No. 99MCA082A1
SERIES No. 198

QM-Data

QM-Data 300

3D Data Processing Unit

User's Manual [Software Guide (1)]

Read this User's Manual thoroughly
before operating the instrument. After reading,
retain it close at hand for future reference.

Mitutoyo

CONVENTIONS USED IN THIS MANUAL

Safety Precautions

To ensure that instruments are operated correctly and safely, Mitutoyo manuals use various safety symbols (Signal Words and Safety Alert Symbols) to identify and warn against hazards and potential accidents.

The following signs indicate **general** warnings:

DANGER

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

WARNING

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

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury or property damage.

The following signs indicate **specific** warnings or prohibited actions, or indicate a mandatory action:

Alerts the user to a specific hazardous situation. The given example means “Caution, risk of electric shock”.

Prohibits a specific action. The given example means “Do not disassemble”.

Specifies a required action. The given example means “Ground”.

CONVENTIONS USED IN THIS MANUAL

Types of Notes

The following types of **notes** are used in this manual to help the operator obtain reliable measurement data through correct instrument operation.

IMPORTANT

- An *important note* provides information essential to the completion of a task. You cannot disregard this note to complete the task.
- An *important note* is a type of precaution, which if neglected could result in a loss of data, decreased accuracy or instrument malfunction/failure.

NOTE A *note* emphasizes or supplements important points of the main text. It also supplies information about specific situations (e.g., memory limitations, equipment configurations, or details that apply to specific versions of a program).

TIP A *tip* is a type of note that helps the user apply the techniques and procedures described in the text to his or her specific needs.
It also provides reference information associated with the topic being discussed.

CONTENTS

SERVICE NETWORK

1 OVERVIEW

This chapter describes the characteristics of the 3D data processing unit “QM-Data”.

1.1 Characteristics

The 3D data processing unit “QM-Data” is a data processing unit for CMMs (Coordinate Measuring Machines). This compact data processing unit offers the characteristics listed below.

1. User-friendly operation

1) Automatic feature recognition function (AI function)

The “QM-Data” is equipped with an automatic feature recognition function (or AI function (Artificial Intelligence function)) which uses powerful algorithms developed by Mitutoyo Corporation. By using this automatic feature recognition function, you do not need to specify the type of feature to be measured, before starting measurement. Namely, you simply measure a workpiece, so that the “QM-Data” automatically recognizes the type of the measured feature from the measured data and outputs the measurement results.

2) Gage-like measurement

With conventional data processing systems, even if you want to quickly measure dimensions such as width, height, or hole diameter, you always have to establish the coordinate system beforehand. On the contrary, with the “QM-Data”, all you need to do is select the icons for the desired measurements and measure the workpiece. At this time, you do not have to be conscious of establishing or aligning the part coordinate system.

3) One-touch operation using function keys

We have eliminated the need for mouse-based operation by linking the operation icons to the function keys ([F1] to [F12]), enabling one-touch control for easier operation.

2. Wide range of processing functions

The “QM-Data” has functions same as those in the Mitutoyo’s PC-based data processing software system. Therefore, the “QM-Data” can perform smooth measurements even of complicated workpieces.

3. Expandability

The following additional functions are available as optional software:

- Temperature compensation function
- Optimum coordinate system establishing function or best fit function (QMFit)
- Drawing function of various geometrical deviations (QMGraph)
- Measuring a Contour function (QMScan)
- Simple statistical processing function (QMStat)

4. Multilingual support

The “QM-Data” supports seven languages (Japanese, English, German, French, Italian, Spanish and Portuguese). The displayed language can easily be selected from the "SYSTEM MENU".

5. Comprehensible screen constitution

The required measurement positions or measurement procedures are shown on the LCD (Liquid Crystal Display) as shown below. The screen also has the functional icons that are assigned to function keys, and the status icons that represent the current operating statuses.

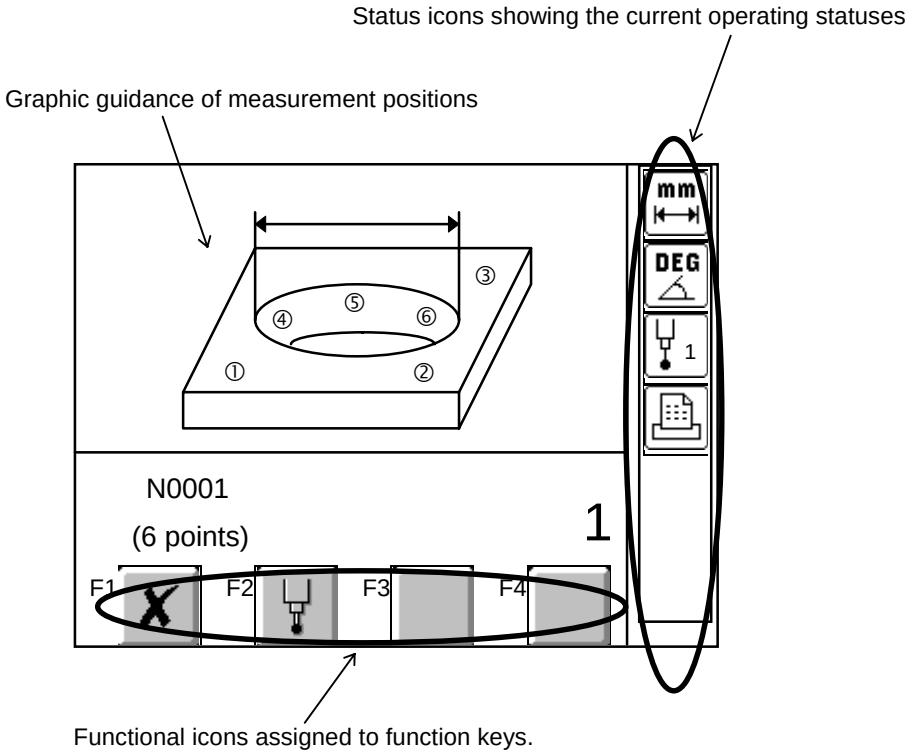


Figure 1-1

2 BASIC OPERATIONS

This chapter describes basic operations of the “QM-Data”.

2.1 Key Panel Layout

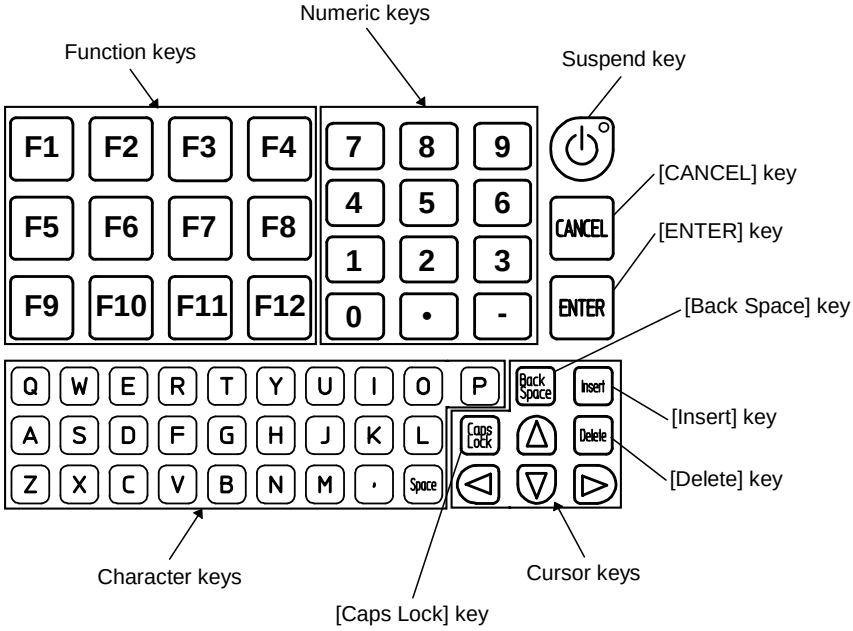


Figure 2-1

1) Function keys

Used to select functions. The function keys (F1 to F12) correspond to the assigned function icons.

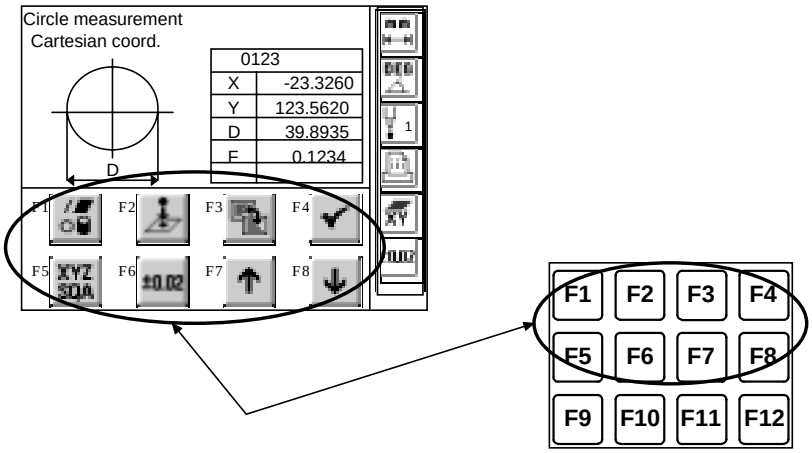


Figure 2-2

2) Numeric keys

Used to enter a numerical value, for example a nominal value.

3) Character keys

Used to enter text, for example a file name.

4) Cursor keys

Used to move the cursor.

5) Suspend key

Used to set the “QM-Data” to Suspend mode. When the “QM-Data” is in Suspend mode, the LCD goes blank and the LED above the Suspend key turns red. Press the Suspend key again to cancel Suspend mode.

6) [CANCEL] key

Used to cancel one measurement point, or go back to the previous menu.

7) [ENTER] key

Used to confirm an entry or selection and transfer to the next step.

8) [Caps Lock] key

Used to switch between uppercase and lowercase text.

9) [Back Space] key

Used to delete the character to the left of the cursor.

10) [Insert] key

Used to switch between Insert mode (insert text) and Replace mode (overwrite text).

11) [Delete] key

Used to delete the character in the cursor position.

2.2 Status Display

On the “QM-Data”, the measurement statuses are shown on the right-hand side of the display screen. Table 2-1 lists the status display icons.

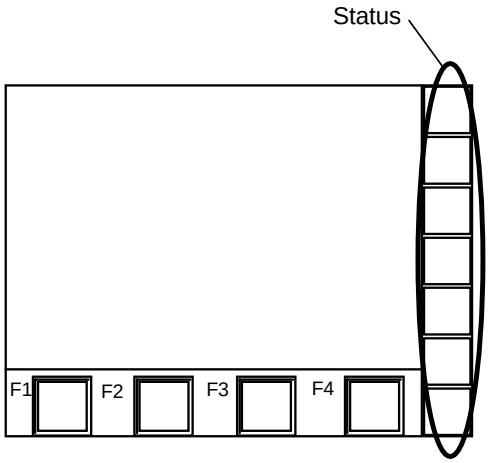
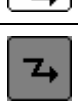


Figure 2-3

Table 2-1

Type of status	Icon	Meaning of status
Unit of length		Displayed for mm
		Displayed for inch
Unit of angle		Displayed for decimal notation (degree)
		Displayed for sexagesimal notation (degree-minute-second)
Probe number		Shows the probe number
Printing		Displayed when only the measurement results which are out of tolerance are printed out
		Displayed when the measurement results only are printed out
		Displayed when all the measurement results and operation procedures are printed out
		Displayed when printing is off
Reference plane		Displayed when the XY plane is the reference plane
		Displayed when the YZ plane is the reference plane
		Displayed when the ZX plane is the reference plane
Tolerance judgment		Displayed when tolerance judgment is ON
		Displayed when tolerance judgment is OFF
External output		Displayed when RS232C output is ON.
		Displayed when measured data file output is ON.
		Displayed when statistical data file output is ON.
		Displayed when MeasurLink output is ON.
		Displayed when outputting is OFF.

2.3 General Measurement Flowchart

Figure 2-4 gives an overview of the flow of measurement.

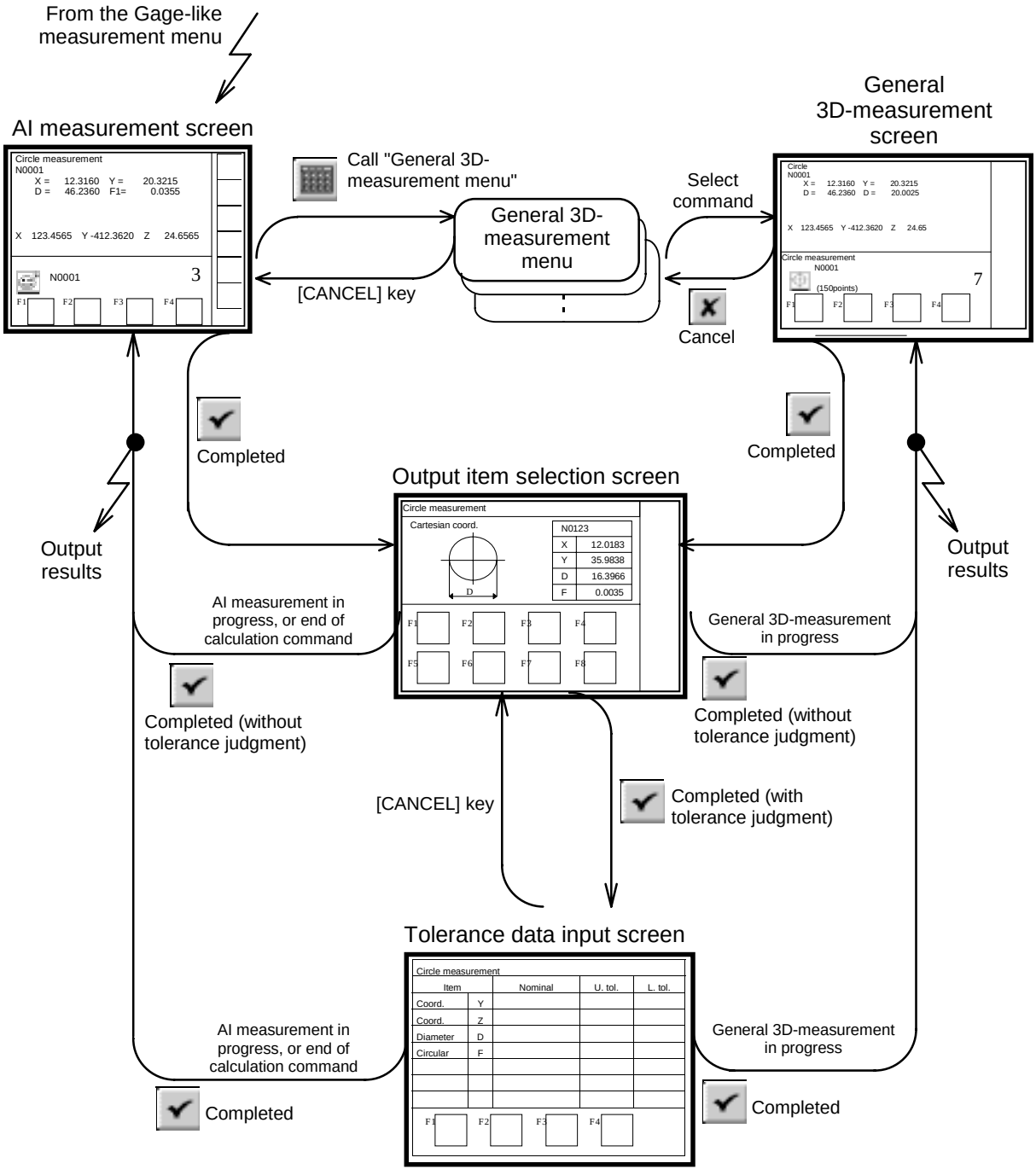


Figure 2-4

2.4 AI Function

2.4.1 What is the AI Function?

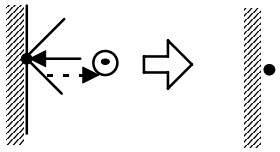
The AI function (Artificial Intelligence function) (Automatic feature recognition function) is a function of automatically recognizing the type of feature after the measurement is taken. Therefore, by using the AI function, you do not need to specify which feature to measure before taking a measurement.

2.4.2 Relationship between Measured Data and Obtained Feature

Required measured data and measurement method depend on features to be measured. Relationships between measured data and obtained features are described below. In the figures in this paragraph, the marks have following meanings:

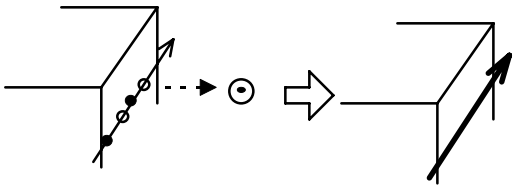
- ● Required minimum measurement points
- ○ Additional measurement points other than the required minimum points
- ⊙ Position into which the probe should be finally moved

1) Side plane (Side point)



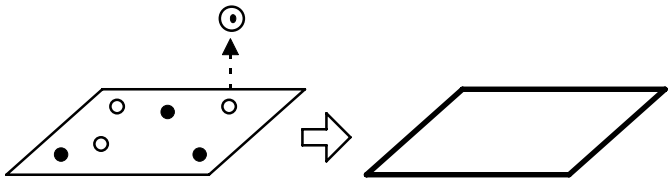
Measure one point on a side plane perpendicular to the X, Y, or Z axis, then move the probe away from the side plane in its normal direction. The AI function automatically recognizes that the measured feature is a side plane feature.

2) Straight line



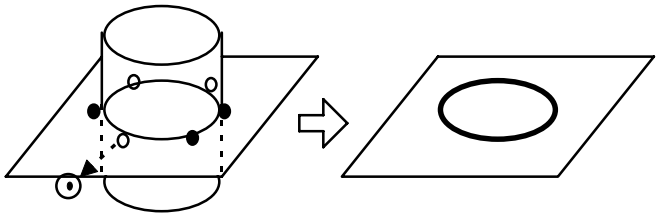
Measure two or more points on a plane at the same level or height, then move the probe away from the plane in its normal direction. The AI function automatically recognizes that the measured feature is a straight line feature.

3) Plane



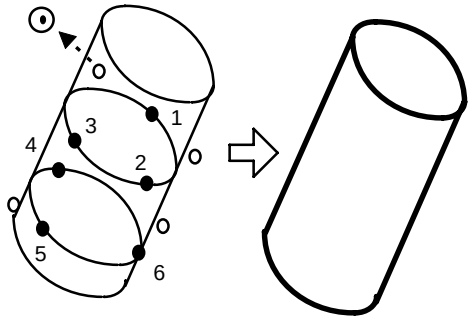
Measure three or more points on a plane, then move the probe away from the plane in its normal direction. The AI function automatically recognizes that the measured feature is a plane feature.

4) Circle



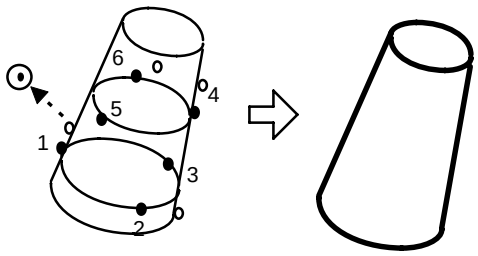
Measure three or more points on a cylinder or a cone at the same level, then move the probe away from the circle in the radial direction. The AI function automatically recognizes that the measured feature is a circle feature.

5) Cylinder



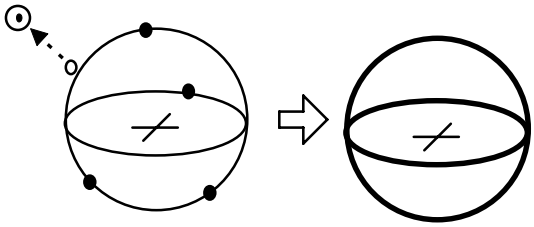
Measure three points on a cylinder at one level, then measure three points on the cylinder at another level, then measure several points on the cylinder at arbitrary positions if you want, and finally move the probe away from the cylinder in the radial direction. The AI function automatically recognizes that the measured feature is a cylinder feature.

6) Cone



Measure three points on a cone at one level, then measure three points on the cone at another level, then measure several points on the cone at arbitrary positions if you want, and finally move the probe away from the cone in the radial direction. The AI function automatically recognizes that the measured feature is a cone feature.

7) Sphere



Measure four or five points on a sphere, then move the probe away from the sphere in the radial direction. The AI function automatically recognizes that the measured feature is a sphere feature.

2.4.3 AI Measurement Screen

Figure 2-5 shows the screen of AI measurement.

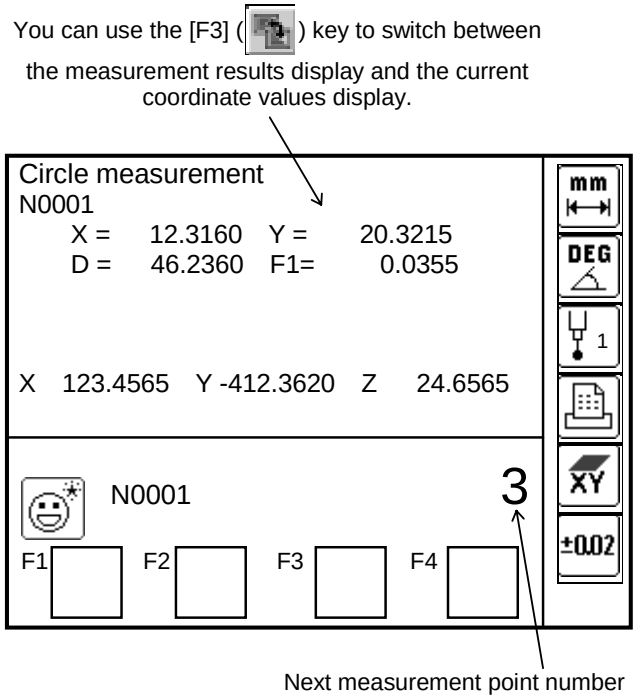
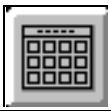
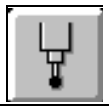


Figure 2-5

Table 2-2

Key operation	Function
F1 	Calling the General 3D-measurement menu. (See Section 2.5)
F2 	Calling the probe function menu for interrupting measurement. (See Section 2.9)
F3 	Switching the displayed information or displaying a supplementary or auxiliary screen. (See Section 2.8)
F4 	Completing a measurement to obtain a feature.
[CANCEL] key	Canceling one measured point.

If you take measurements at the required number of points and then press the [F4] () key , measurement ends and the “QM-Data” automatically recognizes the type of the measured feature and calculates the measurement results. Then the output item selection screen is displayed (see Section 2.6).

2.5 General 3D-measurement Functions

2.5.1 Selecting General 3D-measurement menu

When you press the [F1] ( ) key in the AI measurement screen, the general 3D-measurement menu appears and you can use any of the commands described in Chapters 4 to 13. Figure 2-6 shows the command selection flow. The general 3D-measurement menu has a tree structure or hierarchical structure.

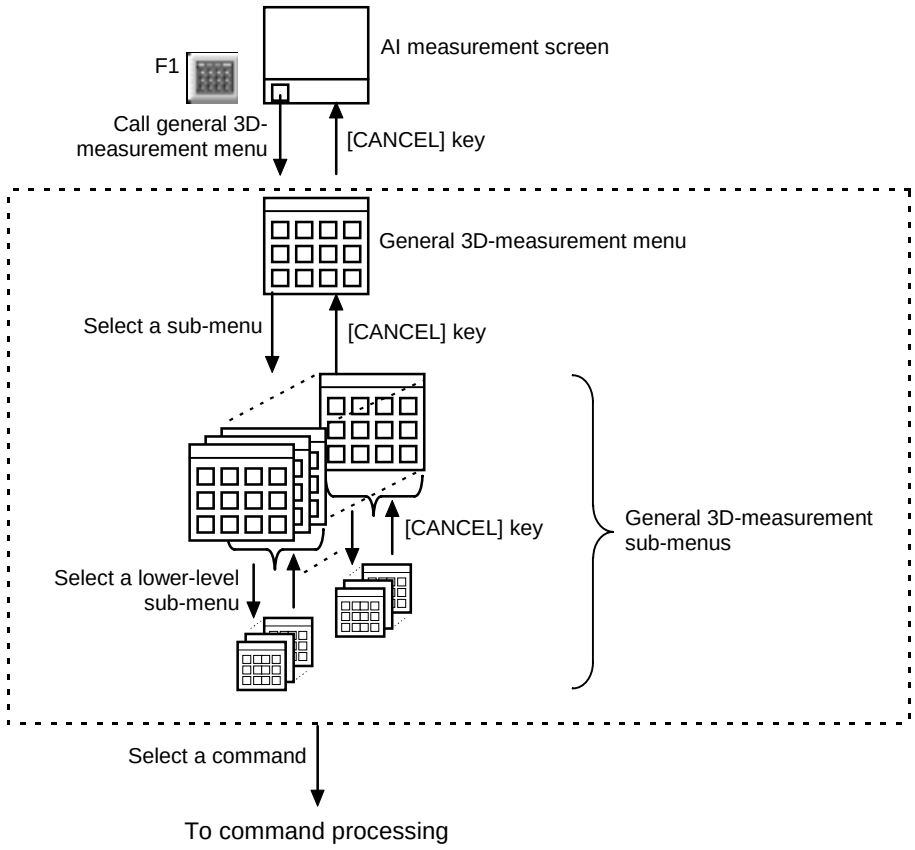


Figure 2-6

2.5.2 Processing Flow for General 3D-measurement Commands

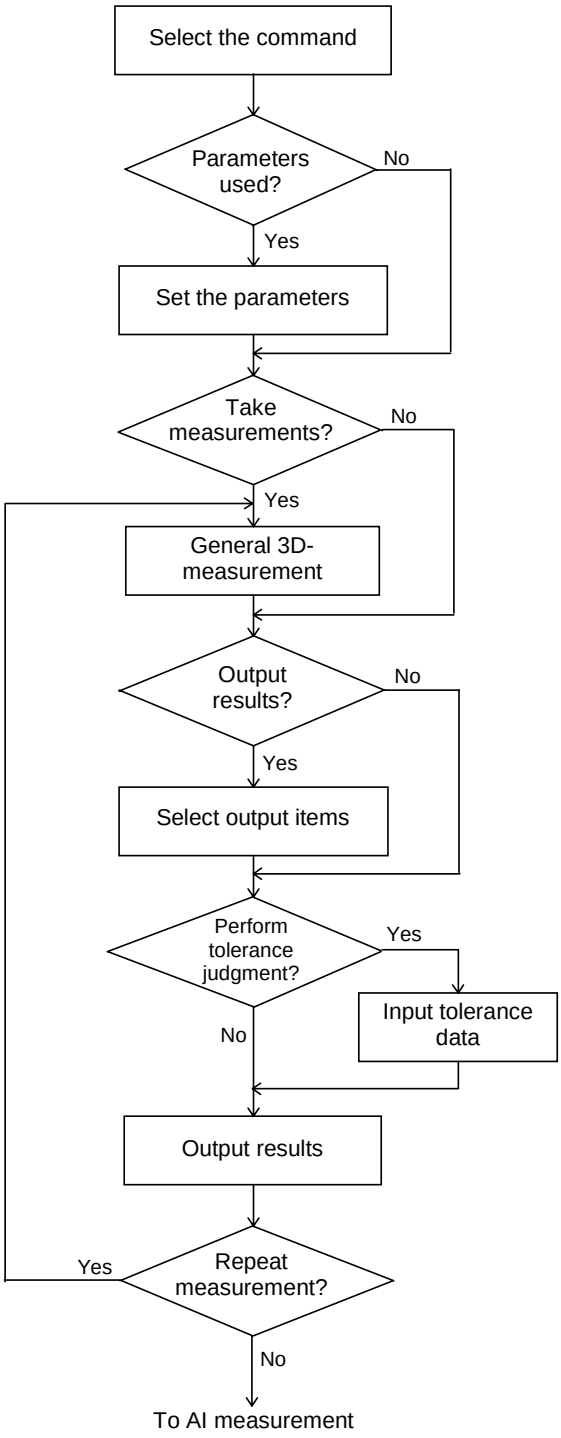


Figure 2-7

2.5.3 Entering Parameters

When you select a command that requires parameters to be entered, a parameter input screen appears. Enter the required parameters as indicated by the on-screen guidance messages. When you have finished entering the parameters, press the [F4] ( ) key.

When you are entering parameters, a parameter selection box < parameter > will sometimes be displayed. When this kind of box is displayed, you can use the left and right cursor keys to change the parameter setting.

