Diskette eject button	This button causes the diskette to be ejected from the diskette drive

Note: The keybutton functions and procedures described in the remainder of this chapter assume that the standard AML/2 Manufacturing Control System software is being used. This software can, however, be modified. If your software has been modified, the keybutton functions described in this section might not work the same way.

Servo Power Module Operator Control Panel

The operator control panel on the Servo Power Module is designed to guide you in the operation of the AML/2 Manufacturing Control System by means of indicator lights on several of the buttons. These lights blink to indicate that some action is pending on a key or is in progress, and they stay steadily lit when an operation associated with the key has been completed.

Figure   5-7. Servo Power Module Operator Control Panel
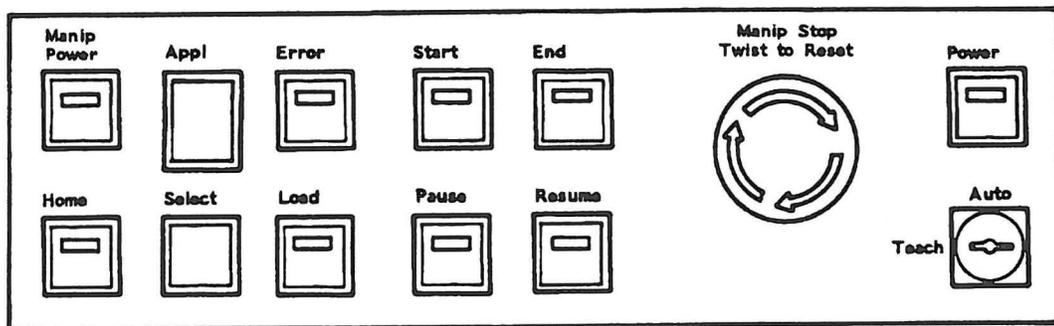
Button/Light	Description of Function
On/Off	This switch turns on and turns off power to the Servo Power Module.
Power	This light indicates when power is on to the Servo Power Module.
Manip Power	This light blinks when system power is on, prompting you to press the button to power up the manipulator. When manipulator power is on, the light stays lit.
Manip Stop	Push this large red button in to turn off power to the manipulator and to quickly halt manipulator motion. After use, twist the button clockwise to permit restoration of power using the **Manip Power** button. *This button does not remove system power.*
Teach/Auto	This key switch selects the manipulator operating mode. "Teach" is used to ensure safer, slow movement of joints when using pendant keys. "Auto" is for running applications.
Error	This indicator lights when an error occurs.
Home	Push this button to move the manipulator tool tip to its "home" position. (This is required before running most programs.) The light blinks while the tool tip moves to home position. After the tool tip reaches home, the light stays steadily lit, even when the tool tip is moved away from home.
Select	Press this button to select a program for loading. Each time this button is pressed, the number shown on the display above the button increases by one (from "1" to "7", and then back to "1").
Load	Press this button to load the program chosen with the **Select** button. The light blinks while the program is being loaded, and then stays steadily lit when loading is complete.
Start	Press this button to start the loaded program from the beginning. The light stays steadily lit while the program is running.
Resume	Press this button to restart a program from the point where it was stopped by an error, **Manip Stop, End,** or **Pause.**
End	Press this button while a program is running to stop it at the end of the next complete cycle. The light blinks when the stop is pending (unless pushed again to cancel), and then it stays steadily lit after the program has ended until the program is resumed or restarted.
Pause	Press this button while a program is running to stop it when it reaches the next PAUSE statement in the program, or the end of the next complete cycle, if that comes first. The light blinks when the pause is pending (unless pushed again to cancel), and then it stays lit, after the program has paused, until the program is resumed or restarted.

Remote Manip Stop Button

A second large red **Manip Stop** button in a hand-held box is connected to the Servo Power Module by a cable. This button is identical in appearance and function to the Manip Stop button on the SPM. operator control panel.

As indicated on the face of the button, once you have pushed in this button to drop power to the manipulator, you must rotate the button clockwise to permit restoration of power using the **Manip Power** button.

Note: If the **Manip Power** blinks but the manipulator will not power up, make sure that both **Manip Stop** buttons have been reset. Someone might have pressed one of them to drop power to the manipulator and then forgotten to reset it afterwards.

Pendant

The pendant is a hand-held key-entry control and display device that can be connected to the SPM. It is used for the direct control of several manipulator functions. The pendant is not included with the basic system, but is available as an optional accessory, since a single pendant can be shared among several manipulators.

The pendant is used primarily for the "teach" function, but it is also required for maintenance to retrieve error codes and select diagnostics. When used, the pendant is connected to the SPM. by the cable assembly to which the remote **Manip Stop** button is attached, as shown in Figure 5-8 on page 5-12.

The pendant consists of:

- A keypad with 32 keys, each with a built-in indicator light, used to directly control a number of manipulator functions.

  The keybuttons and the lights are programmable. Thus the operator is provided an easy means of interaction with the application — that is, keybuttons for input and lights for visual output.

- A 64-character display for viewing system error messages and information related to pendant functions.

  This light display is four lines, with 16 characters per line. The display can be used to read out a verbal or coded operator or system messages.

- A pendant-enable safety switch which must be held closed with light pressure on either side of the pendant to permit activation of any pendant key functions.

  During "teach" mode, all manipulator movements are inhibited unless the pendant enable switch is held closed.

Use of the pendant is described in "Using the Pendant" on page 5-28.

Remote Manipulator Stop button
(push to stop; twist to reset)

Door in open
position

Display screen
(4 lines, 16 characters
per line)

Pendant latch release
(one on each side)

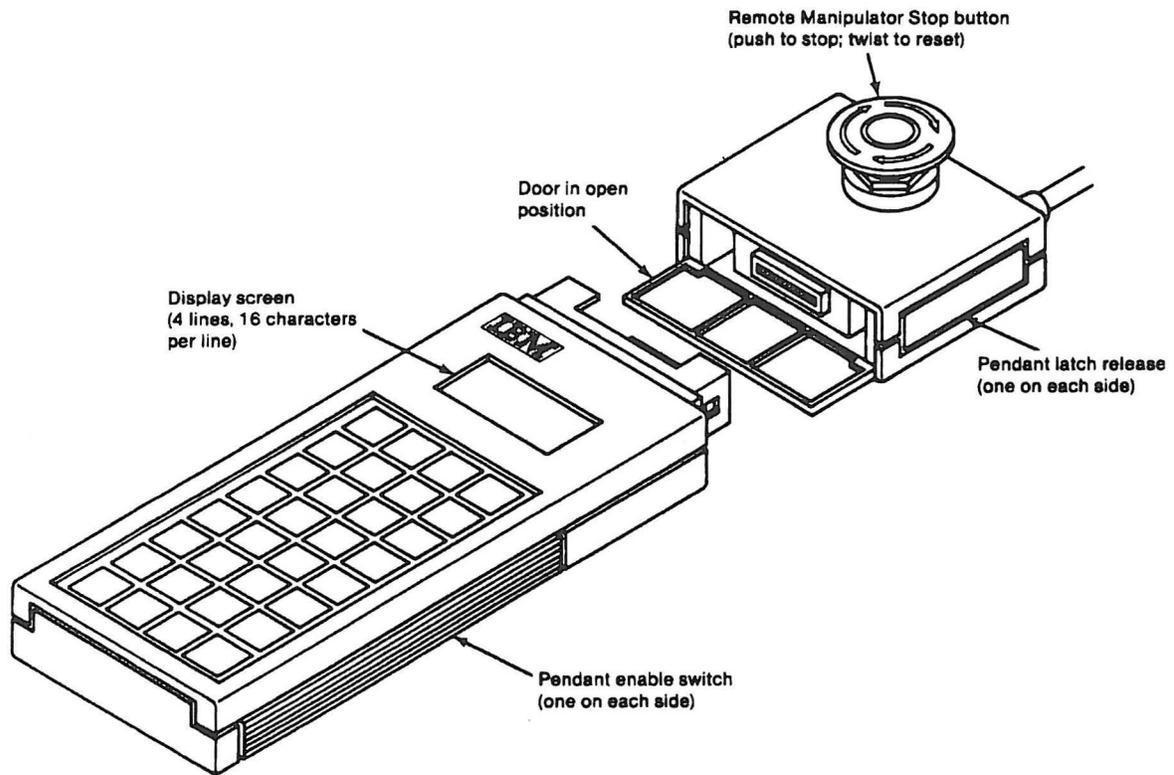Pendant enable switch
(one on each side)

