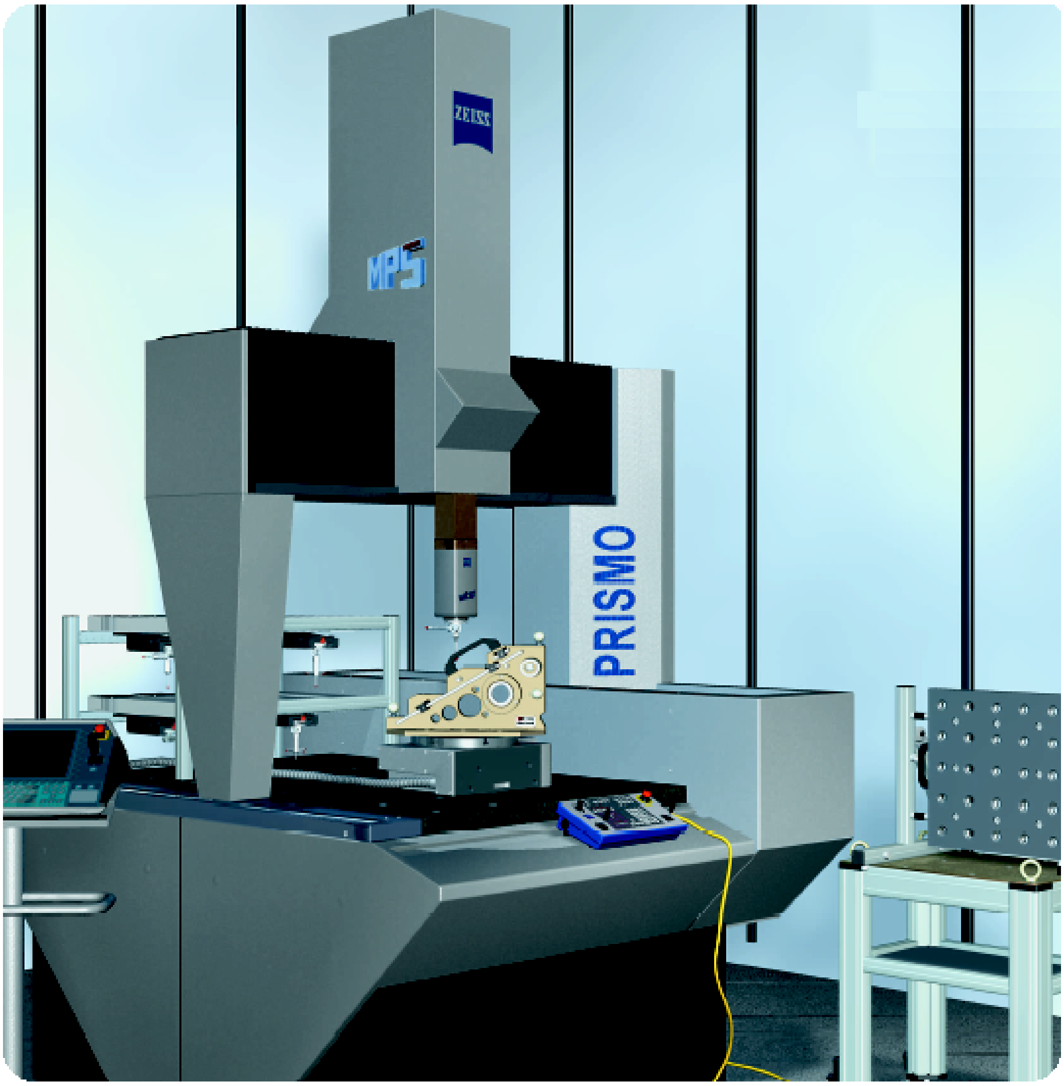
UMESS UX Basic course

Seminar papers



Carl Zeiss 3D Metrology Services

Subject to modifications!

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Worksheet 1: User interface

1.1 Starting the computer

Switching on the computer and screen
Starting the UMESS measuring software
Entering the operator

You will find detailed information in the "Starting and Operating the UX Measuring Software" manual in section 2.2.