2.5.4 General 3D-measurement Screen

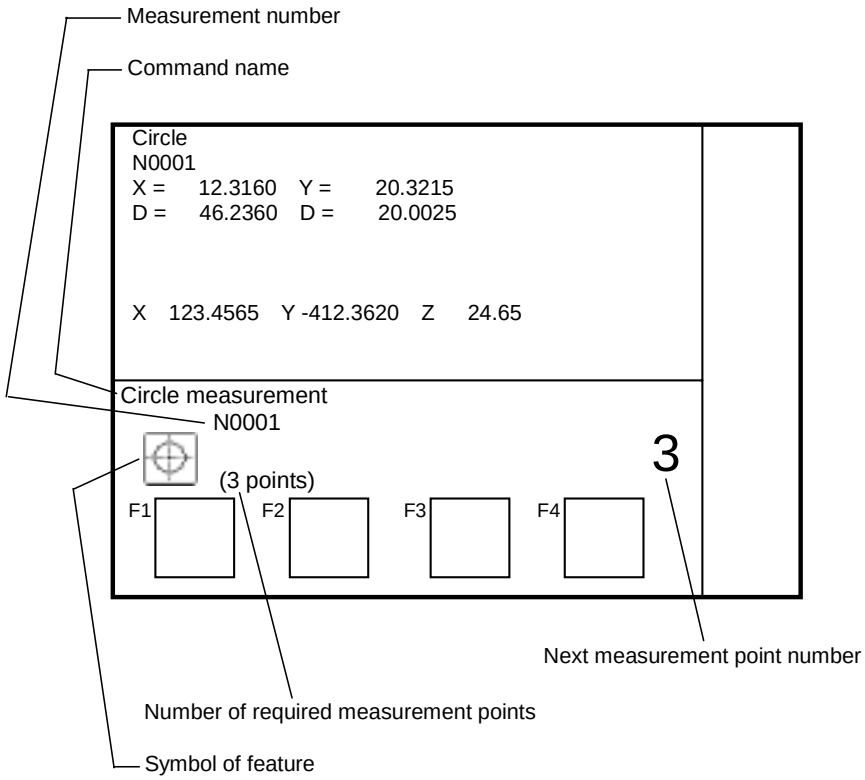
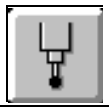


Figure 2-8

Table 2-3

Key operation	Function
F1 	Canceling measurement and returning to the General 3D-measurement menu.
F2 	Calling the probe function menu for interrupting measurement. (See Section 2.9)
F3 	Switching the displayed information or displaying a supplementary or auxiliary screen. (See Section 2.8)
F4 	Terminating measurement and calculating a feature.
[CANCEL] key	Canceling the last measured point.

When you have completed measurement data input for the required number of points, press the [F4] () key to go to the Output item selection screen. On the other hand, if the number of measurement points is fixed, as for the command of aligning the reference plane with offset values (see Section 8.6), the processing automatically proceeds to the Output item selection screen when the required number of points has been measured.

The same command can be repeated after the results are output. To cancel a command once it has been started, press the [F1] () key in this screen.

2.6 Output Item Selection Screen

Use this screen to select the items for output. When you have completed the measurements, you can display this screen and select the items to be output.

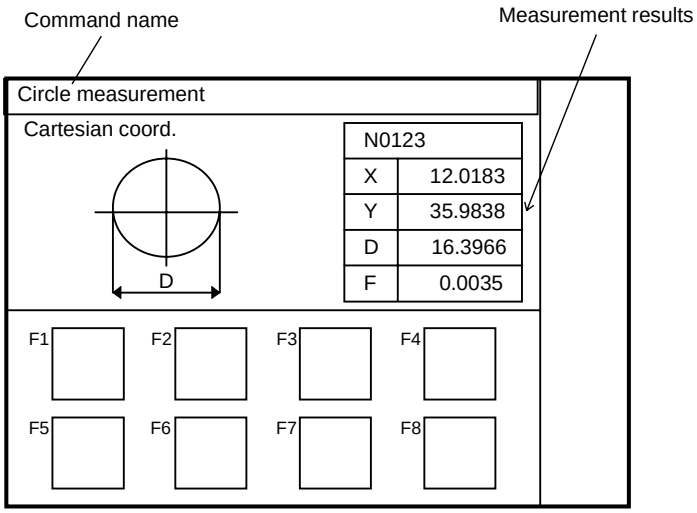


Figure 2-9

Table 2-4

Key operation	Function
F1 	Press this key to change the type of feature. **Note:** This icon is displayed in the AI measurement mode.
F1 	Canceling processing and moving to AI measurement. **Note:** This icon is displayed in the General 3D-measurement mode.
F2 	Displaying the supplementary setting screen. The settings designated in that screen are used to recalculate features. (See Section 2.10)
F3 	Displaying the screen for changing screens. (See Section 2.8)
F4 	Ending processing.
F5 	Displaying the screen for arbitrarily designating output items. (Output items can be designated by using output symbols.)
F6 	Switching tolerance judgment ON or OFF.
F7 	Displaying the previous pattern of output items.
F8 	Displaying the next pattern of output items.

If the following symbols are selected in the arbitrary designation screen of output items (

), positional tolerance judgment is performed, namely positional deviation and positional tolerance are compared. Note that the following symbols are displayed only when the tolerance judgment function is set to ON.

Table 2-5

Symbol	Contents
TPx	Single-axis positional deviation for the X axis
TPy	Single-axis positional deviation for the Y axis
TPz	Single-axis positional deviation for the Z axis
TP2D	Two-axis positional deviation (Nominal values along the two Cartesian coordinate axes in the reference plane are specified.)
TPpol.	Two-axis positional deviation (Nominal values according to the polar coordinate system are specified.)
TP3D	Three-axis positional deviation (Nominal values according to the three-dimensional Cartesian coordinate system are specified.)
TPcyl.	Three-axis positional deviation (Nominal values according to the cylindrical coordinate system are specified.)
TPsph.	Three-axis positional deviation (Nominal values according to the spherical coordinate system are specified.)
MM	MMC positional deviation (Nominal values along the two Cartesian coordinate axes in the reference plane are specified.)
LM	LMC positional deviation (Nominal values along the two Cartesian coordinate axes in the reference plane are specified.)
MMpol.	MMC positional deviation (Nominal values according to the polar coordinate system are specified.)
LMpol.	LMC positional deviation (Nominal values according to the polar coordinate system are specified.)

NOTE (1): MMC stands for Maximum Material Condition, and the MMC positional deviation is the positional deviation when the maximum material principle is applied.

NOTE (2): LMC stands for Least Material Condition, and the LMC positional deviation is the positional deviation when the least material principle is applied.

NOTE (3): MMC positional deviation and LMC positional deviation can be applied only to circle features.

Select the results for output (X, Y, Z, D, etc.). Use the [F7] () and [F8] () keys to switch between the patterns of output items. If the desired pattern of output items has been selected, press the [F4] () key.

If “Without tolerance judgment” is specified, the measurement results are output and then processing moves to the measurement screen (Namely, “AI measurement screen” (see Section 2.4.3) or “General 3D-measurement screen” (see Section 2.5.4)). On the other hand, if “With tolerance judgment” is specified, processing moves to the Tolerance data input screen (see Section 2.7).

2.7 Tolerance Data Input Screen

In this screen you can enter nominal values and upper and lower tolerances for tolerance judgment.

This screen appears when you select “With tolerance judgment” in the Output item selection screen (see Section 2.6).

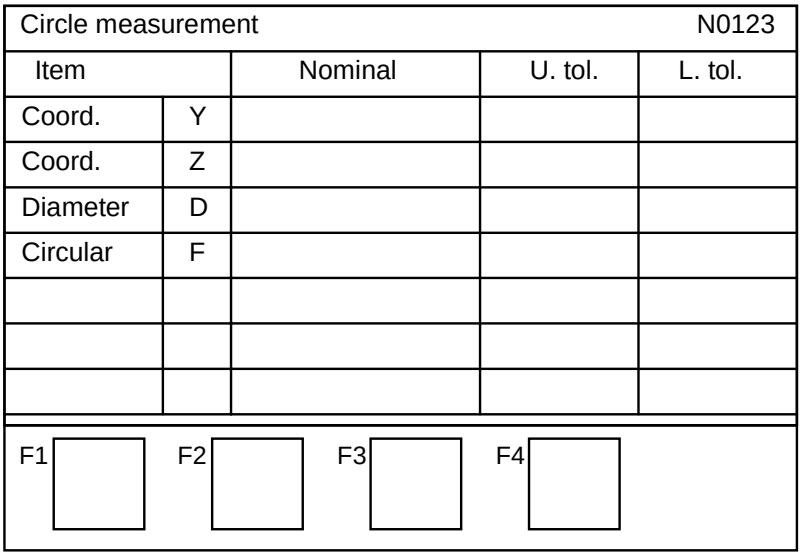


Figure 2-10

Table 2-6

Key operation	Function
F1 	Canceling the processing and returning to the AI measurement screen.
F4 	Outputting the results and then returning to the AI measurement screen.

You can use the cursor keys to move the input field. If there are too many items to fit in one screen, you can also use the cursor keys to scroll the screen.

When you have finished entering the settings, press the [F4] () key.

<Setting Tolerance Data>

The information entered varies depending on the item for which tolerance judgment should be performed. There are four basic types of setting, as shown below.

(1) Tolerance judgment for ordinary deviation

This designation method is used for dimensions and angles.

Item	Nominal	U. tol.	L. tol.
X	Nominal value	Upper tolerance	Lower tolerance

(2) Tolerance judgment for geometrical deviation

Item	Nominal	U. tol.	L. tol.
F4		Geometrical tolerance	

(3) Tolerance judgment for positional deviation

If there are multiple coordinate value items, enter a positional tolerance only in the upper tolerance column for the last item.

Item	Nominal	U. tol.	L. tol.
TP			
X	Nominal value		
Y	Nominal value	Positional tolerance	

(4) Tolerance judgment for MMC/LMC positional deviation

Item	Nominal	U. tol.	L. tol.
MM			
X	Nominal value		
Y	Nominal value	Positional tolerance	
D1	Nominal value	Upper tolerance	Lower tolerance

Note: Enter data in the shaded columns ( ).

2.8 Screen Change Function

This function can be used by pressing the [F3] () key in a measurement screen (namely, the AI measurement screen described in Section 2.4.3 or the General 3D-measurement screen described in Section 2.5.4), or in the Output item selection screen described in Section 2.6.

1. In a measurement screen (the AI measurement screen described in Section 2.4.3 or the General 3D-measurement screen described in Section 2.5.4), the information displayed changes between the following two types of information.
   (1) Display of measurement results
   (2) Display of current coordinate values
   (3) Element position drawing function
   (For detailed information about the element position drawing function, refer to "2.8.1 Element Position Drawing Function".

2. Select the coordinate system format displayed in the measurement screen.
   (1) Cartesian coordinate system
   (2) Cylindrical coordinate system
   (3) Spherical coordinate system
   (See Chapter 3 for more information on the coordinate system formats.)

3. Use the function keys below to temporarily display the supplementary screens.

F5  Used to display the unit, program version etc.

F6  Used to display measurement results on the entire screen.

F7  Displays again a graph that has been drawn with drawing commands such as QMGraph (option).

F8  Used to display the optional temperature sensor reading and the coefficient of thermal expansion of the workpiece.

2.8.1 Element Position Drawing Function

This element position drawing function displays measured element on the screen. With this function you can recognize which shape of workpiece is currently measured.

The current probe position (current counter display position) is indicated with a white circle. Also, the current origin position is indicated with a cross hair.

A measured element is automatically changed to an appropriate display magnification so it is contained in the screen area.

To display an element position graph, select [Element position drawing function] from the parameters of the screen change function. You can select the following settings by pressing the [F1] () key with the element drawing screen being displayed.

You can draw a maximum of 30 elements at this time from the most recently measured element.

(1)Drawing plane

When drawing an element select one of the following planes on which to draw the element.

Drawing plane: XY plane, XZ plane, YZ plane, - YZ plane, - XZ plane, - XY plane

(2)Selection of start drawing element

Specify the element from which to start drawing.

Enter a number that specifies the element from which measured elements to be drawn.

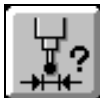
If 0 is entered, drawing will start from the next measured element.

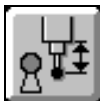
2.9 Probe Function for Interrupting Measurement

You can use this function to change the probe posture or replace probes in the middle of taking measurements.

Pressing the [F2] () key in a measurement screen (namely, the AI measurement screen described in Section 2.4.3 or the General 3D-measurement screen described in Section 2.5.4) activates this function. The processing shown below can then be performed.

F1  Designating probe tip number. (Same as the command described in Section 7.1)

F2  Keying-in probe tip diameter. (Same as the command described in Section 7.3)

F3  Calibrating probe tip position. (Same as the command described in Section 7.2)

F5  Keying-in the distance from the workpiece at which a dummy measurement point is automatically input. (Same as the command described in Section 7.12)

F6  Measurement end setup function
For detailed information, refer to “2.9.1 Measurement End Setup Function”.

F8  Switching the touch signal probe ON or OFF. The current state of the touch signal probe switch can be confirmed by checking which icon below is displayed on the LCD.

The commands executed by this function differ from the similar commands described in Chapter 7 in the following ways:

- The commands executed by this function are not written into a part program.
- The commands in this function can be used for interrupting processing during execution of a part program (namely, in the Repeat mode).

2.9.1 Measurement End Setup Function

The measurement end setup function is a function to add a method of finishing measurement in addition to the [F4] (). This function is used at the end of the measurement by AI function and multi-point measurement.

Following methods can be added.

(1)Measurement end with the foot switch

Measurement will end by pressing the foot switch. The measurement cannot be executed by the foot switch under this setting.

(2)Automatic measurement end

Measurement will automatically end when the specified time has passed after measurement. (Selectable time interval range: 1 second to 60 seconds)

This method is not adapted to the contour measurement (option).

When [F4] () is pressed, the setting up function is completed and returns to probe function for Interrupting Measurement.

2.10 Supplementary Setting Function

This function is activated when you press the [F2] () key in the Output item selection screen described in Section 2.6. This function can be used to change the calculation conditions.

(1) Reference Plane

The XY, YZ or ZX plane can be designated as the reference plane (see Chapter 3).

(2) Projection (specifying projection method)

Reference plane projection, inclined plane projection, rotational projection, or spatial projection can be selected.

Reference plane projection:	Performing projection onto the reference plane designated in the above (1).
Inclined plane projection:	Performing projection onto the inclined plane (see Section 8.11).
Rotational projection:	Performing projection onto the projection plane for rotational projection (see Section 8.10)
Spatial projection:	Performing projection onto the plane which includes the measurement point and is parallel to the reference plane. Note that this can only be specified for circle measurement (see Section 4.10).

(3) Shift (specifying calculation method for multi-point measurement)

Calculation method used for multi-point measurement can be specified. There are two calculation methods, namely Mean and Datum.

Mean:	Obtaining the feature using the least square method.
Datum:	Shifting the feature obtained by the least square method to the most projected measurement point.

[Example]

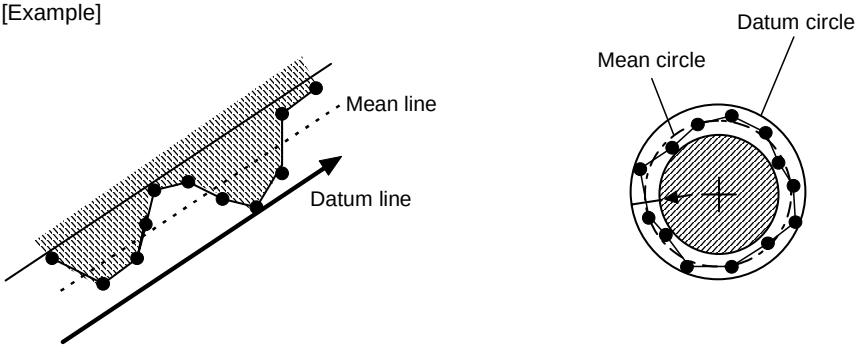


Figure 2-11

3 BASIC KNOWLEDGE

This chapter explains the basic knowledge of 3D measurement.

3.1 Basic Knowledge

3.1.1 Coordinate Systems

There are two types of coordinate systems, namely the machine coordinate system and the part coordinate system.

3.1.1.1 Machine Coordinate System

The machine coordinate system (MCS) is a coordinate system which axes extend along the Linear Scales installed on the X, Y, and Z axes of the coordinate measuring machine (CMM). The origin of the MCS can be moved, but the orientation of the axes of the MCS cannot be changed.

The machine coordinate system is the basis coordinate system upon which the QM-Data performs various calculations. The origin of the machine coordinate system (MCS) is located at the center of the master ball.

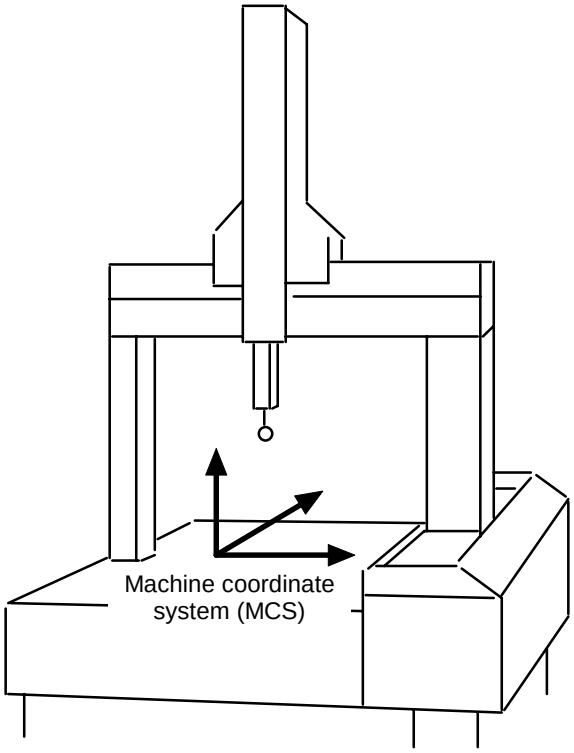


Figure 3-1

3.1.1.2 Part Coordinate System

The coordinate system used by the user to align the position and orientation of the workpiece is called the part coordinate system (PCS).

The part coordinate system is defined by measuring portions of the workpiece that serve as the reference. Distances from the reference are obtained by calculating coordinate values in the part coordinate system. For efficient measurement, it is important to create a part coordinate system that is well suited to the nominal reference (drawing reference) or the machining reference.

If no part coordinate system is defined, the machine coordinate system (MCS) is used instead of the part coordinate system.

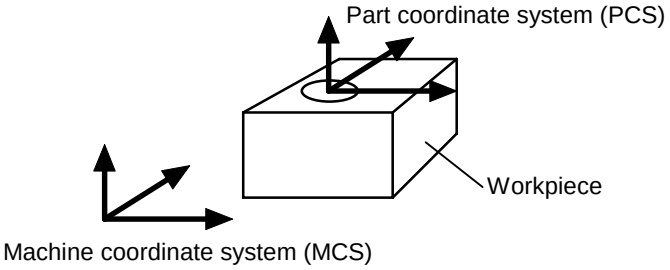


Figure 3-2

3.1.2 Axis Name and Reference Plane

In drawings, dimensions of a workpiece are normally shown on two-dimensional planes using the front, plan and side views.

To produce measurement results conformable to drawings with a coordinate measurement machine (CMM), the front, plan and side views are represented by the ZX, XY, and YZ planes respectively. Since the names of the two axes are different in the three planes (namely, the Z and X axes in the ZX plane, the X and Y axes in the XY plane, and the Y and Z axes in the YZ plane), three additional axis names are introduced. These additional axis names are the “first and second axes” which are the axes in the plane of measurement, and the “third axis” which is perpendicular to the plane of measurement.

The plane that includes the first and second axes is called the reference plane.

3.1.2.1 Axis Name

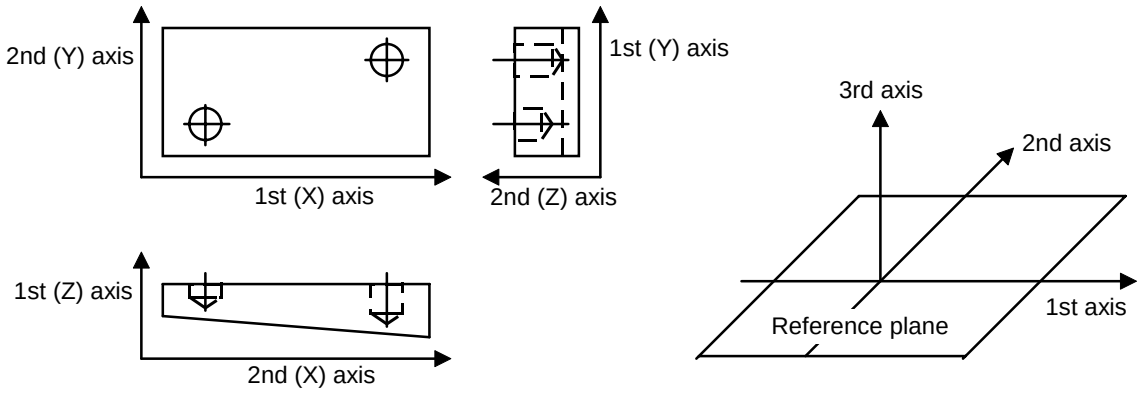


Figure 3-3

3.1.2.2 Reference Plane

The reference planes for a coordinate measurement machine are the three planes XY, YZ and ZX. Table 3-1 shows the relationship between the three reference planes and the axis names.

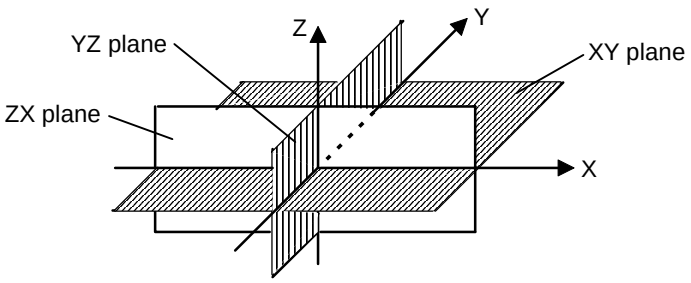


Figure 3-4

Table 3-1

	1st axis	2nd axis	3rd axis
XY plane	X	Y	Z
YZ plane	Y	Z	X
ZX plane	Z	X	Y

3.1.2.3 Right-handed Coordinate System

The positive and negative directions for each axis are defined according to the right-handed coordinate system.

When you extend the fingers of your right hand as shown in Figure 3-5, the fingers correspond to axes as follows:

Thumb : 1st axis
Forefinger : 2nd axis
Middle finger : 3rd axis

The positive direction for each axis is the direction in which the corresponding finger is pointing.

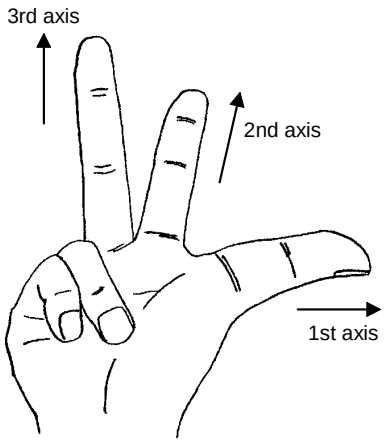
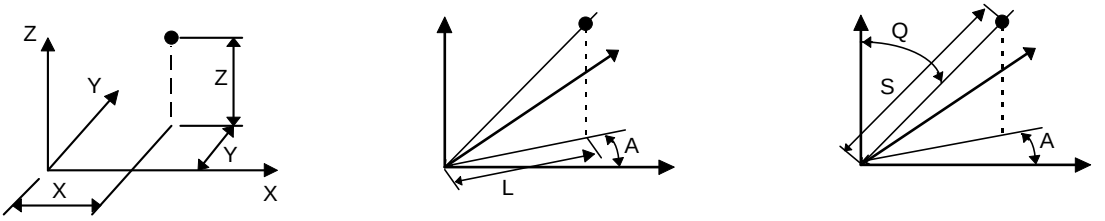


Figure 3-5

3.1.2.4 Coordinate System Format

There are three ways of representing coordinate values, as shown in Figure 3-6.



Cartesian coordinate system　　Cylindrical coordinate system　　Spherical coordinate system

Figure 3-6

In Figure 3-6,

X, Y, Z : Coordinates
L : Radial distance in cylindrical coordinate system
S : Radial distance in spherical coordinate system
Q : Polar angle in spherical coordinate system (degree)
A : Projection angle (Azimuthal angle in spherical coordinate system) (degree)

In addition, the two-dimensional coordinate system represented by “L” and “A” above is referred to as the polar coordinate system.

1) Supplementary explanation about (I, J, K)

In Section 3.1.2.1. “Axis Name”, the first axis, the second axis, and the third axis are described. (I, J, K) are used to represent these three axes:

I: the first axis
J: the second axis
K: the third axis

For example, in a cylindrical coordinate system, coordinate values are keyed in according to the following format.

L: Radial distance value,
A: Projection angle value, and
K: Coordinate value of the third axis

2) Supplementary explanation about keying in direction

There are three methods for keying in a direction as shown below. The method for keying in a direction can be selected when performing the keying-in operation.

(1) Direction cosine

The direction is represented by direction cosine (L, M, N).

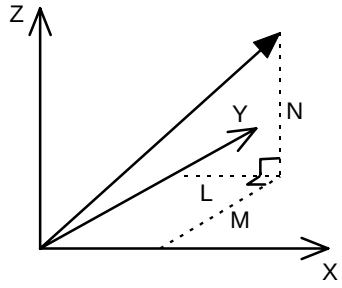


Figure 3-7

(2) Polar angles

The direction is represented by a projected angle (CI) from the first axis (I) on the reference plane and an angle (W) from the third axis (K).

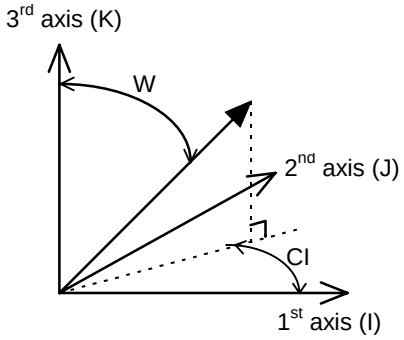


Figure 3-8

(3) Projected angles

The direction is represented by a projected angle (CI) from the first axis (I) on the reference plane and a projected angle (CJ) from the second axis (J) on the JK plane.

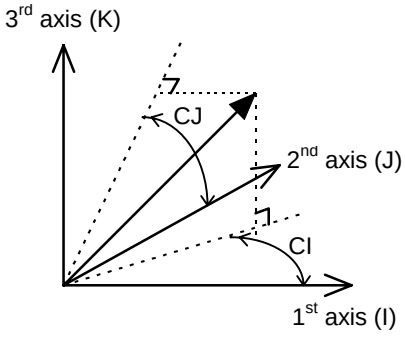


Figure 3-9

3.1.3 Direction and Angle of Rotation

Rotation angle in the reference plane is regarded as being in the positive direction when the rotation moves counterclockwise around the third axis.

Also, angle (A) in a cylindrical or spherical coordinate system is the angle from the positive direction on the first axis.

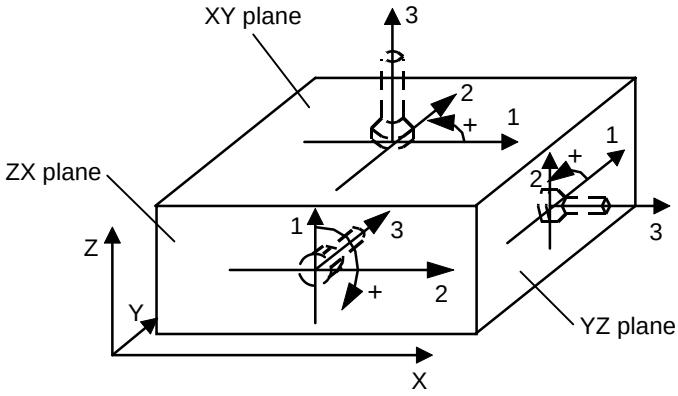


Figure 3-10

3.1.4 Units Used

This section describes the units used on the QM-Data.

3.1.4.1 Length

The two units of length are mm and inch. (1 inch = 25.4 mm)
The default unit of length is mm.

