Motoman® NX100 Controller

Multi-Layer Welding Function Manual

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Chapter 1
Introduction

1.1 About This Document

This manual provides instructions for the NX Multi-Layer Welding Function. For detailed information regarding your specific system, please refer to your system documentation package (refer to Section 1.3).

This Function Manual contains the following chapters –

CHAPTER 1 – INTRODUCTION
This chapter provides general information about the Multi-Layer Welding, a list of reference documents, and customer support contact information.

CHAPTER 2 – SAFETY
This chapter provides general information regarding the safe installation, maintenance, and operation of the Multi-Layer Welding.

CHAPTER 3 – OPERATION
This chapter provides an overview of Multi-Layer Welding.

1.2 Overview

The Multi-Layer function provides ease of programming for multi-layer welding. The system is designed around a Motoman NX controller, COMARC unit and complete welding package.

The Multi-Layer function is used to weld workpieces with multiple layers which otherwise cannot be satisfactorily welded with a single layer. Multi-layer welded workpieces are generally thick and create problems such as “variations in welding accuracy”, “distortion during welding”, and “positioning errors due to setting error”. Simply reproducing the taught path is not enough to attain high-quality welding.

To solve these problems, Search and Arc Sensing functions are used. The first layer is welded while the path is corrected using Arc Sensing. The corrected path is then stored and jobs for the 2nd and following layers are created automatically based on the stored path.

The Multi-Layer function includes the following features:

- Adaptive welding software (start point detection function (Touch Sense), and through arc seam tracking (ComArc)
- Quick programming and touch-up of multi-layer weldments
- Improved touch sensing routines (macro jobs)
- 3D Shift: Translational and Rotational touch sensing / path shifting
- ComArc Path Memory (single robot controller only)
- Enhanced welding condition adjustment (while welding) affects wire feed speed, voltage, travel speed, weaving parameters, contact-tip-to-work distance, and position in weld joint

Point Variables

The taught position data on the 1st layer is registered as point variables. The point variables are used in combination with shift amounts to create the additional welding layers. By using point variables, the time required for teaching the second and the following layers is reduced.

Memory and Playback Function

The Multi-Layer Function stores the Arc Sense corrected first layer path and reproduces the stored path on the second and the following layers. Storing the corrected path for the second and the following layers, allows the user to select either the same or reversed direction welding for subsequent layers.

Search and Shift Functions

Several touch sensing patterns are available via macro job instructions. These instructions calculate the amount of deviation from the taught position and shifts the following steps accordingly. One instruction executes the search and shift functions, simplifying the operation. Specifying the shift type (i.e. shift in parallel, or shift in rotation) simplifies correction of the workpiece positioning error. The taught position can then be modified in Teach mode. Modification of the taught point is easy since it is not necessary to change the target position on the master workpiece.

Overriding Welding Condition Function

Welding conditions can be adjusted and changed during playback operation. This allows “realtime” adjustment of welding conditions such as arc sensing current / offsets and weaving amplitude, as well as wire feeds speed, voltage, and welding travel speed.

1.3 Reference Documentation

For additional information on individual components of the Multi-Layer Welding system, refer to the following documentation that is included with your system –

- Motoman *NX100 ComArc Manual* (P/N 150602-1)
- Motoman *NX100 Start Point Detection Function Manual* (P/N 150601-1)
- Motoman *NX100 Controller Manual* (P/N 149201-1)
- Motoman *NX100 Maintenance Manual* (P/N 150133-1)
- Motoman *NX100 Operator's Manual for Arc Welding* (P/N 149235-1)
- Motoman *NX100 Concurrent I/O Manual* (P/N 149230-1)
- Motoman *NX100 Independent / Coordinated Control Function Manual* (P/N 149648-1)
- Motoman *INFORM User's Manual* (P/N 150078-1)
- Vendor manuals for system components and assemblies not manufactured by Motoman

1.4 Customer Support Information

If you need assistance with any aspect of your system, please contact Motoman Customer Support at the following 24-hour telephone number –

937. 847. 3200

For routine technical inquiries, you can also contact Motoman Customer Support at the following e-mail address –

techsupport@motoman.com

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

Note: Please use e-mail for routine inquiries, only. If you have an urgent or emergency need for service, replacement parts, or information, you must contact Motoman Customer Support at the telephone number shown above.

Please have the following information ready before you call –

• System	Multi-Layer Welding
• Robots	EA1400N, EA1900N, etc.
• Primary Application	Arc Welding
• Controller	NX100
• Software Version	Access this information on the Programming Pendant LCD display screen by accessing MAIN MENU ➡ SYSTEM INFO ➡ VERSION
• Robot Serial Number	Located on robot data plate
• Robot Sales Order Number	Located on NX100 controller data plate

Notes

Chapter 2
Safety

2.1 Introduction

It is the purchaser's responsibility to ensure that all local, county, state, and national codes, regulations, rules, or laws relating to safety and safe operating conditions for each installation are met and followed.

We suggest that you obtain and review a copy of the ANSI/RIA National Safety Standard for Industrial Robots and Robot Systems. This information can be obtained from the Robotic Industries Association by requesting ANSI/RIA R15.06-1999. The address is as follows:

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

Ultimately, the best safeguard is trained personnel. The user is responsible for providing personnel who are adequately trained to operate, program, and maintain the robot cell. THE ROBOT MUST NOT BE OPERATED BY PERSONNEL WHO HAVE NOT BEEN TRAINED!

We recommend that all personnel who intend to operate, program, repair, or use the robot system be trained in an approved Motoman training course and become familiar with the proper operation of the system.

This safety chapter addresses the following –

- Standard Conventions (Section 2.2)
- General Safeguarding Tips (Section 2.3)
- Mechanical Safety Devices (Section 2.4)
- Installation Safety (Section 2.5)
- Programming, Operation, and Maintenance Safety (Section 2.6)

2.2 Standard Conventions

This manual includes the following alerts – in descending order of severity – that are essential to the safety of personnel and equipment. As you read this manual, pay close attention to these alerts to insure safety when installing, operating, programming, and maintaining this equipment.

DANGER!
Information appearing in a DANGER concerns the protection of personnel from the immediate and imminent hazards that, if not avoided, will result in immediate, serious personal injury or loss of life in addition to equipment damage.

WARNING!
Information appearing in a WARNING concerns the protection of personnel and equipment from potential hazards that can result in personal injury or loss of life in addition to equipment damage.

CAUTION!
Information appearing in a CAUTION concerns the protection of personnel and equipment, software, and data from hazards that can result in minor personal injury or equipment damage.

Note: Information appearing in a Note provides additional information which is helpful in understanding the item being explained.

2.3 General Safeguarding Tips

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

- Improper operation can result in personal injury and/or damage to the equipment. Only trained personnel familiar with the operation of this robot, the operator's manuals, the system equipment, and options and accessories should be permitted to operate this robot system.
- Do not enter the robot cell while it is in automatic operation. Programmers must have the teach pendant when they enter the robot cell.
- Improper connections can damage the robot. All connections must be made within the standard voltage and current ratings of the robot I/O (Inputs and Outputs).

- The robot must be placed in Emergency Stop (E-Stop) mode whenever it is not in use.
- In accordance with ANSI/RIA R15.06-1999, section 4.2.5, Sources of Energy, use lockout/tagout procedures during equipment maintenance. Refer also to Section 1910.147 (29CFR, Part 1910), Occupational Safety and Health Standards for General Industry (OSHA).

2.4 Mechanical Safety Devices

The safe operation of the robot, positioner, auxiliary equipment, and system is ultimately the user's responsibility. The conditions under which the equipment will be operated safely should be reviewed by the user. The user must be aware of the various national codes, ANSI/RIA R15.06-1999 safety standards, and other local codes that may pertain to the installation and use of industrial equipment. Additional safety measures for personnel and equipment may be required depending on system installation, operation, and/or location.

The following safety equipment is provided as standard –

- Safety fences and barriers
- Light curtains and/or safety mats
- Door interlocks
- Emergency stop palm buttons located on operator station, robot controller, and programming pendant

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

2.5 Installation Safety

Safe installation is essential for protection of people and equipment. The following suggestions are intended to supplement, but not replace, existing federal, local, and state laws and regulations. Additional safety measures for personnel and equipment may be required depending on system installation, operation, and/or location. Installation tips are as follows –

- Be sure that only qualified personnel familiar with national codes, local codes, and ANSI/RIA R15.06-1999 safety standards are permitted to install the equipment.
- Identify the work envelope of each robot with floor markings, signs, and barriers.
- Position all controllers outside the robot work envelope.
- Whenever possible, install safety fences to protect against unauthorized entry into the work envelope.
- Eliminate areas where personnel might get trapped between a moving robot and other equipment (pinch points).
- Provide sufficient room inside the workcell to permit safe teaching and maintenance procedures.

2.6 Programming, Operation, and Maintenance Safety

All operators, programmers, plant and tooling engineers, maintenance personnel, supervisors, and anyone working near the robot must become familiar with the operation of this equipment. Improper operation can result in personal injury and/or damage to the equipment. Only trained personnel familiar with the operation, manuals, electrical design, and equipment interconnections of this robot should be permitted to program, operate, and maintain the system. All personnel involved with the operation of the equipment must understand potential dangers of operation.

- Inspect the robot and work envelope to be sure no potentially hazardous conditions exist. Be sure the area is clean and free of water, oil, debris, etc.
- Be sure that all safeguards are in place. Check all safety equipment for proper operation. Repair or replace any non-functioning safety equipment immediately.
- Do not enter the robot cell while it is in automatic operation. Be sure that only the person holding the programming pendant enters the workcell.
- Check the E-Stop button on the programming pendant for proper operation before programming. The robot must be placed in Emergency Stop (E-Stop) mode whenever it is not in use.
- Back up all programs and jobs onto suitable media before program changes are made. To avoid loss of information, programs, or jobs, a backup must always be made before any service procedures are done and before any changes are made to options, accessories, or equipment.
- Any modifications to PART 1, System Section, of the robot controller concurrent I/O program can cause severe personal injury or death, as well as damage to the robot! Do not make any modifications to PART 1, System Section. Making any changes without the written permission of Motoman will VOID YOUR WARRANTY!
- Some operations require standard passwords and some require special passwords. Special passwords are for Motoman use only. YOUR WARRANTY WILL BE VOID if you use these special passwords.
- The robot controller allows modifications of PART 2, User Section, of the concurrent I/O program and modifications to controller parameters for maximum robot performance. Great care must be taken when making these modifications. All modifications made to the controller will change the way the robot operates and can cause severe personal injury or death, as well as damage the robot and other parts of the system. Double-check all modifications under every mode of robot operation to ensure that you have not created hazards or dangerous situations.
- Check and test any new or modified program at low speed for at least one full cycle.
- This equipment has multiple sources of electrical supply. Electrical interconnections are made between the controller and other equipment. Disconnect and lockout/tagout all electrical circuits before making any modifications or connections.
- Do not perform any maintenance procedures before reading and understanding the proper procedures in the appropriate manual.
- Use proper replacement parts.
- Improper connections can damage the robot. All connections must be made within the standard voltage and current ratings of the robot I/O (Inputs and Outputs).

Chapter 3

Operation

This chapter provides operating procedures and precautions for the Multi-Layer Welding function. For additional information, refer to specific component manuals that are part of the Multi-Layer Welding Function documentation package (refer to Section 1.3).

The Multi-Layer Welding function is based on Macro Jobs. Touch sense routines and corresponding Shift commands are contained within macro jobs. Positions are recorded in the Detail Edit screen for the various macros, and ‘Reference Points' used to record master part locations are automatically defined by the macro jobs. The macro job is called from the weld job, and touch sensing and shifting are accomplished with minimal teaching, setup, and touch-up. Additional macro jobs accomplish such tasks as: position shifting, torch rotation, vector calculations, gap measurements, and others.

Comarc memory is added so that only the first pass of a multi-pass procedure needs to be seam tracked.

New system variables have been defined to increase the flexibility and functionality of the Inform programming language. Also, new commands are available to allow greater adaptability of welding related functions to part variations. For instance, adjustment of welding conditions during welding, has been augmented (using the Condition Adjust Screen) to include the following process variables: current (wire feed speed), voltage, velocity (travel speed), weave amplitude, Comarc U/D and L/R conditions. A series of S3C parameters control the sensitivity of these real-time adjustments.

Finally, the new robot position variable (Point variable) allows for quick programming and shifting for multi-pass welds. The Point variable and is denoted in a MOV instruction as Txxx.

3.1 Coordinate Systems

3.1.1 Switching Euler Coordinates ON/OFF in Teach mode

Parameter S2C618 is used to set the coordinate system used by World Coordinates when Jogging the robot in Teach mode. This parameter can be set as follows:

0=Euler Coordinates (A, B, C rotations)

1=Traditional Coordinates (Rx, Ry, Rz rotation).

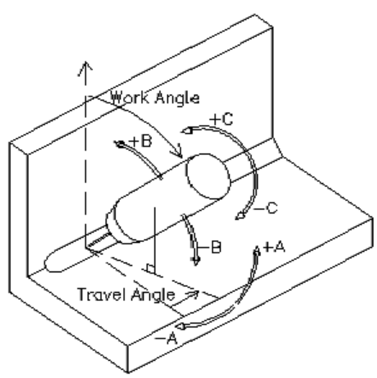
3.1.2 Robot and Base Frame Coordinates

The Robot Frame and Base Frame coordinate systems use the A,B, and C rotation directions as described below:

A: The A rotation directions adjust the welding travel angle of the torch (very similar to the Rz direction of the standard World Coordinate system). +A produces a counter-clockwise rotation (when viewing from above) and -A produces a clockwise rotation.