Figure   5-8. Pendant Being Connected to the Remote Manip Stop Button
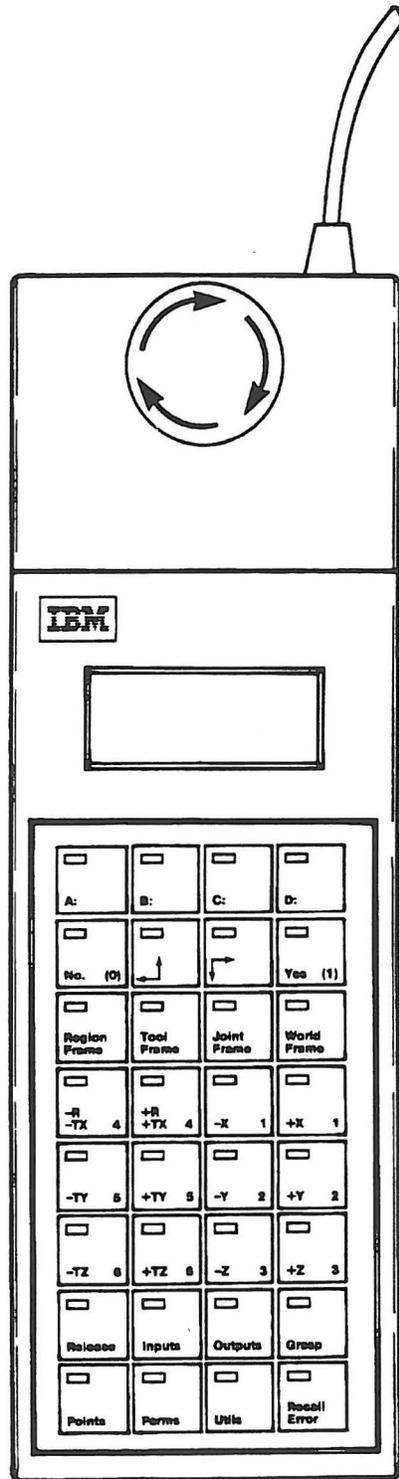
Figure 5-9. Pendant, Showing Standard Key Overlay

The standard pendant overlay defines the 32 pushbuttons as follows:

A:	General purpose
B:	General purpose
C:	General purpose
D:	General purpose
No (0)	General purpose; turns DO point off
(←↑)	Cursor Left/Scroll up
(↓→)	Cursor Right/Scroll down
Yes (1)	General purpose; turns DO point on
Region Frame	Frame select, points relate to region
Tool Frame	Frame select, points relate to roll axis orientation
Joint Frame	Frame select, points relate to individual axis
World Frame	Frame select, points relate to X/Y plane
-R/-TX, 4	Axis motion
+R/+TX, 4	Axis motion
-X, 1	Axis motion
+X, 1	Axis motion
-TY, 5	Axis motion
+TY, 5	Axis motion
-Y, 2	Axis motion
+Y, 2	Axis motion
-TZ, 6	Axis motion
+TZ, 6	Axis motion
-Z, 3	Axis motion
+Z, 3	Axis motion
Release	Open gripper
Inputs	DI/DO mode, selects DI
Outputs	DI/DO mode, selects DO
Grasp	Close gripper
Points	Select teach mode, displays global points
Parms	Motion parameters menu, allows modification
Utils	Utility programs menu, allows selection
Recall Error	Displays error code to the pendant

Diskettes

This chapter explains:

- What a diskette is
- How to identify a 3.5 inch diskette
- How to insert diskettes
- How to remove diskettes.
- Write-protecting diskettes

What Is a Diskette?

The diskette used by "drive A:" of a manufacturing system is a 3.5 inch, 1.44MB (uses 2.0 MB diskettes), magnetic disk inside a protective plastic case. Diskettes are used to store data. For a manufacturing system, diskettes are used to store the AML/2 Manufacturing Control System and its associated software, as well as application programs.

Note: The pendant and the remote Manip Stop button both have magnets on the back for operator convenience. They must not be placed on or near diskettes.

Identifying 3.5 Inch Diskettes

A 1MB diskette looks like this:
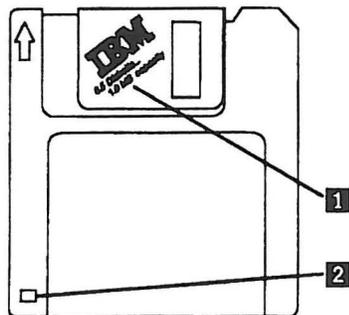
It is usually labeled "1.0 MB capacity" or "2HC" 1 **, and has a square cutout** 2 **.**

A 2MB diskette looks like this:
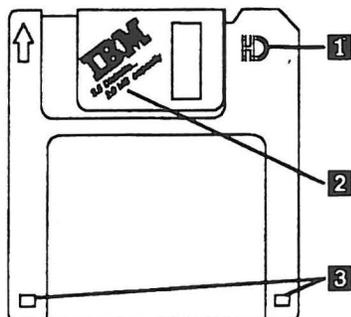
It has the letters "HD" 1 **, is usually labeled "2.0 MB capacity"** 2 **, and has two square cutouts** 3 **.**

Inserting a Diskette into the Diskette Drive

To insert a diskette in the diskette drive:

1. Unlock the drive cover door and open it.
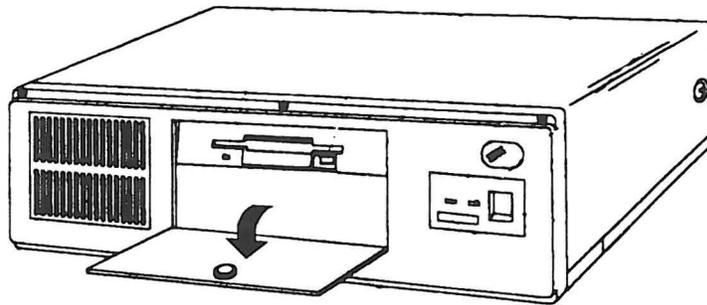
2. Insert the diskette in the diskette drive as shown.