[Example] 189.541 mm
1.194 inch

3.1.4.2 Angle

The two units of angle are degree (decimal notation) and degree-minute-second (sexagesimal notation). The default unit of angle is degree-minute-second (sexagesimal notation). Note that a sexagesimal angle of 12°38’47” is displayed as 12.3847.

3.1.5 Measurement Terminology

3.1.5.1 Measurement and Measured Point

The term “measurement” refers to the process by which the tip of the probe touches the workpiece and coordinate values are input. Measurement can be performed using a touch signal probe or using a foot switch.

The point at which the measurement is taken is called the “measured point” or “measurement point”. The position of the measured point is the center of the tip ball of the probe.

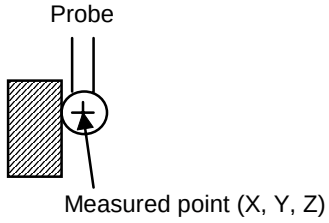
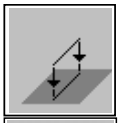


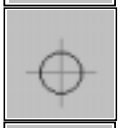
Figure 3-11

3.1.6 Command

A command refers to the action of selecting an icon in the measurement menu on the QM-Data so that the corresponding measurement and processing are performed.

[Example]

Projected straight line measurement: 

Circle feature measurement: 

Keying in probe tip diameter: 

3.1.7 Feature

A feature is an item constituting a geometrical shape (geometrical properties such as a point, a line and a cylinder).

The QM-Data can handle ten types of feature: point, straight line, plane, circle, ellipse, sphere, cylinder, cone, distance and angle. While distance and angle are not shapes, they are regarded as features on the QM-Data.

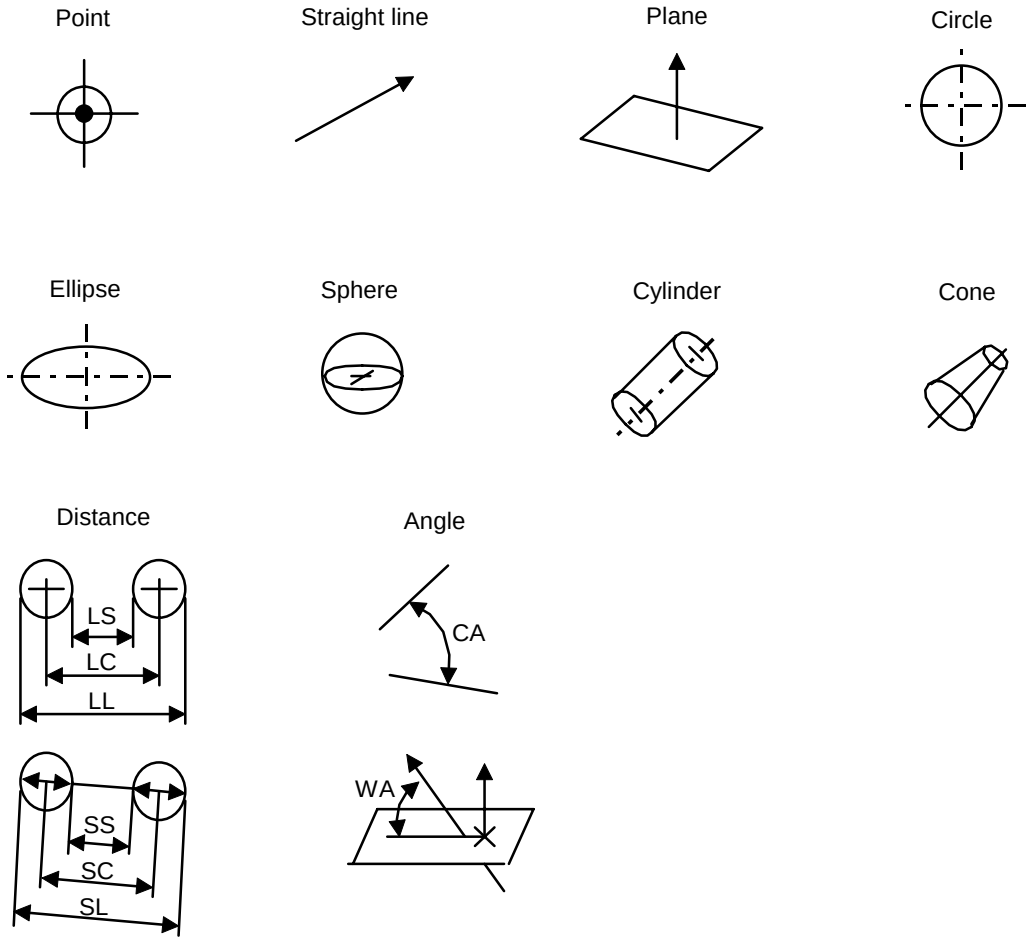


Figure 3-12

3.1.8 Automatic Dummy Point

When a circle is measured, the same command is used to measure the inside diameter and the outside diameter (see Section 4.10). Center coordinates of the tip ball of the probe are entered as the measurement point data.

Therefore, for example, when you measure an inside diameter of 20 mm with a 4-mm diameter probe, the result (D) should be 18 mm. For an outside diameter of 20 mm the result (D) should be 22 mm.

However, the correct diameter (D = 20 mm) is actually displayed for both the inside and outside diameters. This is because the QM-Data automatically judges whether the measurement is an inside or outside diameter and compensates for the probe tip radius.

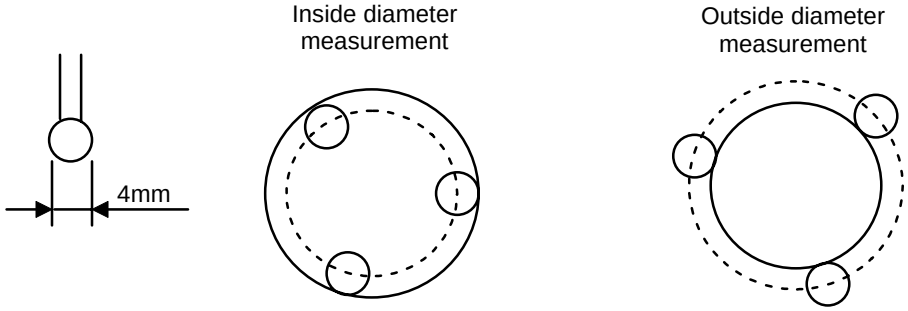


Figure 3-13

An example of circle measurement is used to explain this judgment method, referring to Figure 3-11. In this example, the circle is measured at three points. After the third point is measured, in which direction does the probe move? For an inside diameter it should move inwards, and for an outside diameter it should move outwards. At that point, a dummy measurement point is automatically input.

The QM-Data program uses the positional data of the dummy measurement point to judge whether the measurement is an inside diameter or an outside diameter. Namely, if the dummy measurement point positions inside the circle measured at three points, the measurement is judged to be an inside diameter; and if the dummy measurement point positions outside the circle measured at three points, the measurement is judged to be an outside diameter. The QM-Data program then compensates accordingly for the probe tip radius and displays the correct measurement result.

In this manner, the data which is automatically input after substantial measurement and used to compensate for the probe tip radius is called the “Automatic dummy point”. In addition, the direction from the automatic dummy point to the last measured point is called the “Measurement direction” or “Approach direction”.

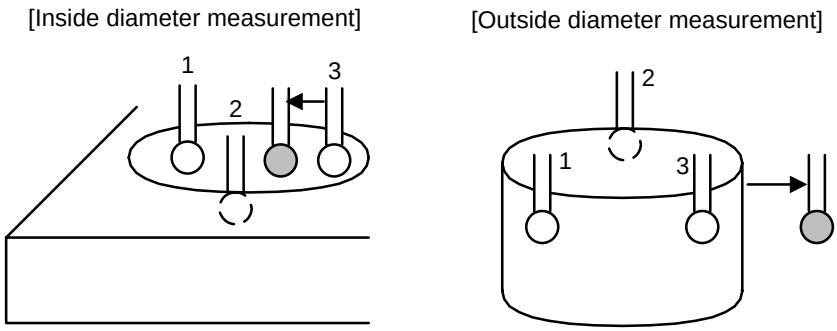


Figure 3-14

The same approach is used for straight lines and planes. When measuring a straight line, a straight line formed by two measurement points is compensated by the probe tip radius. When measuring a plane, a plane formed by three measurement points is compensated by the probe tip radius in the direction perpendicular to the plane.

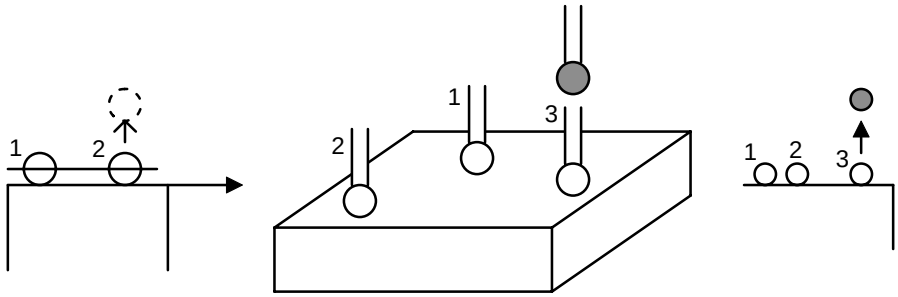


Figure 3-15

When measuring a side plane (see Section 4.2), the measured point is compensated by the probe tip radius in a direction parallel to one of the axes of the part coordinate system. Care must be taken with the direction in which the probe is moved after measurement, as shown in Figure 3-13. Namely, after measurement, move the probe into the shaded area ( ) in Figure 3-13 so that the automatically input dummy point positions in the shaded area.

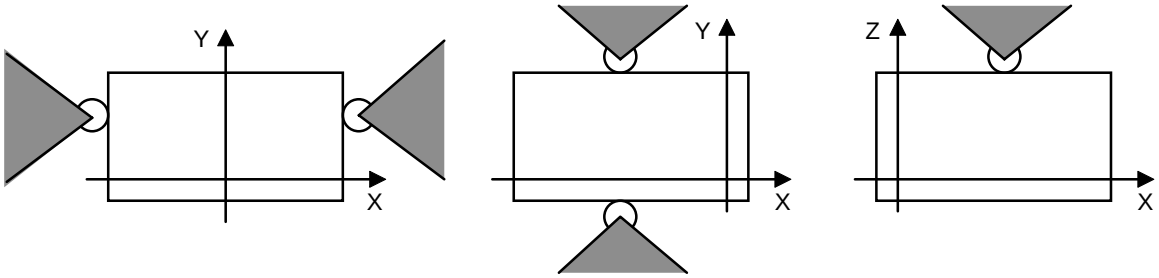
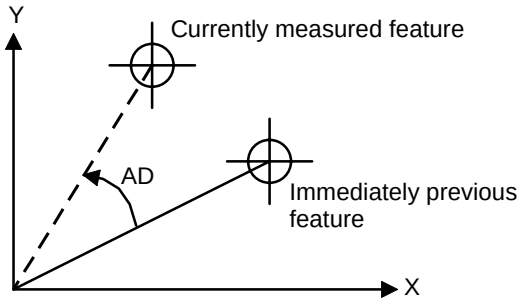


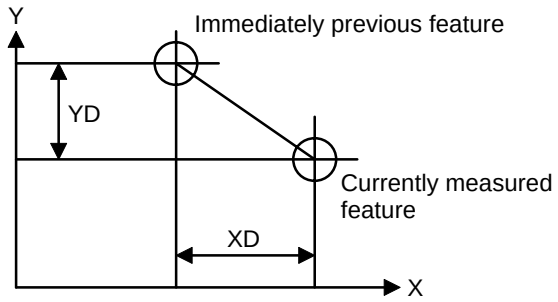
Figure 3-16

3.1.9 Immediately Previous Feature

The feature obtained immediately prior to the process currently being performed is called the “immediately previous feature”.



(To calculate the difference in the angles)



(To calculate the difference between the X and Y coordinates)

Figure 3-17

3.1.10 Keying In

The process of using the key panel to enter the numerical values needed for setting measurement conditions is called “keying in”.

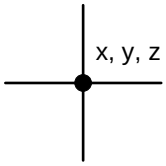
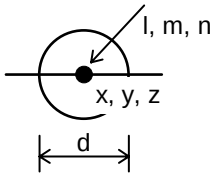
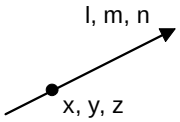
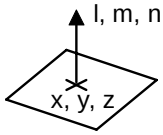
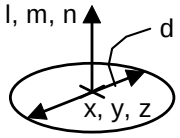
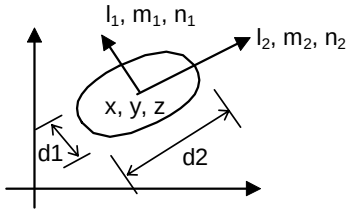
3.2 Feature Structures and Memory Functions

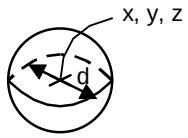
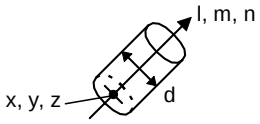
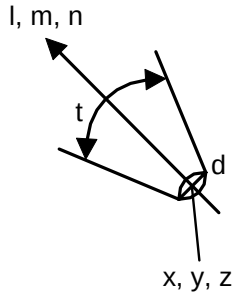
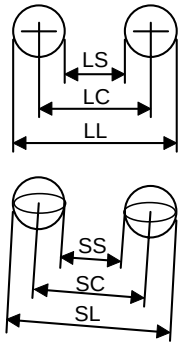
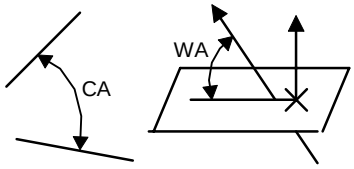
3.2.1 Feature Data

The data obtained through a feature measurement is referred to as feature data. This feature data is used by the QM-Data software to perform calculations. In the QM-Data, features are stored in form of feature data.

Table 3-2 shows the contents of the feature data in each type of feature measurement.

Table 3-2

Feature	Stored feature (feature data)	Remarks
Point <*1>		x, y, z : Position
Point with approach direction <*1>		x, y, z : Position l, m, n : Approach direction or measurement direction d : Probe tip diameter
Straight line <*1>		x, y, z : Position l, m, n : Line direction
Plane <*1>		x, y, z : Position l, m, n : Normal direction
Circle <*1>		x, y, z : Center position l, m, n : Center axis direction d : Diameter
Ellipse		x, y, z : Center position l_1, m_1, n_1 : Center axis direction l_2, m_2, n_2 : Major axis direction d1 : Minor axis diameter d2 : Major axis diameter

Feature	Stored feature (feature data)	Remarks
Sphere		x, y, z : Center position d : Diameter
Cylinder <*1> <*2>		x, y, z : Center position l, m, n : Center axis direction d : Diameter
Cone <*1> <*3>		x, y, z : Center position l, m, n : Center axis direction t : Cone full angle d : Diameter
Distance		LS : Projected minimum distance LC : Projected distance between centers LL : Projected maximum distance SS : Spatial minimum distance SC : Spatial distance between centers SL : Spatial maximum distance
Angle		CA : Projected intersection angle WA : Spatial intersection angle

<*1> Direction data

The direction data of features is expressed as a direction cosine (l, m, n). The direction cosine is a set of projected lengths along the respective axes (X, Y and Z) when the length of the direction vector is taken as 1. (This value “1” has no unit but for convenience can be thought of as 1 mm or 1 m.)

l : X axis direction cosine
m : Y axis direction cosine
n : Z axis direction cosine

[Examples of direction data]

1) Vertical cylinder → l = 0, m = 0, n = 1

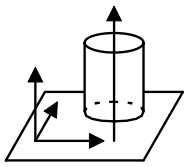


Figure 3-18

2) Cylinder parallel to the reference plane and the first axis → l = 1, m = 0, n = 0

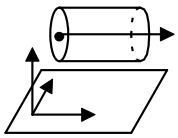


Figure 3-19

3) Cylinder inclined at 45° when seen from any axis → l ≅ 0.577, m ≅ 0.577, n ≅ 0.577

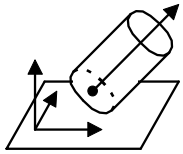


Figure 3-20

<*2> Cylinder feature data

When measuring a cylinder or a stepped cylinder (see Sections 4.15 and 4.16), the point data of the “center position” is taken as being the projection on the cylinder axis of the first measurement point.

In addition, when measuring a stepped cylinder, obtained feature data has two diameters, one for each step.

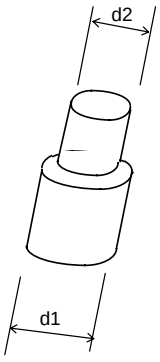


Figure 3-21

<*3> Cone feature data

When measuring a cone (see Section 4.17), the point data of the “center position” is taken as being the projection on the cone axis of the first measurement point.

The cone full angle “t” is a negative value if the diameter reduces in the direction of the cone axis and a positive value if the diameter increases in the direction of the cone axis.

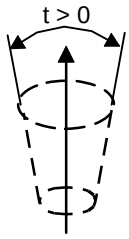


Figure 3-22

The diameter “d” is the diameter of the intersecting circle between the cone and the plane perpendicular to the cone axis and including the point data of the “center position”.

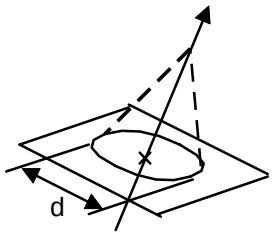


Figure 3-23

3.2.2 Feature Result

The numerical data obtained through a feature measurement and being able to be output to the LCD or the printer is referred to as the “feature result”.

3.2.3 Feature Memory Function

The feature data obtained through feature measurement can be stored and used as required in other calculations. This is called the “Feature memory function”.

The “Feature memory function” provides the four types of function listed in Table 3-3.

Table 3-3

Type	(1) Specified memory	(2) Automatic memory
Memory capacity (max.)	1000 features	150 features
Description	• Containing areas for 1000 features and being used by specifying an memory address (1 to 1000).	• New feature results are stored in this memory each time a feature is measured or calculated. • The memory numbers all increment by 1 each time a measurement or a calculation is performed. • The memory number of the last measured result is always 1.
Storage method	After measurement, execute the “Save feature to (specified) memory” command (see Section 6.1) and specify a storage destination address from 1 to 1000.	After measurement, feature data is automatically stored in memory address 1. At this time, data already stored in memory is shifted 1 address down and the data in address 150 is replaced.

Type	(3) Reference definition memory	(4) Raw data memory
Memory capacity (max.)	7 features (fixed)	10 features
Description	Handling the following coordinate system data as plane, straight line, or point features: XY plane, YZ plane, ZX plane, X axis, Y axis, Z axis, and Origin	Storing all the raw measured data at a multi-point measurement.
Storage method	Stored automatically. Each time the coordinate system is changed, the stored data is automatically updated.	After measurement, execute the “Save feature to (specified) memory” command (see Section 6.1) and specify a storage destination address from 1 to 10. Raw measured data is stored concurrently when a feature is stored in one of the address 1 to 10 in specified memory.

Now the memory functions are explained in more detail. See Section 6.1 for more information on the “specified memory”.

1) Automatic memory storage function

(1) When a measurement command or calculation command is executed to obtain a feature data, that feature result is automatically stored in automatic memory address 1.

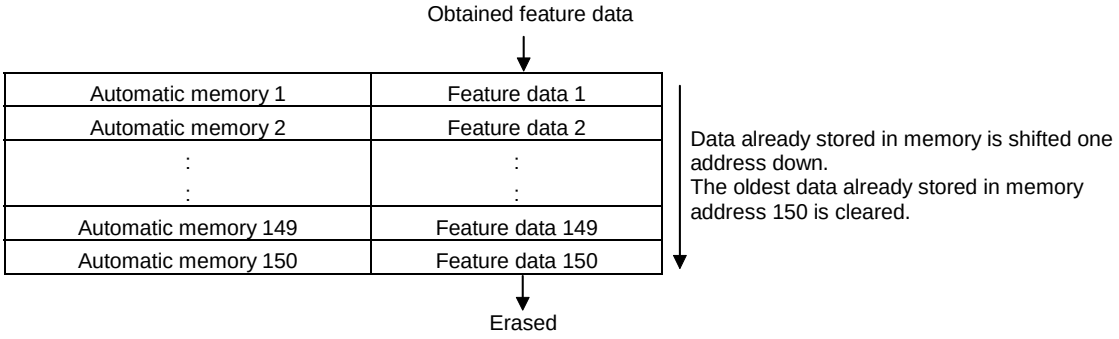


Figure 3-24

(2) When two features are obtained, for example when intersection point calculation is performed, both features are stored in the automatic memory.

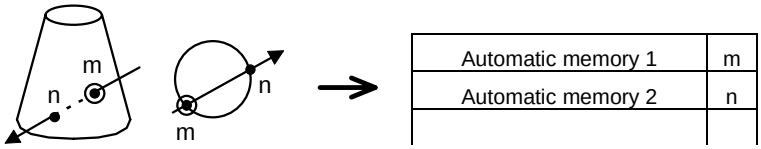


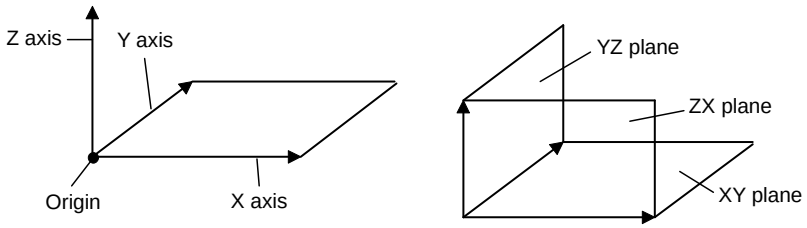
Figure 3-25

(3) Feature stored in automatic memory 1 is called the “immediately previous feature”.

(4) The contents of the automatic memory are cleared when you exit from the “General 3D-measurement mode” to go to the “Gage-like measurement mode” or the “System menu mode”.

2) Reference definition memory function

Reference planes, reference axes, and origin of the current coordinate system can be recalled as feature data, by using this function.



Origin	Used as point data
X axis Y axis Z axis	Used as straight line data
XY plane YZ plane ZX plane	Used as plane data

Figure 3-26

3) Recalling feature data

When executing a command that recalls and processes feature data in the memory, designate the memory type, the memory address (memory number) and the measurement point number.

Table 3-4

Memory to be recalled	Specified memory	Automatic memory	Reference definition memory	Raw data memory
Memory type	Specified memory	Automatic memory	Origin X axis Y axis Z axis XY plane YZ plane ZX plane	Raw data memory
Memory address (Memory No.)	1 ~ 1000	1 ~ 150	None	1 ~ 10
Measurement point number	None	None	None	1 ~ 150

1) Recalling feature data at coordinate system setting or at feature combination calculation

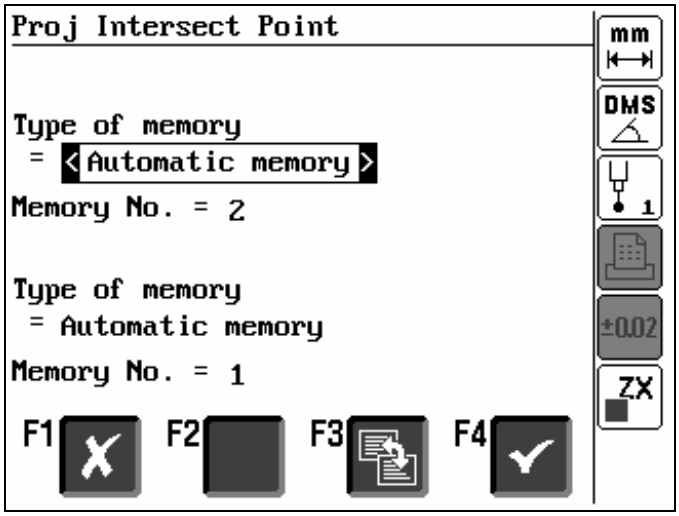


Figure 3-27

At the coordinate system setting or alignment, or at the feature combination calculation, feature data can be recalled from the specified memory, the automatic memory, and the reference definition memory. Necessary memory numbers should be designated one by one according to the guidance displayed on the LCD.

2) Recalling feature data at feature construction (or in a command recalling a plurality of feature data)

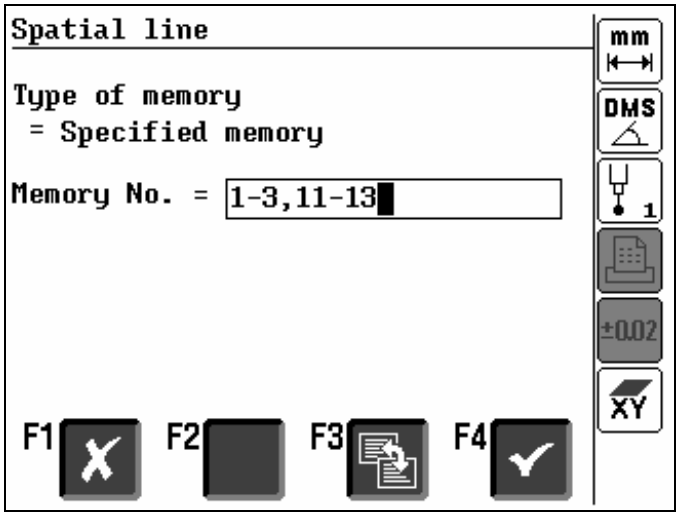


Figure 3-28

At the feature construction (or in a command recalling a plurality of feature data), feature data can be recalled from the specified memory, the automatic memory, and the raw data memory. A plurality of necessary memory numbers should be designated in the following ways according to the guidance displayed on the LCD.

(1) Designation of consecutive memory numbers

Representation method: [Starting number]- [Ending number]

<Example> 2-5 → Four feature data from memory No.2 to memory No. 5

(2) General designation of a plurality of memory numbers

Representation method: [Number (or consecutive numbers)],[Number (or consecutive numbers)],...

<Example> 2,11-13,20

NOTE: When recalling feature data from the raw data memory, designate only one memory number at first. Then according to the guidance displayed on the LCD, designate a plurality of point numbers according to the above methods.

3) Concerning representation of memory number

In the measurement result output, and when displaying the list in the part program's Edit mode, the recalled feature is represented in the following manner.

Table 3-5

Memory type	Representation	Example
Specified memory	Number	10 (Specified memory No. 10 is recalled.)
Automatic memory	:Number	:3 (Automatic memory No. 3 is recalled.)
Raw data memory	Number!Point number	2!1-2!5 (1st to 5th points corresponding to specified memory No. 2 are recalled.)

Note that reference data in the reference definition memory is represented in the following manner.

Table 3-6

Reference data	Representation
X axis	:191
Y axis	:192
Z axis	:193
XY plane	:194
YZ plane	:195
ZX plane	:196
Origin	:197

4 FEATURE MEASUREMENT FUNCTION

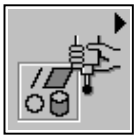
This chapter describes how to measure features such as points, straight lines, planes and circles.

The feature measurement function provides the following commands:

1) Measure point with approach direction
2) Measure side point (Cartesian coordinate axis)
3) Measure side point (polar coordinate axis)
4) Measure side point (spherical coordinate axis)
5) Measure side point (projected normal direction)
6) Measure side point (spatial normal direction)
7) Measure point
8) Measure projected straight line
9) Measure plane
10) Measure circle
11) Measure circle with known radius
12) Measure corner circle
13) Measure ellipse
14) Measure sphere
15) Measure cylinder
16) Measure stepped cylinder
17) Measure cone

[Key operations to access Feature measurement function]

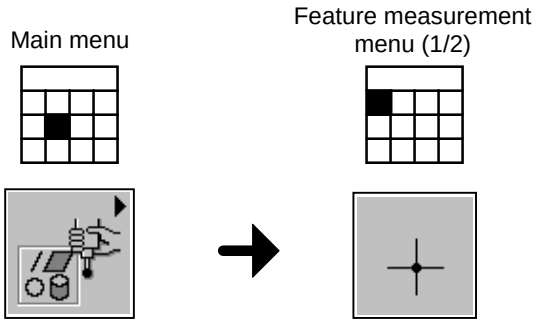
Main menu



Note: To view the next page menu of feature measurement function, press the function key corresponding to the → icon.

4.1 Measuring Point with Approach Direction

[Key operation]



[Function]

This command is used to measure one or multiple points and obtain a point feature with an approach direction (measurement direction) and a probe tip diameter.

Namely, this command is used to measure between one and 150 points for a point feature and then calculate the coordinates of the point feature. In multi-point measurement, the coordinates for the mean point are calculated. If rotational projection is designated, the coordinates are calculated for the point rotated and projected onto the specified projection plane for rotational projection (see Section 8.10).