B: The B rotation directions adjust the welding work angle of the torch. For horizontal position welding, a work angle of 40 to 50 degrees is often used. The +B direction can be used to increase (makes more vertical) the work angle, while the -B direction decreases (makes more horizontal) the work angle. It is important to understand that the +B direction initially rotates the torch towards the upper leg (to a more vertical orientation).

C: The C rotation directions are analogous to the Rz direction of the standard tool coordinate system. The travel and work angles remain fixed as the torch is rotated in C.



3.1.3 Tool Frame Coordinates

Tool Frame orientation is based on the posture and orientation of the welding torch. With this reference frame, as the torch position is rotated, so is the X and Y Tool Frame directions. Description of the Tool Frame is listed below.

X: This direction (the direction vector) is always parallel to the World Coordinates X-Y Plane (it is always parallel to the ground). The +X direction points in the direction that the torch is pointing. This direction vector can be visualized as the direction that the shadow of the torch is pointing, if a light source is placed directly above the torch. As the torch is rotated about a vertical axis (e.g. the Z axis) the X direction is changed accordingly.

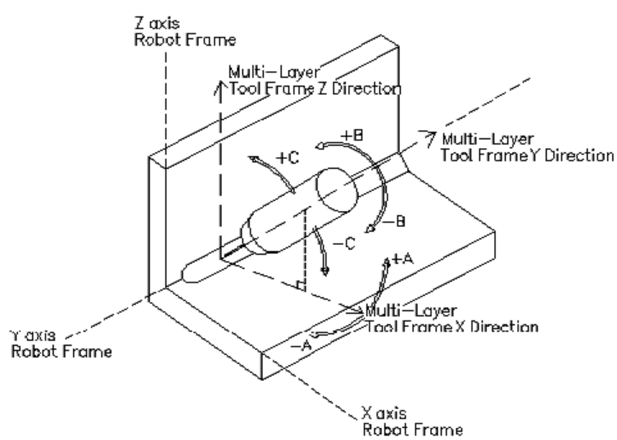
Y: This direction is coaxial with Z-direction in the standard Tool Coordinates. The +Y direction increases the contact tip-to-work distance (increases the 'stick-out').

Z: This is the same direction as the Z direction of the World Coordinate system. This direction is always perpendicular to the X-Y World Coordinates plane.

A: The A rotation directions are the same as the A direction of World Coordinates - this affects the travel angle of the welding torch

B: The B rotation directions are same as the C direction of World Coordinates - this does not affect either the work or travel angles

C: The C rotation directions are the same as the B direction of World Coordinates - this affects the work angle of the welding torch



3.1.4 Euler Angles

The optimum robot posture for welding is controlled by Euler angles. This differs from robot control in ordinary coordinate systems as described below.

The Euler angles in the base coordinate system are as follows:

A: The angle between the X-axis and the Z-axis of the tool coordinate system as projected on the X-Y plane of the base coordinate system $(-180^\circ < A \leq 180^\circ)$

B: The angle between the Z-axis of the tool coordinate system and the X-Y plane of the base coordinate system $(-90^\circ < B \leq 90^\circ)$

C: The angle to move X- and W-axis of the tool coordinate system on X- and Y-axis where X, Y, and Z, are the axes in such coordinate system as Z-axis of the base coordinate system is moved on Z-axis of the tool coordinate system by rotating the base coordinate system around Z-axis and then around Y-axis $(-180^\circ < C \leq 180^\circ)$:

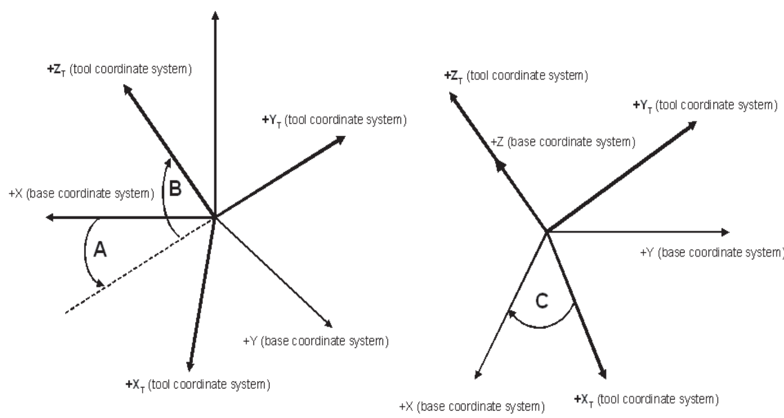


Figure 1 Euler Angles

3.1.5 Cartesian Coordinate System

When the Cartesian coordinate system is selected, pressing the X, Y, or Z keys moves the tool parallel to the X, Y, or Z axis in the base coordinate system. Accordingly, pressing an axis key changes the tool posture without changing the position of the tool center point as shown in Fig. 2.

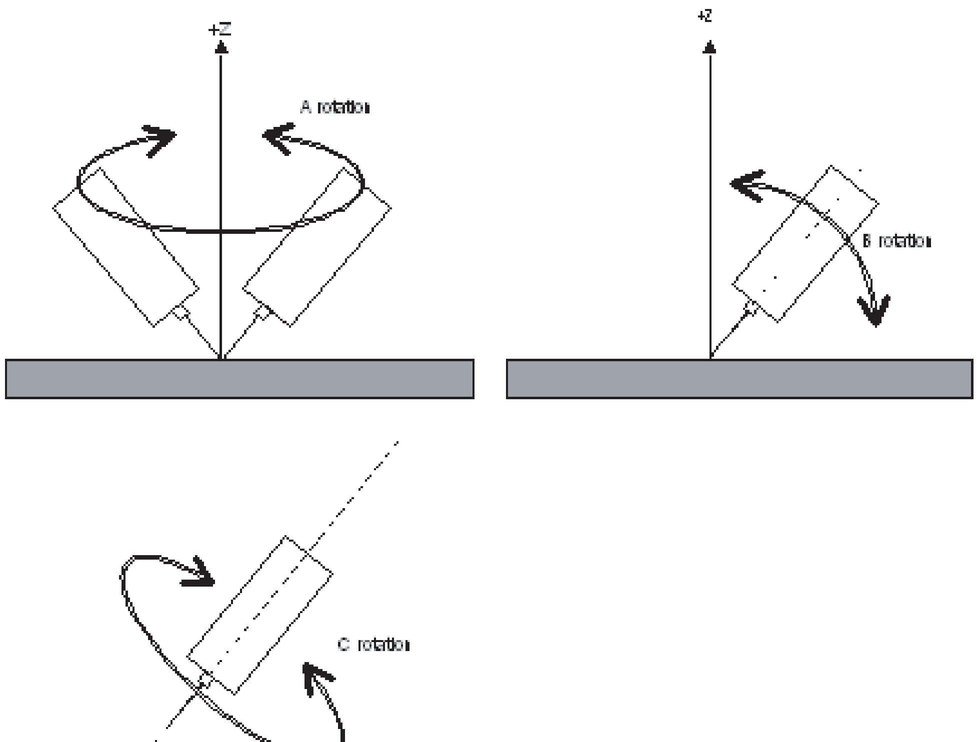


Figure 2 Jog Motion in Posture Control

A: Rotates around the Z-axis in the base coordinate system

B: Rotates the tool in horizontal and vertical motion to the X-Y plane

C: Rotates around the tool axis

3.1.6 Tool coordinate system

When the tool coordinate system is selected, the robot moves as shown in Fig. 3. The posture is changed in the same way as in the Cartesian coordinate system.

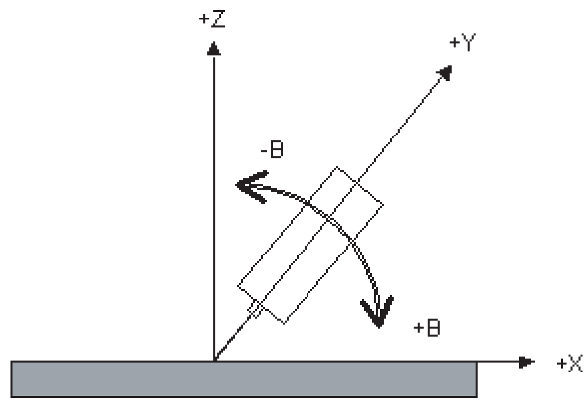


Figure 3 Jog Motion in Tool Coordinate System

3.2 Multi-layer Welding Tool Shift Function

For multi-layer welding, teaching the welding path on the 1st layer and shifting the taught positions to weld on the second and following layers can greatly reduce the time required for teaching.

3.2.1 Tool Shift Coordinate System

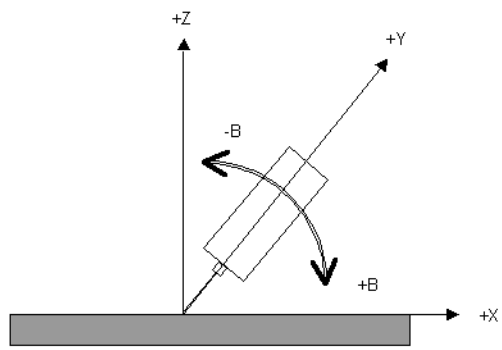
The coordinates for the multi-layer welding tool shift function are determined by the positional relation between the robot coordinate and the tool coordinate.

Multi-layer welding tool shift coordinate X: Z-axis of the tool coordinate projected on X-Y plane of the robot coordinate system

Multi-layer welding tool shift coordinate Y: Direction to Z-axis of the tool coordinate

Multi-layer welding tool shift coordinate Z: Direction to Z-axis of the robot coordinate

Multi-layer welding tool shift coordinate B: Posture angle from X-axis of the multi-layer welding tool shift coordinate in the direction to Z-axis



When using posture angle setting with the multi-layer tool shift function, the multi-layer tool shift coordinates A and C can not be set.

3.2.2 Registering ToolShift

Specifying the TF tag in the SFTON (shift ON) instruction, shifts the taught positions for the move instructions by the amount set in the position variable (P***) in the multi-layer tool shift coordinate system.

Instruction: SFTON
Format: SFTON P000 TF

3.3 Point Variables

Point variables store and manage taught position data in the robot jobs. The point variables can be used to move the robot to the same position multiple times in one job. Registering taught position data to a point variable reduces the time required for teaching within the job.

Differences between Point variables and Position variables (P***)

- Position variables can be read or written from/to all jobs while the Point variables can only be used in the job where they are registered. Therefore, identical numbers can be used for Point variables in other jobs.
- Both position data and Shift amount can be stored in a Position variable. However, only position data can be stored in Point variables.
- 128 position variables are available as standard (can be expanded to 5,000). A Point variable is created when a Move instruction is registered in the job The Point variable number can be set arbitrarily in the range from 0 to 9999.
- By using the instructions SET and SETE, a position can be registered to a Position variable. However, these instructions can not be used to register a position to a Point variable.
- Position variables can not be deleted (they can be left without position data). Point variables are deleted when the job where they are registered is deleted.

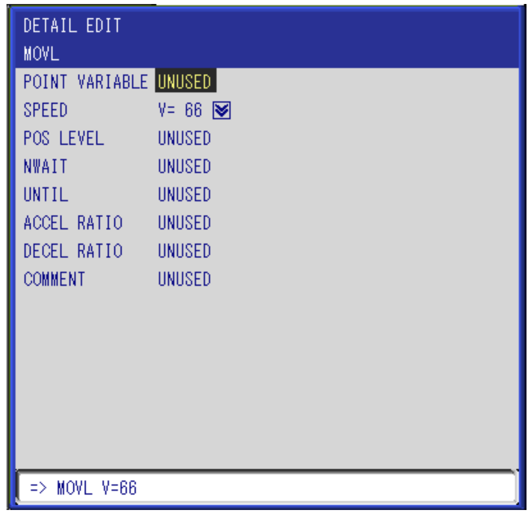
Point Variables are robot position variables used for multi-pass welding. These variables can be defined in one part of the job and then recalled in other portions of the job. For example, point variable T101 can be set as the start of weld pass 1 (step 4:MOVJ V=25.0 T101). It can then be recalled at the start of weld pass number 3 (step 10:MOVJ VJ=25.0 T101) and shifted to produce the required overlap. The point variable can only be re-used in the job that originally defined it. In this way, the point variable is similar to a local P variable.

The convenience of the Point Variable is that only the first weld pass needs to be programmed. Additional weld paths can use the same Point Variables used in the first weld pass, and the SFTON command can be used to shift the Point Variable the required amount.

3.3.1 Registering Point Variables

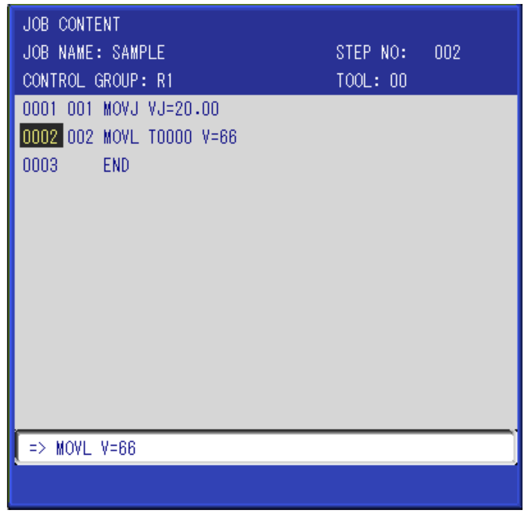
To replace the position data of a move instruction with a Point variable, proceed as follows:

1. Move the cursor to the instruction area, and press [SELECT] twice on the desired move instruction. The detail edit screen for the move instruction appears.
2. Select “UNUSED” for “POINT VARIABLE,” and select “T”.