1. To switch on: Activate the power switch on the computer and screen.
   Note: This procedure only applies when working with a separate computer station. If you are working on the measuring machine you have to switch on the control.
2. The computer operating system is started automatically. This boot procedure stops when a window is displayed (CZ Session Control) in which you can select which activity you want to carry out.
3. Click on the UMESS icon in the CZ Session Control window.
4. As we will first be working without a measuring machine, confirm the message "without CMM?" by clicking on "YES" or by:
5. Pressing the F1 key on the keyboard.
6. The window with the "OPERATOR" prompt is displayed.
7. Enter your name and press the ENTER key.
8. The UMESS Main Menu and the protocol window are displayed.
9. The software is now operational.

Caution! If a measuring machine is connected, an automatic reference point travel is carried out instead of what is described under point 4 above.

1.2 Working with windows

Moving
Sizing
Icons and icon box

"Starting and Operating the UX Measuring Software" manual, Section 4

1. Move the protocol window below the UMESS Main Menu so that both are visible and do not cover one another.
2. Enlarge the size of the protocol window so that the space below the main menu is filled.
3. Click on the dot symbol in the header bar: To reduce the window to an icon and restore the window from the icon box.

1.3 Operating structure

Calling up of functions
- Pictogram
- Pulldown menu
- DIs

"Starting and Operating the UX Measuring Software" manual, Section 6

1. Calling up a function using a pictogram:
2. Calling up the same function with pulldown menu
3. Calling up a function using the DI.
4. Switching between the pictogram assignments:
5. Copying a pictogram.
6. Generating a pictogram from a DI.
7. Replacing pictogram 6501 with 15228.
8. Hiding, displaying, horizontal pictogram, ...

Input boxes:
- YES/NO boxes and numerical boxes
- Softkeys on the computer and screen

1. Calling up the function input window from 1.3
2. Inputs in YES/NO boxes, numerical boxes, text boxes
3. Ending an input page with TERMIN, BACK

2. Calibration

Why do we need to calibrate probes ?

With three dimensional measurement, a workpiece almost always has to be probed from several sides. In order to be able to reach all the points required for the measurement without having to reclamp the workpiece, we use a so-called probe configuration.

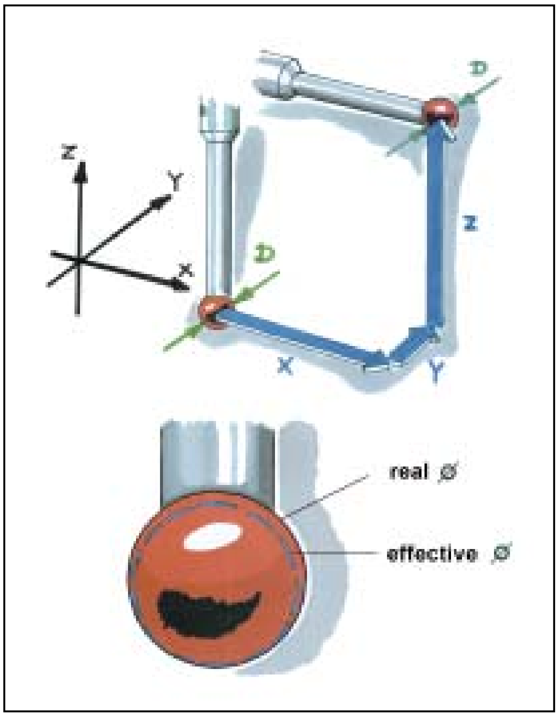
A probe configuration can be made up of a maximum of 25 probes. The 25 probes are divided into five sets of five, the so-called probe combinations.
A probe configuration therefore consists of a maximum 5 combinations each with a maximum of five probes.

The individual probes are fixed to the plate, e.g. in the shape of a star. You can also make part-specific arrangements using connecting elements such as extensions or joints. The probe mount (e.g. plate or cone) is fixed to the probe head.