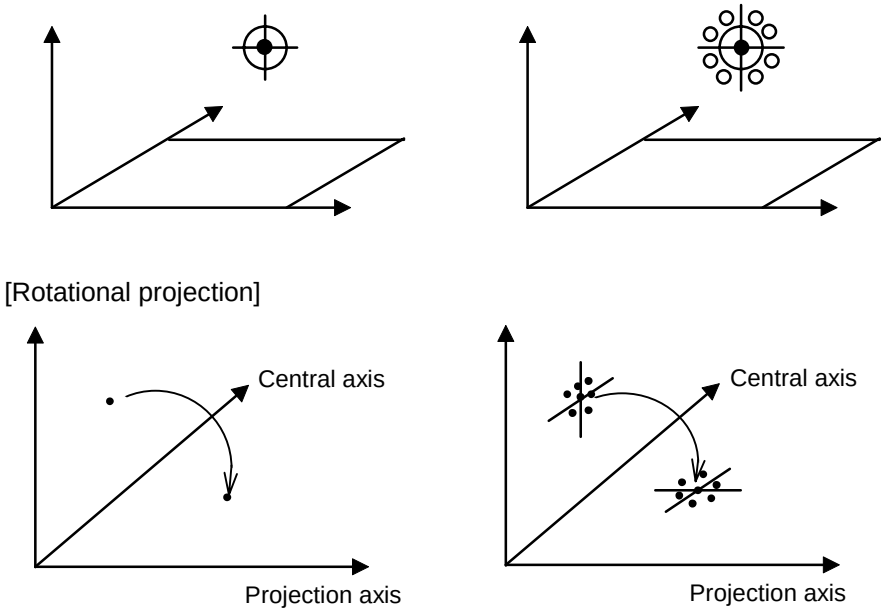


Figure 4-1

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the F4 (✔) key.
4) Select the items for output. (See Chapter 2.)

NOTE • If this point feature is recalled in distance calculation or feature construction calculation, probe tip radius compensation is performed at that point.

TIP • Probe tip radius compensation is not performed by this command.

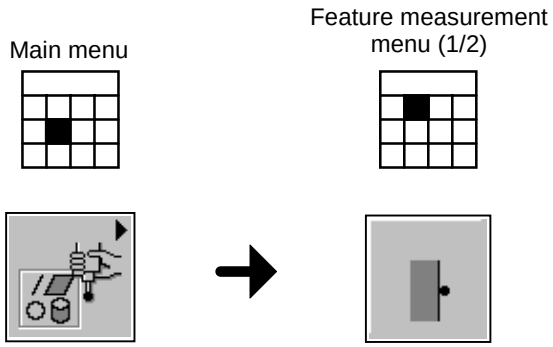
• The calculated probe tip diameter is the mean diameter.

• The measurement direction (or approach direction) is that of the final point data.

• You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select rotational projection.

4.2 Measuring Side Point (Cartesian Coordinate Axis)

[Key operation]



[Function]

This command is used to measure a compensated point feature where probe tip radius is compensated along one of the Cartesian coordinate axes.

Namely, this command is used to measure between one and 150 points, then compensate probe tip radius in one of the X, Y and Z axis directions, and thus obtain the side plane (side point) coordinates. In multi-point measurement, the coordinates are calculated for the mean point or the datum point (the furthest point in the opposite direction to the probe tip radius compensation direction; see Paragraph (3) in Section 2.10).

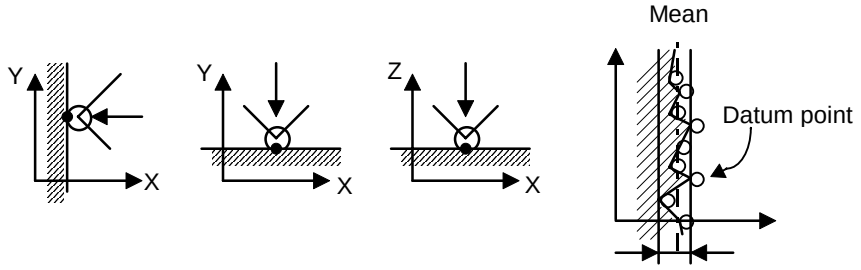


Figure 4-2

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the **F4** (✔) key.
4) Select the items for output. (See Chapter 2.)

NOTE

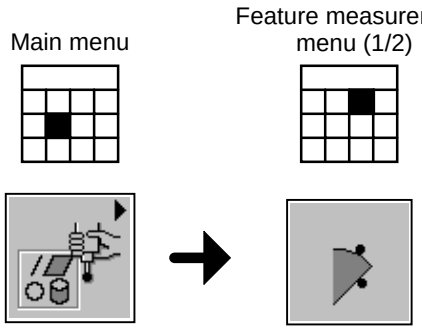
- When the Auto-dummy distance is set to 0, probe tip radius compensation is not performed because no measurement direction is obtained. (The auto-dummy distance is the distance from the workpiece at which a dummy measurement point is automatically input for determining the direction for the probe tip radius compensation (see Section 3.1.8).)

TIP

- The probe tip radius compensation direction (positive or negative along the X, Y or Z axis) is automatically determined according to the measurement direction for the measurement point.
- By using the output symbol “U” for the output item, only coordinate value of the axis of the probe tip radius compensation direction can be output.
- The difference between maximum coordinate and minimum coordinate for the side plane can be obtained using the output symbol “F8”.
- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select datum calculation.

4.3 Measuring Side Point (Polar Coordinate Axis)

[Key operation]



[Function]

This command is used to measure a compensated point feature where the probe tip radius is compensated along one of the polar coordinate axes.

This command performs measurement along the radial direction or the angular direction. Namely, this command is used to measure between one and 150 points, then perform the probe tip radius compensation in the radial direction (L) or angular direction (A), and thus obtain the side surface (side point) coordinates. In multi-point measurement, the side surface coordinates are calculated for the mean point or the datum point (the furthest point in the opposite direction to the probe tip radius compensation direction; see Paragraph (3) in Section 2.10).

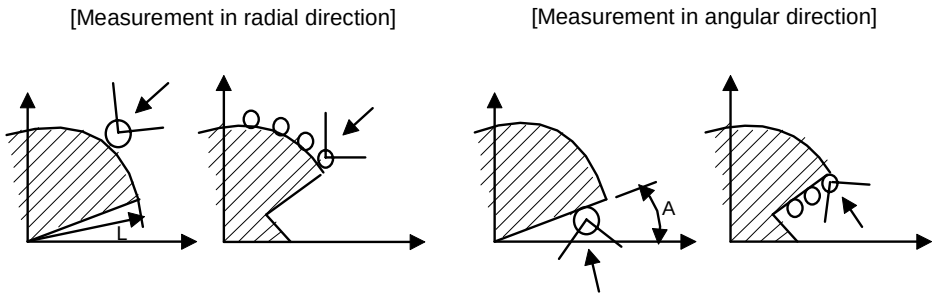


Figure 4-3

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

NOTE • Perform radial direction measurement and angular direction measurement separately.

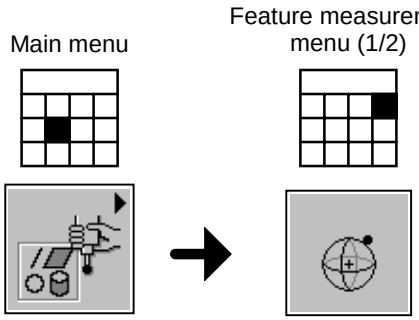
TIP • The type of measurement (radial direction measurement or angular direction measurement) and the probe tip radius compensation direction are determined by the measurement direction (or approach direction) for the final measurement point when the measurement points are projected onto the reference plane.

• The difference between the maximum coordinate and the minimum coordinate for the side surface can be calculated using output symbol “F8”.

• You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to define the projection plane (reference plane) temporarily for this command and to select the calculation method (mean or datum) for this command.

4.4 Measuring Side Point (Spherical Coordinate Axis)

[Key operation]



[Function]

This command is used to measure a compensated point feature where the probe tip radius is compensated in radial direction in spherical coordinate system.

Namely, this command is used to measure between one and 150 points, then perform the probe tip radius compensation in the spatial radial direction (S), and thus obtain the side surface (side point) coordinates. In multi-point measurement, the side surface coordinates are calculated for the mean point or the datum point (the furthest point in the opposite direction to the probe tip radius compensation direction; see Paragraph (3) in Section 2.10).

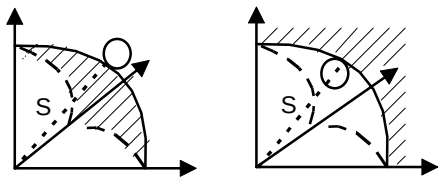


Figure 4-4

[Procedure]

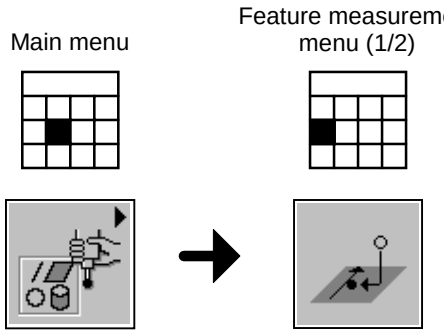
1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

TIP

- The probe tip radius compensation direction is determined by the measurement direction (or approach direction) for the final measurement point.
- The difference between the maximum coordinate and the minimum coordinate for the side surface can be calculated using output symbol “F8”.
- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select the calculation method (mean or datum) for this command.

4.5 Measuring Side Point (Projected Normal Direction)

[Key operation]



[Function]

This command is used to measure a compensated point feature where the probe tip radius is compensated on the reference plane and along the normal direction of the immediately previous feature.

Namely, this command is used to measure between one and 150 points, project the measured points on to the reference plane, then perform the probe tip radius compensation in the direction perpendicular to the immediately previous feature projected onto the reference plane, and thus obtain the side surface (side point) coordinates. In multi-point measurement, the side surface coordinates are calculated for the mean point or the datum point (the furthest point in the opposite direction to the probe tip radius compensation direction; see Paragraph (3) in Section 2.10).

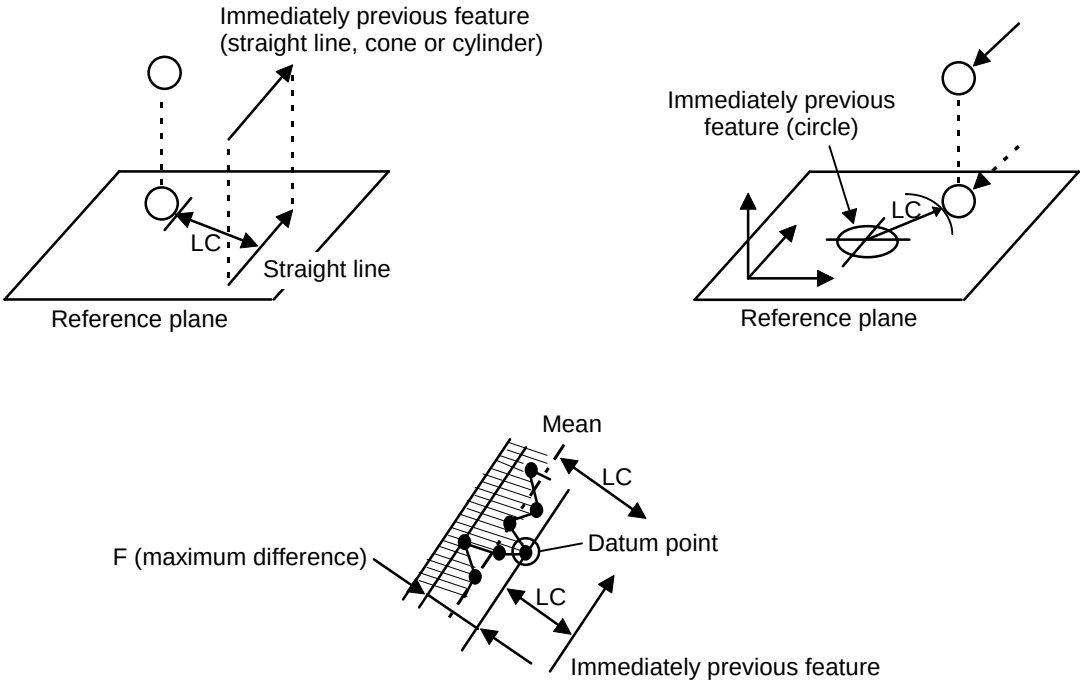


Figure 4-5

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the **F4** (✔) key.
4) Select the items for output. (See Chapter 2.)

NOTE • In this command, only a line component feature (straight line, cone or cylinder) or a circle feature can be an immediately previous feature.

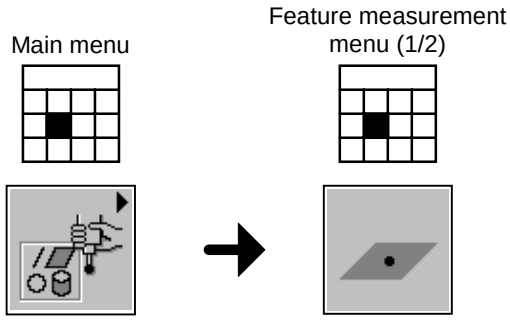
TIP • The maximum difference (the difference between the maximum coordinate and the minimum coordinate) for the side surface can be calculated using output symbol “F8”.

• The projection plane used for the projection can be changed after measurement.

• You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to define the projection plane (reference plane) temporarily for this command and to select the calculation method (mean or datum) for this command.

4.6 Measuring Side Point (Spatial Normal Direction)

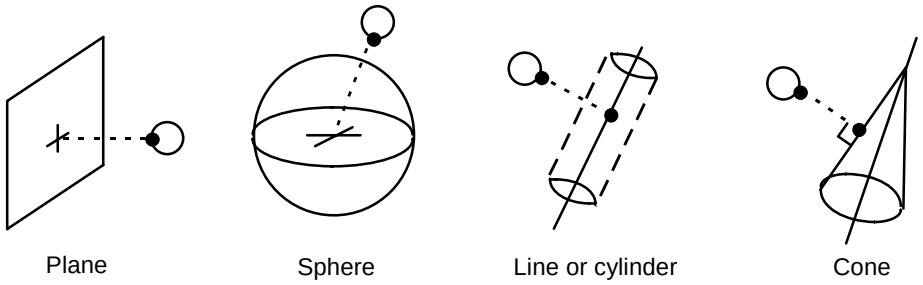
[Key operation]



[Function]

This command is used to measure a compensated point feature where the probe tip radius is compensated in the normal direction of the immediately previous feature.

Namely, this command is used to measure between one and 150 points, perform the probe tip radius compensation in the direction perpendicular to the immediately previous feature, and thus obtain the side surface (side point) coordinates. If the immediately previous feature is a cone, the probe tip radius is compensated in the direction perpendicular to the cone surface. In multi-point measurement, the side surface coordinates are calculated for the mean point or the datum point (the furthest point in the opposite direction to the probe tip radius compensation direction; see Paragraph (3) in Section 2.10).



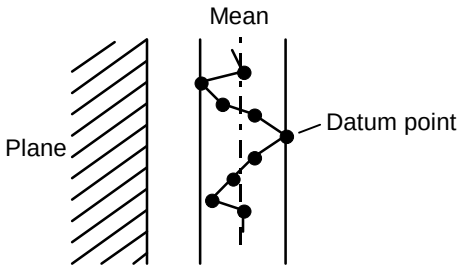


Figure 4-6

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

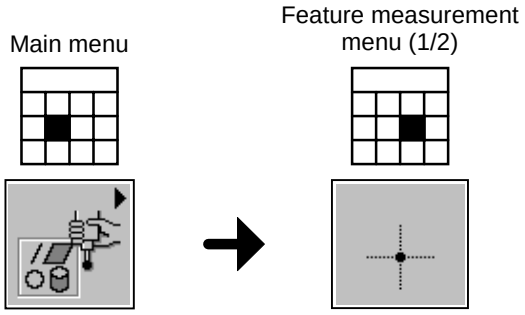
NOTE • In this command, only a line component feature (straight line, cone or cylinder), a point feature, a sphere feature, or a plane feature can be an immediately previous feature.

TIP • The maximum difference (the difference between the maximum coordinate and the minimum coordinate) for the side surface can be calculated using output symbol “F8”.

• You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select the calculation method (mean or datum) for this command.

4.7 Measuring Point

[Key operation]



[Function]

This command is used to measure between one and 150 points for a point feature and calculate the coordinates of the point feature. In multi-point measurement, the coordinates of the point feature are calculated for the mean point. If rotational projection is designated, the coordinates are calculated for the points rotated and projected onto the specified projection plane for rotational projection (see Section 8.10). The calculated point feature data has coordinates (x, y, z) and a probe diameter (d) of 0, and does not have measurement direction (or approach direction).

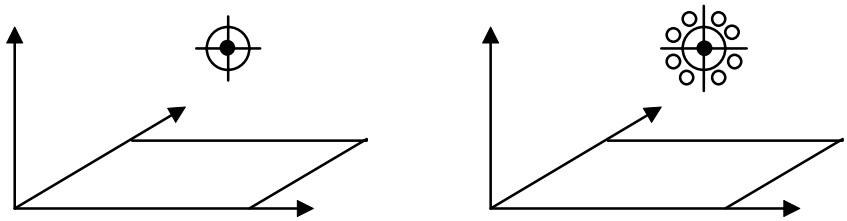


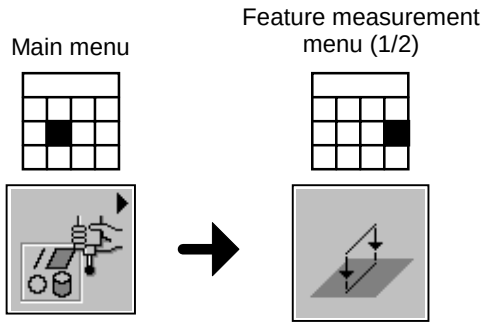
Figure 4-7

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at one or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

4.8 Measuring Projected Straight Line

[Key operation]



[Function]

This command is used to measure between two and 150 points, project all the measured points onto the projection plane, perform probe tip radius compensation and calculate the line feature. The line direction runs from the first measured point to the final measured point. If an inclined plane is specified, all the measured points are projected onto the inclined plane and the line feature is calculated on the inclined plane. In multi-point measurement, the datum line is calculated or the mean line is calculated using the least square method. If rotational projection is designated, the line feature is calculated after all the measured points are rotated and projected onto the specified projection plane for rotational projection (see Section 8.10).

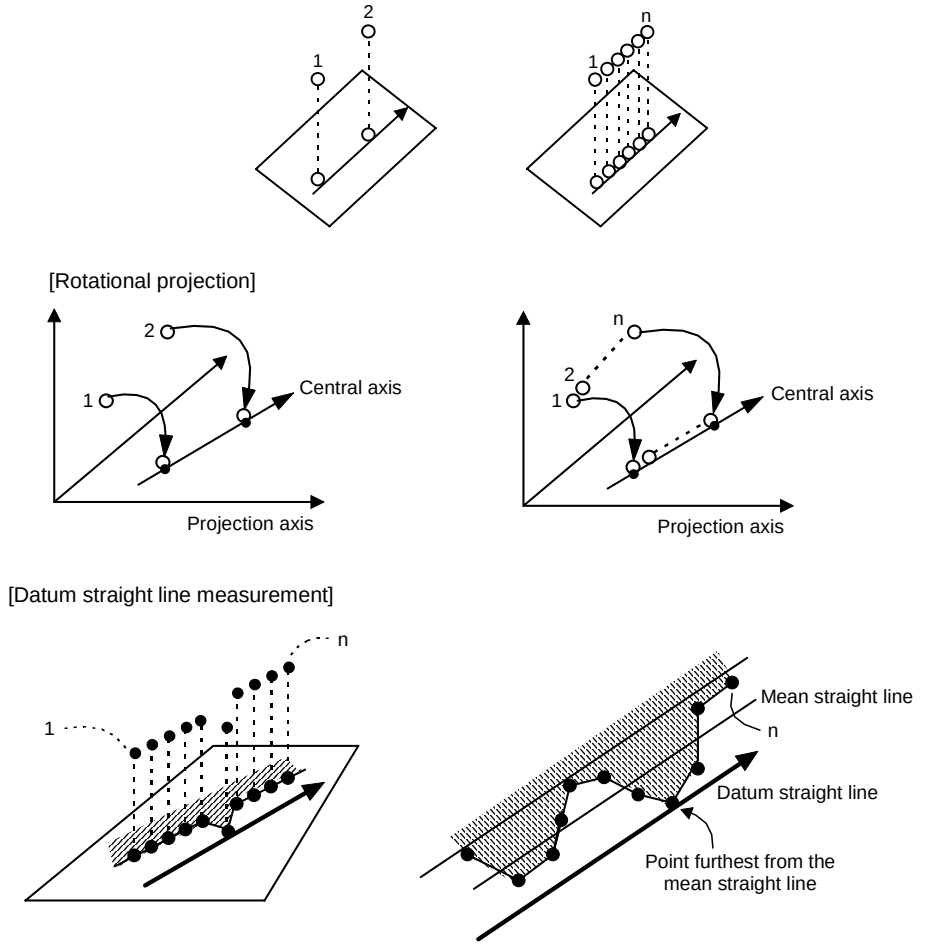


Figure 4-8

[Procedure]

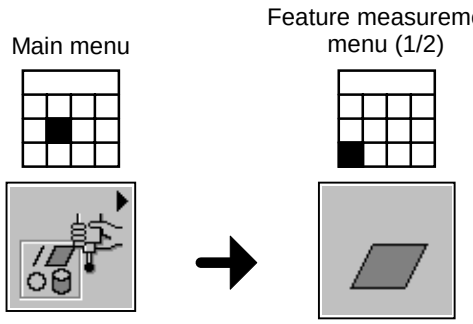
1) Select this measurement command from the menu.
2) Take measurements at two or more points.
3) When you have completed the measurements, press the F4 (✔) key.
4) Select the items for output. (See Chapter 2.)

TIP

- Output symbol “F1” can be used to calculate the straightness.
- The straight line feature data has the coordinates of the first measured point (x, y, z), the direction cosine (l, m, n) and the line length (h).
- You can use the Supplementary setting function in the Output item selection screen (See Section 2.10) to select the settings for projection and to select the calculation method (mean or datum) for this command.

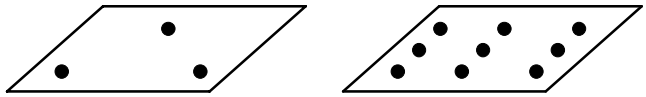
4.9 Measuring Plane

[Key operation]



[Function]

This command is used to measure between three and 150 points to calculate a plane feature. In multi-point measurement, the mean plane is calculated using the least square method. In datum measurement, the datum plane is determined by translating the mean plane to the most distant point in the opposite direction to that used in probe tip radius compensation (see Paragraph (3) in Section 2.10).



[Datum measurement]

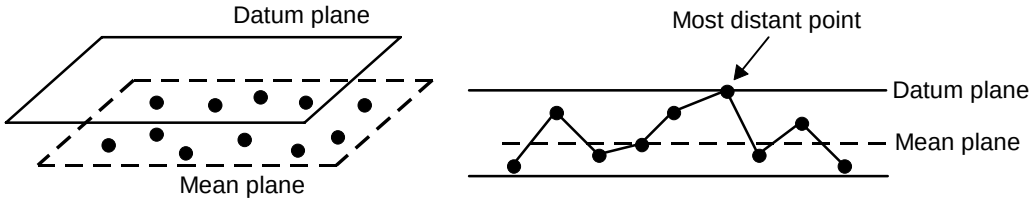


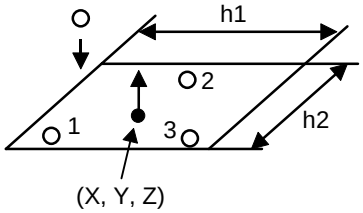
Figure 4-9

[Procedure]

1) Select this measurement command from the menu.
2) Take measurements at three or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

TIP • The plane feature data includes the coordinates of one point (the center of gravity) in the plane (x, y, z), the direction cosine of the normal line (l, m, n) and the measured width (h1, h2).

• The normal direction of the plane feature is the opposite of the measurement direction for the final measurement point.

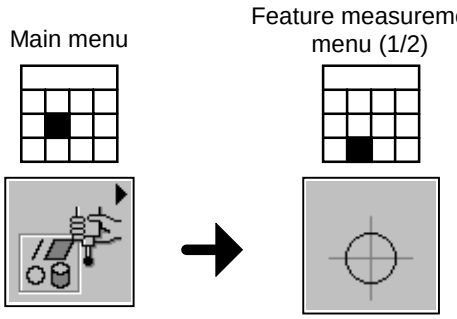


• Output symbol “F2” can be used to calculate the flatness.

• You can use the Supplementary setting function in the Output item selection screen (See Section 2.10) to select the settings for projection and to select the calculation method (mean or datum) for this command.

4.10 Measuring Circle

[Key operation]



[Function]

This command is used to measure projected circles, spatial circles or projected datum circles. The command takes measurements at between three and 150 points. In projected circle measurement, all measured pints are projected onto the reference plane, and then a projected circle feature is determined. In spatial circle measurement, all measured points are projected onto a plane that includes the first measured point and is parallel to the reference plane, and then a spatial circle feature is determined. If an inclined plane is specified, all measured points are projected onto the inclined plane, and then a circle feature is determined. In projected datum circle measurement, all measured pints are projected onto the projection plane, and then the datum circle feature is calculated.

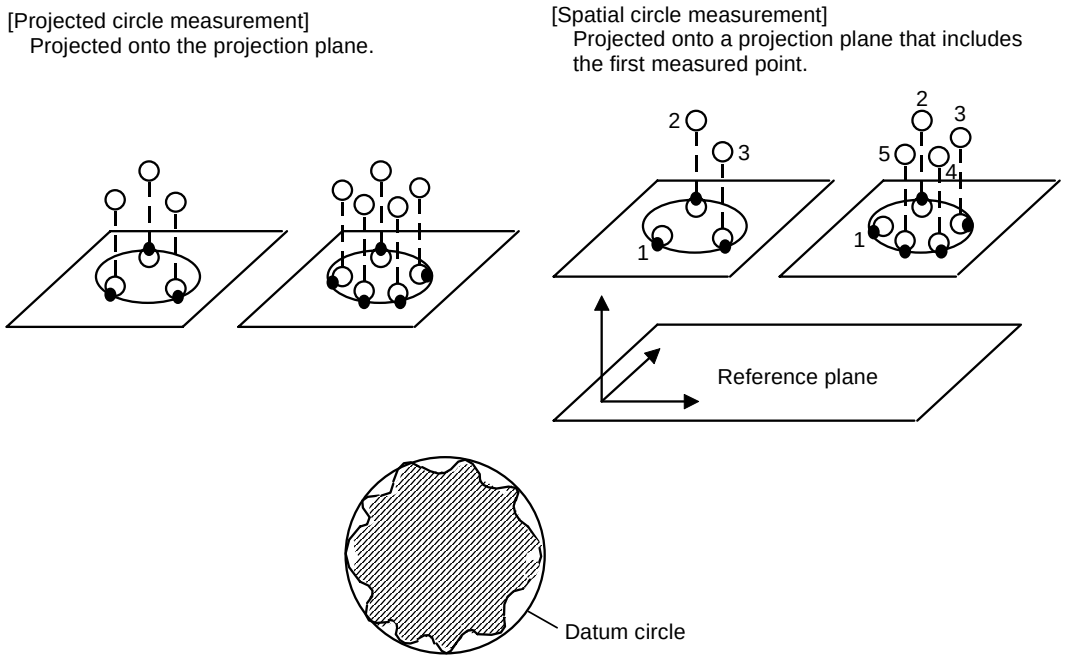


Figure 4-10

[Procedure]

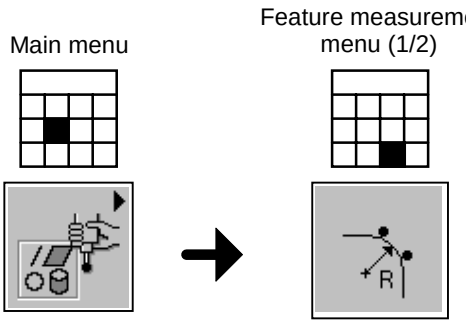
1) Select this measurement command from the menu.
2) Take measurements at three or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

TIP

- In multi-point measurement, output symbol “F3” can be used to calculate the circularity (or roundness).
- From the measurement direction for the final measurement point, this command automatically determines whether the circle is an internal circle (hole), an external circle (shaft) or neither. For datum circle measurement, the following applies:
  Internal → The maximum inscribed circle is obtained.
  External → The minimum circumscribed circle is obtained.
- You can use the Supplementary setting function in the Output item selection screen (See Section 2.10) to select the settings for projection and to select the calculation method (mean or datum) for this command.