   Note: Make sure that the diskette label faces upwards and the metal-shutter end is inserted first.
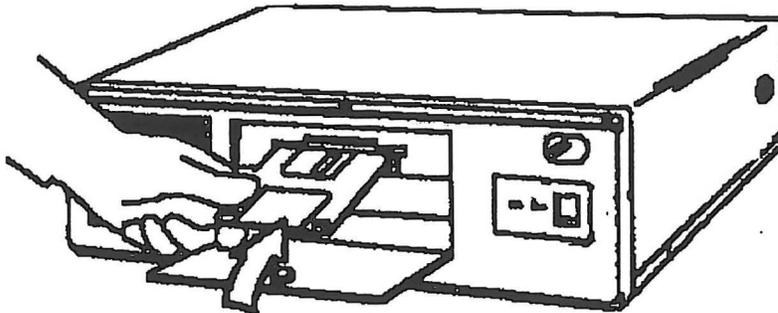
3. Push the diskette all the way in.

4. Power on the manufacturing system as described in "Powering Up the Manufacturing System" on page 5-21.

In a moment, the diskette drive's in-use light will blink. That light lets you know that the system is using the diskette drive.

Warning:

Do NOT push the diskette eject button when the in-use light is on.

Removing a Diskette from the Diskette Drive

To remove a diskette from the diskette drive:

1. Open the drive cover door.

2. Make sure that the in-use light is off.

3. Press the diskette eject button.

4. Remove the diskette.

Write-Protecting Diskettes

It is possible to format a diskette or write (record) information onto a diskette unintentionally. Important information could be lost. For this reason, you should write-protect important diskettes. Some diskettes like the diagnostic diskette in the back of this manual are permanently write protected. When diskettes are write protected, you can read from the diskettes, but you cannot write to them.

For 3.5 inch diskettes, to locate the write protect switch, turn the diskette over, with the label facing down.

— *To prevent writing* to a diskette, slide the switch down.
— *To allow writing* onto a diskette, slide the switch up.

Write-Protect Switch   Not Write Protected   Write Protected
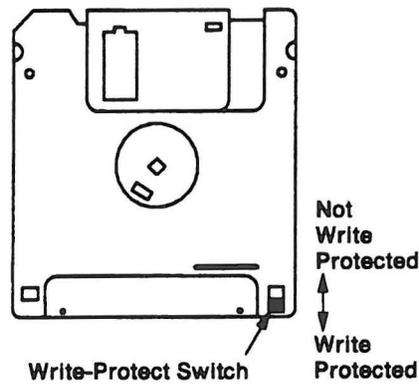
Operation

This chapter describes the step-by-step procedures for operating the manufacturing system using the operator control panel and the pendant. The individual operations that are described are:

- Running Application Programs (page 5-20)

  - Powering up
  - Homing the manipulator
  - Selecting, loading, and running an application
  - Stopping and restarting an application
  - Powering down

- Using the pendant (page 5-28)

  - Teach mode
  - Moving the manipulator
  - Using the **Grasp** and **Release** keys
  - Displaying and setting digital input/digital output points

- Teaching point locations (page 5-39)

- Using the Teach Package (page 5-40)

  - Loading
  - Teaching points
  - Ending a teaching session

- Diagnosing and recovering from errors (page 5-49)

Warning:

Before you apply power to the system or attempt to operate it, make sure that you have read and understand all precautions and warnings included in the "Safety" section in the front of this manual. You should also understand the information given in the previous chapters of this manual and be familiar with the controls and indicators described.

Note: The keybutton functions and procedures described in this chapter assume that the standard AML/2 Manufacturing Control System software is being used. This software can, however, be modified. If your software has been modified, the keybutton functions described in this section might not work the same way.

Running Application Programs

This section describes the steps that you perform to complete all procedures of ordinary manufacturing system operation while running application programs.

Note: Before powering up, the AML/2 Manufacturing Control System software must be installed in the 7537 Motion Controller. If your manufacturing system contains the standard diskette drive only (that is, an optional fixed disk drive is not installed), a 3.5 inch diskette containing the AML/2 software must be inserted in diskette drive A. However, if your 7537 is equipped with an optional fixed disk, the system software should be installed on the fixed disk and no diskette should be in the diskette drive. (The following instructions assume that a fixed disk drive is not installed.)

Powering Up the Manufacturing System

Warning:

Always exercise extreme caution when power to the manipulator is on. Because the manipulator moves through the workspace at high velocity, sudden or unexpected manipulator movements could result in injury to personnel and/or damage to equipment in the work area.

Pushing in the large red mushroom-shaped **Manip Stop** button on the SPM operator control panel turns off power to the manipulator and stops it quickly.

Note: Before attempting to power up the manufacturing system, be sure that the **Manip Stop** button is in the reset position.

1. Insert the AML/2 Manufacturing Control System software diskette into diskette drive A (as described in "Inserting a Diskette into the Diskette Drive" on page 5-16).

2. Turn power on to the 7537 by pressing the power button in to the On position.

3. Turn power on to the Servo Power Module by switching the power switch to the On position.

   This will cause the **Power** light on the SPM operator control panel to light and the system software in the 7537 diskette (or disk) drive to begin loading.

   Note: Because a number of internal test routines are executed during loading, this procedure may take several minutes to complete.

4. When the system software has finished loading, the light on the **Manip Power** button will start to blink. When this happens, press the **Manip Power** button to turn on power to the manipulator.

   Warning:

   The light will stop blinking and remain lit, indicating that manipulator power is on.

You should always home the manipulator before selecting, loading, and starting an application program. Homing the manipulator is also required when the manufacturing system gives a message that the manipulator is not homed.

To home the manipulator, follow the procedure given in "Homing the Manipulator" on page 5-22.

Homing the Manipulator

Warning:

Always exercise extreme caution when power to the manipulator is on. Because the manipulator moves through the workspace at high velocity, sudden or unexpected manipulator movements could result in injury to personnel and/or damage to equipment in the work area.

Pushing in the large red mushroom-shaped **Manip Stop** button on the SPM operator control panel turns off power to the manipulator and stops it quickly.

You should always home the manipulator before selecting, loading, and starting an application program. Homing the manipulator is also required when the manufacturing system gives a message that the manipulator is not homed.

To home the manipulator, do the following: ·

1. If the Manufacturing System *does not* have power on already, power it up as described in "Powering Up the Manufacturing System" on page 5-21.

2. Check the manipulator workspace to make certain that the moving arm will clear any fixtures or objects in the workspace when it is returned to "home" position.

3. Press the **Home** button to return the manipulator to its home position.

   The light on the **Home** button will blink while the manipulator is moving home and will stay lit when home is reached.

Selecting, Loading, and Starting an Application Program

Warning:

Always exercise extreme caution when power to the manipulator is on. Because the manipulator moves through the workspace at high velocity, sudden or unexpected manipulator movements could result in injury to personnel and/or damage to equipment in the work area.

Pushing in the large red mushroom-shaped **Manip Stop** button on the SPM operator control panel turns off power to the manipulator and stops it quickly.

To select, load, and run an application program, do the following:

1. If the Manufacturing System *does not* have power on already, power it up as described in "Powering Up the Manufacturing System" on page 5-21. (Be sure to home the manipulator, as instructed.)