Spatial arrangement and probe tip radius

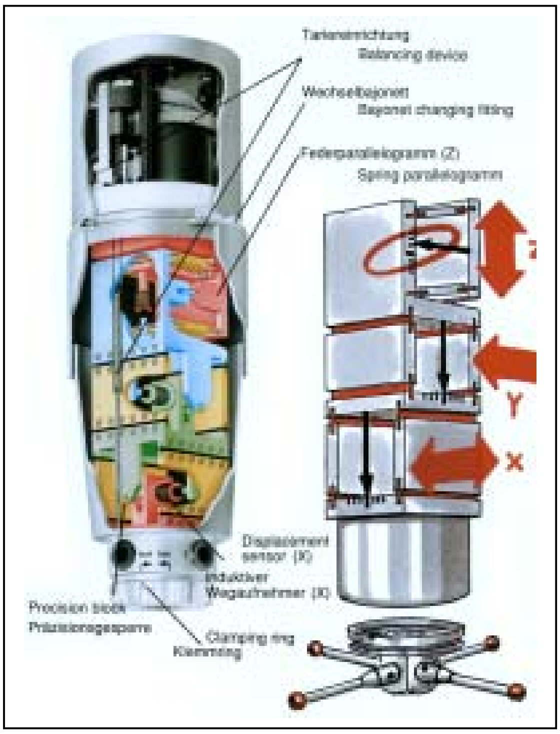
For different probes to supply the same results during a later measurement, the computer must know the following data:
.

- the position of a reference probe,
- the spatial arrangement of individual probes to the reference probe (from the probe to the reference probe),
- the radius of the probe tips.



This is exactly what happens during the probe calibration.
After the calibration, the computer recognizes the distances of the center of the probe tips to the center point of the reference probe tip and the effective probe tip diameter for each probe.

Measuring probe head



The measuring probe head counterbalances automatically.

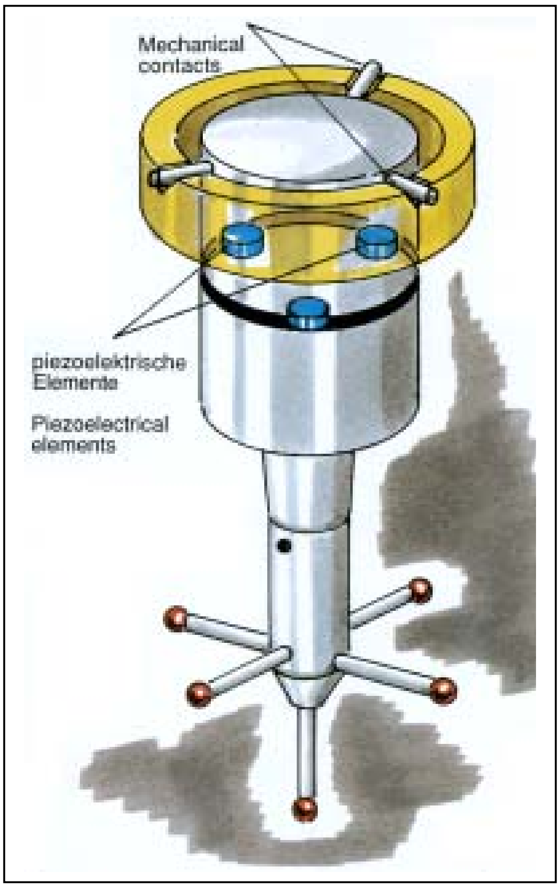
The measuring force is set to 0.2N as default value.
You can choose another measuring force if required: 0.05 N to 1 N (1.6N).

Basically the following applies:
Low measuring forces for long thin probes and elastic materials.
High measuring forces for fast scanning and self-centering probing.

You should refer to the machine manual for the permissible probe weights and extensions.
The following should be understood as a guideline only:

Universal probe head 600 g and extensions up to 300 mm
Vast probe head 300g and extensions up to 300 mm.