3. Press [SELECT], and enter a Point variable number. The entered Point variable number (T0000) appears in the input buffer line.
4. Press [ENTER].

5. Press [ENTER] again. The contents are registered in the job. If another Point variable with the same number has already been used in the same job, the previously used Point variable is registered, even if no taught position data is specified in the Point variable. The newly created and numbered Point variable has no taught position data regardless of SERVO ON/OFF status.



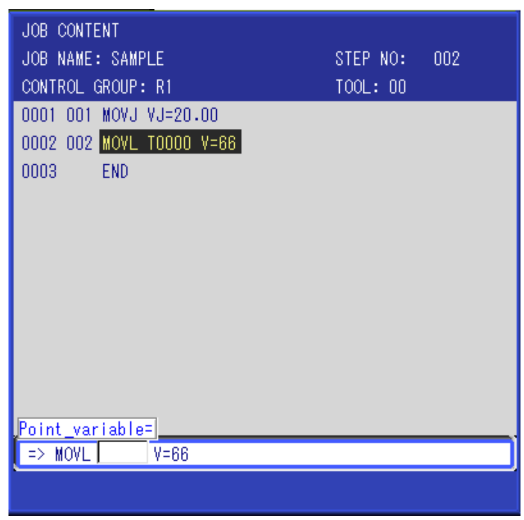
Note: When a Point variable with no taught position data specified is registered, "" is indicated for the TOOL number in the job content display.*

Note: The job in which the point variable with no taught position data specified is registered can not be loaded/saved by FC2 (same as Position variables).

3.3.2 Changing the Number of the Point Variable

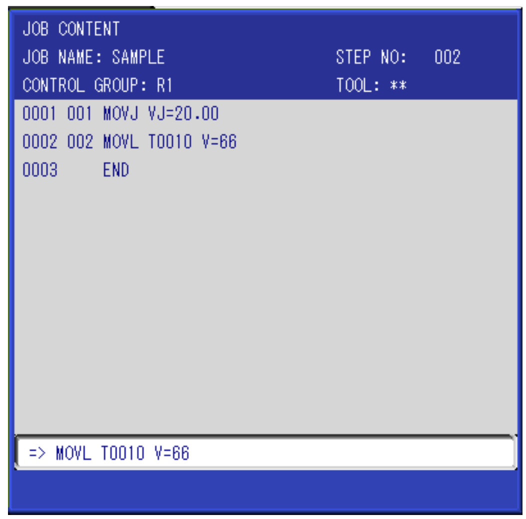
There are two ways to change the number of a point variable.

1. Cursor to the instruction area, and press [SELECT] on the desired move instruction.
2. Cursor to the point variable whose number you wish to change, and press [SELECT].



3. Press [SELECT], and enter a Point variable number. The entered point variable number (e.g.T0011) appears in the input buffer line.
4. Press [ENTER].

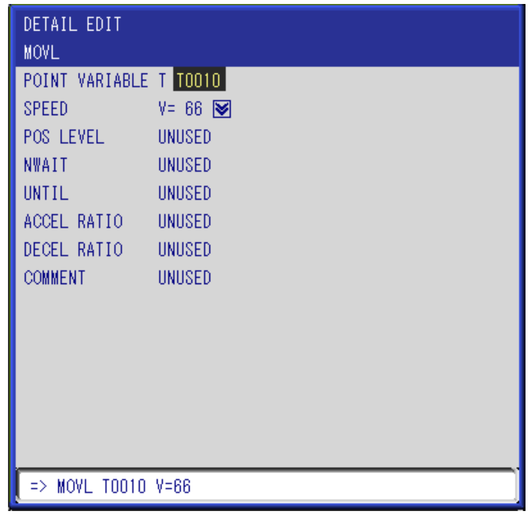
5. Enter a Point variable number and press [ENTER]. The entered contents are registered in the job. If another Point variable with the same number has already been used in the same job, the previously used Point variable is registered, even if no taught position data is specified in the Point variable. Newly created and numbered Point variables have no taught position data regardless of SERVO ON/OFF status.



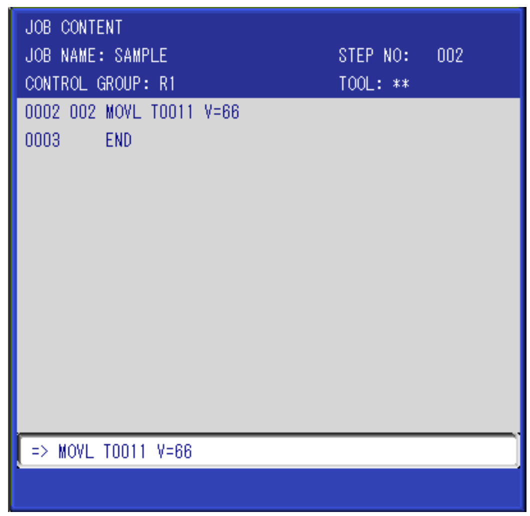
Note: When a Point variable with no taught position data specified is registered, "" is displayed for the TOOL number on the JOB CONTENT screen.*

Note: The job in which the Point variable with no taught position data specified is registered can not be loaded/saved by FC2 (same as for the position variables).

1. Move the cursor to the instruction area, and press [SELECT] twice on the desired Move instruction]. The Detail Edit display for the Move instruction appears.
2. Enter a Point variable number.
3. Press [ENTER]. The entered Point variable number (e.g. T0011) appears in the input buffer line.



4. Press [ENTER]. The Point variable number is registered in the job. If another Point variable with the same number has already been used in the same job, the previously used Point variable is registered, even if no taught position data is specified in the Point variable. The newly created and numbered Point variable has no taught position data regardless of SERVO ON/OFF status.



Note: When a point variable with no taught position data specified is registered, "" is indicated for the TOOL number in the job content display.*

Note: The job in which the point variable with no taught position data specified is registered can not be loaded/saved by FC2 (same as for the position variables).

3.3.3 Registering a Move Instruction Together with a Point Variable

To register a Move instruction with a Point variable, proceed as follows:

1. Press [MOTION TYPE] to select the desired Move instruction. The entered contents are registered in the job. If another Point variable with the same number has already been used in the same job, the previously used point variable is registered, even if no taught position data is specified in the point variable. The newly created and numbered point variable has no taught position data regardless of SERVO ON/OFF status.

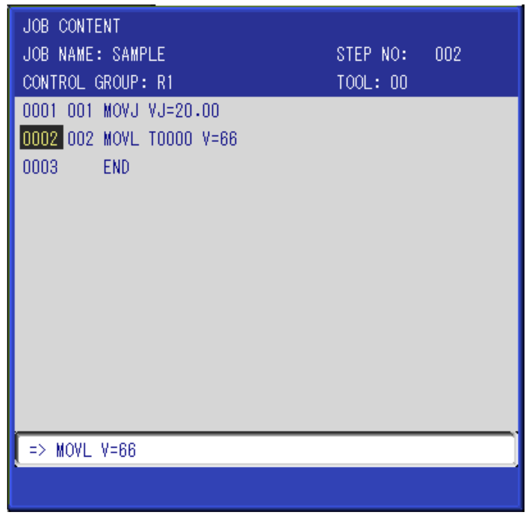
Note: When a point variable with no taught position data specified is registered, "" is indicated for the TOOL number in the job content display.*

Note: The job in which the point variable with no taught position data specified is registered can not be loaded/saved by FC2 (same as for the position variables).

3.3.4 Deleting a Point Variable

Deleting a Move Instruction

1. Cursor to the line number of the Move instruction to be deleted.



2. Press [DELETE] and [ENTER].

Note: If a deleted point variable is not used in other Move instructions in the same job, it is registered as unused, but retains the taught position data. However, point variables in unused status are deleted when another job is selected. Move instructions with point variables having no taught position data are also deleted.

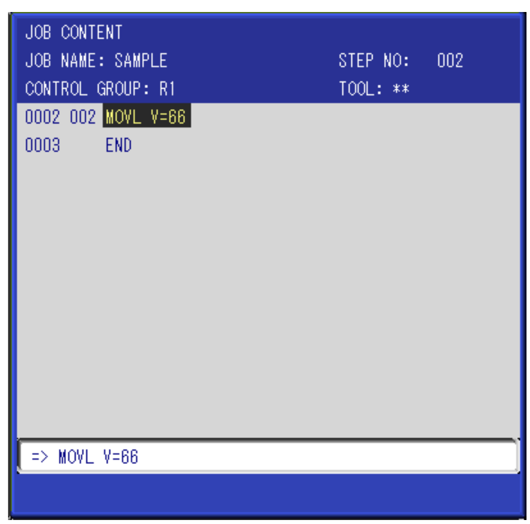
Deleting the Point variable designation

1. Cursor to the instruction area, and press [SELECT] twice on the desired Move instruction. The Detail Edit screen appears.

2. Select the point variable (e.g. T0010) to be deleted, and select “UNUSED” for “POS LEVEL,” “NWAIT,” and “UNTIL”.

3. Press [ENTER]. The modified contents appear in the input buffer line.

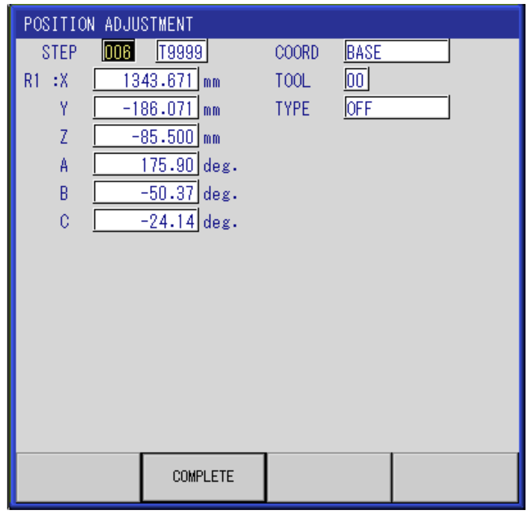
4. Press [ENTER]. The modification is registered in the job. The taught position data for the deleted Point variable is reregistered.



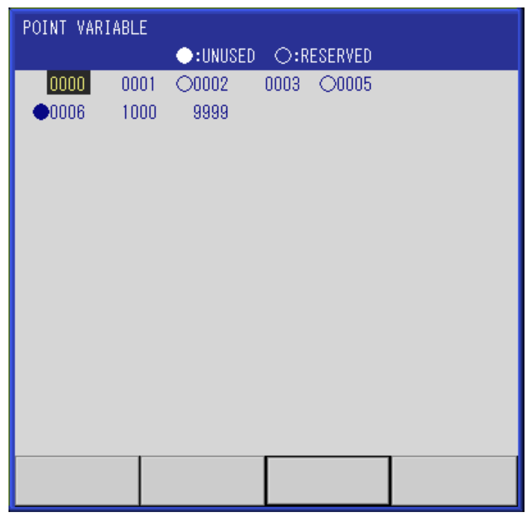
3.3.5 Editing the Point Variable (Taught Position Data)

Taught position data can be edited by entering a numerical value.

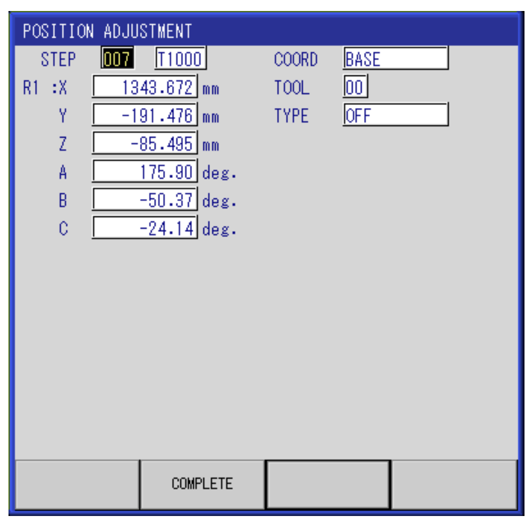
1. In JOB CONTENT display, select [POSITION ADJUSTMENT] from the [UTILITY] pull-down menu*. The position adjustment display appears.



2. Select an item to be changed in the position adjustment display. Selecting the point variable displays the list of Point variables. Select a Point variable whose position data is to be corrected.



3. Enter a numeric value, and press [ENTER].[
4. Select “COMPLETE”.



3.4 ComArc Path Memory and Playback Function

The ComArc path memory and playback function is used to correct the robot motion path by the amount measured by the ComArc sensor. The Comarc sampling frequency is set in the SxE parameters. The ComArc sensor measures and saves the correction amount during welding of the first layer. This correction amount is then used adjust the second and following layers for the correct robot motion path.

The corrected path can be reproduced in the reverse direction of the first layer, for welding of the second and following layers.

Note: The COMARC function and expanded memory is required to use the memory and playback function.