   If the Manufacturing System *does* have power on already, see if the **Home** light on the operator control panel is lit. If it is not, press the **Home** button to send the manipulator to its "home" position.

2. Turn the **Teach/Auto** key switch on the SPM control panel to the "Auto" position.

3. Select the application program you want to run using the **Select** button.

   Each time you press this button, the number displayed directly above the button will increase by 1 until it reaches 7; then it will start over again at 1. To select an application program, press the **Select** button until the number displayed is the same as the application number of the program you want to run.

4. After you have selected the desired program, press the **Load** button to load the program into memory from the diskette (or fixed disk).

   The light on the **Load** button will blink while the program is loading. When the light stops blinking and remains lit, the program has finished loading and is ready to run.

5. Press the **Start** button on the SPM operator control panel to begin execution of the application program currently displayed.

The light on the **Start** button will stay lit as long as the application program is running.

Stopping and Restarting an Application Program

When an application program runs from beginning to end, it has completed one *cycle of operation*. Unless it has been specifically programmed to stop after running for a fixed number of cycles, an application will run repeatedly after the **Start** button has been pressed — starting over again from the beginning after completing each cycle of operation, until some action stops it.

There are several ways that the operator can stop an application:

Use the End button

To cause the application to stop when the current cycle of operation is complete, press the **End** button.

The light on the **End** button will blink while the application is completing its current cycle of operation. When it completes that cycle, execution of the application will stop, and the light on the **End** button will remain lit.

At this point, you can do either of the following:

- Press the **Start** or **Resume** button to resume execution of the application.

- Select, load, and run another application as described in "Selecting, Loading, and Starting an Application Program."

If you press the **End** button a second time while the program is completing its current cycle of operation (that is, while the light on the **End** button is blinking), you will cancel the pending instruction to end the program at the completion of the current cycle, the light will stop blinking, and the program will continue to run.

Use the Pause button

To stop the application before the current cycle of operation has ended, press the **Pause** button.

This will cause the application to stop at the next PAUSE statement in the program, or at the end of the cycle if that comes before any PAUSE statements are encountered. PAUSE statements can be placed in an application program anywhere that it is convenient to suspend program execution (for example, where a pause will not upset the timing of the application).

The light on the **Pause** button will blink while the program continues to run. When the program stops, the **Pause** light stops blinking and stays lit. If the end of the program is reached before a PAUSE statement, the program will stop at the end and the **End** light will be lit. In this case, the **Pause** light goes off.

If you press the **Pause** button a second time when a pause is pending (that is, while the light on the **Pause** button is blinking), you will cancel the pending pause, the light will stop blinking, and the program will continue to run.

When you have stopped an application with the **Pause** button, you can do any one of the following:

- Press the **Resume** button to resume execution of the current program from the program statement immediately following the PAUSE statement.

- Press the **Start** button to restart the current application program at its beginning.

  Warning: Before restarting in this fashion, it is important to make certain that all aspects of the application, including peripheral tooling, are in a compatible state to resume program execution.

- Select, load, and run another application as described in "Selecting, Loading, and Starting an Application Program" on page 5-23.

Use the Manip Stop button

To stop the application immediately, press the **Manip Stop** button. This stops the application and also drops power to the manipulator servo motors.

Although manipulator power is shut off when you press the **Manip Stop** button, the motion control system keeps track of the position of the manipulator arm, even if one or more joints are moved manually while the power is down. This makes it possible to restore manipulator power by resetting the **Manip Stop** button and pressing the **Manip Power** button, followed by pressing the **Resume** button, thus resuming the application without re-homing the manipulator arm.

Warning: Before resuming execution in this fashion, it is important to make certain that all aspects of the application, including peripheral tooling, are in a compatible state to resume program execution.

After pressing **Manip Power** you can do any of the operations described for the **Pause** button: that is, resume the application, start over at the beginning of the cycle, or select and run a new application.

Use the Teach/Auto keyswitch

Turning the **Teach/Auto** keyswitch to the "Teach" position will stop the application program when the current motion completes, without dropping power. After the key is turned back to the Auto position, you can resume, start over at the beginning of the cycle, or select and run a new application as previously described.

As stated before, a new application may be selected and run after the current application has been stopped. However, the first move in the new application will be *from the current manipulator position.* Be sure that it is safe to move from the current position to the first location in the new program. If you are not sure, it is wise to first move to the home position (by pressing the **Home** button), because homing is a slow-speed, usually safe sequence of motions and any application should be able to begin from the home position.

Powering Down the Manufacturing System

To power down the system, perform the following steps:

1. If an application program is running, stop the application as described in "Stopping and Restarting an Application Program" on page 5-24.

2. If you wish, you may return the manipulator arm to its home position, as described in "Powering Up the Manufacturing System" on page 5-21.

3. Press the **Manip Stop** button on the SPM control panel to turn power to the manipulator off.

   Note: When you attempt to power up the system again, it will be necessary to twist the **Manip Stop** button clockwise to reset it.

4. Set the power controls on the 7537 and the SPM control panel to the "Off" position to shut off all power to the system.

The power-down sequence is now complete.

Using the Pendant

As explained in "Pendant" on page 5-11, the pendant is a hand-held control device that can be connected to the SPM to control a number of manipulator functions directly. The pendant is not included with the basic system, but is available as an optional accessory, since a single pendant can be shared among several manipulators.

When used, the pendant is connected to the SPM. by the cable assembly to which the remote **Manip Stop** button is attached, as shown in Figure 5-8 on page 5-12.

Using the Pendant in Teach Mode

Some pendant operations can be performed during the execution of programmed applications with the system in "Auto" mode if explicitly programmed by the application; however, most pendant functions are performed with the system in "Teach" mode. This section describes the pendant functions that are performed in "Teach" mode, including:

- Safe movement of manipulator joints in the workspace
  - in joint frame
  - in world frame
  - in tool frame
  - in region frame

- Using the **Grasp** and **Release** keys

- Displaying current status of DI/DO points and resetting DO points.

To use the pendant:

1. Connect the pendant to the remote **Manip Stop** cable as shown in Figure 5-8 on page 5-12.

2. Power up the manufacturing system as described in "Powering Up the Manu-facturing System" on page 5-21.

3. Turn the **Teach/Auto** key switch to the "Teach" position.

4. Look at the pendant display. It will look like one of the two screens shown in Figure 5-10, depending on whether or not the manipulator has been homed. (If the **Home** light is on, it has been homed. Otherwise, it has not.)

```
X:   200.00 MM
Y:  -100.00 MM
Z:  - 90.00 MM
R:     0.00 DG
```
Manipulator Location
Screen

```
NO POSITION
AVAILABLE
MANIP UNHOMED
```
Manipulator Unhomed
Message

Figure 5-10. Manipulator Location Screens

When either of these screens is displayed, you can use the buttons on the pendant to move the manipulator. (*Remember*: The pendant-enable safety switch on either side of the pendant must be held closed to permit activation of any pendant key functions.)

Also, if your configuration contains more than four axes. not all of them can be displayed at once. In this case, the scroll keys (←↑ and ↓→) can be used to scroll up and down to see the data for all of the axes in groups of four.

5. By pressing the **Parms** button on the pendant, the data will be displayed in joint coordinates for all axes. Pressing **Parms** again will return the display to the normal state.