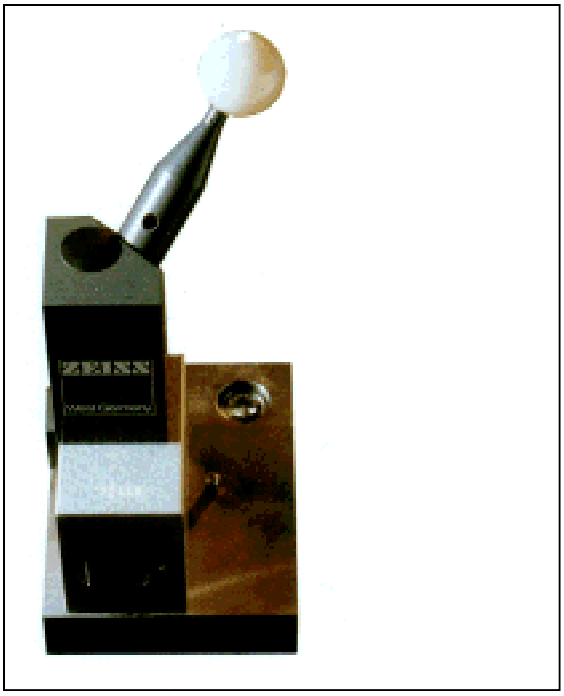
Trigger probe head



Probe weight:
Standard 300 g, for machines with higher acceleration 200 g.
Here too you must refer to the machine manual for the exact values.

The probe weight is counterbalanced by rotating the knurled nut after clamping the probe. You cannot preselect a measuring force for the trigger probe head. A probing impulse is created even with a measuring force smaller than 0.01N.

Calibration standard for the probe calibration



A calibration standard is required for determining the effective probe diameters and lengths. A sphere is used with a particularly small form error (smaller than 0.2 µm).
The diameter of the sphere is defined in the software. Therefore when carrying out the probe calibration you must always use the calibration sphere supplied with the measuring machine, this is identified by its serial number.

Position of the calibration sphere

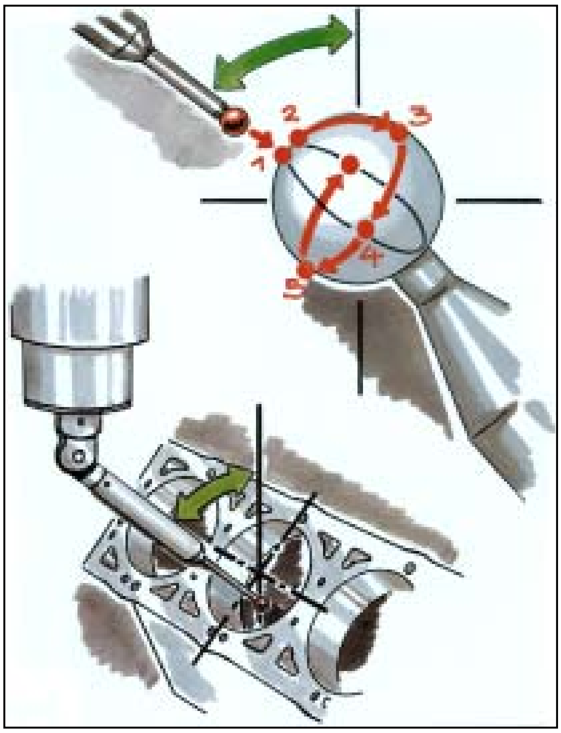
As different correction values are effective during the mathematical correction of the guideway errors in the entire measuring range, the computer must know the position of the calibration sphere.

The position of the calibration sphere is first defined.
The calibration sphere is screwed to the workpiece table, this can be placed almost anywhere on the table. You just have to make sure that it can be probed with all probes without the machine reaching its limit positions or causing a collision with a workpiece.

You should not change the position of the calibration sphere during the calibration.
Exception: A collision has occurred with the shaft of the calibration sphere or with a probe.

In this case the calibration sphere can be rotated but its position must be redefined.