3.4.1 Instructions for Memory and Playback Function

Memory and playback function instructions are listed below:

Sensor Instructions				
MENON	Function	Starts the memory and playback function.		
	Instruction Item	Data 1	REC	Saves the path correction amount measured by COMARC.
			PLY	Executes the corrected path in the forward direction.
			BACKPLY	Executes the corrected path in the reverse direction.
		Data 2	MPF# (File Number)	1 to 50
MEMOF	Function	Cancels the memory and playback function.		
	Instruction Item	None		
Arithmetic Instructions				
CLEAR	Function	Deletes playback file.		
	Instruction Item	MPF		Deletes all the memory and playback files.

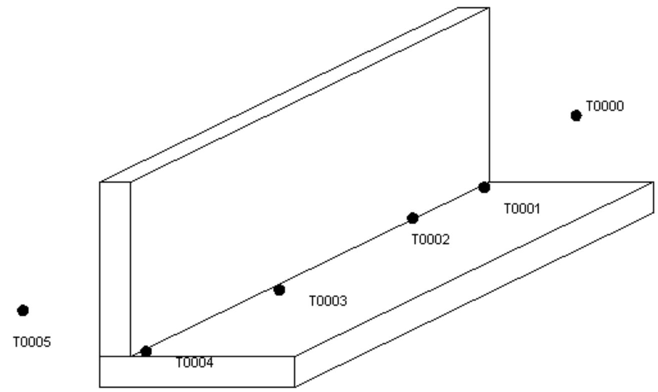
Sample Job

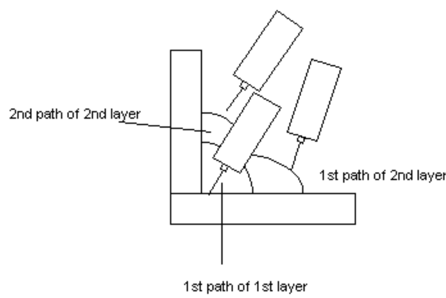
This sample job creates a welding job with two layers and three paths alternating directions.

Turn ON ComArc arc sense function during the first weld layer. Weld the first path of the second layer in the reverse direction of the first path. Then, weld the second path of the second layer in the same direction as the first layer.

NOP	
MOVJ VJ=100	Stand-by point
MOVJ VJ=60	Moves the robot to the approach position.
MOVL T0000 V=200	Welding start position T0000
ARCON AC=330 AV=30 V=40	
COMARCON AMP=1.0 FREQ=3.5••	Starts the ComArc arc sensor.
MEMON REC MPF#(1)	Starts saving operation for memory and playback function.
MOVL T0001	
MOVL T0002	
MOVL T0003	
MOVL T0004	
MEMOF	Stops memory and playback function.
COMARCOF	Stops arc sensor.
ARCOF AC=200 AV=25 T=0.1	End of welding on 1st layer
GETS PX000 $PX040	Get correction amount measured by COMARC function.
SFTON P000 BF	Shift for correction amount.
'2Layer 1Path	(Welding on 1st path of 2nd layer)
MOVL T0005	Moves robot to 2nd layer approach position.
SFTON P001 TF	Shifts welding start position for 1st path of 2nd layer.
MOVL T0004 V=200	
ARCON AC=250 AV=28 V=40	
MEMON BACKPLY MPF#(1)	Starts reproduction of welding on 1st layer in reverse direction.

MOVL T0003	
MOVL T0002	
MOVL T0001	
MOVL T0000	
MEMOF	
ARCOF AC=180 AV=20 T=0.1	
SFTOF	Cancel shift function.
'2Layer 2path	(Welding on 2nd path of 2nd layer)
MOVL V=200	Move robot to approach position for 2nd layer.
SFTON P002 TF	Shift welding start position for 2nd path of 2nd layer.
MOVL T0000 V=200	
ARCON AC=200 AV=25 T=0.1	
MEMON PLY MPF#(1)	Start the reproduction of welding on 1st layer in forward direction.
MOVL T0001	
MOVL T0002	
MOVL T0003	
MOVL T0004	
MEMOF	Cancel memory replay function.
ARCOF AC=180 AV=20 T=0.1	
MOVL T0005	
MOVJ VJ=100	

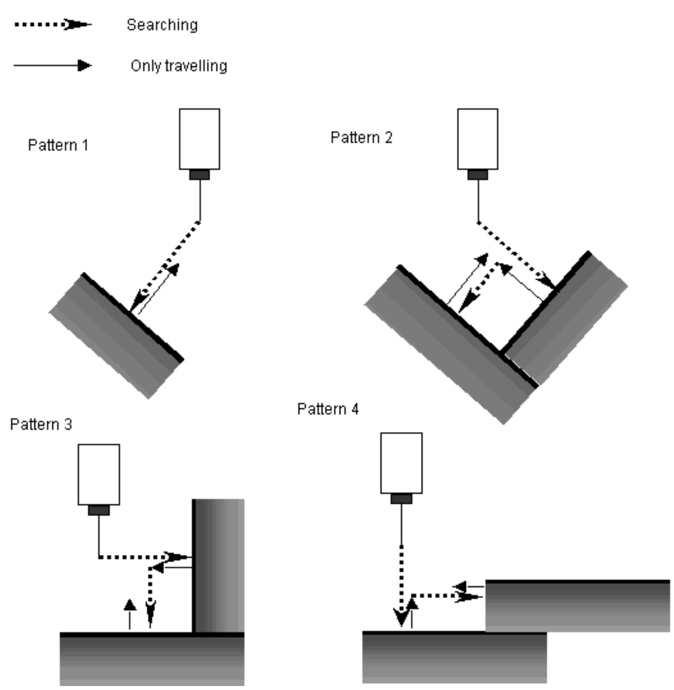

T0000
T0001
T0002
T0003
T0004
T0005


2nd path of 2nd layer
1st path of 2nd layer
1st path of 1st layer

3.5 Search and Shift Function

The search and shift function detects workpiece position error using the Touch Sense and Shift functions to search and correct the taught position.

The SRSFT instruction starts searching from a point where the tool end is not in contact with the workpiece and stops searching when the tool end contacts the workpiece. The four search motion patterns are shown below:

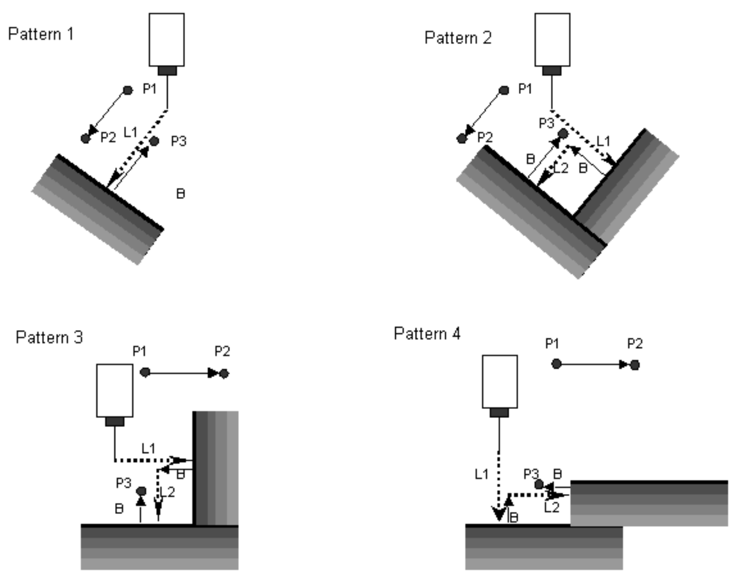


3.5.1 Items to be Set for SRSFT Instruction

Set the following items for SRSFT instruction.

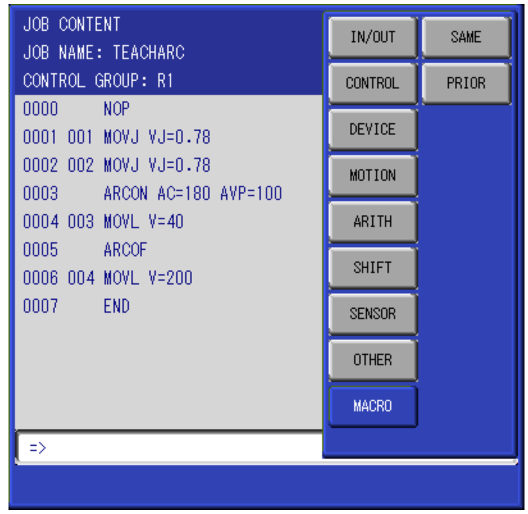
Item	Contents
PATTERN	Search motion pattern (The numbers correspond to the patterns shown below) 1 = one touch 2 = center of groove 3 = two touch: first touch is to the upper leg, the second is to the lower leg 4 = two touch: first touch is to the lower leg, the second is to the upper leg
SHIFT	0 = no shift 1 = parallel shift 2 = shift in rotation

Item	Contents
VELOCITY	Touch Sense search speed in units of cm/min.
DIR_START (P1)	Position P1 in the figure below
DIR_END (P2)	Position P2 in the figure below
OFFSET 1 (L1)	Search distance for first touch - L1 in the figure below (in units of mm)
OFFSET 2 (L2)	Search distance for second touch - L2 in the figure below (in units of mm)
RETRACT AMOUNT	The distance B in the figure below (in units of mm)
MAX. SEARCH DISTANCE	An alarm occurs if search is not ended within the set travel distance.
END_POINT (P3)	The search end position (position P3 in the figure below)

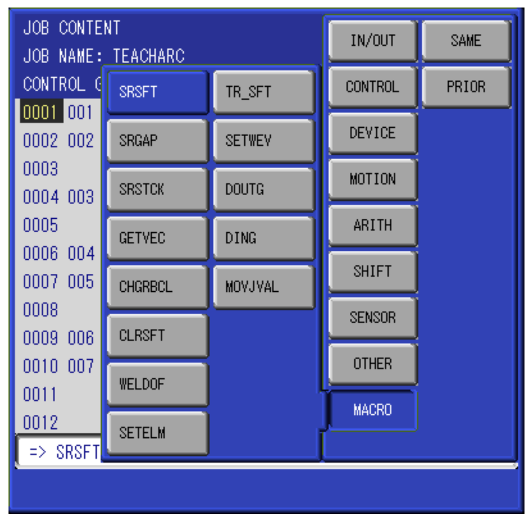


3.5.2 Registering Shift Function

1. Move the cursor to the address area.
2. Press [INFORM LIST].



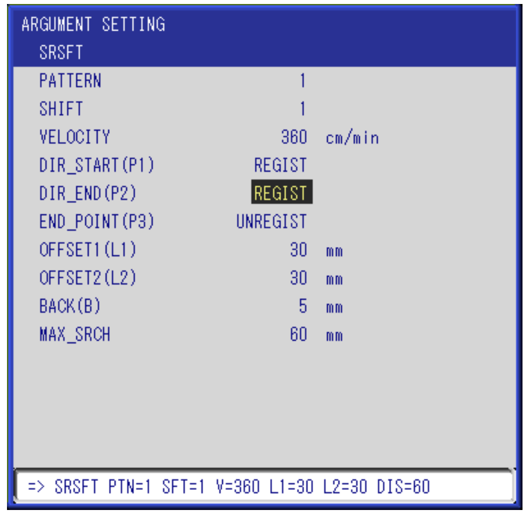
3. Select “MACRO”. The macro instruction list appears.
4. Select on the SRSFT Macro Instruction and then press [INSERT]>[ENTER] to place the instruction into the robot job.



5. Cursor to the instruction side of the robot job and press [SELECT] > [SELECT] on the SRSFT macro instruction. The argument setting display for SRSFT instruction appears.
6. Move the manipulator to the travel start point (P1), and press [MODIFY] with the cursor on “UNREGIST” of P1, then press [ENTER] to register the position of P1.

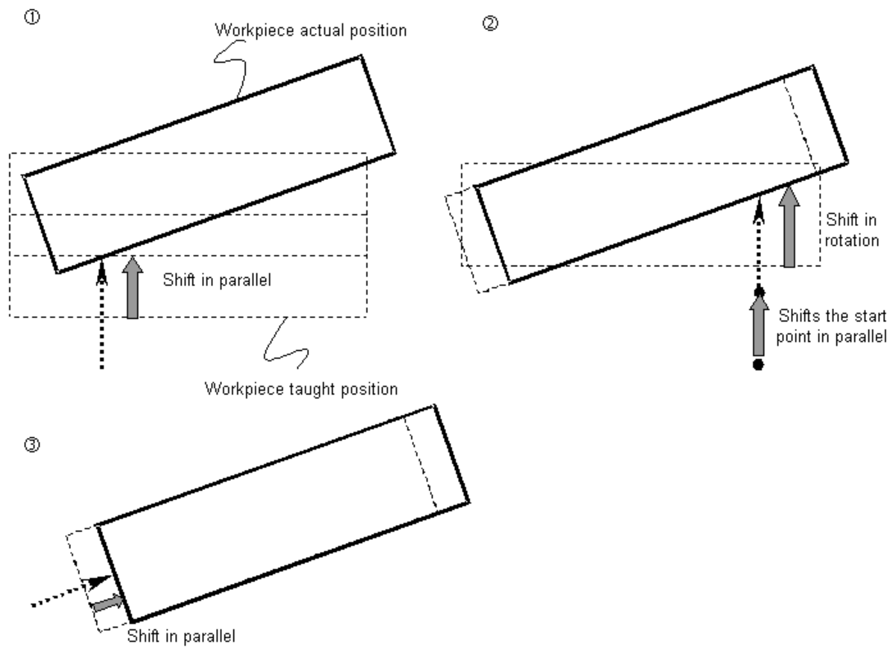
Note: While viewing the Argument Setting screen you can forward to a REGISTERED position by placing the cursor on the REGISTERED line and then pressing INT LOCK + FWD

7. Move the manipulator to the travel end point (P2), and press [MODIFY] with the cursor on “UNREGIST” of P2, then press [ENTER] to register the position of P2.
8. Press and hold the TEST START key. The manipulator begins moving, searching for the location of the DIR_START(P1) Registered position. When the robot finally stops, cursor to DIR_START(P1) and again press MODIFY > ENTER.
9. Press [ENTER] twice to return to the job content display.