4.11 Measuring Circle with Known Radius

[Key operation]



[Function]

This command is used to measure between two and 150 points to calculate a circle with a known radius on the reference plane.

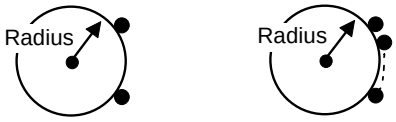
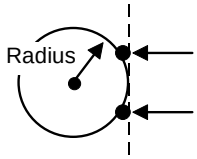


Figure 4-11

[Procedure]

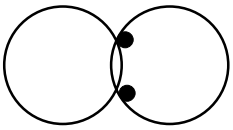
1) Select this measurement command from the menu.
2) Input the radius and select the circle type (hole or shaft).
3) Take measurements at two or more points.
4) When you have completed the measurements, press the F4 (✔) key.
5) Select the items for output. (See Chapter 2.)

NOTE • The measurement direction (or approach direction) for the last measurement point should be perpendicular to the line joining the first and last measurement points. If the measurement direction for the final measurement point is parallel to this line, an error may occur in the direction of the probe tip radius compensation.



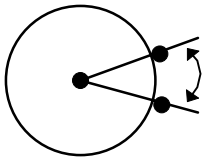
NOTE

- If the specified circle type (hole or shaft) or measurement direction for the last measurement point is incorrect, an incorrect circle is calculated.



Correct circle Incorrect circle obtained when hole or shaft is specified wrongly

- If the input points are within a narrow area, there is a greater likelihood of error in determining the center position of the circle. Therefore, pay attention to take measurement so that measurement points span at least 90°.



Narrow area increases the risk of center coordinate error.

Error for narrow area =
(circularity + measurement deviation) x radius / input points span

- Ensure that the first and last measurement points are approximately 90° apart. If they are 180° apart or almost in the same position, errors may occur and the calculated circle may be incorrect.

- Always use the last measurement point that has a measurement direction. If the last measurement point is measured with the distance for automatic dummy point input of 0, the software cannot calculate the circle since it cannot ascertain the measurement direction.

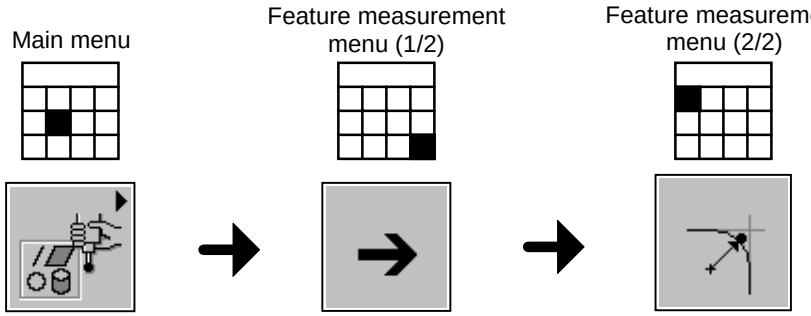
TIP

- Output symbol “F3” can be used to calculate the circularity (or roundness).

- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to define the projection plane (reference plane) temporarily for this command.

4.12 Measuring Corner Circle

[Key operation]



[Function]

This command is used to recall two straight lines and measure one point to calculate a circle tangent to the two straight lines in the reference plane.

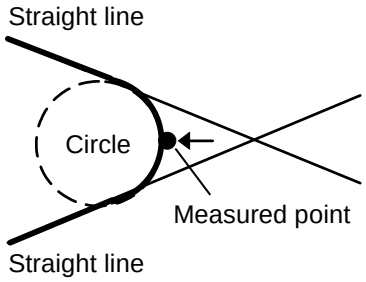
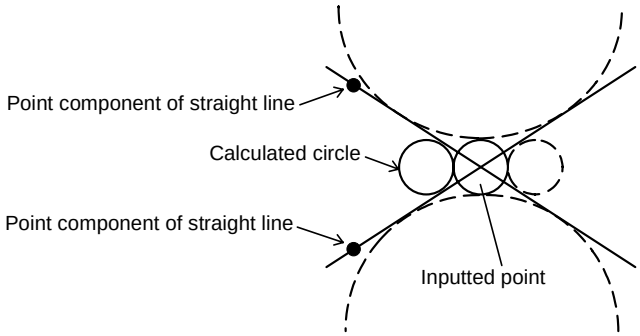


Figure 4-12

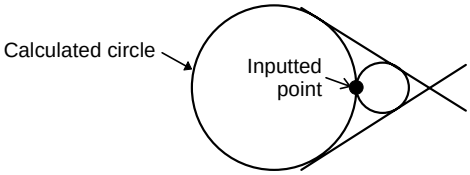
[Procedure]

1) Select this measurement command from the menu.
2) Recall the two straight lines from memory.
3) Measure one point.
4) Select the items for output. (See Chapter 2.)

NOTE • There are multiple circles that will be tangent to two straight lines, but this processing calculates a circle that fits in the range between the point (or position) components of the two straight lines (see Section 3.2.1).



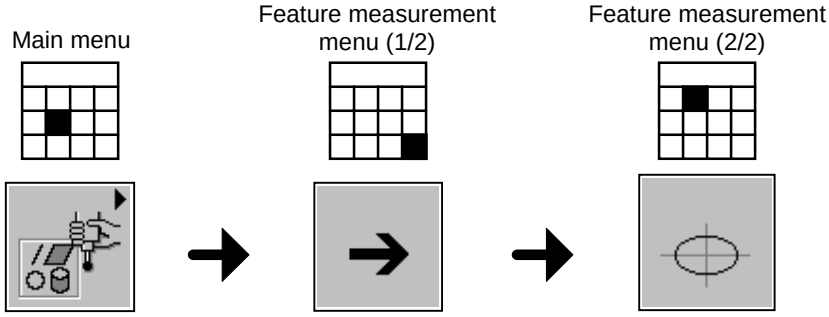
NOTE • If there are two circles within the above-mentioned range, the circle that is distant from the intersection of the two straight lines is calculated. Accordingly, this command is usually used to measure a corner between two surfaces.



• You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to define the projection plane (reference plane) temporarily for this command.

4.13 Measuring Ellipse

[Key operation]



[Function]

This command is used to measure between five and 150 points, project all the measured points onto the projection plane and calculate the ellipse feature. If an inclined plane is specified, all the measured data are projected onto the inclined plane and the ellipse feature is calculated on the inclined plane. In multi-point measurement, the mean ellipse is calculated using the least square method.

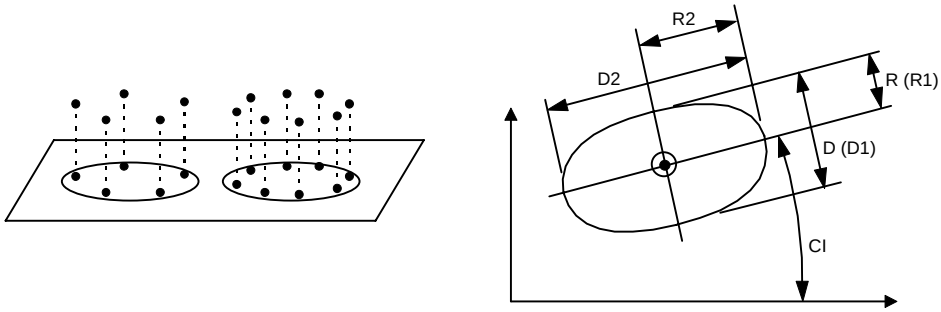


Figure 4-13

[Procedure]

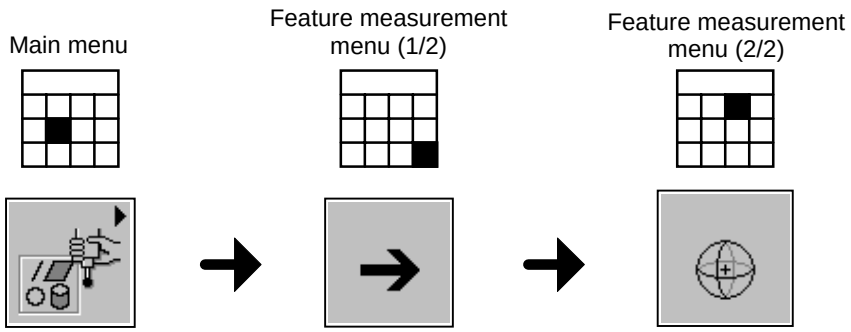
1) Select this measurement command from the menu.
2) Take measurements at five or more points.
3) When you have completed the measurements, press the F4 (✔) key.
4) Select the items for output. (See Chapter 2.)

TIP

- In multi-point measurement, the output symbol “F8” can be used to calculate the form deviation.
- From the measurement direction for the last measurement point, this command automatically determines whether the ellipse is an internal ellipse (hole), an external ellipse (shaft) or neither.
- The feature result output symbol “CI” represents the intersection angle of the first axis of the coordinate system and the major axis of the ellipse.
- You can use the Supplementary setting function in the Output item selection screen (See Section 2.10) to select the settings for projection.

4.14 Measuring Sphere

[Key operation]



[Function]

This command is used to measure between four and 150 points to calculate the sphere feature. In multi-point measurement, the mean sphere or datum sphere is calculated using the least square method.

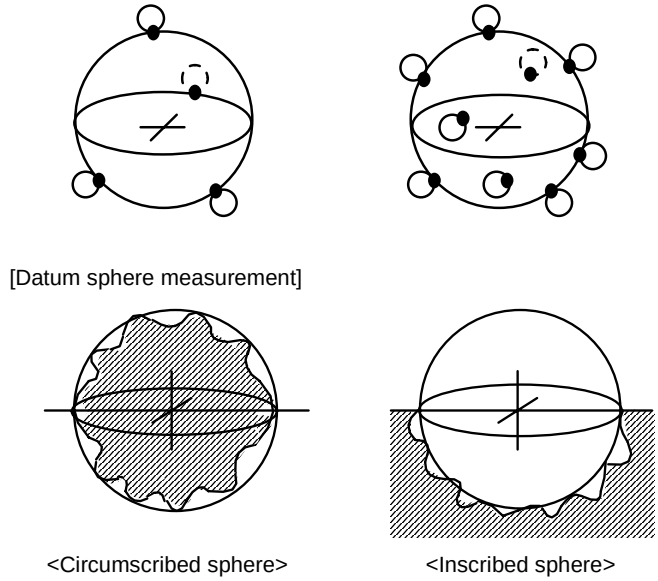


Figure 4-14

[Procedure]

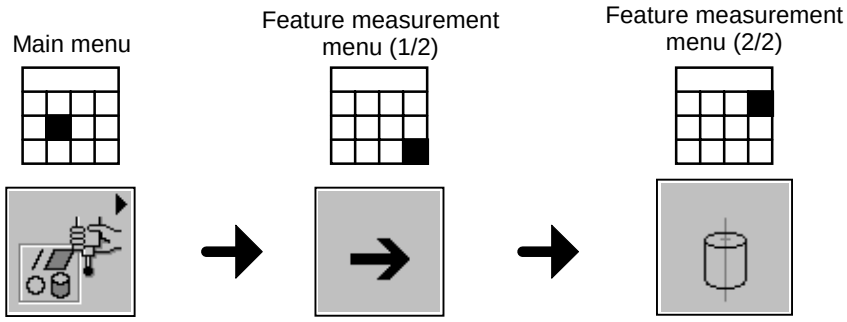
1) Select this measurement command from the menu.
2) Take measurements at four or more points.
3) When you have completed the measurements, press the F4 ( ) key.
4) Select the items for output. (See Chapter 2.)

TIP

- From the measurement direction for the last measurement point, this command automatically determines whether the sphere is an internal sphere, an external sphere or neither. For datum measurement, the following applies:
  Internal → The maximum inscribed sphere is obtained.
  External → The minimum circumscribed sphere is obtained.
- In multi-point measurement, output symbol “F4” can be used to calculate the sphericity.
- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select the calculation method (mean or datum) for this command.

4.15 Measuring Cylinder

[Key operation]



[Function]

This command is used to measure between six and 150 points to calculate the cylinder feature. The mean cylinder or datum cylinder is calculated using the least square method.

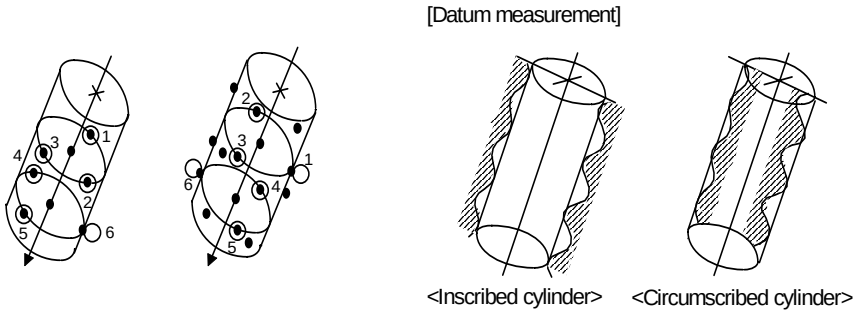


Figure 4-15

[Procedure]

1) Select this measurement command from the menu.
2) Measure three points on the same level cross-section of the cylinder.
3) Measure another three points on another level cross-section of the cylinder.
4) If measurement is to be taken at seven or more points, measure the necessary points from 7th point on the cylinder surface.
5) When you have completed the measurements, press the F4 ( ) key.
6) Select the items for output. (See Chapter 2.)

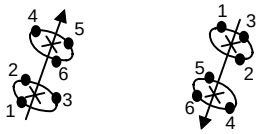
NOTE • Measure the first six points on two-level cross-sections with three measurements taken on each.

TIP

- From the measurement direction for the last measurement point, this command automatically determines whether the cylinder is an internal cylinder (cylindrical hole), an external cylinder (cylindrical shaft) or neither. For datum measurement, the following applies:

  Internal → The maximum inscribed cylinder is obtained.
  External → The minimum circumscribed cylinder is obtained.

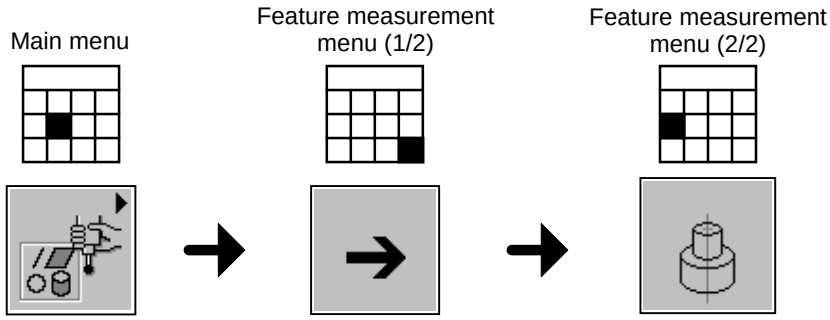
- If the last measurement point does not have measurement direction, the mean cylinder is calculated even in datum measurement.
- In multi-point measurement, output symbol “F5” can be used to calculate the cylindricity.
- The center axis direction of the obtained cylinder feature runs from measurement points 1-3 towards points 4-6.



- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select the calculation method (mean or datum) for this command.

4.16 Measuring Stepped Cylinder

[Key operation]



[Function]

This command is used to measure between six and 150 points to calculate a stepped cylinder feature with two different diameters. In multi-point measurement, the mean stepped cylinder is calculated using the least square method.

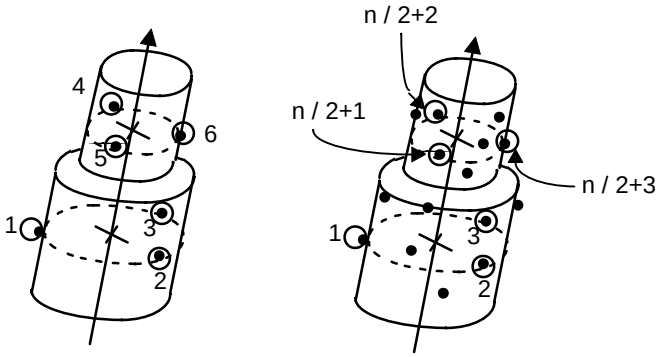


Figure 4-16

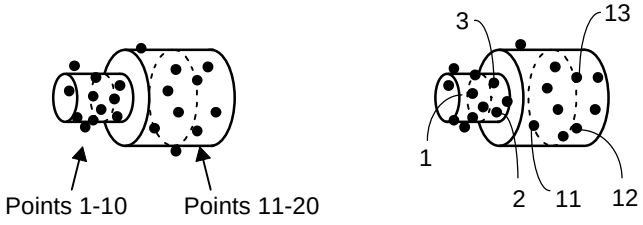
[Procedure]

1) Select this measurement command from the menu.
2) Measure between three and 75 points on the first cylindrical portion of the cylinder.
3) Measure the same number of points on the second cylindrical portion of the cylinder.
4) When you have completed the measurements, press the **F4** (✔) key.
5) Select the items for output. (See Chapter 2.)

NOTE • Measure the same number of points on each cylindrical portion of the stepped cylinder.

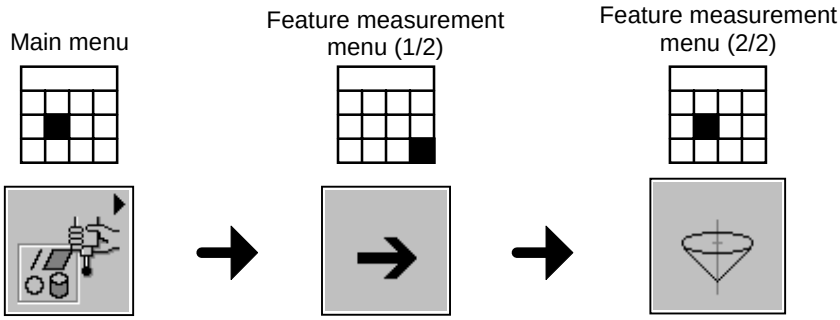
• Measure the first three points on each of the first and second cylindrical portions on one cross-section on each cylindrical portion, the two cross-sections being at different positions along the stepped cylinder axis.

[For 20 measurement points]



4.17 Measuring Cone

[Key operation]



[Function]

This command is used to measure between six and 150 points to calculate a cone feature. In multi-point measurement, the mean cone or datum cone is calculated using the least square method.

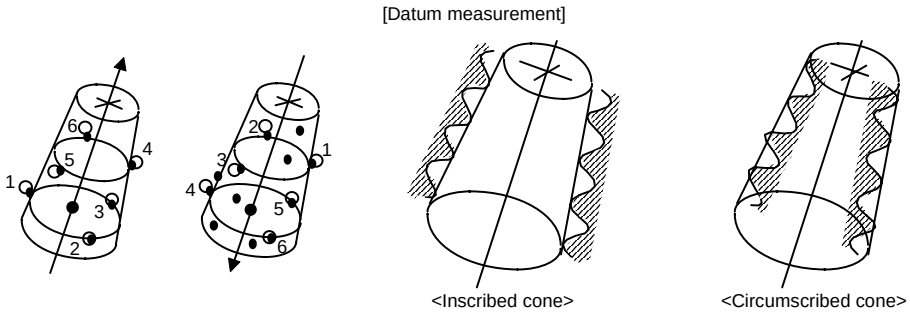


Figure 4-17

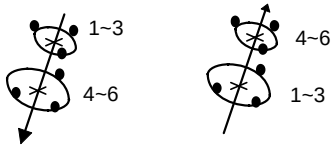
[Procedure]

1) Select this measurement command from the menu.
2) Measure three points on the same level cross-section of the cone.
3) Measure another three points on another level cross-section of the cone.
4) If seven or more points are to be measured, measure the necessary points from 7th point on the cone surface.
5) When you have completed the measurements, press the **F4** (✔) key.
6) Select the items for output. (See Chapter 2.)

NOTE • Measure the first six points on two-level cross-sections with three measurements taken on each.

TIP

- From the measurement direction for the last measurement point, this command automatically determines whether the cone is an internal cone (conical hole), an external cone (conical shaft) or neither. For datum measurement, the following applies:
  Internal → The maximum inscribed cone is obtained.
  External → The minimum circumscribed cone is obtained.
- If the last measurement point does not have measurement direction, the mean cone is calculated even in datum measurement.
- In multi-point measurement, output symbol “F6” can be used to calculate the conicity.
- The center axis direction of the obtained cone feature runs from measurement points 1-3 towards points 4-6.



- You can use the Supplementary setting function in the Output item selection screen (see Section 2.10) to select the calculation method (mean or datum) for this command.

5 FEATURE CONSTRUCTION FUNCTION

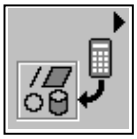
This chapter describes the function that mathematically constructs a new feature from features obtained previously.

The feature construction function uses commands that mathematically construct a new feature using a plurality of feature data stored in the memory. The commands in the feature construction function are listed below:

1) Constructing projected line
   Constructing a projected line feature mathematically from measured features.
2) Constructing spatial line
   Constructing a spatial line feature mathematically from measured features.
3) Constructing plane
   Constructing a plane feature mathematically from measured features.
4) Constructing circle
   Constructing a circle feature mathematically from measured features.
5) Constructing circle with known radius
   Constructing a circle feature with a known radius mathematically from measured features.
6) Constructing ellipse
   Constructing an ellipse feature mathematically from measured features.
7) Constructing sphere
   Constructing a sphere feature mathematically from measured features.
8) Constructing cylinder
   Constructing a cylinder feature mathematically from measured features.
9) Constructing stepped cylinder
   Constructing a stepped cylinder feature mathematically from measured features.
10) Constructing cone
    Constructing a cone feature mathematically from measured features.

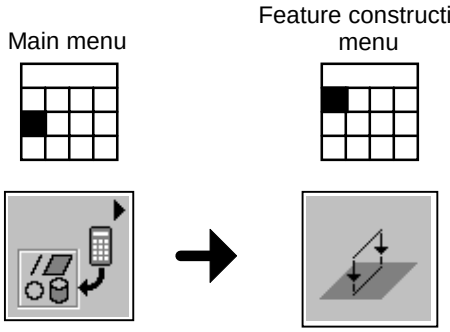
[Key operations to access Feature construction functions]

Main menu

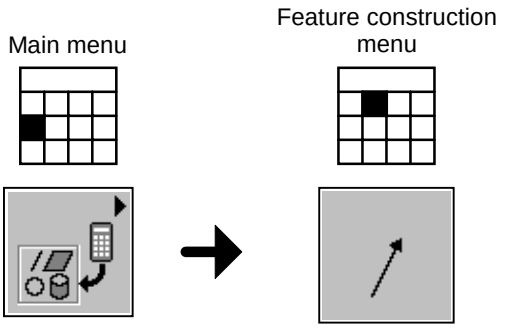


5.1 Key Operations

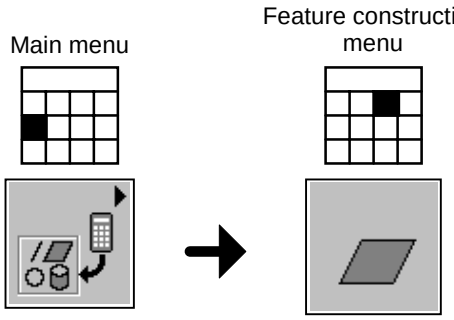
[Key operations for Constructing projected line]



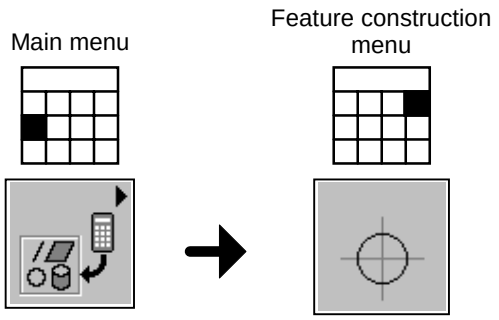
[Key operations for Constructing spatial line]



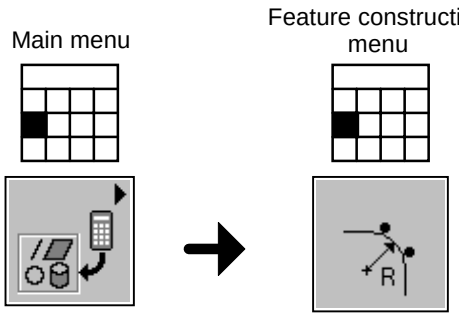
[Key operations for Constructing plane]



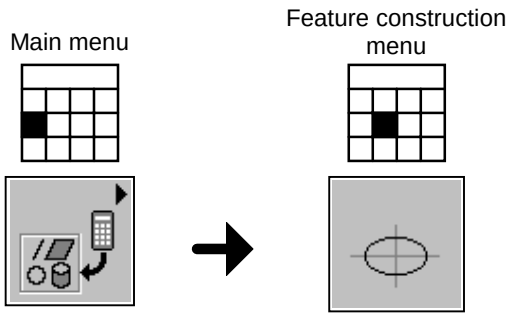
[Key operations for Constructing circle]



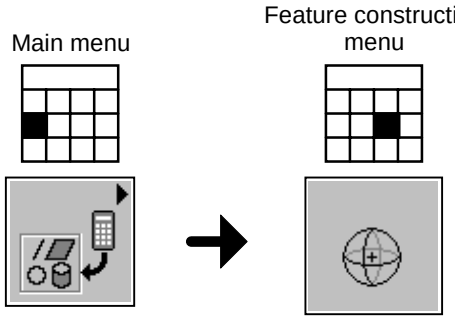
[Key operations for Constructing circle with known radius]



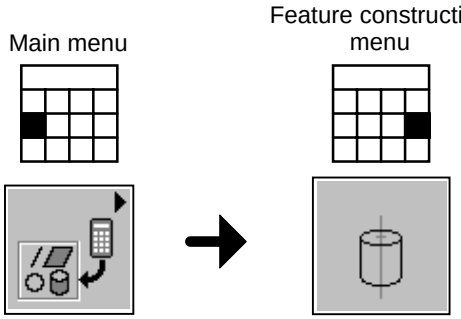
[Key operations for Constructing ellipse]



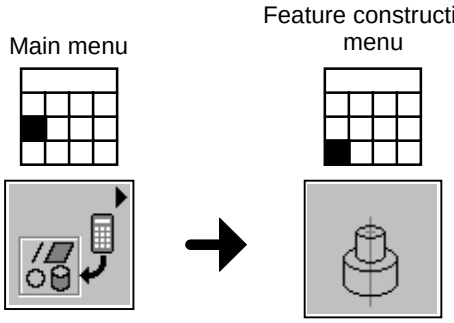
[Key operations for Constructing sphere]



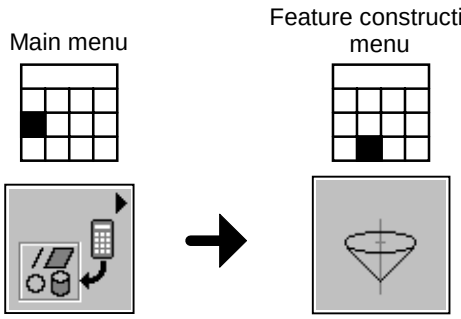
[Key operations for Constructing cylinder]



[Key operations for Constructing stepped cylinder]



[Key operations for Constructing cone]



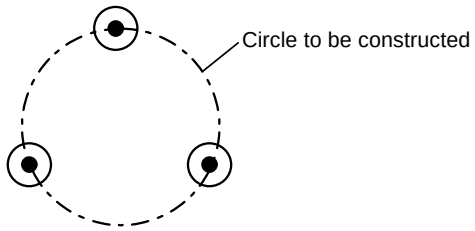
5.2 Outline of Feature Construction Function

[Overview]

In the feature measurement function described in Chapter 4, a feature is obtained from measured data. On the other hand, in the feature construction function, a new feature is mathematically constructed by using features data obtained previously and stored in the memory. The position components (or point components) of the stored features data are used to construct a new feature.

[Example]

To construct a circle that runs through the center points of three previously measured circles as shown in the figure below, recall those three circle features in the "Construct circle" command.



See Chapter 4 for the calculation details, since the calculations used in this chapter are the same as those described in Chapter 4.