Probing strategy



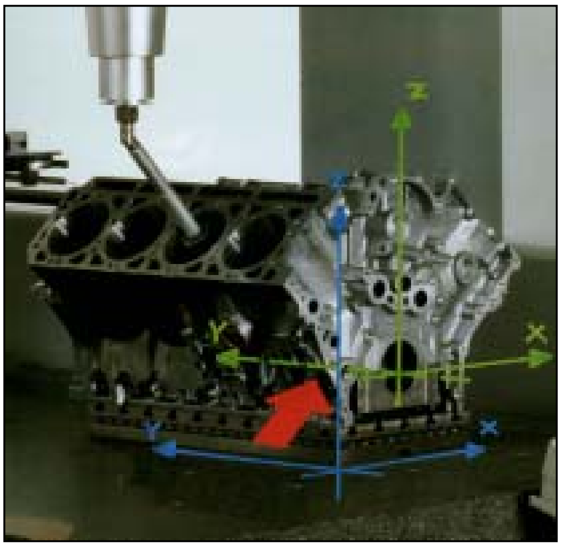
The calibration sphere is probed with each probe in the probe configuration as follows: Number of probings: 6

Procedure and sequence of probings: see figure on right.

This probing strategy should only be used for manual probings.
An automatic run should always be used for the calibration, taking the probe bend into consideration (tensor calibration).

Only in an automatic mode, can the machine continually produce the same probings with regard to approach behavior and reproducibility.

Probing direction during the probe calibration

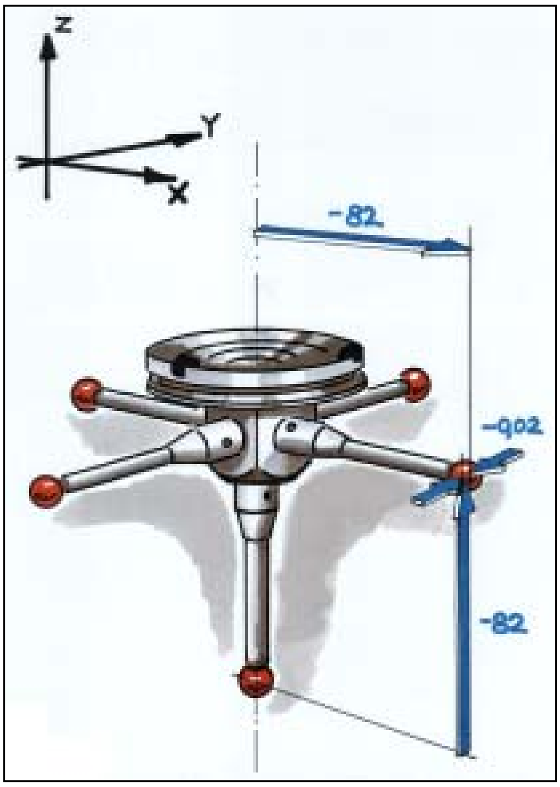


The geometry of the workpiece which you want to measure should already be taken into consideration during the calibration, as the following example shows.

Example: For this V8 engine we are probing in the direction of the cylinder bores. And it is this direction, that is the direction of the normals onto the inclined surface, which is to be taken into consideration during the probe calibration.

Meaning of the information in the probe data list

After the calibration, the probe data is listed in the system window. If the calibration has finished, the data is saved on the hard disk and in the main memory of the computer. The probe data should be listed in the record as a complete configuration.



Meaning of the data in the probe data list

XM	center coordinates of the probe tip
YM	center coordinates of the probe tip
ZM	center coordinates of the probe tip
R	effective probe tip radius
S	standard deviation
SD	code for the method of calibration

```
Configuration =    2
Co No         Coordinates          Radius   Force Temp.  Date   Stand Dev SD
============================================================================
 1 1     .0017     .0002    9.0009    2.4077   .00    .0  10.11.1997  .0004  ---
 1 2    -.1277   37.8958    9.0834    2.4084   .00    .0   6.11.1997  .0021  ---
 1 3   37.6466     .0443   12.9475    2.4091   .00    .0   6.11.1997  .0021  ---
 1 4    -.0729  -37.5741    9.0813    2.4081   .00    .0   6.11.1997  .0007  ---
 1 5  -37.6766     .0556   13.2876    2.4069   .00    .0   6.11.1997  .0002  ---
============================================================================
 Reference configuration =    1
No              Coordinates                                 Date
============================================================================
1 1    -.0523    -.1667    0.3589                        26.11.1997
================================================================================
```

Reference probe:
The master probe is always the reference probe for all the probes in a configuration.