Sample SRSFT Job

SFTOF3D	Cancels 3-dimensional shift.
MOVJ VJ=60	
SRSFT PTN=3 SFT=1 V=360••	Searches for 1st point (Shift in parallel). ①
MOVJ VJ=60	
SRSFT PTN=3 SFT=2 V=360••	Searches for 2nd point (Shift in rotation). ②
MOVJ VJ=60	
SRSFT PTN=1 SFT=1 V=360••	Searches for 3rd point (Shift in parallel). ③
MOVJ VJ=60	
MOVL V=200	Moves to the welding start point.

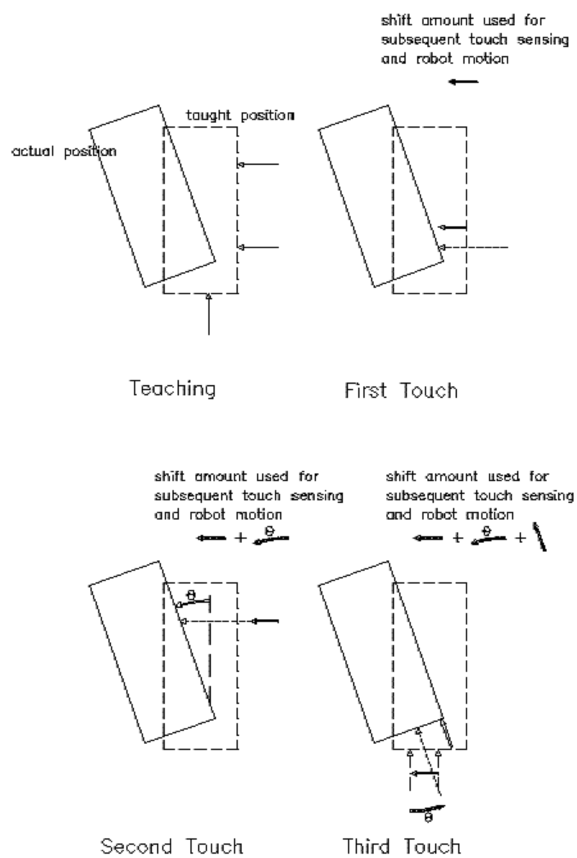


3.5.3 3D Touch

3D touch (3D shifting) is used to account for part rotation as well as part translation variations. The sequence requires at least two (2) separate touch sense routines to be executed (e.g. SRSFT > MOV > SRSFT). The first touch routine must be based on a parallel shift (SFT=1) and is used to define a parallel (translational) shift amount as well as the origin for the second, rotation shift. The second shift is based on a rotation shift (SFT=2) and uses the previous parallel shift as the origin for rotation.

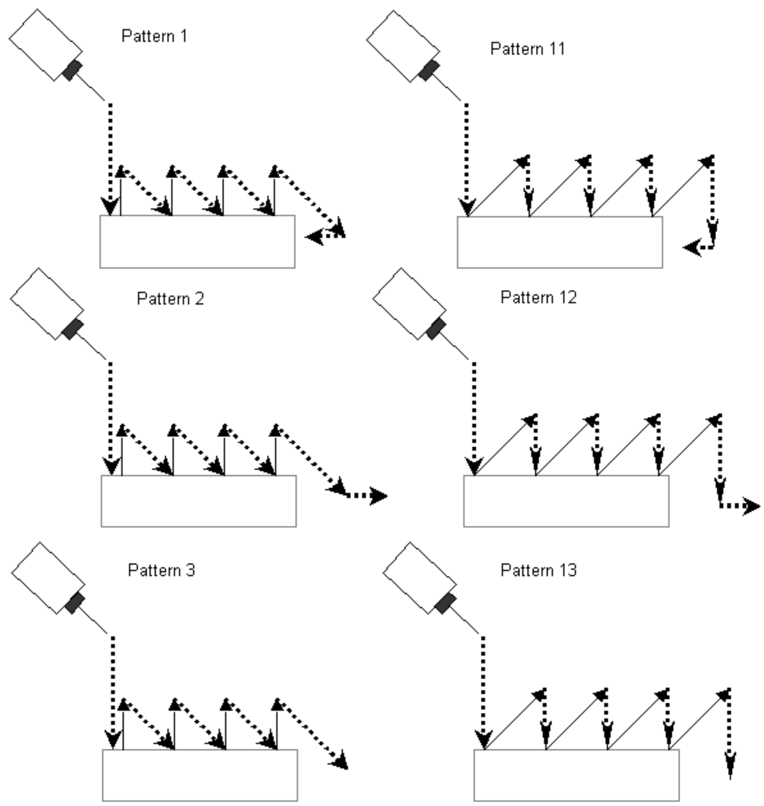
The three touch sensing Macro Jobs (SRSFT, SRGAP, and SRSTCK) automatically execute a 3D Shift (which can be parallel, rotation, or both) after their touch sense routines are complete.

SFTOF 3D	Cancels any 3D shifting
MOVJ VJ=100.0	
SRSFT PTN=1 SFT=1 …	First Touch - translational
MOVJ VJ=100.0	
SRSFT PTN=1 SFT=2 …	Second Touch - rotational
MOVJ VJ=100.0	
SRSFT PTN=1 SFT=1 …	Third Touch - translational
MOVJ VJ=100.0	
MOVJ VJ=22.0	Welding start point
ARCON ASF#(4)	


shift amount used for
subsequent touch sensing
and robot motion
taught position
actual position
Teaching
First Touch
shift amount used for
subsequent touch sensing
and robot motion
shift amount used for
subsequent touch sensing
and robot motion
Second Touch
Third Touch

3.6 Search Function for Sticking (SRSTCK)

The search function for sticking detects the edge face of the workpiece. There are 6 searching patterns. After the robot touches (touch sensing) the face the robot moves a pre-defined amount toward the edge and touches again. It repeats this cycle until if finds the end of the face.

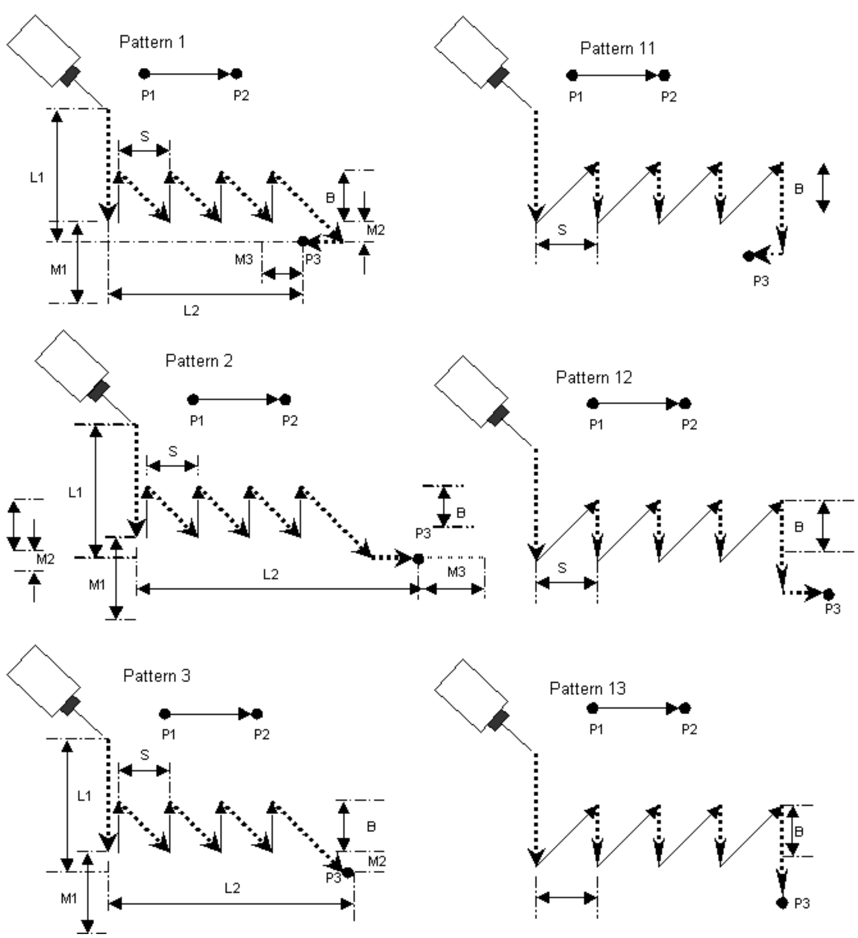


3.6.1 Items to be Set for SRSTCK Instruction

Set the following items for SRSTCK instruction:

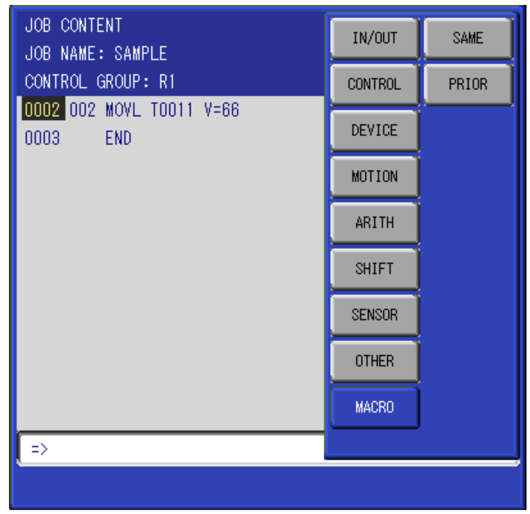
Item	Contents
PATTERN	Search pattern (See the patterns below)
SHIFT	Shift type 0 (no shift), 1 (shift in parallel), 2 (shift in rotation)
VELOCITY	Search speed in units of cm/min.
DIR_START (P1)	Position P1 in the figure below
DIR_END (P3)	Position P2 in the figure below

Item	**Contents**
OFFSET 1 (L1)	The distance L1 in the figure below (in units of mm)
OFFSET 2 (L2)	The distance L2 in the figure below (in units of mm)
RETRACT AMOUNT (B)	The retract distance after the search
INITIAL MAX. SEARCH DISTANCE (M1)	The distance M1 in the figure below (in units of mm)
STICK FEED (S)	The feed pitch S in the figure below (in units of mm)
MAX SEARCH DISTANCE	The maximum distance for searching (in units of mm)
EDGE DETECTING DISTANCE (M2)	If nothing is detected within this distance, the end of this distance is considered as the edge (in units of mm).
EDGE SEARCH SPEED	Final searching speed in units of cm/min.
EDGE SEARCH OFFSET (M3)	The distance M3 in the figure below (in units of mm)
END_POINT (P3)	Search end position

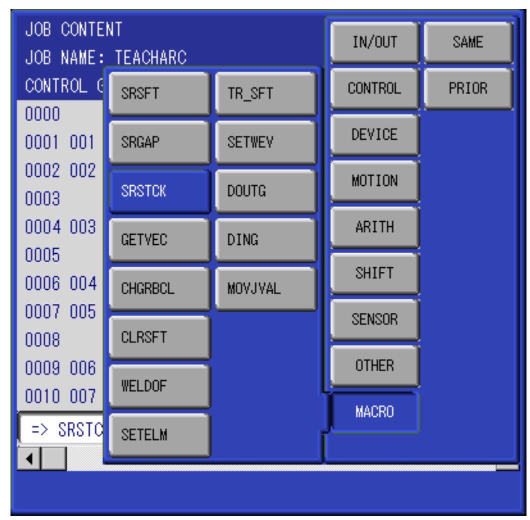


3.7 Registering

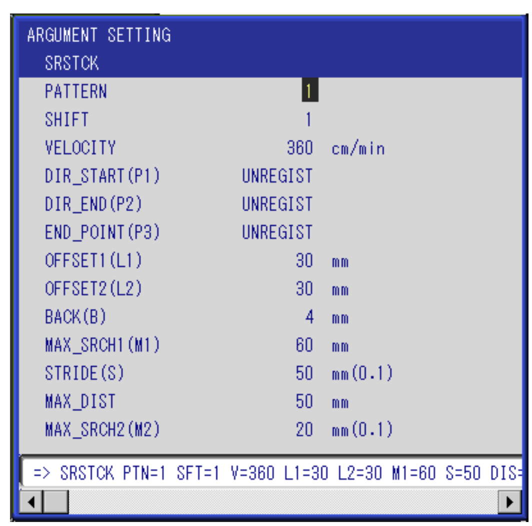
1. Move the cursor to the address area.
2. Press [INFORM LIST].



3. Select “MACRO”. The macro instruction list appears.
4. Select on the SRSTCK Macro Instruction and then press [INSERT]>[ENTER] to place the instruction into the robot job.