However, calculation method for a spatial line is not described in Chapter 4. Therefore, the "Construct spatial line" command is described in Section 5.3.

[Procedure]

1) Select a feature construction command from the menu.
2) If that command function requires parameters, enter the parameters.
3) Recall features data from the memory.
4) When you have finished inputting the data, press the F4 ( ) key.
5) Select the items for output. (See Chapter 2.)

NOTE

- The data used in constructing a feature are the position components (or point components) of the previously obtained features (such as the center position of a circle feature). For more information on position components, refer to the explanations in Section 3.2.
- When you recall a point feature with approach direction in the feature construction commands, the probe tip radius compensation is performed for that point feature.

5.3 Constructing Spatial Line

[Function]

Recalls two or more features from the memory to construct a spatial line feature.

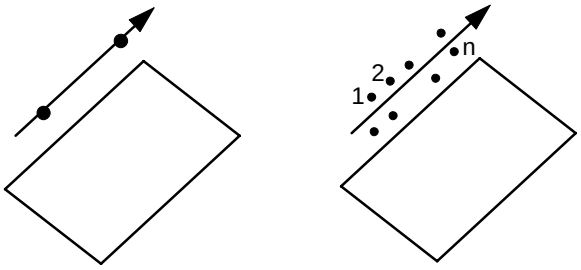


Figure 5-1

[Procedure]

1) Select this command from the menu.
2) Recall features from the memory.
3) When you have finished inputting the data, press the F4 (✔) key.
4) Select the items for output. (See Chapter 2.)

TIP
- This command does not perform the probe tip radius compensation.
- The line direction runs from the first point to the final point.
- The output symbol “F1” can be used to calculate the straightness.

MEMO

6 FEATURE COMBINATION CALCULATION AND KEYING-IN FUNCTIONS

This chapter describes the functions for determining features using either feature combination calculation or keying-in operation.

These functions provide commands that determine features either by keying-in operation or by calculation process of combining features.

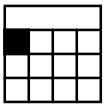
The feature combination calculation and keying-in functions provide the following commands:

1) Store feature in specified memory
2) Calculate point
3) Calculate straight line
4) Calculate plane
5) Calculate circle
6) Calculate distance
7) Calculate intersection angle
8) Calculate orientation deviation
9) Change feature type or move feature
10) Key in feature

6.1 Storing Feature in Specified Memory

[Key operation]

Main menu



[Function]

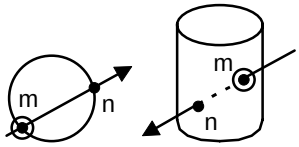
This function stores or saves the last obtained feature in the specified memory.

[Procedure]

1) Select this command from the menu.
2) Designate the address in specified memory (1 to 1000).
   - ➢ The last obtained feature is stored.

NOTE • If data is already stored in the designated address in specified memory, that data is overwritten.

TIP • If multiple features are obtained in the last operation, for example the operation of calculating spatial intersection point described in Section 6.2.2, you can store multiple features by designating multiple storage addresses.



• If multiple storage addresses are designated when only one feature is obtained, the feature is only stored in the first address.

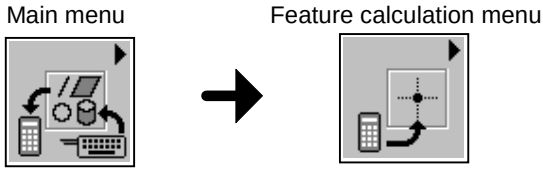
• The data in the specified memory (1 to 1000) is not erased when the power is switched off.

6.2 Calculating Point

Point calculation function includes the following commands:

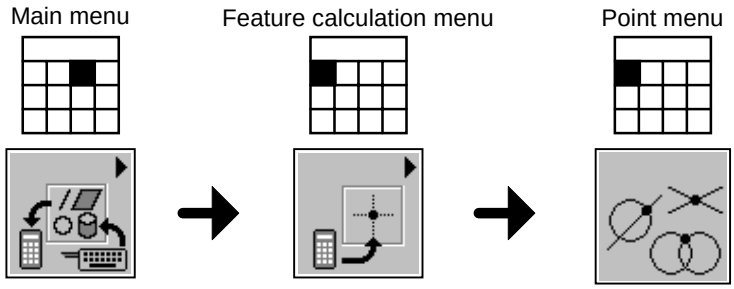
1) Calculate projected intersection point
2) Calculate spatial intersection point
3) Calculate bisection point
4) Calculate point of tangency

[Key operations to access Point calculation function]



6.2.1 Calculating Projected Intersection Point

[Key operation]



[Function]

Recalls two line-component features (line, cylinder or cone) or circle features, projects them onto the reference plane and then calculates the intersection points.

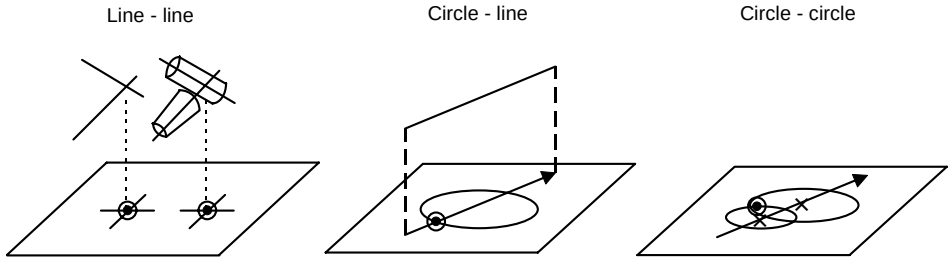


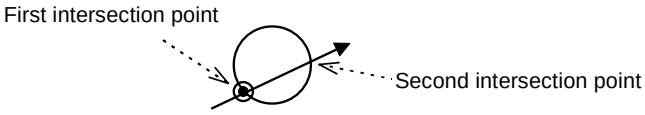
Figure 6-1

[Procedure]

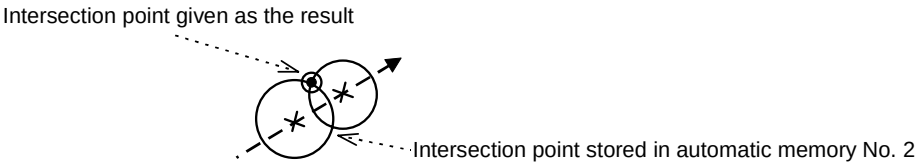
1) Select this command from the menu.
2) Recall two line-component features (line, cylinder or cone) or circle features from the feature memory.
   - The projected intersection points are calculated.
3) Select the items for output. (See Chapter 2.)

TIP

- The result of this command for a line intersecting a circle is the first intersection point in the line direction. The second intersection point is stored in the automatic memory No. 2.



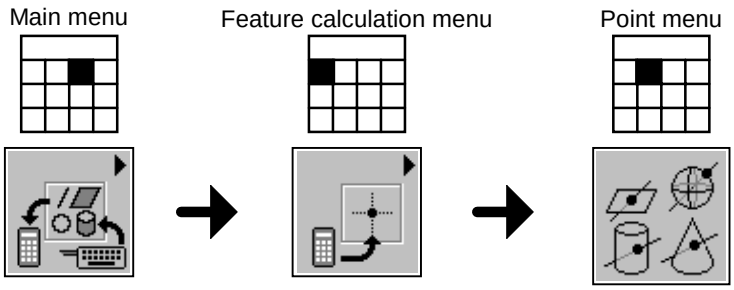
- For the intersection points of two circles, the result of this command is the left-hand intersection point relative to the direction in which a line runs when drawn from the center of the first circle to the center of the second circle. The right-hand intersection point is stored in the automatic memory No. 2.



- You can use the supplementary setting key in the Output item selection screen (see Chapter 2) to select the reference plane (projection plane).

6.2.2 Calculating Spatial Intersection Point

[Key operation]



[Function]

Recalls a plane, cylinder, cone or sphere feature and a line-component feature (line, cylinder or cone) and then calculates the intersection points.

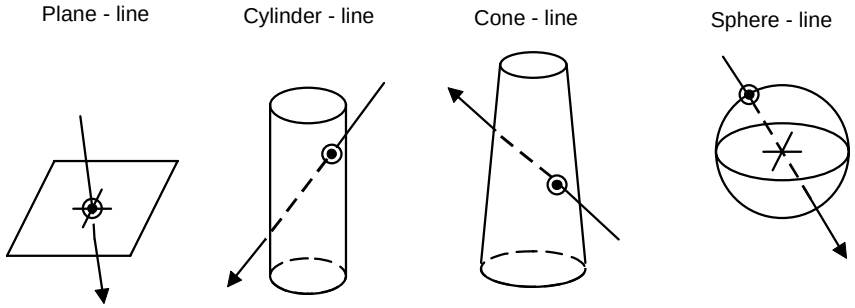


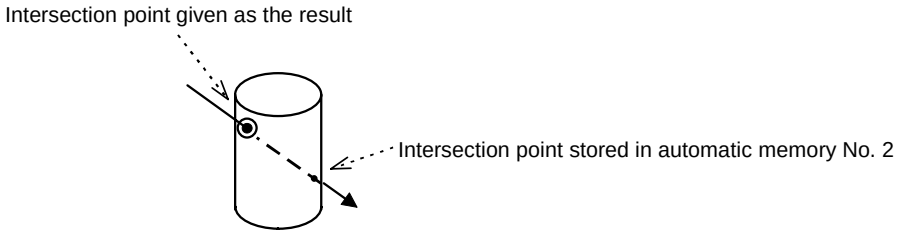
Figure 6-2

[Procedure]

1) Select this command from the menu.
2) Recall a plane, cylinder, cone or sphere feature and a line-component feature (line, cylinder or cone) from the feature memory.
   - ➢ The spatial intersection points are calculated.
3) Select the items for output. (See Chapter 2.)

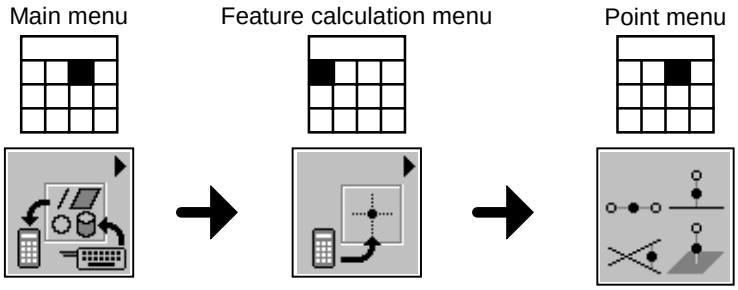
NOTE • Specify a plane, cylinder, cone or sphere feature as the first feature and a line-component feature (line, cylinder or cone) as the second feature.

TIP • If there are two intersection points, the result of this command is the first intersection point. The second intersection point is stored in the automatic memory No. 2.



6.2.3 Calculating Bisection Point

[Key operation]



[Function]

Recalls a feature combination shown below and calculates the bisection point between the two features.

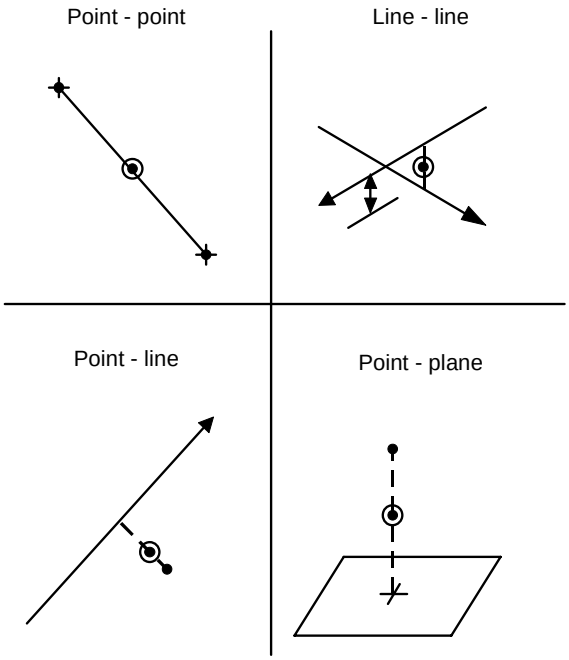


Figure 6-3

[Procedure]

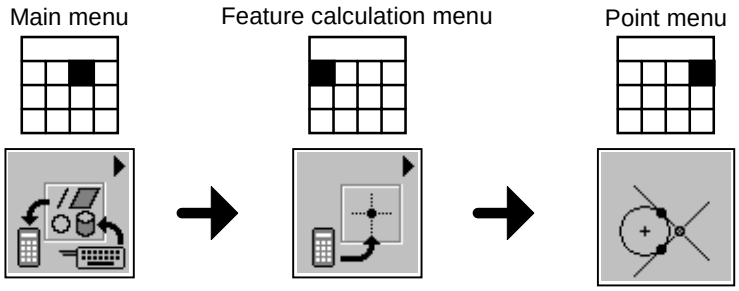
1) Select this command from the menu.
2) Recall a feature combination shown above from the feature memory.
   - ➢ The bisection point is calculated.
3) Select the items for output. (See Chapter 2.)

NOTE • Probe tip radius compensation is not performed even when a point feature is measured point data.

TIP • The bisection point for two line-component features is the bisection point on the shortest-distance line between the two line-component features. If the two line-component features are perfectly parallel, the bisection point cannot be calculated.

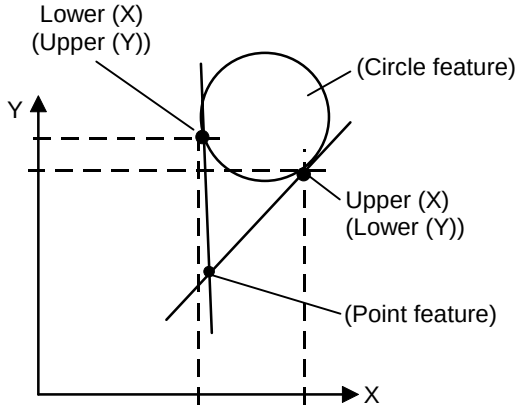
6.2.4 Calculating Point of Tangency

[Key operation]



[Function]

Recalls a point feature and a circle feature, projects them onto the reference plane, and then calculates the tangent point of the circle and a line drawn through the point. Either of the two tangent points can be selected (see figure below).



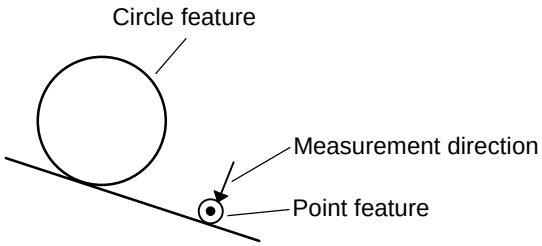
<In the case of the XY plane>

Figure 6-4

[Procedure]

1) Select this command from the menu.
2) Select the tangent point using the parameter menu ("Upper (X)", "Lower (X)", "Upper (Y)", "Lower (Y)", "Upper (Z)", "Lower (Z)").
3) Recall a point feature and a circle feature from the feature memory.
   - ➢ The tangent point is calculated.
4) Select the items for output. (See Chapter 2.)

NOTE • If the point feature has a measurement direction (or approach direction), probe tip radius compensation is performed.



• You can use the supplementary setting key in the Output item selection screen (see Chapter 2) to select the reference plane (projection plane).

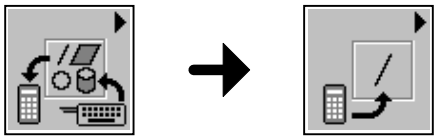
6.3 Calculating Straight Line

Line calculation function includes the following commands:

1) Calculate intersecting line
2) Calculate bisection line
3) Calculate tangent line

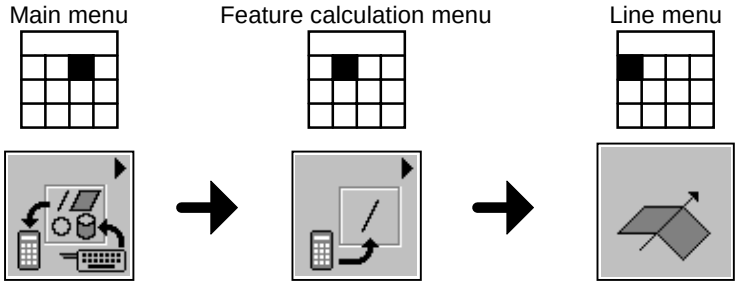
[Key operations to access Line calculation function]

Main menu → Feature calculation menu



6.3.1 Calculating Intersecting Line

[Key operation]



[Function]

Recalls two plane features and calculates the intersecting line of the two planes.

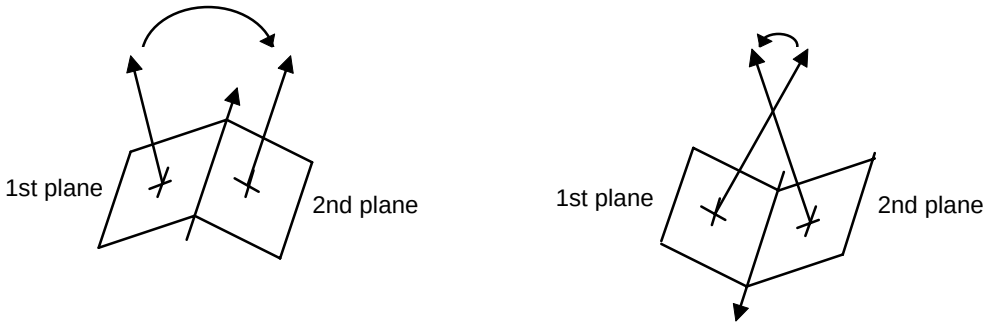


Figure 6-5

[Procedure]

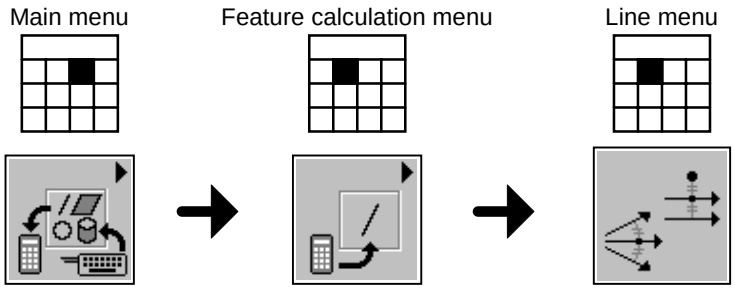
1) Select this command from the menu.
2) Recall two plane features from the feature memory.
   - ➢ The intersecting line is calculated.
3) Select the items for output. (See Chapter 2.)

TIP

- The point data (or position data) of the intersecting line is the projected point of the point data of the first plane onto the intersecting line.
- Considering the direction from the first plane's normal direction towards the second plane's normal direction as the clockwise direction, the direction of the intersecting line extends toward the back of this clock. (Namely, the direction of the intersecting line is the direction of the vector product of the normal vectors of the two planes.)

6.3.2 Calculating Bisection Line

[Key operation]



[Function]

Recalls two line-component features (line, cylinder or cone) or recalls a point-component feature (point, circle, ellipse or sphere) and a line-component feature (line, cylinder or cone), and then calculates the bisection line.

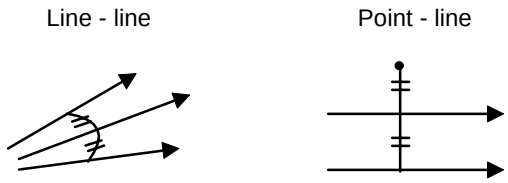


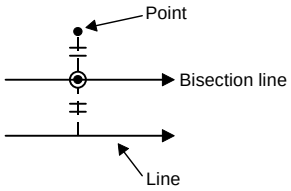
Figure 6-6

[Procedure]

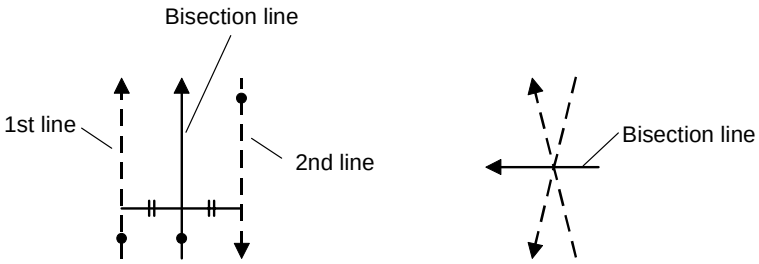
1) Select this command from the menu.
2) Recall two line-component features (line, cylinder or cone) or recall a point-component feature (point, circle, ellipse or sphere) and a line-component feature (line, cylinder or cone) from the feature memory.
   - ➢ The bisection line is calculated.
3) Select the items for output. (See Chapter 2.)

NOTE • Probe tip radius compensation is not performed even for a point feature having a measurement direction (or approach direction).

TIP • The bisection line for a point and line combination is taken as a line parallel to the line and including the bisection point of the point and the line.

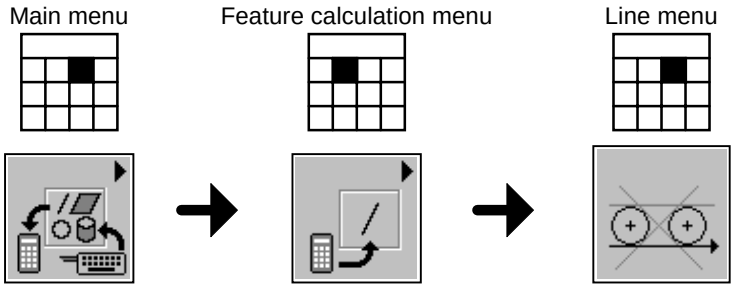


• If two lines are perfectly parallel and run in opposite directions, the calculated bisection line runs in the direction of the first line. If the lines are even slightly inclined to each other, the bisection line runs in the direction between the two lines' directions.



6.3.3 Calculating Tangent Line

[Key operation]



[Function]

This command is used to recall two circle features, project them onto the reference plane and calculate the tangent line.

Parameters are used to select which of the four possible tangent lines is calculated.

The selected parameter specifies whether the coordinate value of the point at which the tangent line touches the circle feature is upper or lower.

<An example in which the tangent line “A” is calculated for the two circle features below>

Parameter (1) for the first circle feature → "Upper (Y)"
Parameter (2) for the second circle feature → "Upper (Y)"

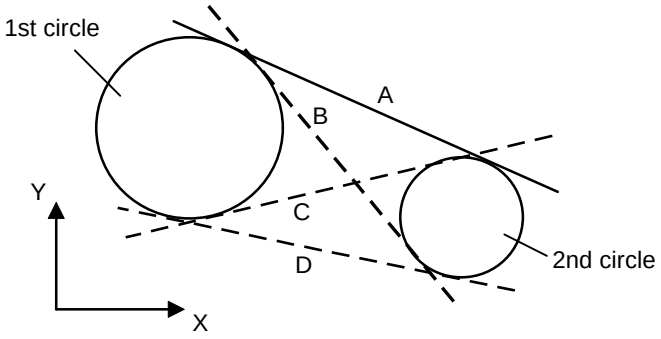


Figure 6-7

[Procedure]

1) Select this command from the menu.
2) Select the parameters ("Upper (X)", "Lower (X)", "Upper (Y)", "Lower (Y)", "Upper (Z)", "Lower (Z)") used to select the tangent line for each circle feature.
3) Recall two circle features from the feature memory.
   - The tangent line is calculated.
4) Select the items for output. (See Chapter 2.)

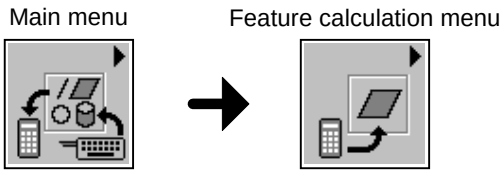
NOTE • You can use the supplementary setting key in the Output item selection screen (see Chapter 2) to select the reference plane (projection plane).

6.4 Calculating Plane

Plane calculation function includes the following command:

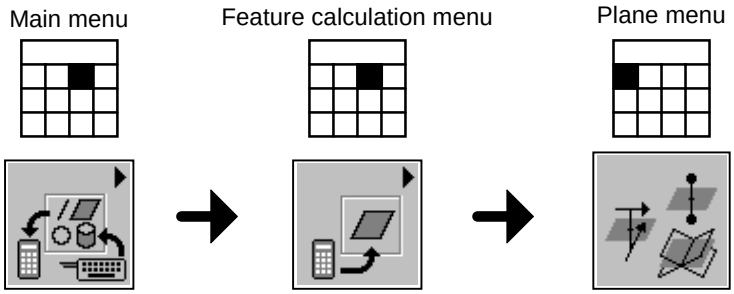
1) Calculate bisection plane

[Key operations to access Plane calculation function]



6.4.1 Calculating Bisection Plane

[Key operation]



[Function]

Recalls two plane features, or recalls two line-component features (line, cylinder or cone), or recalls two point-component features (point, circle, ellipse or sphere), then calculates the bisection plane between the two features.

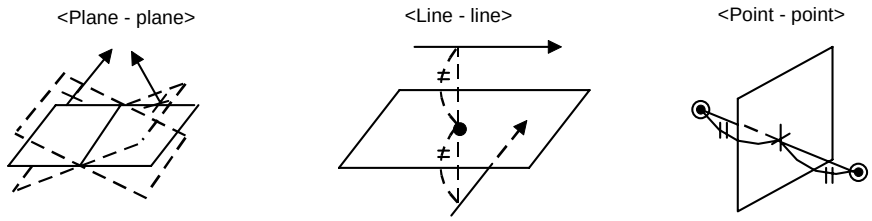


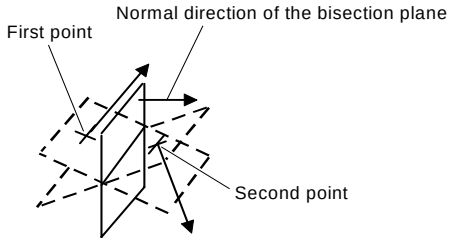
Figure 6-8

[Procedure]

1) Select this command from the menu.
2) Recall two plane features, or recall two line-component features (line, cylinder or cone), or recall two point-component features (point, circle, ellipse or sphere) from the feature memory.
   - The bisection plane is calculated.
3) Select the items for output. (See Chapter 2.)

NOTE

- Note that the calculated bisection plane differs depending on the normal directions of the two plane features.
- The normal direction of the bisection plane for two points runs from the first point to the second point.



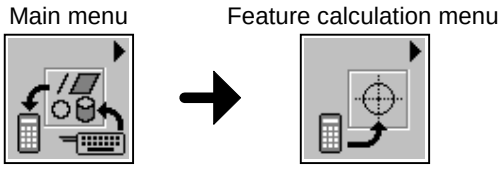
- The normal direction of the bisection plane for two lines would be facing the back of a clock when the clockwise direction of that clock is taken as the direction from the first line towards the second line. (Namely, the normal direction of the bisection plane is the direction of the vector product of the direction vectors of the two lines.)
- The point data (or position data) of the bisection plane is the projected point of the point data of the first feature onto the bisection plane.

6.5 Calculating Circle

Circle calculation function includes the following commands:

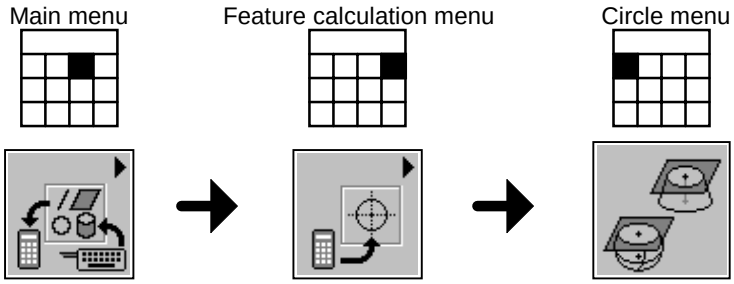
1) Calculate intersecting circle
2) Calculate cross-sectional circle of cone

[Key operations to access Circle calculation function]



6.5.1 Calculating Intersecting Circle

[Key operation]



[Function]

Recalls a plane feature and a cone feature, a plane feature and a sphere feature, or two sphere features, then calculates the intersecting circle.