Moving the Manipulator with the Pendant

To get acquainted with the pendant keys and display, perform the following pendant operations.

Moving in the Joint Frame: You may put the system in the "joint" frame of reference after entering "Teach" mode by pressing the **Joint Frame** button. If the manipulator has not been homed upon entering "Teach" mode, the "manipulator not homed" message will be displayed and the light on the **Joint Frame** key will be lit, indicating that the system is in the "joint" frame of reference.

When the manipulator is unhomed, the joints can only be moved with the pendant in "joint" frame, which permits you to move the manipulator joints $\theta 1$ and $\theta 2$, roll, and Z independently. This capability is useful if, for example, it is necessary to move one or more of the joints before homing is possible.

Assuming that the manipulator is unhomed when you switch to "Teach" mode (that is, that the "manipulator not homed" message appears on the pendant display), follow these steps to move the joints in the "joint" frame before homing.
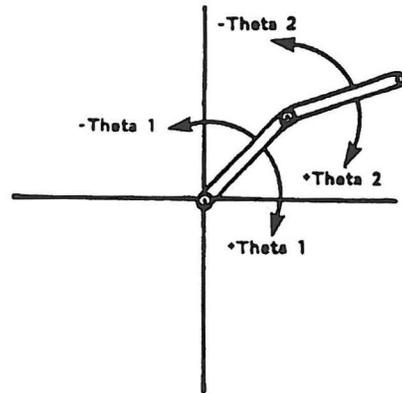

Figure 5-11. Movement in Joint Frame

1. Moving the $\theta 1$ joint

   Press the **+X** key, then the **-X** key. Note that the first joint of the manipulator (Theta 1) rotates back and forth about the post.

   a. Pressing the **+X** key causes the arm to rotate in the positive Theta 1 direction (counterclockwise as viewed from above).

   b. Pressing the **-X** key causes it to rotate in the negative Theta 1 direction (clockwise as viewed from above).

2. Moving the $\theta 2$ joint

   Press the **+Y** key, then the **-Y** key. Note that the second joint of the manipulator (Theta 2) rotates back and forth about the elbow.

   a. Pressing the **+Y** key causes the arm to rotate in the positive Theta 2 direction (counterclockwise as viewed from above).

   b. Pressing the **-Y** key causes it to rotate in the negative Theta 2 direction (clockwise as viewed from above).

3. Moving the tool tip up and down

   a. Press the **+Z** key to move the manipulator tool tip in the positive Z direction (up).

   b. Press the **-Z** key to move the manipulator tool tip in the negative Z direction (down).

4. Rotating the Z-shaft (roll)

   a. Press the **+R** key to rotate the Z-shaft in the positive roll direction (counterclockwise as viewed from above).

   b. Press the **-R** key to rotate the z-shaft in the negative roll direction (clockwise as viewed from above).

You can also use the joint frame after the manipulator has been homed. Just press the **Joint Frame** button first.

When the system is in joint frame:

- If the manipulator has been homed (that is, the **Home** light is on), the tool tip location is displayed in world frame coordinates, and the coordinates are updated on the display as the arm is moved.

- If the manipulator has not been homed (that is, the **Home** light is not on), the tool tip location is not displayed.

Moving in the World Frame: To use the world frame, the manipulator must be homed first. If it hasn't already been homed, turn the keyswitch back to "Auto" and press the **Home** button. After the arm has moved to Home, turn the keyswitch back to "Teach."

The "manipulator location" screen, shown in Figure 5-10 on page 5-28, will display the current x, y, z, and roll values. In addition, the light on the **World Frame** key will go on.

To move the manipulator in "world frame", use the same set of pendant keys that you used for "Moving in the Joint Frame" on page 5-29.

Note that when you move the manipulator using the pendant keys described here, the selected axis will first move a very small amount and will then move with increasing speed in the chosen direction. The maximum speed will not exceed 250 mm/sec.

Figure 5-12. Movement in World Frame

1. Movements along the X-axis

   a. Press the key marked +**X** to move the manipulator tool tip in the positive X direction.

   b. Press the key marked -**X** to move the manipulator tool tip in the negative X direction.

2. Movements along the Y-axis

   a. Press the key marked +**Y** to move the manipulator tool tip in the positive Y direction.

   b. Press the key marked -**Y** to move the manipulator tool tip in the negative Y direction.

3. Pressing the +**Z** and -**Z** keys and the +**R** and -**R** keys in world frame has exactly the same effect on manipulator movement as in joint frame, as described in steps 3 through 4 in "Moving in the Joint Frame" on page 5-29.

Notice that as you move the manipulator using these keys, the manipulator position display changes to show the current tool tip position in the world frame of reference.

Moving in the Tool Frame: Placing the system in the tool frame of reference changes the X and Y axes so that they align with the current angle of roll. This capability is provided to allow straight-line movements relative to some fixture not oriented along the standard X and Y axes in the workspace.

When moving in the tool frame, a different set of pendant buttons is used than when in world or joint frame. The buttons that are used are those with "T"s on them, like +TZ.

Note that when you move the manipulator using the pendant keys described here, the selected axis will first move a very small amount and will then move with increasing speed in the chosen direction. The maximum speed will not exceed 250 mm/sec.
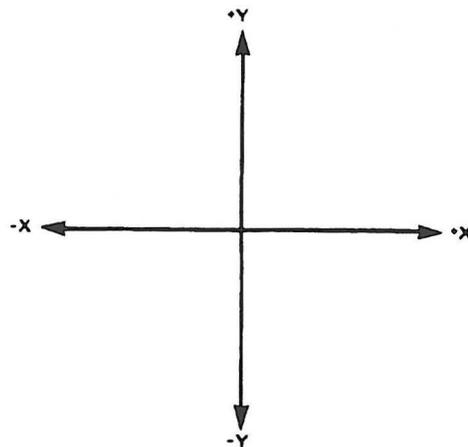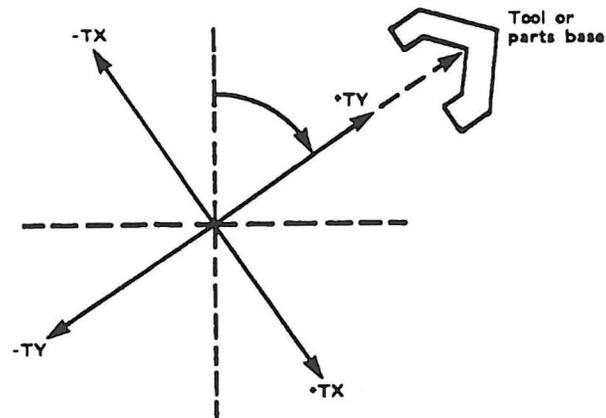

Figure   5-13. Movement in Tool Frame

Follow these steps to use "tool" frame:

1. While the system is still in world or joint frame, press the +R/+TX or -R/-TX keys as required until the roll angle is at any angle other than 0 degrees, as indicated on the pendant display. For purposes of this practice demonstration, you might try an angle of approximately 45 degrees.

2. Now press the **Tool Frame** key to enter "tool" frame. The light on the **Tool Frame** key will go on.

3. Press the +R/+TX key, then the -R/-TX key.

   Note that the tool tip moves in a straight line (just as in the world frame), but since the roll angle has been changed by 45 degrees, the X axis is now at a 45 degree angle to where it was in the world frame.