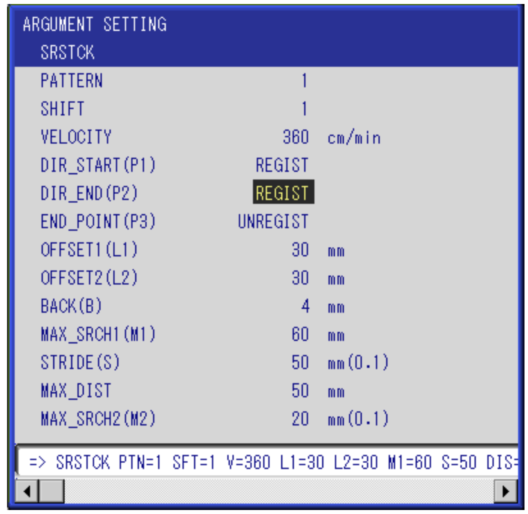


5. Cursor to the instruction side of the robot job and press SELECT> SELECT on the SRSTCK macro instruction. The argument setting display for SRSTCK instruction appears.



6. Move the manipulator to the travel start point (P1). With the cursor on “UNREGIST” of P1, press [MODIFY].

7. Press [ENTER] to register the position of P1.



Note: While viewing the Argument Setting screen you can forward to a REGISTERED position by placing the cursor on the REGISTERED line and then pressing INT LOCK + FWD

8. Move the manipulator to the travel end point (P2). With the cursor on “UNREGIST” of P2, press [MODIFY].

9. Press [ENTER] to register the position of P2.

10. Press [ENTER] twice to return to the job content display.

11. From the job content display, press [INTERLOCK] + [TEST START] to execute the SRSTCK instruction. The manipulator starts searching and stops. Register the manipulator stop position for END_POINT (P3) in the argument setting display.

3.8 Shift Function

The shift function shifts each registered job position between the SFTON and SFTOF instructions.

You must specify a coordinate system for the shift amount, in the SFTON instruction. The following coordinate systems can be specified:

BF - Base Frame

RF - Robot Frame

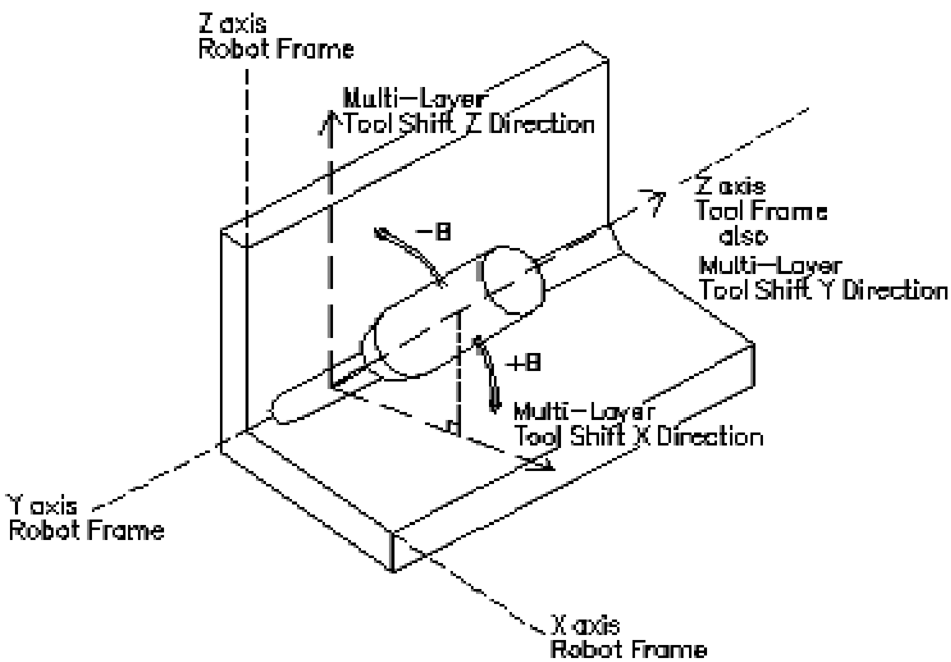
TF - Tool Frame

UF - User Frame

BP - Travelling Axis

EX - External Axis (station axis)

TF: The TOOL SHIFT reference frame is designed for shifting welds made in the horizontal position. The Tool Shift reference frame is different from that of the Tool Frame. The Tool Shift (TF) X direction is derived from the projection of the Tool Frame Z axis onto the robot frame X-Y plane.



Several SFTON instructions can be used to provide simultaneous shifting in multiple reference frames. When two SFTON instructions with different coordinate systems are executed consecutively, the positions are shifted for the specified two shift amounts. If two SFTON instructions with the same reference frame are executed consecutively, only the last SFTON instruction is executed.

Example:

```
SFTON  P000  BF   (100.000 mm to X direction is specified in P000)
SFTON  P001  RF   (100.000 mm to Y direction is specified in P001)
MOVL  V=100       (Shifts the position for 100.000 mm to X direction in
                  the base coordinate system, and for 100.000 mm to Y
                  direction in the robot coordinate system.)
```

When two SFTON instructions with the same coordinate system specified are executed, only the last STFON instruction is valid.

Example:

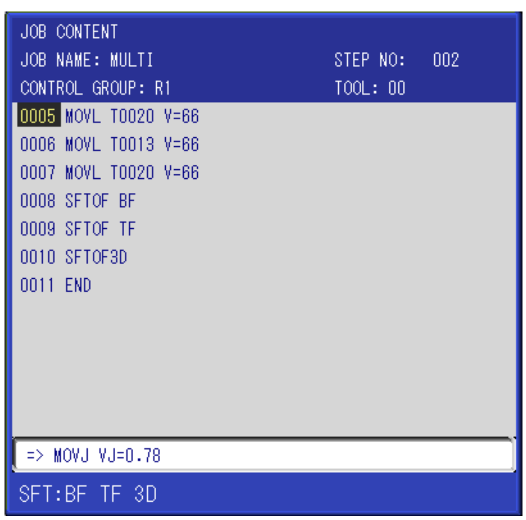
```
SFTON  P000  BF   (100.000 mm to X direction is specified in P000.)
SFTON  P001  BF   (100.000 mm to Y direction is specified in P001.)
MOVL  V=100       (Shifts the positions for 100.000 mm to Y direction in
                  the base coordinate system.)
```

The SFTOF instruction can specify a specific coordinate system you want the shift function disabled. When a coordinate system is not specified, the shift function for all coordinate systems is cancelled.

3.8.1 Continuity of Shift Function

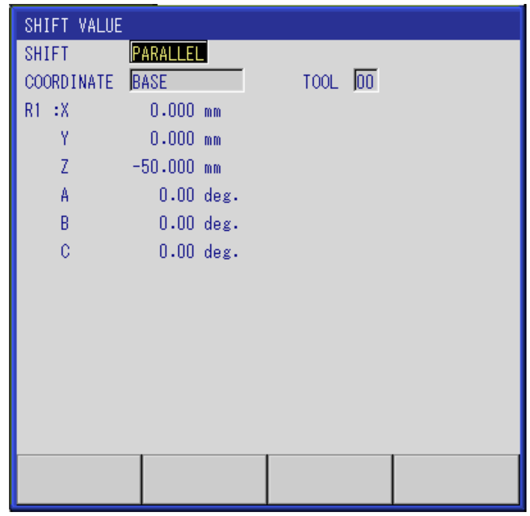
A SFT XX message appears at the bottom of the teach pendant screen when a Shift Command (SFTON or SFTON3D) is executed. While this message is displayed, all robot motion is shifted, in teach or play. The shift function is cancelled using the SFTOF instruction or selecting another job. Position data that is added or modified while the Shift function is active, is recorded minus the shift amount. The newly taught position data can be corrected during the welding of the 2nd and following layers. Because of this feature, the master part is not needed for touch-up. The SFT XX message appearing at the bottom of the teach pendant screen refers to the coordinate being used for shifting (e.g. TF, BF, 3D). The robot continues to shift all points until a SFTOF command is executed, or when a new job is selected.

During the Shift operation, “SFT” and the coordinate system that is specified in the SFTON instruction are indicated on the job content display.

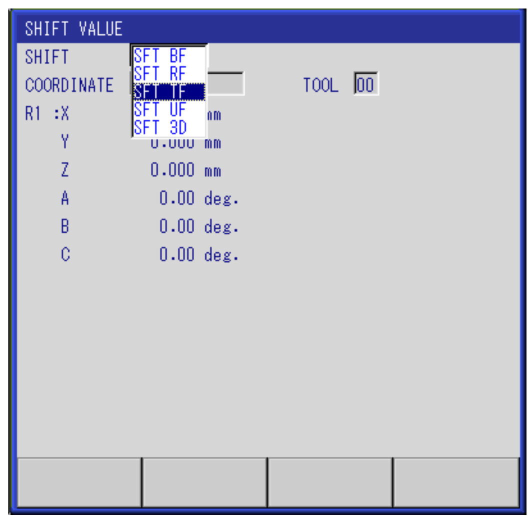


3.8.2 Shift Amount Display

1. Select {ROBOT} from the top menu.
2. Select {SHIFT} from the sub menu. The shift amount display appears.



3. Select a shift type. Selecting a shift type, “PARALLEL” or “3D,” and a coordinate, “BASE,” “ROBOT,” “TOOL,” and “USER,” displays the shift amounts in the corresponding coordinate system.



3.9 Multi-Pass Path Shifting: TR_SFT Macro

When programming a multi-pass weldment, the direction of each subsequent weld pass is reversed, and the work angle is typically changed to optimize weld fusion, bead appearance, and travel speed. The TR_SFT macro is used to easily accomplish translations and rotations of the welding torch to achieve shifted weld paths.

The TR_SFT macro command uses the following arguments:

Type	**Shifting can be based on either a Tool Shift (1) or a Robot Frame Shift (2)**
X	translation distance in the X direction (mm)
Y	translation distance in the Y direction (mm)
Z	translation distance in the Z direction (mm)
A	rotation in the A direction (degrees)
B	rotation in the B direction (degrees)
C	rotation in the C direction (degrees)

The following example demonstrates a typical use of this command. TYPE=2, Robot Frame Shift (as opposed to TYPE=1: Tool Shift) is used. The Contact-tip-to-work distance is increased by 5mm, the programmed point is moved upwards along the upper leg by 4mm, the torch is rotated to a 10deg push (a clockwise rotation when looking from above), and a +15deg change in the work angle which yields a more-vertical torch posture.

```
MOVL
TR_SFT TYPE=2 X=0 Y=5 Z=4 A=10 B=-15 C=0
MOVL
ARCON
MOVL
ARCOF
CLRSFT TF=1
MOVL
```

3.10 Unit Vector / Vector Length: GETVEC Macro

Multi-layer welding typically involves cascading of adjacent weld layers to reduce stress risers and provide good aesthetics. To cascade welds so the weld length of each weld layer is shorter than that of the previous layer, a shift of the starting point towards the end point (and the end point toward the start point) is needed. To develop a shift amount, a direction is developed and a distance is applied to the direction.

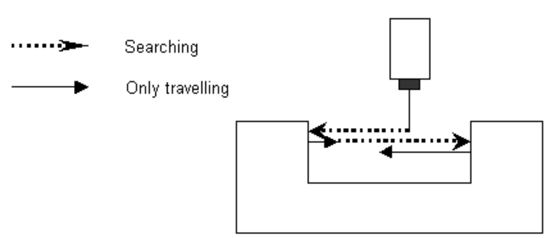
A vector is a geometric descriptor containing both a direction (e.g. +45 from the +X-axis in the X-Y plane and -20 from the +Z-axis) and a distance (e.g. 20mm). To develop a shift direction for Multi-layer shifting, a unit vector is used. The definition of a unit vector is a vector that specifies a direction, but no distance (1mm for the Multi-layer software). The GETVEC command takes the data from a P variable, which contains both direction and distance, and produces a unit vector and a distance value. It then writes the unit vector to a P variable (the length of a unit vector is 1, so combining all three X, Y, and Z components results in a vector length of 1mm) and the distance value to an R variable. An example of the GETVEC command is shown below.

GETVEC P4 R4 P16

The above command takes the variable P16 and develops a unit vector based on the direction of P16 and writes it to P4. It also takes the length of P16 and writes that distance to R4. An application of this would be: subtracting the welding start point location from the end point location (which develops a vector which points from the end point to the start point), place this vector amount into a P variable, and then use the GETVEC command to break the distance down to a length of 1mm. If you want to cascade the weld layers 5mm per layer, the unit vector P variable is then multiplied by 5 to produce a 5mm vector length. Finally, a SFTON command is used with this new 5mm vector.

3.11 Bevelling Width Measuring Function

This function determines the width of a bevel joint and writes the value to a variable (D variable). This variable data can then be used with the WVADJ command to affect travel speed and/or weaving amplitude.The bevelling width measuring function measures the bevelling width using the search function. The measured width is stored in the specified variable number using the SRGAP instruction. According to the measured bevelling width, the welding conditions are changed. The tool stop position after the search is the center of the bevelling.