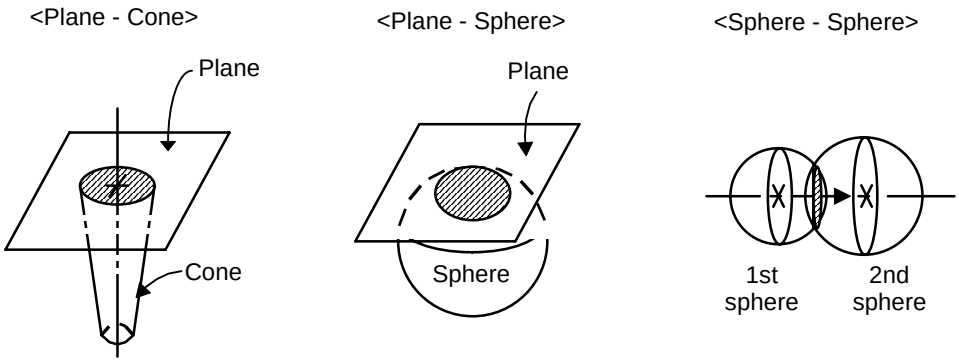


Figure 6-9

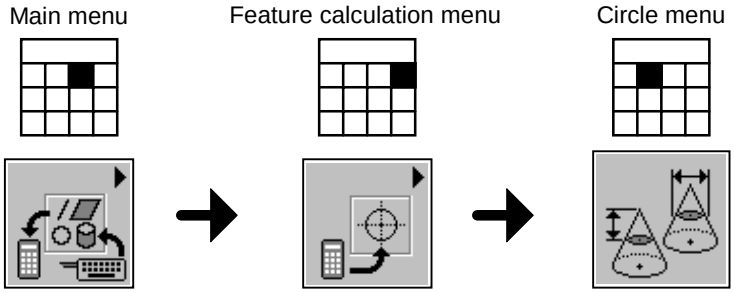
[Procedure]

1) Select this command from the menu.
2) Recall a plane feature and a cone feature, a plane feature and a sphere feature, or two sphere features from the feature memory.
   - The intersecting circle is calculated.
3) Select the items for output. (See Chapter 2.)

TIP
- The diameter of the intersecting circle for a plane and a cone is taken to be the diameter of the intersecting circle in a plane perpendicular to the cone axis and passing through the intersection point of the plane and the cone axis.
- The center axis direction of the intersecting circle for two spheres runs from the first sphere to the second sphere.

6.5.2 Calculating Cross-sectional Circle of Cone

[Key operation]



[Function]

Recalls a cone feature, then calculates the cross-sectional circle in a plane at a specified distance from the apex of the cone and perpendicular to the cone axis, or calculates the cross-sectional circle having a specified diameter on the same axis as the cone axis.

<At a specified distance from the apex>

<Specified diameter>

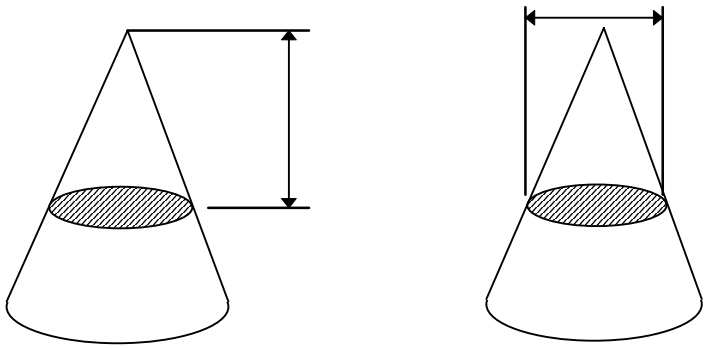


Figure 6-10

[Procedure]

1) Select this command from the menu.
2) Select the specification method (“distance from the cone apex” or “diameter”).
3) Enter the distance for the “distance from the cone apex” specification, or the diameter for the “diameter” specification.
4) Recall a cone feature from the feature memory.
   - The cross-sectional circle is calculated.
5) Select the items for output. (See Chapter 2.)

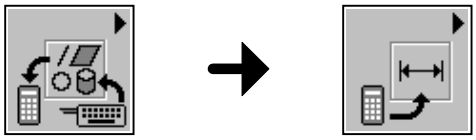
6.6 Calculating Distance

Distance calculation function includes the following commands:

1) Calculate projected distance
2) Calculate spatial distance

[Key operations to access Distance calculation function]

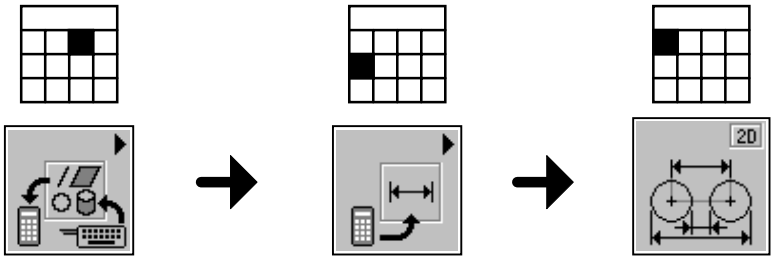
Main menu → Feature calculation menu



6.6.1 Calculating Projected Distance

[Key operation]

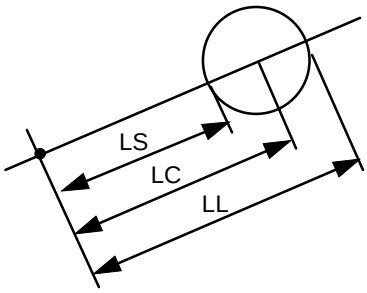
Main menu → Feature calculation menu → Distance menu



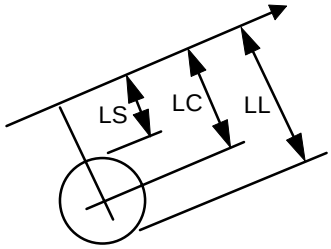
[Function]

Recalls two features, projects them onto the reference plane, and then calculates the distance between the two features.

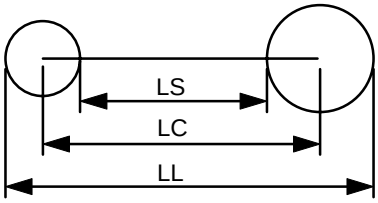
<Point feature and circle feature>



<Line feature and circle feature>



<Circle feature and circle feature>



LS: Minimum distance
LC: Center to center distance
LL: Maximum distance

Figure 6-11

[Procedure]

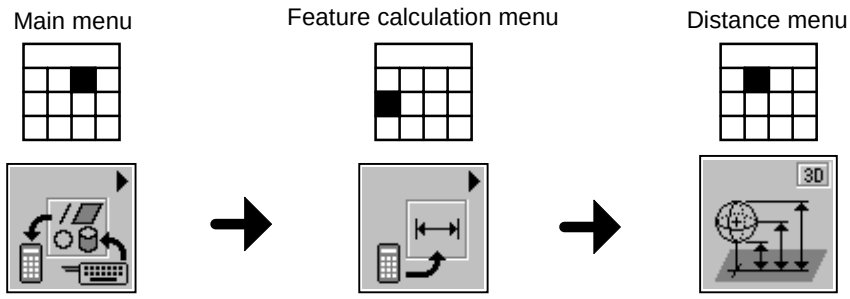
1) Select this command from the menu.
2) Recall two features from the feature memory.
   - ➢ The distances between the projected features are calculated.
3) Select the items for output. (See Chapter 2.)

TIP

- The calculated results are stored in the automatic memory from address 1, beginning with the center to center distance, then the minimum distance and finally the maximum distance.
- You can use the supplementary setting key in the Output item selection screen (see Chapter 2) to select the reference plane (projection plane).

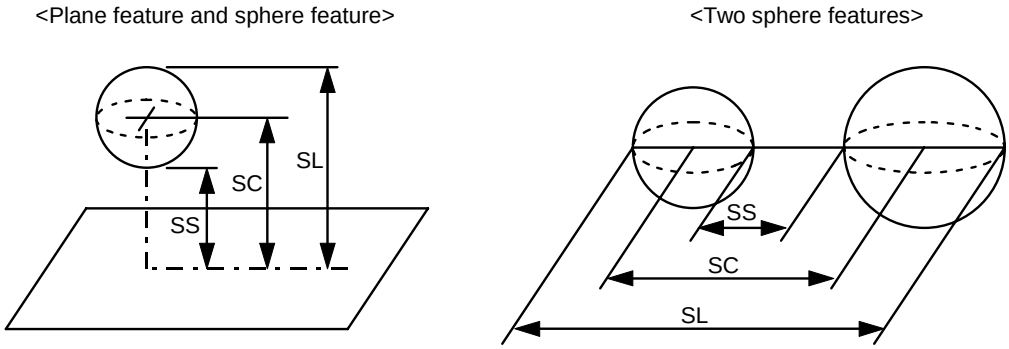
6.6.2 Calculating Spatial Distance

[Key operation]



[Function]

Recalls two features, then calculates the spatial distance between the two features.



SS: Minimum distance
SC: Center to center distance
SL: Maximum distance

Figure 6-12

[Procedure]

1) Select this command from the menu.
2) Recall two features from the feature memory.
   - ➢ The spatial distances between the features are calculated.
3) Select the items for output. (See Chapter 2.)

TIP • The calculated results are stored in the automatic memory from address 1, beginning with the center to center distance, then the minimum distance and finally the maximum distance.

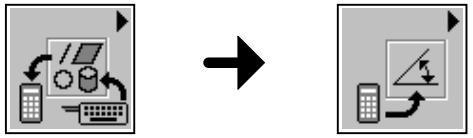
6.7 Calculating Intersection Angle

Intersection angle calculation function includes the following commands:

1) Calculate projected intersection angle
2) Calculate spatial intersection angle

[Key operations to access Intersection angle calculation function]

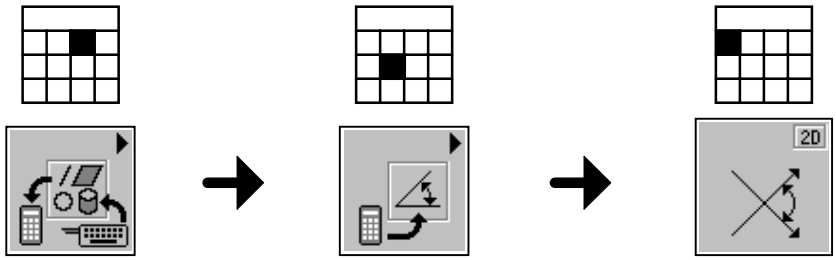
Main menu → Feature calculation menu



6.7.1 Calculating Projected Intersection Angle

[Key operation]

Main menu → Feature calculation menu → Intersection angle menu



[Function]

Recalls two features, projects them onto the reference plane, and then calculates the intersection angle (CA).

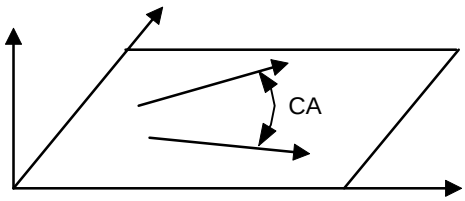
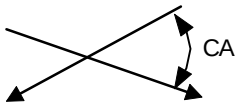


Figure 6-13

[Procedure]

1) Select this command from the menu.
2) Recall two features from the feature memory.
   - The projected intersection angle for the two features is calculated.
3) Select the items for output. (See Chapter 2.)

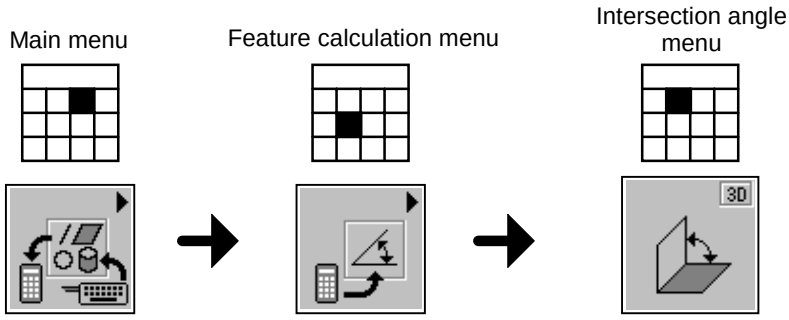
TIP • The angle calculated by this command is the acute angle (0° to 90°).



• You can use the supplementary setting key in the Output item selection screen (see Chapter 2) to select the reference plane (projection plane).

6.7.2 Calculating Spatial Intersection Angle

[Key operation]



[Function]

Recalls two features, and then calculates the spatial intersection angle (WA) of the two features.

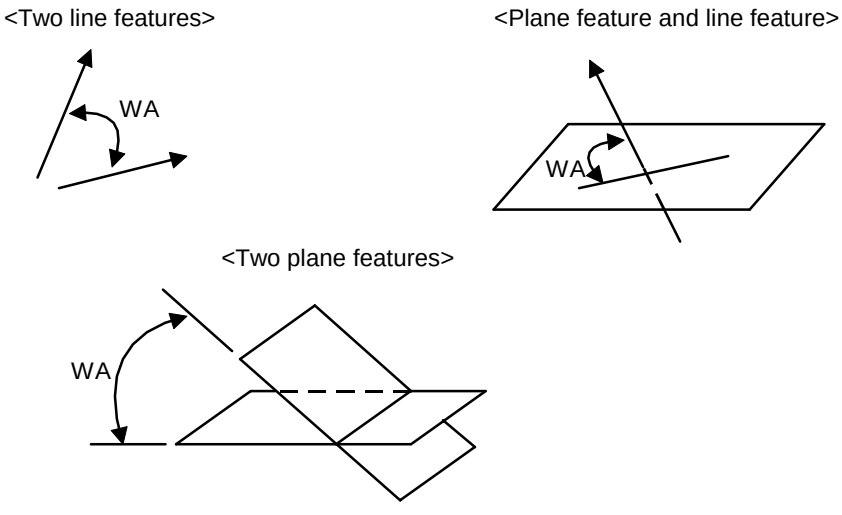
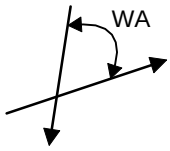


Figure 6-14

[Procedure]

1) Select this command from the menu.
2) Recall two features from the feature memory.
   - ➢ The spatial intersection angle of the two features is calculated.
3) Select the items for output. (See Chapter 2.)

NOTE • The intersection angle calculated by this command for two plane features or two line features is the acute angle.



• The intersection angle calculated by this command for a plane feature and a line feature is the angle (0° ~ 90°) formed by the plane and the line.

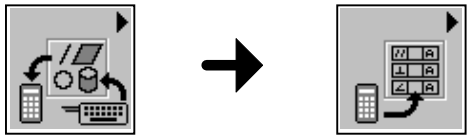
6.8 Calculating Orientation Deviation

Orientation deviation's calculation function includes the following commands:

1) Calculate parallelism
2) Calculate perpendicularity
3) Calculate angularity

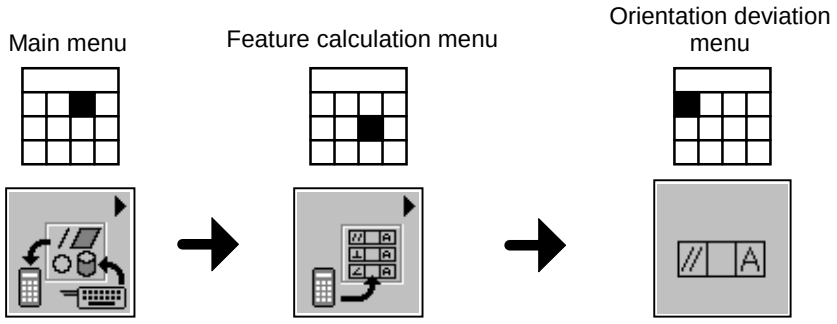
[Key operations to access Orientation deviation's calculation function]

Main menu → Feature calculation menu



6.8.1 Calculating Parallelism

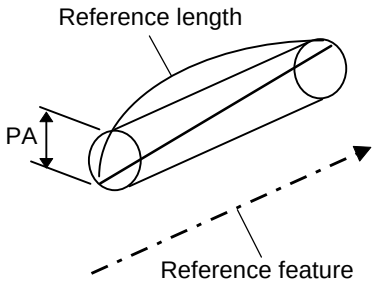
[Key operation]



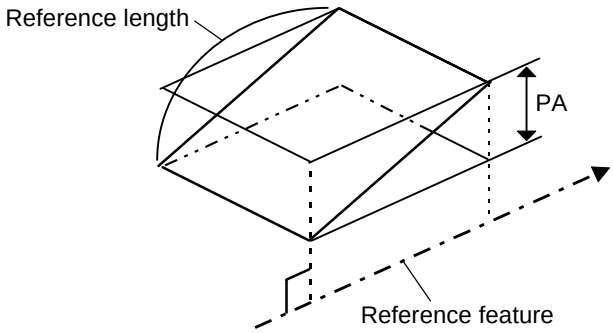
[Function]

Calculates the “parallelism per specified reference length (PA)” of a line-component feature (line, cylinder or cone) or plane feature relative to a line-component feature or plane feature that serves as the reference.

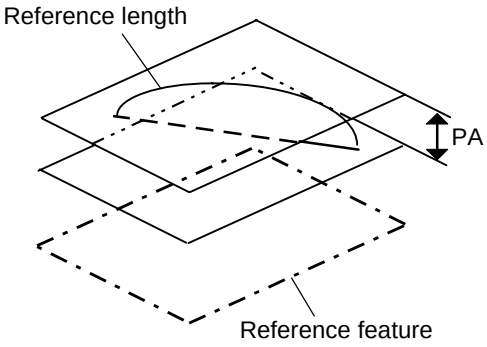
<Line (reference) - Line>



<Line (reference) - Plane>



<Plane (reference) - Line>



<Plane (reference) - Plane>

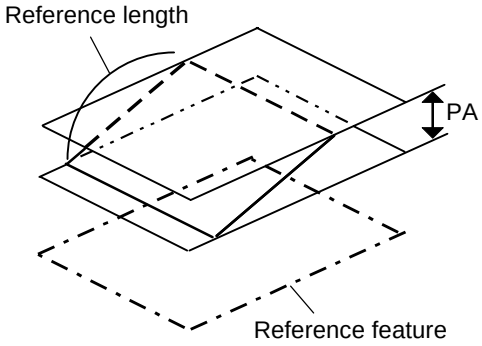


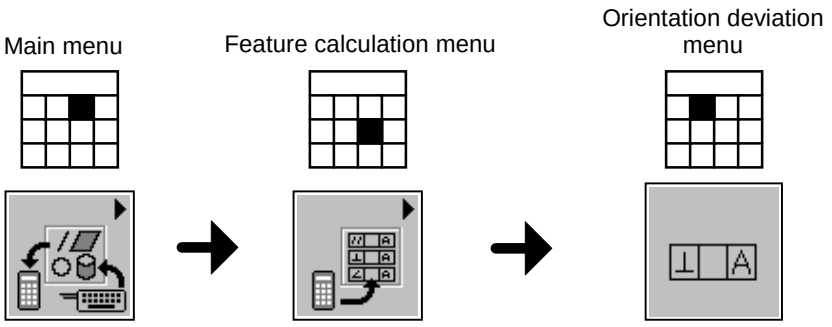
Figure 6-15

[Procedure]

1) Select this command from the menu.
2) Enter the reference length.
3) Recall the feature to be used as the reference and the feature to be used for the parallelism calculation from the feature memory.
   - ➢ The parallelism per reference length is calculated.
4) Select the items for output. (See Chapter 2.)

6.8.2 Calculating Perpendicularity

[Key operation]



[Function]

Calculates the “perpendicularity per specified reference length (VT)” of a line-component feature (line, cylinder or cone) or plane feature relative to a line-component feature or plane feature that serves as the reference.

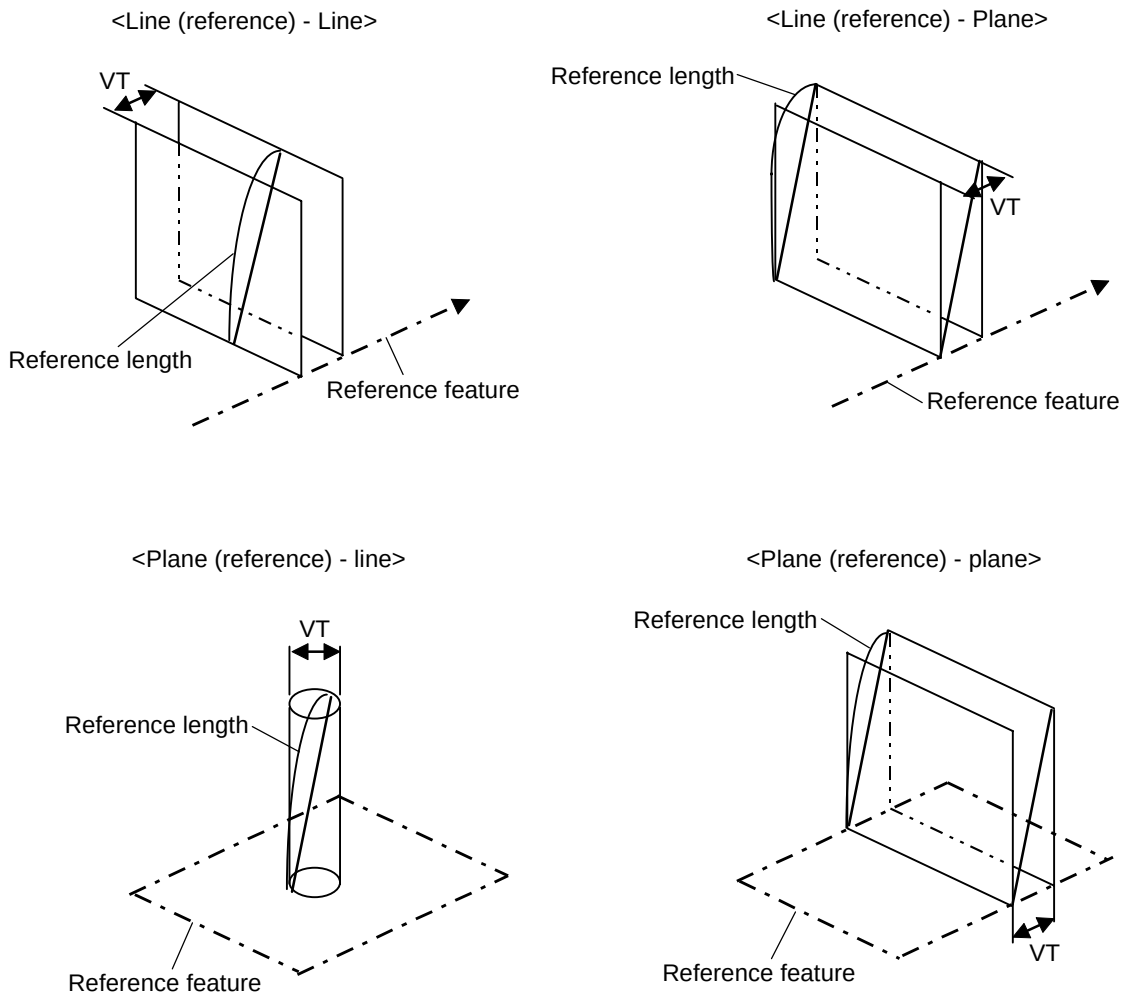


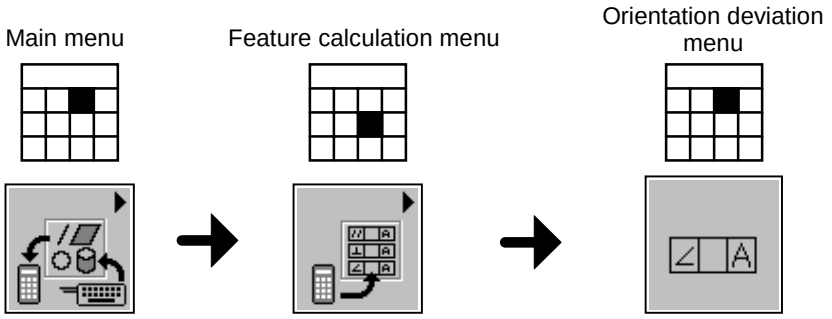
Figure 6-16

[Procedure]

1) Select this command from the menu.
2) Enter the reference length.
3) Recall the feature to be used as the reference and the feature to be used for the perpendicularity calculation from the feature memory.
   - The perpendicularity per reference length is calculated.
4) Select the items for output. (See Chapter 2.)

6.8.3 Calculating Angularity

[Key operation]



[Function]

Calculates the “angularity for a specified inclination angle and reference length” of a line-component feature (line, cylinder or cone) or plane feature relative to a line-component feature or plane feature that serves as the reference.

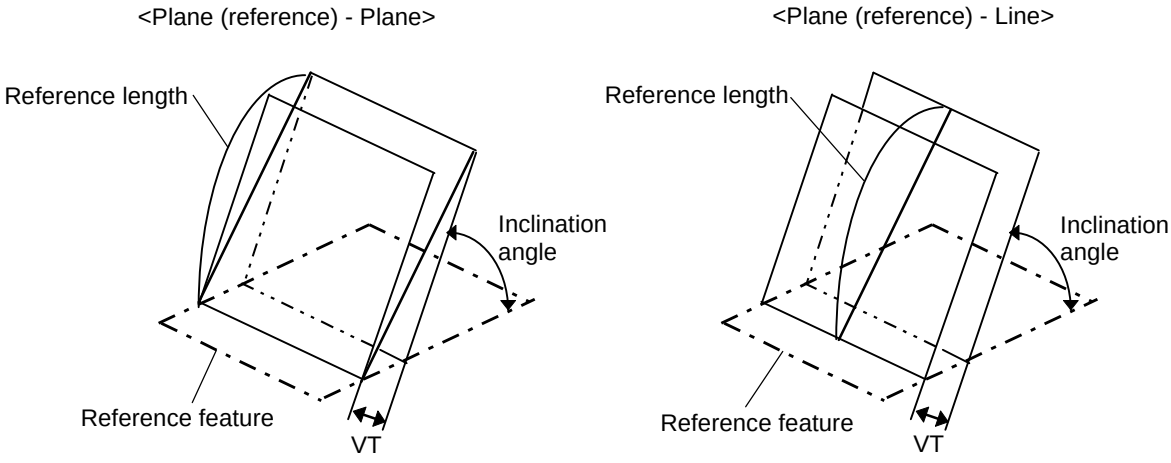


Figure 6-17

[Procedure]

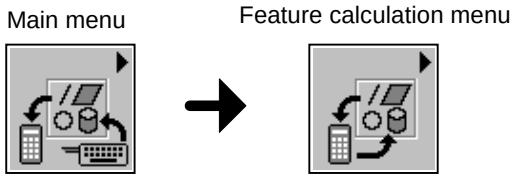
1) Select this command from the menu.
2) Enter the reference length and inclination angle.
3) Recall the feature to be used as the reference and the feature to be used for the angularity calculation from the feature memory.
   - The angularity is calculated.
4) Select the items for output. (See Chapter 2.)

6.9 Changing Feature Type or Moving Feature

Feature type change and feature movement functions include the following commands:

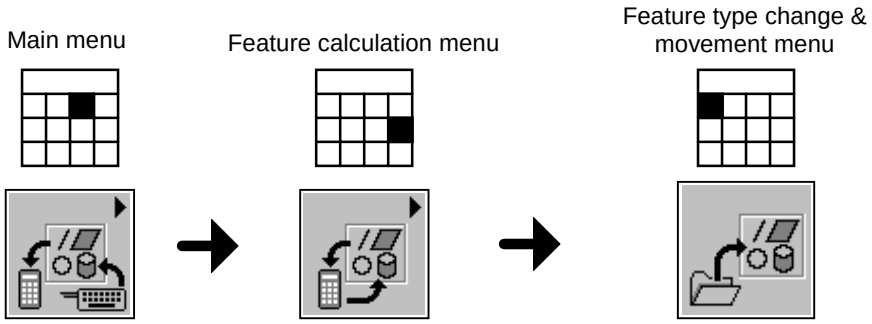
1) Recall feature
2) Project one feature on another feature
3) Change feature type
4) Conform feature direction

[Key operations to access Feature type change and movement function]



6.9.1 Recalling Feature

[Key operation]



[Function]

Recalls a feature and re-outputs it in the current coordinate system.

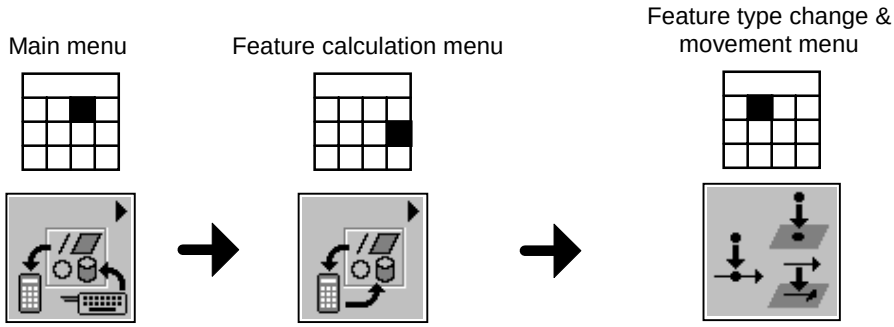
[Procedure]

1) Select this command from the menu.
2) Recall a feature from the feature memory.
   - ➢ The recalled feature is re-output in the current coordinate system.
3) Select the items for output. (See Chapter 2.)