4. Press the +TY key, then the -TY key.

   Note again that the tool tip moves back and forth along the Y axis, which has been shifted 45 degrees from its normal position in the world frame of reference.

5. Press the +TZ key, then the -TZ key. Since the angle of roll doesn't affect the Z (or vertical) axis, these keys have the same effect as the +Z and -Z keys used in the "world" and "joint" frames.

Note: There is no roll button defined in tool frame. The setting of the roll angle is determined upon entering tool frame and cannot be changed until tool frame is exited.

As you move the manipulator with these three pairs of keys, note that the manipulator location display changes to indicate the current end-of-arm location *in world frame values.*

Region Frame: You cannot enter "region" frame by pressing the **Region Frame** button as we did with "world", "joint", and "tool" frames — the system automatically enters "region" frame when appropriate. Since that happens only when using the Teach Package, discussion of the use of the "region" frame is contained in "Using the Teach Package," later in this chapter.

Using the Grasp and Release Keys

If your manipulator is fitted with a gripper tool at the end of the Z shaft, press the **Grasp** key, then the **Release** key to close and open the gripper. If there is no gripper tool on your manipulator, pressing these keys has no effect.

Displaying and Setting Digital I/O Points

The pendant can also be used to display the current values of all of the digital input points and digital output points configured in your system. Digital output points may be set "on" or "off" using the pendant, as described below; digital input point settings may be displayed, but their settings may not be changed.

To get acquainted with the use of the pendant to display the current·status of digital input (DI) points and digital output (DO) points and to change the settings of DO points, follow the steps listed below.

Displaying and Setting Digital Output Points

1. Press the **Outputs** key. The light on the **Outputs** key will be lit and a screen like the one shown in Figure 5-14 will be displayed.

```
0000 0000 0000
0000 0000 0000


PT: 1    OFF
```

Figure 5-14. Digital Output (DO) Point Display Screen

The display shows three groups of four digits per line on the top two lines. (Note: If fewer than 24 points have been defined, only that number of points is displayed.) Each digit represents the current setting of one of the DO points: 0 means off, and 1 means on.

The first digit at the left on the top line shows the current value of the first DO point; the next number shows the current value of the second point; and so on.

Note that one of the numbers in the display has an underline character under it. This character is the "cursor" and it indicates the digital output point for which current information is displayed on the bottom line of the screen. In Figure 5-14 the cursor is under the first point ("1"), which has a current value of zero; so the bottom line of the display indicates "PT : 1 OFF".

The number on the bottom of the screen refers to the actual DO point number. The DI and DO points on the system are numbered consecutively from 1. Thus, each input and output point in the system has a unique number associated with it. These numbers are determined when you initially configure the DI/DO. These numbers are the numbers used by an application program to reference the DI/DO points, and are the numbers that appear on the bottom of the screen. Note that the numbers associated with outputs are not necessarily consecutive. For example, a system might have DO points 1-8 and 33-48, with DI points in between.

2. Press the ↓→ key (called the **Cursor Right** key). Notice that the cursor moves one position to the right. Each time you press this key, the cursor moves over to the next digit on the right. (If you hold the key down, the cursor moves rapidly.)

   Now press the ←↑ key (called the **Cursor Left** key). Notice that each time you press this key, the cursor moves one position to the left. (If you hold the key down, the cursor moves rapidly.)

If the system is configured with more than 24 DO points, pressing the **Cursor Right** key when the cursor is positioned under the last point shown on the display will cause the next eight DO points to be displayed. For example, if a system had DO points 1-40, and you were initially displaying points 1-24, then the display would be updated to show points 9-32.

3. To change the setting of a DO point, you must first position the cursor under that point on the display.

   Press the **Cursor Right** or **Cursor Left** key as required until the cursor is under the desired DO point on the display. Then press the **Yes (1)** key to set the point on, and the **No (0)** key to turn it off.

4. When you are finished with DO points, press the **Outputs** key again. The DO "point display" screen will disappear, the light on the **Outputs** key will go out, and the "manipulator location" screen will be displayed.

Displaying Digital Input Points: Digital inputs are displayed just like digital outputs, except that, naturally, you cannot change inputs. To display Inputs, press the **Inputs** key. When you're done with inputs, press the **Inputs** key again.

Teaching Point Locations

The pendant functions just described can be used to teach points. When the correct coordinates of a point have been established by guiding the arm to the correct location, they may be manually entered into a program. Or, if you are using a roll-up tool that is attached to the controller (via an RS-232 cable) with the AML/2 Application Development Environment running, you can use the editor Point recall function to place the current manipulator coordinates directly into your program.

It is possible to teach points with the manipulator powered off. This is a useful feature if the position to be taught is very difficult to attain without close human intervention and the safety provided by absence of power is important. In order to do teaching without power, you must press the "Manip Stop" button *before* turning the key switch to "Teach." The message EXCP_MPO will appear on the pendant. When that happens, turn the key switch to "Teach" and manually position the manipulator. The manipulator location screen coordinates will change as the arm is manually moved and these coordinates may still be recalled into your program on the roll-up. To re-power the manipulator, turn the key switch to "Auto" and press the blinking "Manip Power" button to power up the manipulator.

It is also possible to teach points in a program that has already been downloaded to the controller. This is very useful in two situations:

- When an application program is initially written, you can create points, but leave their exact coordinate values to be added to the program later. To do this, you either assign approximate coordinate values or omit them altogether; in the latter case, values of "0" are automatically assigned.

- After point locations have been defined and a program has been run, minor adjustments are often needed for various reasons. This process is referred to as "fine-tuning" of points.

This type of point teaching can be done with a program called the "Teach Package," described in the next section.

Using the Teach Package

The previous section described moving the manipulator and examining DI/DO points with the pendant. The "Teach Package" is a separate program written in AML/2. It comes as part of the AML/2 Manufacturing Control System and provides additional capabilities with the pendant. The "Teach Package" allows you to do the following:

- Load in the PT and WORLDPT definitions of an application program whose points require teaching or fine-tuning.

- Scroll backward and forward through these points until you get to the one you want to teach.

- Guide the manipulator to the correct location of the point.

- Verify in the actual work situation that the location coordinates are defined accurately, and adjust the coordinate values as required using the pendant.

- Update the program (on diskette or disk) with the new point values.

The Teach Package does not require that the development system or roll-up be used. A program already on the controller can be updated using only the pendant. However, the Teach Package will only work properly on an application program if the application program follows certain guidelines. In particular, any points that are to be taught using the Teach Package must have been declared in the application program with the PT or WORLDPT command, and these declarations must be at the global level (outside any subroutines).

Note: In order to use the Teach Package, you must have an application that contains PT or WORLDPT definitions at the global level (outside an application subroutine) already downloaded to the controller.

Loading the Teach Package

Use the following procedure to load the Teach Package in preparation for teaching points in an application.

1. Be sure that the pendant is properly connected to the cable assembly as shown in Figure 5-8 on page 5-12.

2. The manipulator should be powered up and homed.

3. With the key switch in the **Auto** position, use the **Select** button to select the application in which you want to teach some points, *but do not load it*.

4. Turn the **Auto/Teach** key switch to the "Teach" position.

   The "manipulator location" screen, shown in Figure 5-10 on page 5-28, will be displayed.