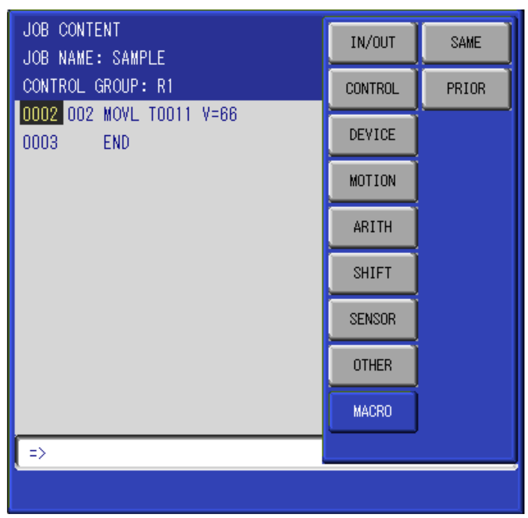


3.11.1 Items to be Set for SRGAP instruction

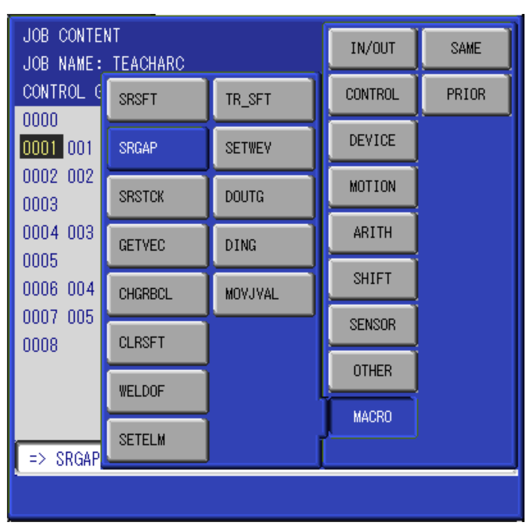
Item	Contents
SHIFT	Shift type: 0: No shift, 1: Shift in parallel, 2: Shift in rotation
VELOCITY	Search speed in units of cm/min.
VARIABLE_No.	Variable number to store the measured bevelling width
DIR_START (P1)	Travel start point P1
DIR_START (P2)	Travel end point P2
END_POINT (P3)	Search end point P3
OFFSET 1 (L1)	Offset amount of the start position (in units of mm)

3.11.2 Registering

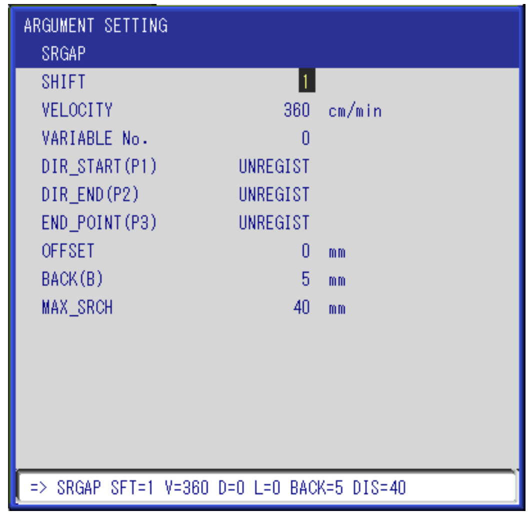
1. Move the cursor to the address area.
2. Press [INFORM LIST].



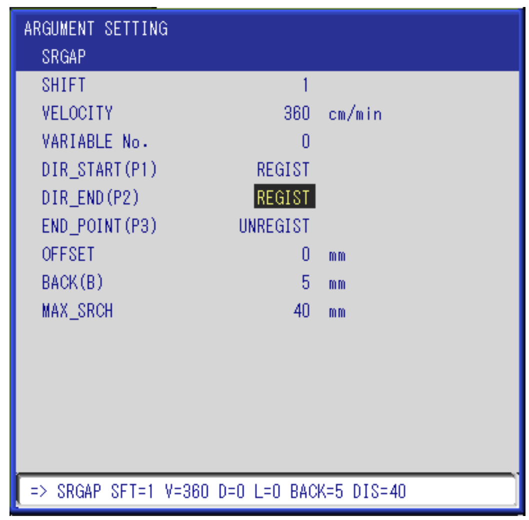
3. Select “MACRO”. The macro instruction list appears.
4. Select on the SRGAP Macro Instruction and then press INSERT > ENTER to place the instruction into the robot job.



5. Cursor to the instruction side of the robot job and press SELECT> SELECT on the SRGAP macro instruction. The argument setting display for SRGAP instruction appears.



6. Move the manipulator to the travel start point (P1). With the cursor on "UNREGIST" of P1, press [MODIFY].



7. Press [ENTER] to register the position of P1.

Note: While viewing the Argument Setting screen you can forward to a REGISTERED position by placing the cursor on the REGISTERED line and then pressing INT LOCK + FWD

8. Move the manipulator to the travel end point (P2), and press [MODIFY] with the cursor on "UNREGIST" of P2.

9. Press [ENTER] to register the position of P2.

10. Press [ENTER] twice to return to the job content display.

11. From the job content display, press [INTERLOCK] + [TEST START] to execute the SRGAP instruction. The manipulator starts searching and stops. Register the manipulator stop position for END_POINT (P3) in the argument setting display.

3.12 Adaptive Weaving

The SRCHGAP macro (see above) is used to measure the width of the weld joint, typically in two places - the weld start and the weld end. Each measurement is recorded into a D variable. An ARCON and WVON command is issued, followed by the WVADJ command. The WVADJ defines a starting and ending value for both the Weave Amplitude and the Welding Travel Speed, and gradually changes these welding parameters across the length of the weld.

3.12.1 WVADJ

Based on touch-sensing data (data from the SRCHGAP macro job), the travel speed and/or amplitude of the weave can be adjusted for varying bevel widths / joint widths. The SRCHGAP function measures the width of the bevel joint and stores that data in a D variable. The WVADJ command contains a 'standard' bevel width and compares the measured bevel width (contained in the D variable) to the standard width. If the measured width is greater, the weave amplitude described with the WVON command is increased and the travel speed is reduced. Conversely, if the measured value is less than the standard setting, the weave amplitude is reduced while the travel speed is increased.

The width of the weld joint is commonly measured at the start and end of the line segment and the weave amplitude is 'sloped' from start to end. In the Detail Edit screen there are five arguments associated with the WVADJ macro job:

Base Value	basic bevel width
Start Point Data	bevel width at the start point
End Point Data	bevel width at the end point
Adjusting Distance	distance over which the bevel width changes
Amplitude Adj. Mode	0=differential adjustment of weave amplitude
	1=proportional adjustment of weave amplitude

The following is a typical implementation of the adaptive weave commands:

```
MOVJ VJ=100.0
SRCHGAP SFT=1 V=360 D=8 L=0 BACK=4 DIS=35
MOVJ VJ=100.0
SRCHGAP SFT=1 V=360 D=25 L=0 BACK=4 DIS=35
MOVJ VJ=100.0
ARCON ASF#(12)
WVON WV#(8)
WVADJ PTN=1 STD=10.0 ST=D008 END=D025 LEN=80.0 ADJMD=0
MOVL
MOVL
WVOF
ARCOF AEF#(4)
```

In the above example, the SRCHGAP routine measures the bevel width at the start and end of the welding joint. The measured widths are stored into two variables, D8 and D25. Welding begins, and the WVADJ command issues starting conditions for weaving amplitude and travel speed. It also defines ending conditions for weaving amplitude and travel speed, and describes the distance (80mm) from the start point in which the weaving amplitude and travel speed will be tapered. The ADJMD argument defines the formula (differential or proportional) that is used to define the corrected weaving amplitude.

When a variable bevel width is used, the welding travel speed is varied to produce the required fill. Travel speed is varied according to the following equation:

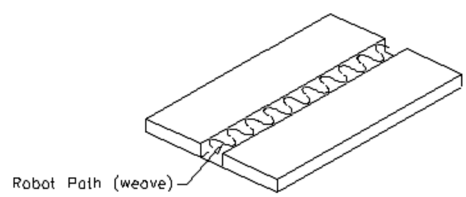
$$\frac{\text{Base Bevel Width}}{\text{Start/End Bevel Width}} \times \text{Base Travel Speed} = \text{Corrected Travel Speed}$$

Travel Speed changes gradually from the start point to the distance described in the WVADJ command. Also, a weaving amplitude change takes place gradually over the same taper distance. The corrected weave amplitude can be determined based on two different methods: differential or proportional. The differential method, which makes a greater change in the corrected amplitude relative to the proportional method, uses the following formula.

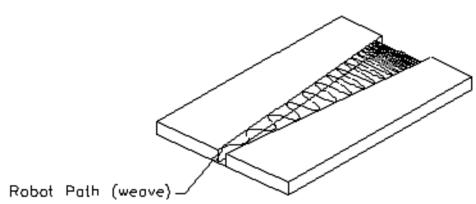
$$\text{Amplitude} + \frac{\text{Start/End Bevel Width} - \text{Base Bevel Width}}{2} = \text{Corrected Amplitude}$$

The proportional method uses this formula:

$$\text{Amplitude} \times \frac{\text{Start/End Bevel Width}}{\text{Base Bevel Width}} = \text{Corrected Amplitude}$$



Taught Weave Pattern and Travel Speed



Adapted Weave Pattern and Travel Speed

3.13 Comarc Path Memory

Multi-pass welding of a weld joint that varies in position can be accomplished using seam finding (touch sensing) combined with seam tracking (Comarc). The seam finding routine finds the start of the first weld pass. Comarc then tracks the joint while welding takes place. This tracked path can be recorded and recalled for subsequent weld layers. The MEMON command is used to record and playback the original seam-tracked path. An example of Comarc Path Memory programming is included in the Multi-Layer Path Programming section below

3.13.1 MEMON Command

If the first weld pass requires seam tracking (Comarc) of the weld joint, the MEMON command can be used to record the corrected robot path. The subsequent passes for the same weld joint, however, do not need to be seam tracked in order to produce the desired weld result. The corrected path of the first weld pass, after being recorded, can be replayed for subsequent weld passes. Playback of the stringer weld pass can be made in both the forward and reverse directions. During playback of the corrected first pass the subsequent weld passes are typically shifted (SFTON command)

The MEMON command has two arguments, which are accessible from the Detail Edit screen.

Data 1	REC = records the corrected (Comarc) weld pass
	PLY = forward playback of the corrected weld pass
Data 2	BACKPLY = reverse playback of the corrected weld pass
	MPF# = the file number in which the corrected weld pass is recorded; 1 to 50

System Requirements: Expanded Memory is required for the storage of up to 50 Comarc-corrected weld passes.

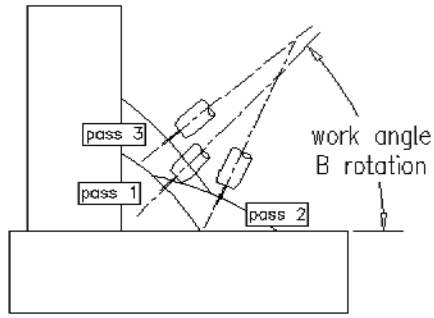
MEMOF

This function disables recording / playback of the MEMON command.

CLEAR

This command is used to clear the information of all MPF files.

3.14 Multi-Pass Programming



The following job produces the above multi-layer weldment.

NOP	
CLEAR MPF	Clears all memory path data
MOVJ VJ=100.0	
SRSFT PTN=1 SFT=2...	Touch sense routine for start point of pass #1 Base Frame (BF) shift amount enabled
GETS PX000 $PX041	Capture BF shift amount from SRSFT macro above
‘ PASS 1	
TR_SFT TYP=1 X=0 Y=0 Z=0 A=-10 B=0 C=0	Tool Shift (TF): travel angle=10deg clockwise
MOVJ T050 VJ=20	Approach point using Point Variable
MOVJ T051 VJ=20	Welding start point
SFTOF BF	Disable BF shift from SRSFT macro above
ARCON AC=300 AV=29.5 TS=45	
COMARCON WV#(4) U/D=...	Enable seam tracking
MOMON REC MPF#(4)	Enable recording of seam tracking corrected path
MOVL T052	
MOVL T053	
MOVL T054	
MEMOF	Disable recording of seam tracking corrected path
COMARCOF	Disable seam tracking

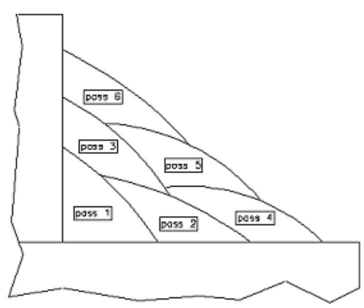
ARCOF AC=175 AV=19 T=0.4	
GETS PX001 $PX040	Last corrected amount from Comarc-corrected path
MOVL T059 V=400	Move to escape point
‘ Pass 2	
TR_SFT TYP=1 X=4 Y=0 Z=0 A=10 B=-10 C=0	TF Shift: 4mm to lower leg, travel angle=10deg counter-clockwise, work angle -10deg
SFTON P001 BF	Path shifting based on last pos. of comarc path
MOVJ T059 VJ=20	
MOVJ T054 VJ=20	
SFTOF BF	Disable BF shift amount
ARCON AC=300 AV=29.5 TS=45	
MOMON BACKPLY MPF#(4)	reverse playback of corrected path
MOVL T053	
MOVL T052	
MOVL T051	
MEMOF	
ARCOF AC=175 AV=19 T=0.4	
MOVL T050 V=400	
‘ Pass 3	
TR_SFT TYP=1 X=0 Y=3 Z=3 A=-10 B=5 C=0	TF Shift: 4mm to upper leg, inc. CTWD 3mm, travel angle=10deg clockwise, work angle +10deg
SFTON P001 BF	Path shift based on SRSFT macro above
MOVJ T050 VJ=20	
MOVJ T051 VJ=20	
SFTOF BF	
ARCON AC=300 AV=29.5 TS=45	
MOMON PLY MPF#(4)	Playback of corrected path

MOVL T052	
MOVL T053	
MEMOF	
ARCOF AC=175 AV=19 T=0.4	
MOVL T059 V=400	

3.14.1 MULTI-PASS EXAMPLE

First a 6-pass weld sequence was programmed. The start point of Pass 1 is programmed to the part. The end point of Pass 1 is determined using the Comarc corrected path and gathered using the GETS command detailed below (stored in P005). A weave is used for Pass 1 (a weave is required for Comarc seam-tracking to function).