TIP • The recalled feature can be stored in the specified memory, as described in Section 6.1.

6.9.2 Projecting One Feature on Another Feature

[Key operation]



[Function]

Projects a point-component feature (point, circle, ellipse or sphere) or line-component feature (line, cylinder or cone) onto a plane feature or line-component feature (line, cylinder or cone).

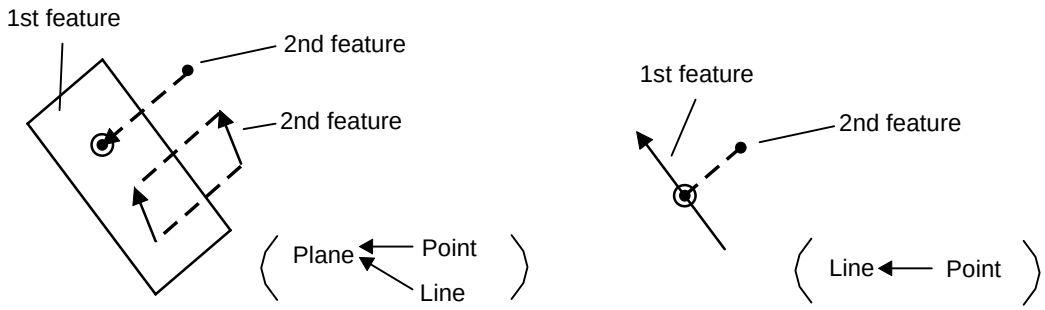


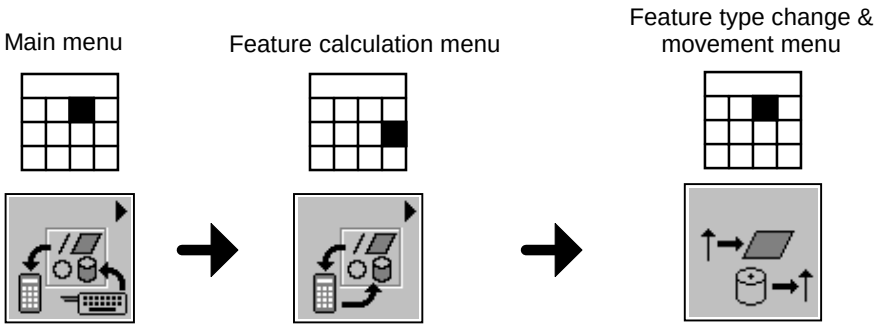
Figure 6-18

[Procedure]

1) Select this command from the menu.
2) Recall a point-component feature (point, circle, ellipse or sphere) or line-component feature (line, cylinder or cone), and a plane feature or line-component feature (line, cylinder or cone) for the projection destination from the feature memory.
   - The point feature or line feature is projected.
3) Select the items for output. (See Chapter 2.)

6.9.3 Changing Feature Type

[Key operation]



[Function]

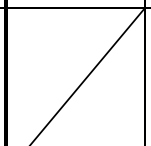
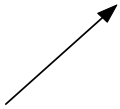
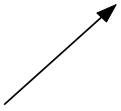
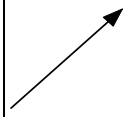
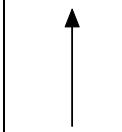
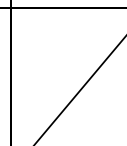
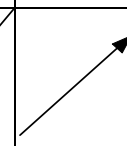
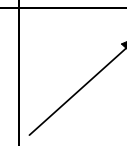
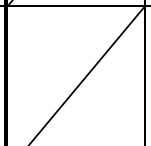
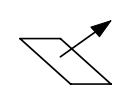
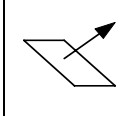
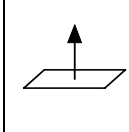
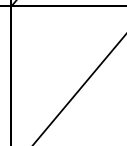
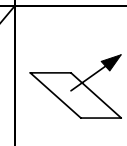
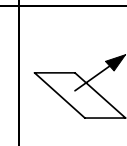
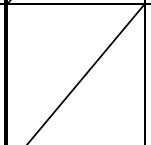
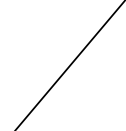
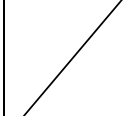
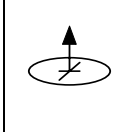
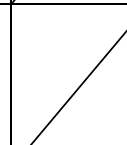
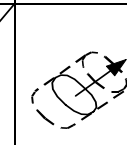
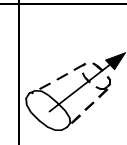
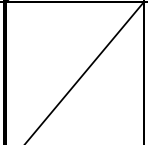
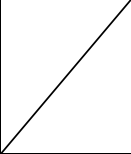
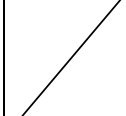
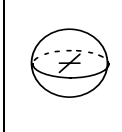
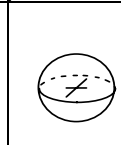
Recalls a feature, then changes or converts it into another type of feature.

[Procedure]

1) Select this command from the menu.
2) Recall a feature to be changed or converted from the feature memory.
   - ➢ The recalled feature is changed or converted into a new type of feature in the current coordinate system.

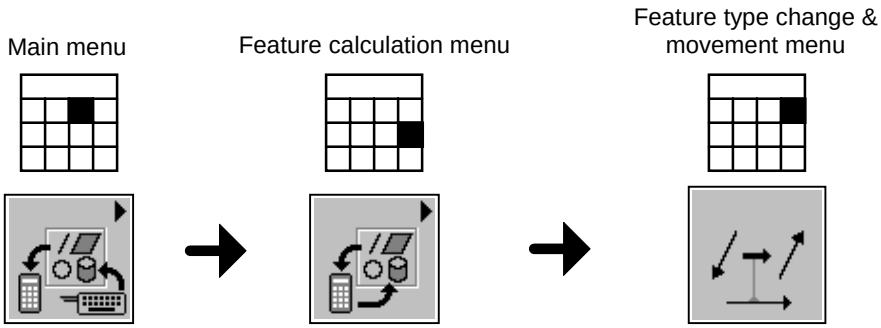
TIP • Table 6-1 shows the possible combinations of the feature before conversion and the feature after conversion.

Table 6-1

After conversion / Before conversion	Point feature	Point feature with approach direction	Line feature	Plane feature	Circle feature	Sphere feature	Cylinder feature	Cone feature
Point feature								
Line feature								
Plane feature								
Circle feature								
Sphere feature								
Cylinder feature								
Cone feature								

6.9.4 Conforming Feature Direction

[Key operation]



[Function]

Aligns the direction of a specified line-component feature (line, cylinder or cone) or plane feature with the direction of the reference line-component feature or plane feature.

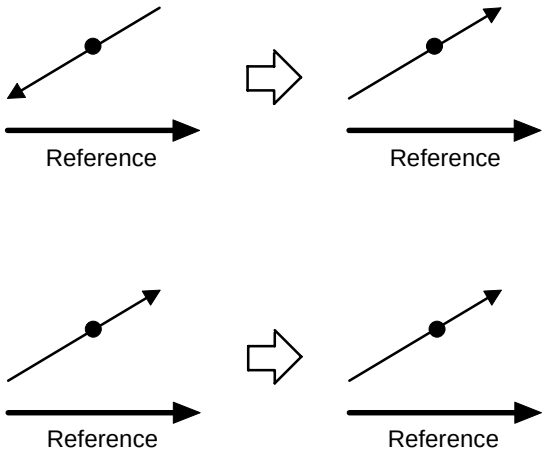


Figure 6-19

[Procedure]

1) Select this command from the menu.
2) Recall the feature that serves as the reference and the feature to be conformed from the feature memory.
   - The direction of the feature is conformed.
3) Select the items for output. (See Chapter 2.)

NOTE • If the feature to be conformed is perpendicular to the referent feature, an error message is displayed.

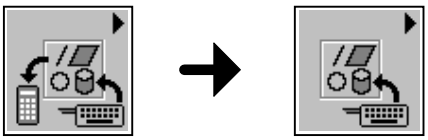
6.10 Keying in Feature

Feature keying-in function includes the following commands:

1) Key in point feature
2) Key in straight line feature
3) Key in plane feature
4) Key in circle feature
5) Key in ellipse feature
6) Key in sphere feature
7) Key in cylinder feature
8) Key in cone feature

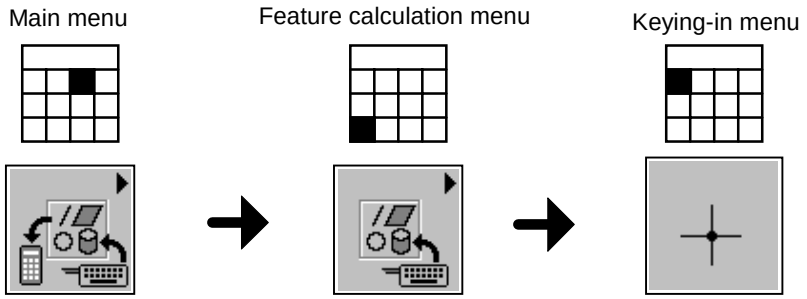
[Key operations to access Feature keying-in function]

Main menu → Feature calculation menu



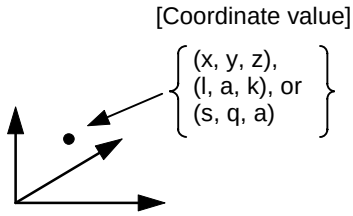
6.10.1 Keying in Point Feature

[Key operation]



[Function]

This command enables the user to key in the point coordinate values to create a point feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-20

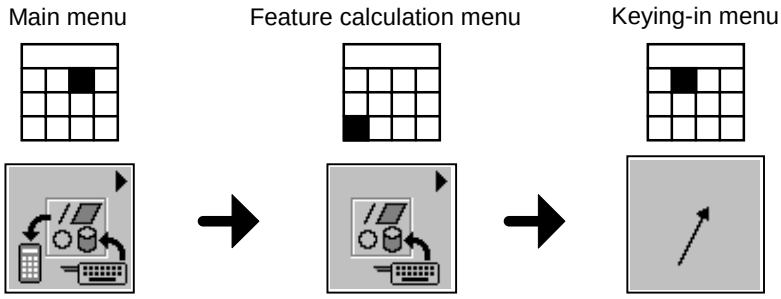
[Procedure]

1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The point feature is created.

TIP
- The value of geometrical deviation “F” is set to 0.
- The feature keyed in can be stored in the specified memory (see Section 6.1).

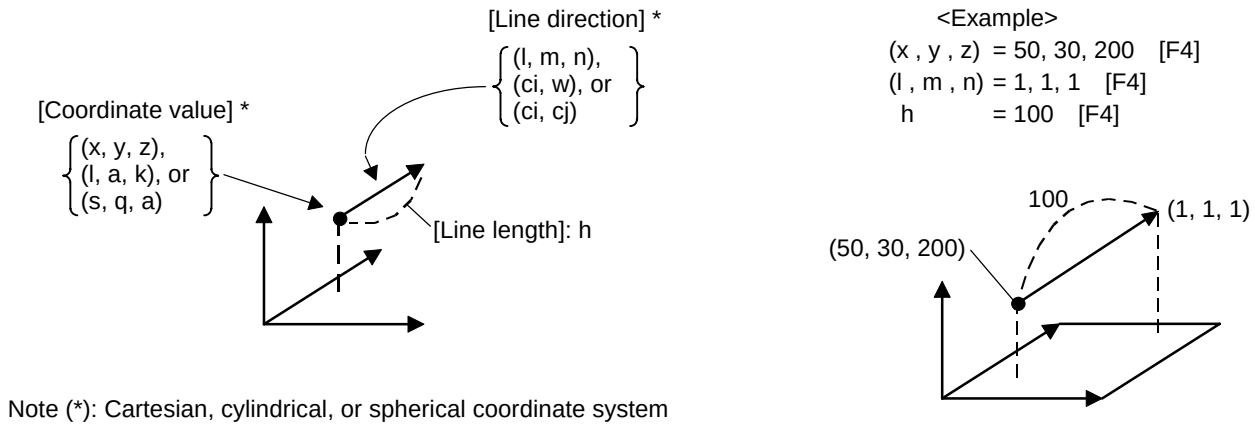
6.10.2 Keying in Straight Line Feature

[Key operation]



[Function]

This command enables the user to key in the coordinate values for one point on a straight line, the direction cosine and the line length, so as to create a straight line feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-21

[Procedure]

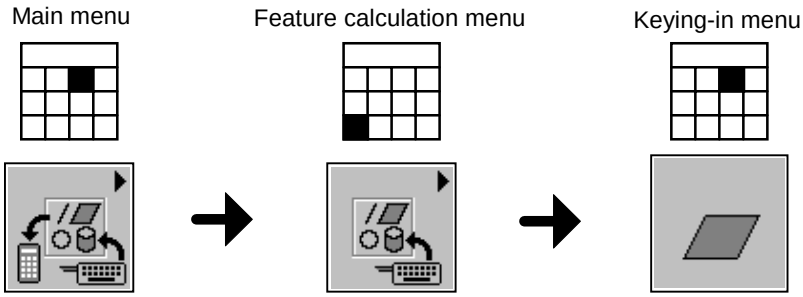
1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The straight line feature is created.

TIP • The value of straightness “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

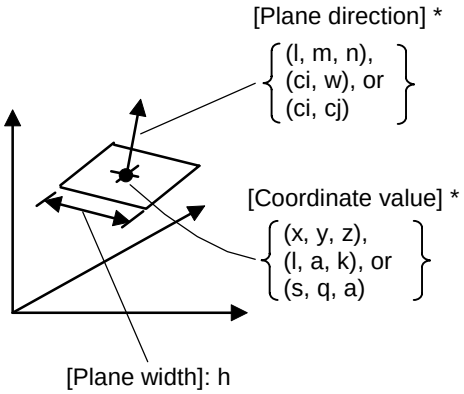
6.10.3 Keying in Plane Feature

[Key operation]



[Function]

This command enables the user to key in the center coordinate values of a plane, the plane direction and the plane width, so as to create a plane feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-22

[Procedure]

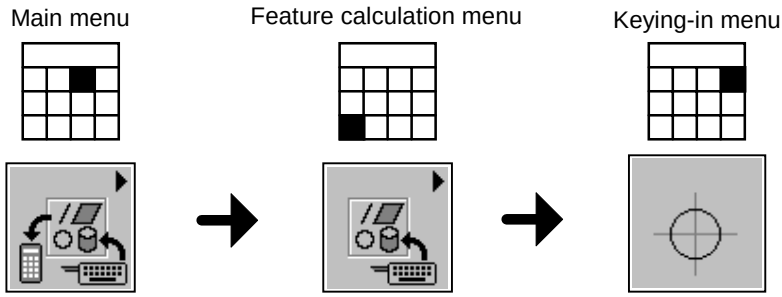
1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The plane feature is created.

TIP • The value of flatness “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

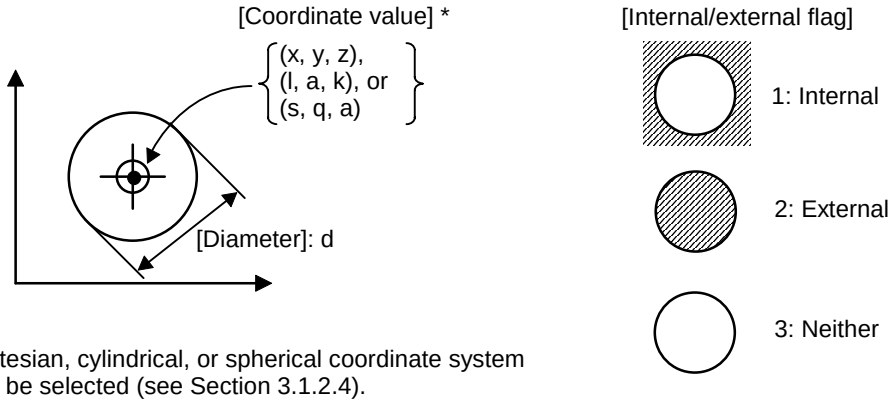
6.10.4 Keying in Circle Feature

[Key operation]



[Function]

This command enables the user to key in the center coordinate values, diameter and internal/external flag of a circle, so as to create a circle feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-23

[Procedure]

1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The circle feature is created.

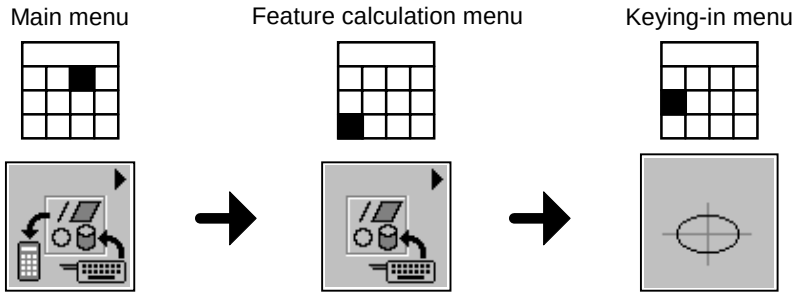
NOTE • The center axis direction of the created circle is same as the normal direction of the reference plane.

TIP • The value of circularity or roundness “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

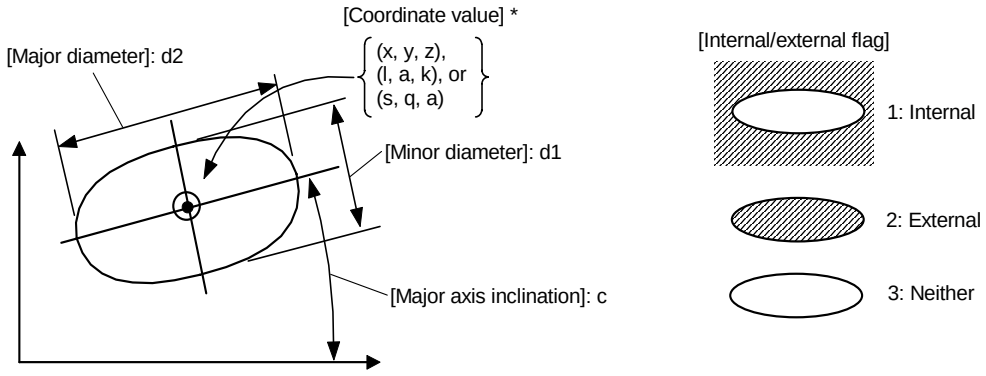
6.10.5 Keying in Ellipse Feature

[Key operation]



[Function]

This command enables the user to key in the center coordinate values, the major axis diameter, the minor axis diameter, the angle between the major axis and the first axis of the coordinate system, and the internal/external flag of an ellipse, so as to create an ellipse feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-24

[Procedure]

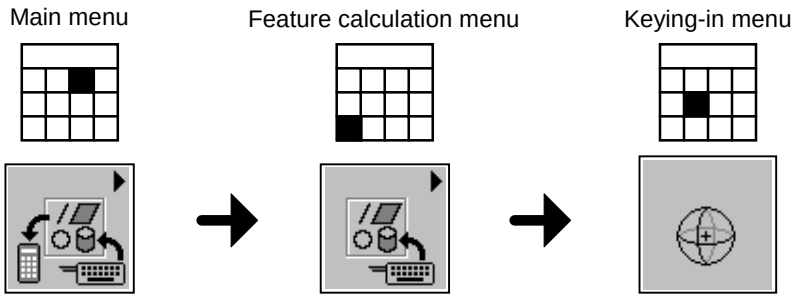
1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The ellipse feature is created.

TIP • The value of geometrical deviation “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

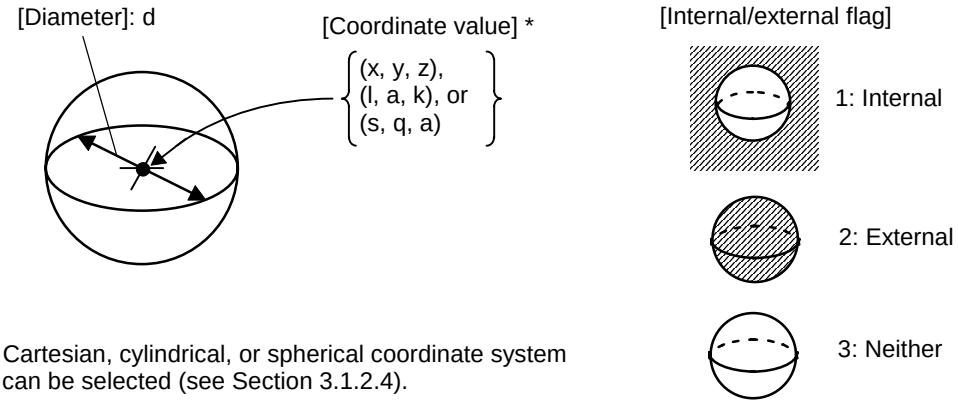
6.10.6 Keying in Sphere Feature

[Key operation]



[Function]

This command enables the user to key in the center coordinate values, diameter and internal/external flag of a sphere, so as to create a sphere feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-25

[Procedure]

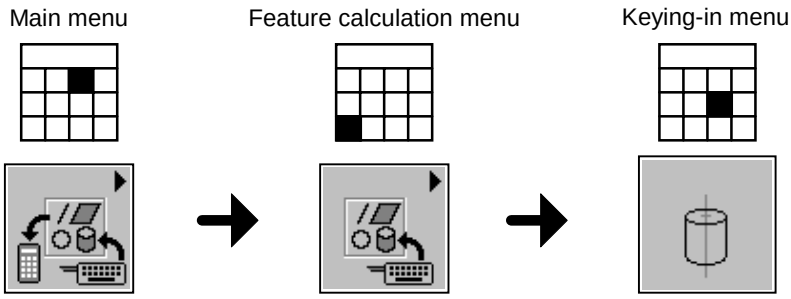
1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The sphere feature is created.

TIP • The value of sphericity “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

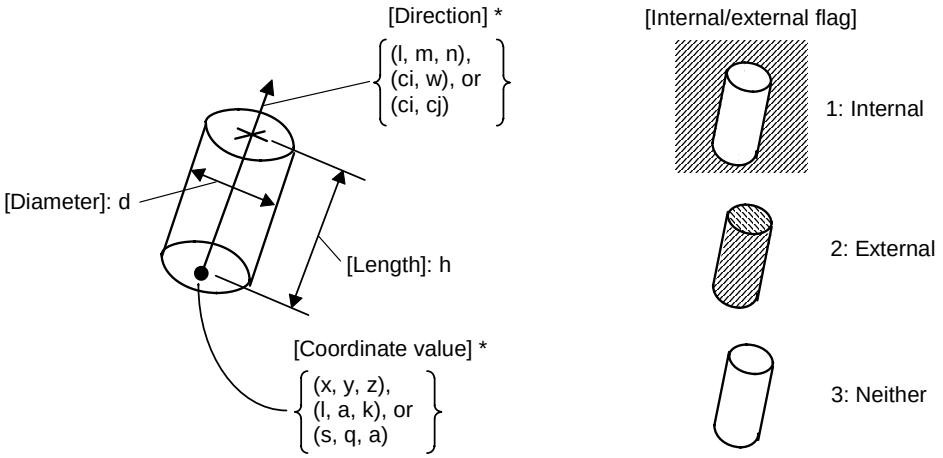
6.10.7 Keying in Cylinder Feature

[Key operation]



[Function]

This command enables the user to key in the coordinate values of one point on the cylinder axis, the cylinder axis direction, the diameter, the length and the internal/external flag of a cylinder, so as to create a cylinder feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

Figure 6-26

[Procedure]

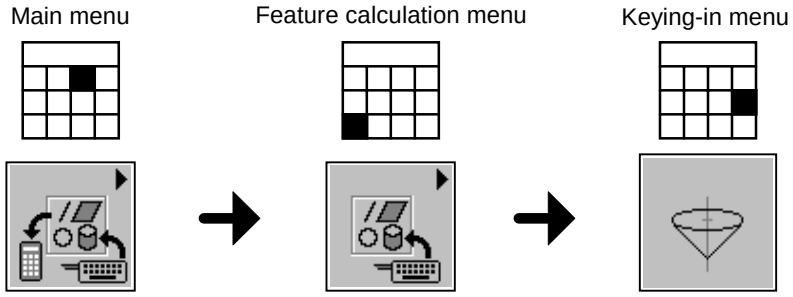
1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The cylinder feature is created.

TIP • The value of cylindricity “F” is set to 0.

• The feature keyed in can be stored in the specified memory (see Section 6.1).

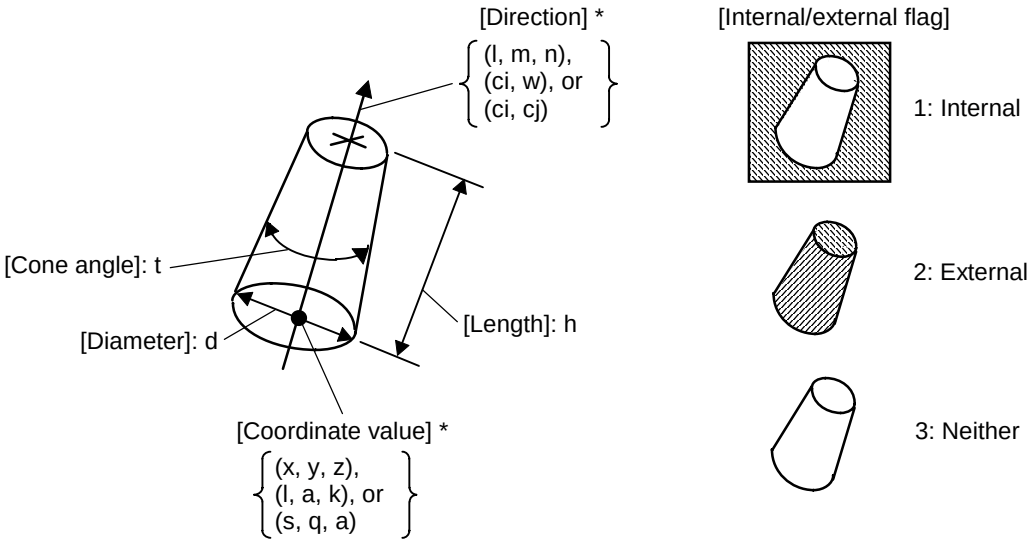
6.10.8 Keying in Cone Feature

[Key operation]



[Function]

This command enables the user to key in the coordinate values of one point on the cone axis, the diameter of the circular cross-section that includes that point, the cone axis direction, the cone full angle, the cone length and the internal/external flag of a cone, so as to create a cone feature.



Note (*): Cartesian, cylindrical, or spherical coordinate system can be selected (see Section 3.1.2.4).

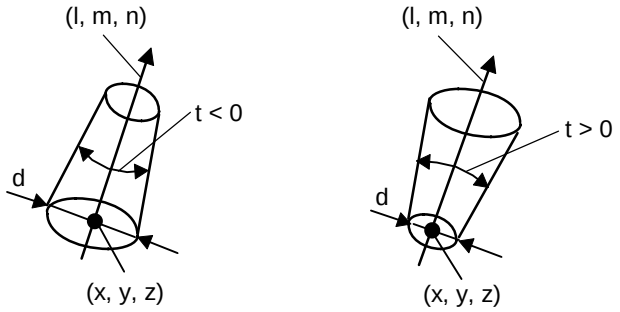
Figure 6-27

[Procedure]

1) Select this command from the menu.
2) Key in data as directed by the on-screen guidance messages.
   - ➢ The cone feature is created.

TIP

- The value of conicity “F” is set to 0.
- The feature keyed in can be stored in the specified memory (see Section 6.1).
- For the cone full angle “t”, enter a negative value if the cone diameter decreases in the cone axis direction and a positive value if the cone diameter increases in the cone axis direction.



Mitutoyo Corporation

20-1, Sakado 1-chome, Takatsu-ku, Kawasaki, Kanagawa 213-0012, Japan
Cable: MITUTOYO Kawasaki
Phone: (044)813-8230 Fax: (044)813-8231