5. Press the **Points** button (lower left corner of pendant).

   This causes the Teach Package to be loaded from disk. The Teach Package will then read in all the PT and WORLDPT definitions at the global level for the application program you previously selected.

Teaching a Point

When the application program you selected has finished loading, you can teach one or more points in the program as described below.

Initial Teaching of Points: The first screen that you will see will look like the following example:

```
FEEDER_1
X:   150  Z: - 78
Y: -200  R:    0
A:MOVETO  D:SAVE
```

Figure 5-15. Point Display Screen

The "point display" screen shows information on the first PT defined in the application program:

- The top line of the display contains the name of the PT in the application program.

  If the actual name is longer than 16 characters, only the first 16 characters of the name are shown. That should be sufficient for you to positively identify the point you are teaching.

  If the point is defined in region terms (it is a WORLDPT), a maximum of 13 characters in the name are shown. The last three characters in the first line show ::R to indicate that this point is in a region.

- The next two lines of the display give the approximate current values for the x, y, z, and roll coordinates for this point. These are world frame values unless the point is a WORLDPT, in which case, they are region frame values.

- The bottom line of the display indicates two choices of action ("A:MOVETO" or "D:SAVE") that you can take at this point. These will be described later.

- If more than four axes are configured, a third option, "C:AXES", will be given instead of the fourth axis data. Pressing this key will scroll the screen through the data for all of the axes.

When the "point display" screen is displayed, you can teach the current point or proceed to a different point.

To go on to a different point: press the (↓→) key (the **Cursor Right** key) or the (←↑) key (the **Cursor Left** key).

Each time that you press the **Cursor Right** key, the display will change to show information on the next point in the program. Each time that you press the **Cursor Left** key, the display will change to show information on the previous point. (If you hold either key down, the points scroll rapidly.)

When the "point display" screen shows information on a point that you want to teach, you can either move to or above the current coordinates of the point (with the "MOVETO" option) or move to the correct location by guiding the manipulator using previously described pendant functions.

Note: If the point was never taught before and was declared with initial coordinates of 0, you cannot use the MOVETO option, because the point 0,0,0,0 is not in the workspace.

When you want to move to the current coordinates of the point, press the **A** key on the pendant to select the "A:MOVETO" option.

The display will change to show the "moving to point" screen:

```
MOVE SPEED: 0.30
MOVE TYPE: NAT
  A: MOVE ABOVE
B:MOVETO  C:EXIT
```

Figure   5-16. Moving to Point Screen

This screen displays the values for the *speed* and *movetype* parameters.

Note: These parameters apply only to the "MOVETO" and "MOVE ABOVE" options. They are *not* "remembered" as part of the point definition. When the application runs, it is the logic and statements in the application that determine the movetype, speed, etc. Be sure that when a point is taught, you teach it in the elbow position (left or right) that will be used in the application. **Warning:** If you use the "MOVETO" or "MOVE ABOVE" option, be sure the movetype you select will not cause the arm to collide with anything.

You can review these values and decide whether or not they must be changed. If you must change any of the parameter values, press the **Parms** key. At that time:

• The light on the **Parms** key will go on.

• The "parameter modification" screen, shown in Figure 5-17, will be displayed.

```
A: SPEED    0.30
B: MOVETYPE NAT
C: ELBOW    EITH
PARMS: EXIT
```

Figure   5-17. Parameter Modification Screen

When this screen is displayed, you can change any of the parameters shown as follows:

1. Press the appropriate key (A, B, or C) for the parameter you want to change.

2. Press the **Cursor Right** or **Cursor Left** key to select the desired value.

   - In the case of "A:SPEED" (which is a numeric value), pressing the **Cursor Right** key increases the value displayed (until the maximum value possible is displayed), while pressing the **Cursor Left** key decreases it (until the minimum value possible is displayed). Holding the cursor key will change the value rapidly.

   - In the case of "B:MOVETYPE", pressing either cursor key will scroll through the possible values of "NAT" (natural arc motion) and "STR" (straight-line motion).

   - In the case of "C:ELBOW", pressing either cursor key will scroll successively through the possible values "RIGH", "LEFT", and "EITH".

3. After changing one of the parameters, you can press another selection key (A, B, or C) and change that parameter until all values displayed are correct.

4. When the values displayed for all three parameters are correct, press the **Parms** key again to return to the "Moving to Point Screen." The new values that you have just set for the *speed* and *movetype* parameters will be displayed on this screen.

Now that you have decided that the displayed parameters for the point you are going to teach are correct (or you've changed them), you are ready to move the manipulator to the point's current coordinates.

You may the press and hold the **A** key to move the manipulator tool tip to a location directly above the point. The position used here has the x, y, and roll coordinates of the point, but the Z shaft is at its uppermost position (z = 0 in world terms).

You may also press and hold the **B** key until the manipulator tool tip has completed its movement to the point.

Note: When you press the **B** key, the move will proceed only while you keep the key pressed. If you release the key (perhaps to avoid running into something) the move will stop immediately and the "point display" screen will return.

If the point you moved the manipulator to is satisfactory, you can go on to the next point by pressing the **Cursor Right** or **Cursor Left** key to select another point. Repeat the teaching process just described for the next point.

If the point you moved the manipulator to is not quite right, you can use the pendant to adjust the point, as described in "Adjusting (Fine Tuning) a Taught Point" on page 5-45.

Adjusting (Fine Tuning) a Taught Point: Press the **Points** key. The light on the **Points** key will go out.

You can now use the pendant manipulator motion keys, as described in "Moving the Manipulator with the Pendant," to move the manipulator tool tip to the exact location in the workspace required for successful execution of the program. You can use the tool, joint, or world frame when teaching the point. If the point is in a region (indicated by ::R after the name of the point), the Region Frame LED will be on, and you can use the region frame also.

Region frame is similar to tool frame in that the X and Y axes are rotated. For region frame, they are rotated to line up with the X and Y axes of the region. Since the region may be tilted, the Z axis in region frame may be tilted.

In region frame, you use the **+X, -X, +Y, -Y, +Z, -Z, +R,** and **-R** buttons, just as for world frame.

You can change from region frame to any of the other frames simply by pressing the appropriate frame button.

When you have positioned the manipulator tool tip in the location that you want to teach, press the **Points** key once again. The following will occur:

- The light on the **Points** key will go on.
- The "point display" screen that you last saw will be displayed again. But, it will still show the old values for the point. This is because you have not saved the new values yet.

If the current location of the arm is correct, press the **D** key to select the "D:SAVE" option. The system will update the point with the current manipulator position. The "point display" screen will also be updated.

Note: At this point, your program on disk has *not* been changed. That doesn't happen until you have taught all the points that need teaching.

If you want to go back to a point that you have already taught and set new values/parameters, just select the point and reteach it as described.

Ending a Teaching Session

When you finish teaching points in the current program, you will probably want to save the program with the new points on the application program diskette (or disk) and try it out. To do this, just turn the key back to AUTO.

You will be prompted as follows:

```
A: SAVE PROGRAM
B: DON'T SAVE
```

The menu gives you only two choices:

- If you choose option A, you will get an additional prompt asking whether you really want to save the new program; that is, replace the old program on the application program diskette (or disk). If you reply yes (press the **Yes (1)** key), the application with any re-taught point locations will be saved.