Passes 2 - 6 are welded without using a weave. After each weld pass is made, the BF, TF, and RF shift amounts are verified (by observing the robot path in Teach Mode) before welding commences for the subsequent weld passes. For proper "cascading" of each weld layer a Unit Vector is calculated based on the start position and end position of the first weld pass. Unit Vectors (variables P1 and P2) are then multiplied by a factor of 10mm for the first layer (Pass 2 and Pass 3), and a value of 20mm for the second layer (Pass 4 - Pass 6). The shift amounts for each weld pass are listed below.



	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6
TR_SFT	0	X=-6		X=-10	X=-6	X=-3
	0	Z = 2	Z = 4	Z = 4	Z = 5	Z = 10
	0	A = 16		A = 16		A = 16
	0	B = 10	B = -5	B = 18	B = 7	
RF shift @ start	P4	P5+10(P1)	P4 +10(P2)	P5+20(P1)	P4 +20(P2)	P5+20(P1)
RF shift @ end	P5	P4 + 10(P2)	P5 + 10(P1)	P4 + 20(P2)	P5 + 20(P1)	P4 + 20(P2)

P1 = Unit vector pointing from end of weld towards start of weld

P2 = Unit vector pointing from start of weld towards end of weld

P4 = Shift amount developed from touch sensing of start of Pass 1. For this testing P4 was set to 0,0,0,0,0,0.

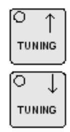
P5 = Final corrected path shift amount (from Comarc path correction) that was gathered from the [GETS PXaaa P$X040] instruction executed at the end of Pass 1.Adaptive Weave

3.15 Welding Condition Adjustment

During playback, each welding condition (i.e. welding current, welding voltage, speed, weaving single amplitude, and sensing) can be adjusted individually using the Condition Adjustment screen and specific keys shown below on the programming pendant. Sensitivity of these keys to changes in the welding conditions is determined by the following parameters:

The adjusted welding conditions can be automatically set for the tag and condition file attached to the instruction to set the welding condition such as ARCON and ARCSET. However, when variables are used for the welding condition or the condition file, this function is invalid.

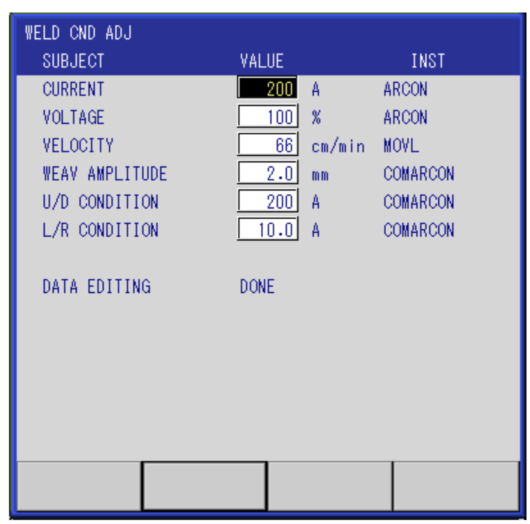
For overriding the welding conditions, the following keys are used:



The units for adjusting the welding conditions by pressing the above keys can be set by the parameters listed in 2.10.5.

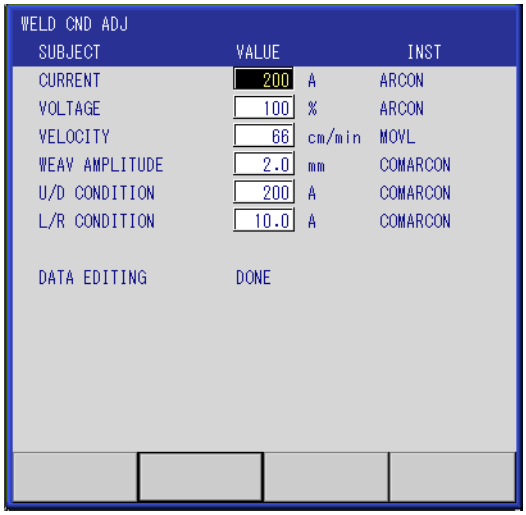
3.15.1 Operation

1. Select “WELD CND ADJ” from “UTILITY” in the job playback display. The welding condition adjustment display appears.
2. Move the cursor to the condition to be adjusted.
3. Adjust the condition by using the specific keys. The welding is executed under the adjusted welding condition.
4. Press [ENTER]. The adjusted welding condition is over written in the condition file of the job.
5. Press [CANCEL]. The job content display appears.



Note: Only the welding condition data that have been set is displayed.
*For example, when the weaving operation is not set, “***” is displayed for “WEAV AMPLITUDE.” And, when COMARC function is not used, “U/D CONDITION” and “L/R CONDITION” are not displayed.*
*When instructions such as ARCOF are executed, the adjustment is disabled and “***” is displayed for each welding condition.*

3.15.2 Welding Condition Adjustment Display



CURRENT

Move the cursor to the data and press the TUNING key to adjust the welding current value. The welding current is specified by the following instructions:

- The instruction item (AC=) to ARCON instruction
- The current value set in the welding start condition file (ASF# (*) specified by ARCON instruction
  (When an enhanced file type is used, the data will not be over written.)
- The instruction item (AC=) to ARCSET instruction
- The instruction item (AC=) to ARCCUR instruction
- The set value by AWELD instruction

When the ARCOF instruction is executed, the welding current adjustment is disabled.
When COMARC function is used, "U/D CONDITION" is changed in proportion to the welding current adjustment.
However, adjusting U/D CONDITION will not change the welding current value.

VOLTAGE

Move the cursor to the data and press the TUNING key to adjust the welding voltage value. The welding voltage is specified by the following instructions:

- The instruction items (AV=, and AVP=) to ARCON instruction
- The voltage value set in the welding start condition file (ASF# (*)) specified by ARCON instruction.
  (when an enhanced type file is used, the data will not be over written.)
- The instruction items (AV=, and AVP=) to ARCSET instruction
- The instruction items (AV=, and AVP=) to ARCVOL instruction
- The set value by VWELD instruction

When ARCOF instruction is executed, the welding voltage adjustment is disabled.

VELOCITY

Move the cursor to the data and press the TUNING key to adjust the robot motion speed. The speed is specified by the following instructions:

- The instruction item (V=) to ARCON instruction
- The speed set in the welding start condition file (ASF# (*)) specified by ARCON instruction
- The instruction item (V=) to ARCSET instruction
- The instruction item (V=) to MOVL (SMOVL), MOVC (SMOVC), or MOVS (SMOVS) instruction.

When ARCOF instruction is executed, the robot motion speed adjustment is disabled.

WEAV AMPLITUDE

Move the cursor to the data and press the specific keys to adjust the weaving single altitude. The weaving single altitude is specified by the following instructions:

- The weaving amplitude set in the welding condition file (WEV# (*)) specified by WVON instruction
- The weaving amplitude set in the weaving condition file (WEV# (*)) specified by COMARCON (SCOMARCON) instruction
- The instruction item (AMP=) to COMARCON (SCOMARCON) instruction
- The instruction item (AMP=) to COMARCSET (SCOMARCST) instruction

When COMARCOF (SCOMARCOF) or WVOF instruction is executed, the weaving amplitude adjustment is disabled.

U/D CONDITION

Move the cursor to the data and press the specific keys to adjust the sensing condition (upward/downward). The upward/downward sensing condition is specified by the following instructions:

- The instruction item (U/D=) to COMARCON (SCOMARCON) instruction
- The instruction item (U/D=) to COMARCSET(SCOMARCST) instruction

When COMARCOF (SCOMARCOF) is executed, the upward/downward sensing adjustment is disabled.

L/R CONDITION

Move the cursor to the data and press the specific keys to adjust the sensing condition (left/right). The left/right side sensing condition is specified by the following instructions:

- The instruction item (L/R=) to COMARCON (SCOMARCON) instruction
- The instruction item (L/R=) to COMARCSET (SCOMARCST) instruction

When COMARCOF (SCOMARCOF) is executed, the left/right side sensing adjustment is disabled.

DATA EDITING

Indicates whether the edition of a instruction or condition file is completed or not.

When the conditions set in the instruction or condition file agree with those set in the welding condition adjustment display, “DONE” is displayed. When not agree, “UNDONE” is displayed.

During adjustment of the welding conditions by pressing the specific key, “UNDONE” is displayed, and when [ENTER] is pressed and the adjusted conditions are registered, “DONE” is displayed.

✍ *Note: The welding current and voltage set in the enhanced type welding condition file can be adjusted by the overriding welding condition function, but the data in the welding condition file will not be over written: the data in the welding condition file will not be replaced by the adjusted data.*

3.15.3 Adjusting Condition Units

When using the specific keys to adjust a condition, the units for each condition can be set by the following parameters. Set the multiplication of the minimum unit of each condition.

Parameter	Meanings	Initial Value
S3C908	The units for adjusting the welding current value (When the specific key is pressed once) Min. units for the current value: 1 A, Min. units for the command value: 0.01 V	1
S3C909	The units for adjusting the welding current value (When the specific key is pressed consecutively) Min. units for the current value: 1 A, Min. units for the command value: 0.01 V	1
S3C910	The units for adjusting the welding voltage value (When the specific key is pressed once) Min. units for the voltage value: 0.1 V or 1%, Min. units for command value: 0.01 V	1
S3C911	The units for adjusting the welding voltage value (When the specific key is pressed consecutively) Min. units for the voltage value: 0.1 V or 1%, Min. units for the command value: 0.01 V	1
S3C912	The units for adjusting the speed (When the specific key is pressed once) Min. units: 1 cm/min.	1
S3C913	The units for adjusting the speed (When the specific key is pressed consecutively) Min. units: 1 cm/min.	1
S3C914	The units for adjusting the weaving single amplitude (When the specific key is pressed once) Min. units: 0.1 mm	1
S3C915	The units for adjusting the weaving single amplitude (When the specific key is pressed consecutively) Min. units: 0.1 mm	1
S1E51	The units for adjusting the sensing U/D condition (When the specific key is pressed once) Min. units: 1 A	1
S1E52	The units for adjusting the sensing U/D condition (When the specific key is pressed consecutively) Min. units: 1A	1
S1E53	The units for adjusting the sensing L/R condition (When the specific key is pressed once) Min. units: 0.1 A	1
S1E54	The units for adjusting the sensing L/R condition (When the specific key is pressed consecutively) Min. units: 0.1 A	1

3.16 System Variables

$PX000: Current interpolated (calculated) robot position in PULSE counts.

$PX001: Current interpolated (calculated) robot position in BASE FRAME (XYZ).

$PX002: Current feedback robot position in PULSE counts.

$PX003: Current feedback robot position in BASE FRAME (XYZ).

$PX004: Robot position of the last executed point.

$PX0011-18: PULSE count data of Reference points (REFP) 1 to 8.

$PX007: Current robot position (XYZ) minus the present shift amount.

$PX040: For multi-layer welding in which travel directions are alternated from one pass to the next, it is often desirable to capture the last correction amount produced by Comarc. The System P variable $PX40 can be used to capture the last shift amount produced by seam tracking. This shift amount can then be used to shift the start of the next, or any other weld pass.

$PX041: Present Base Frame shift amount.

$PX042: Present Robot Frame / Base / Station shift amount.

$PX043: Present Tool shift amount.

$PX045: Present 3D shift amount.

$B045: Reads the 3D Shift execution status. (0=not executing, 1=executing)

3.17 Confirm the Welding Operation in Teach Mode

ARCON/ARCOF instructions can be executed using TEST RUN in Teach mode. Using this operation, it is possible to confirm the welding conditions.

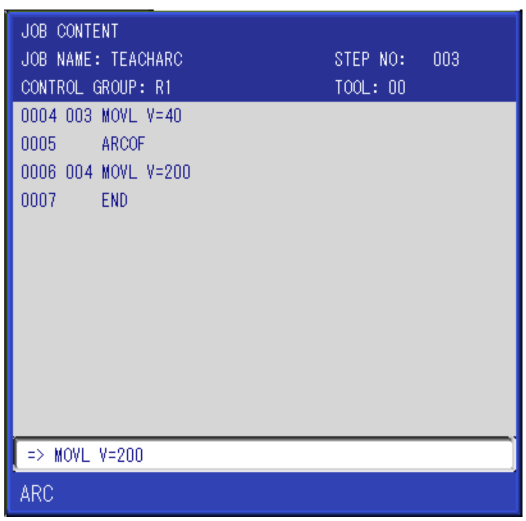
3.17.1 Operation

1. Press [WORK] or [AUX] to turn ON the LED.
2. Execute the test run (execute the welding).
3. Press [WORK] or [AUX] to turn OFF the LED.

Note: If Check Run is enabled, turning ON the WORK LED does not execute welding.

3.17.2 Display

During welding, “ARC” is indicated on the job content display.



“ARC” Indication During Welding

CAUTION!
Executing the test run while “ARC” is indicated on the display executes the welding.

Notes

Numerics

A

B

C

D

E

G

I

L

M

O

P

R

S

T