- If you choose option B, you will get a prompt asking if you want to erase all the changes to PTs and WORLDPTs that you made on the current application. If you respond yes, they are removed. (The application program will not be updated.)

At this point, you can press **Load** and **Start** to try out your program.

If you wish, you can stay in the Teach Package, perhaps to teach points in a different application. To stay in the Teach Package, press the **Utils** key when the "point display" screen (for any point) is displayed. The light on the **Utils** key will go on and the "utility selection" screen, shown in Figure 5-18, will be displayed.

```
A: SAVE PROGRAM
B: DON'T SAVE
C: SELECT PGM
UTILS: EXIT
```

Figure 5-18. Utilities Selection Screen

The menu gives you three choices:

- Option A works just like option A in the previous menu.

- Option B works just like option B in the previous menu.

- Finally, if you choose option C, the system will first prompt you to find out what you want to do with any changes to the current application before loading a new one. If you reply that you do not want to save the current program, you will go on to the application selection prompt. If you do want to save the old one, the system will save it and then go on to the application selection prompt.

If you select option C, the "application selection" screen, shown below will be displayed

```
┌─────────────────────────┐
│ SELECTED PROGRAM        │
│ # 1  APPL1              │
│ >: UP      <: DOWN      │
│ C: LOAD                 │
│                         │
└─────────────────────────┘
```

Figure 5-19. Application Selection Screen

The second line of this screen displays the current application number (1 to 7) followed by the name of the application program identified by that number. Press the ↓→ key or the ←↑ key on the pendant to go backward or forward through the seven applications until you get the one you want. (Note that the program number selected is also displayed on the Servo Power Module operator control panel.) When you find the right one, press the "C:LOAD" key to load that program. Then the "point display" screen for the new program will appear.

To exit without loading the selected program, press the **UTILS** key again.

Insufficient Diskette (or Disk) Space: When a program that has been taught with the Teach Package is saved on the application program diskette (or disk), a new copy is made and then the old one is erased. Therefore, it is possible that there will not be enough storage space for the new copy. The Teach Package checks the available storage space to make sure that the new copy will fit. It does this check when you first save a re-taught value. (Thus you will not re-teach a lot of points and then discover that there is no storage space left for the program.) At this point, if there is not enough space, you will see the display:

```
NOT ENOUGH DISK
SPACE FOR FILE:
APPL1.AML
C: CONTINUE
```

Figure   5-20. Insufficient Disk Space Warning Screen

When this happens, you will need to erase some files from the diskette. This can be done from the roll-up tool, or by taking the diskette to another computer and erasing some files there.

If you press "C: CONTINUE", the requested save will not take place. If you have not erased some files to make more room on your diskette, all further attempts at saving points in this file will cause the above display to re-appear. If you have erased some files, you may again try a "D: SAVE" after pressing "C: CONTINUE".

Diagnosing and Recovering from Errors

Before Starting an Application

Normally after the system has completed loading, the green light on the **Start** button will blink, indicating that the manipulator may now be powered up. If this does not happen and the yellow **Error** light is off, the system software did not complete loading. Make sure that the Servo Power Module is powered up, the correct diskette is correctly inserted, and the diskette load lever is closed. Also, make sure that all of the joints are within their physical limits of travel. If the above items are correct and the system still will not load properly, the diskette may be defective, or there may be a hardware error.

If the **Start** light does not blink and the **Error** light is on, check that none of the joints is at its physical limit of travel. If one or more joints is at a limit, move the arm manually so that the joints are not at their limits.

Note: To move the Z shaft, you must pull the Z-brake release chain under the Theta 2 arm.

If this was the problem, you can press **Resume** and the **Start** light will blink. Then you can proceed with normal operation.

If this was not the problem, plug in the pendant and then press the **Recall Error** key in the lower right corner. Possible messages and their recovery procedures are:

- EXCP_OPENERR: Check for the correct diskette and that the diskette load lever is closed.

- EXCP_OVERRUN: One or more joints is at its limit of travel. Move all joints away from their physical stops; then press **Resume** and proceed with normal operation.

- Anything else: Probable hardware problem.

Errors While Running an Application

If an error occurs during the running of an application, the following things happen:

- The **Error** light on the SPM control panel goes on.

- Power to the manipulator is shut down.

- Error information is displayed on any attached pendant.

- Error information is communicated to a roll-up tool running the Application Development Environment, if one is attached.

Typically, no pendant or roll-up tool will be around when the error occurs. To find out why the **Error** light is lit, you should plug in the pendant and press the pendant's **Recall Error** key. The cause of the error will be displayed. It will be a message with the first five characters: "EXCP_"

The most likely errors and their possible recovery actions are:

- EXCP_NOTHOME — The manipulator was not homed prior to starting the application. Press **Resume**, **Manip Power**, **Home**, and then **Start** to re-start the application.

- EXCP_OVERRUN, EXCP_OUTSIDE — An attempt was made to move outside the workspace. Possibly a point in the application was not taught, and can be taught with the teach package. Otherwise, the problem is due to an application logic error and the application must be corrected. In either case, you cannot resume the application.

- EXCP_RTERR — An error was detected by the motion control software. This is usually an error requiring maintenance on the manipulator (for example, a thermal check). However, it can also be caused when the manipulator is physically unable to complete a move due to an obstacle. This may be correctable by re-teaching a point in the application. This error could also be due to a wrong or defective part to be operated upon (for example a washer with no hole and thus into which a bolt cannot be inserted.) In this case, you may be able to correct the problem manually and then resume the application as described on the next page.

If the **Manip Stop** button is pressed while a move is in progress, the EXCP_RTERR error may be raised in addition to the EXCP_MPO. To recover, reset the **Manip Stop** button, power up the manipulator by pressing the **Manip Power** button, and then press the **Resume** button. When the EXCP_MPO is subsequently raised, follow the instructions on the next page to continue operation.

- EXCP_OPENERR — This may be due to an a bad or incorrectly inserted diskette. If so, correct the problem and resume as described on the next page. Otherwise, there is an application problem.

- EXCP_TIMEOUT — The application timed out waiting for a digital input to be on or off. If it is obvious what is wrong (for example a jammed feeder) you can correct the problem and then resume as described below.

- anything else — There is probably an application error. You cannot resume the application.

For the recoverable types of errors described on the previous page, once you have corrected the problem you can resume as follows:

1. Press the **Resume** button on the SPM operator control panel.

   This will turn off the **Error** light and cause the **Manip Power** light to begin blinking so that you can re-power the manipulator. (Remember that the error caused power to the manipulator to drop.)

2. Be sure that both the manipulator and any associated tooling are in a reasonable state to resume operation.

3. Press the **Manip Power** button to re-power the manipulator.

4. If it appears safe, you can resume the application by pressing the **Resume** button. If the manipulator was moved at all while powered off, it will move slowly back to the point where it was when power was dropped. It will then continue with the next statement in the application program. If a move was in progress, that move will be resumed.

If the error was a hardware problem and was not corrected, you will not be able to start up the manipulator, and hardware service procedures are required. If the problem was not a hardware problem but is not recoverable (for example, a programming error), you can start the manipulator but the resume button will not work. In this case, you can either re- start the application by pressing **Start**, or else press **Select** and **Load** and start a new application.