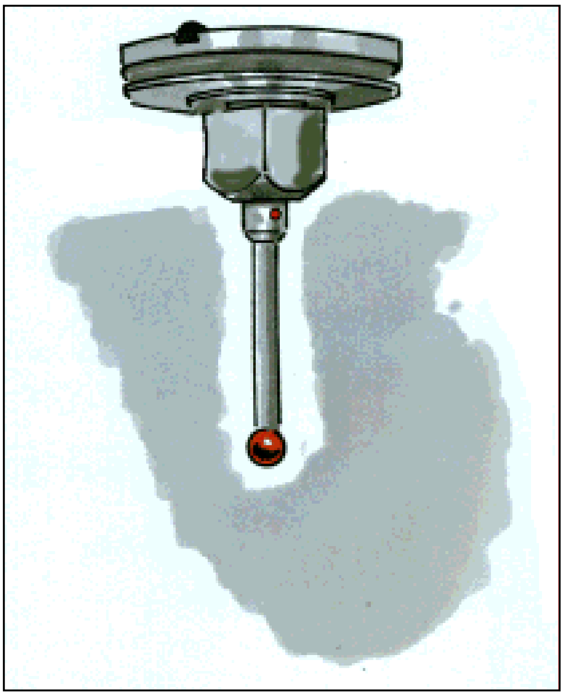
This rule applies for all machines with CAA correction.

Reducing the standard deviation
If the standard deviation S which is output by the computer at the end of each calibration is too high, the calibration must be repeated. The value of the deviation (for a probe tip diameter of 8 mm without extension) should be smaller than twice the resolution of the measuring system in the CMM).

Expressed in figures:

Resolution of the measuring machine:	permissible standard deviation
0.5 µm	smaller than 1 µm
0.2 µm	smaller than 0.4 µm

Recalibration



You often need several configurations with different probe arrangements for the measurement of a workpiece.

The calibration data of all configurations is saved automatically on the hard disk and recalled to the computer after the manual or automatic probe change.
Please note: All the configurations used for the measurement of a workpiece refer to the reference probe.

The master probe becomes the reference probe for all other configurations.

If the calibration sphere is not moved during the configuration calibration, several configurations can be calibrated at once.

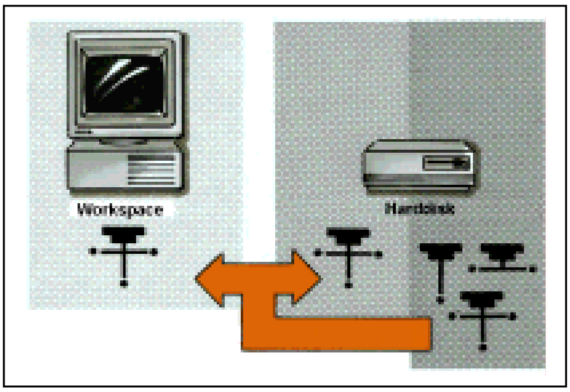
If a probe in the configuration is replaced e.g. because it is defective, or a new probe is inserted, you have to carry out a recalibration.

Procedure for recalibration:

The position of the calibration sphere must be defined with the reference probe. Only then can the calibration take place.

After the calibration, the program saves the data of the individual configurations to the hard disk. If a new configuration is inserted in the CNC measuring program, the computer can call up the relevant probe data from the hard disk.

Saving and loading probe data



We can load probe configurations from the hard disk to the main memory of the computer.
UMESS UX manages a max. 9999 configurations. When the computer is switched on, it uses combination 1 of the configuration used last.

Checking the calibration

Temperature fluctuations in the measuring room can have a lasting influence on the probe calibration. If this is the case, we recommend you carry out the calibration quite often.

Example:
Material: Aluminium
Temperature during the calibration: 20° C length: 200 mm
Temperature during the measurement: 22° C expansion: 9.2 µm

Procedure for checking:

Using the reference probe, measure the calibration sphere as a sphere.
The result we get is the coordinates of the sphere center point.
The center point coordinates of the sphere are set to zero.

The sphere is measured with all the other probes. The coordinate values of the individual probes may only deviate from zero within the range of the measuring uncertainty of the CMM. The sphere diameters must be approximately the same.

General procedure for the probe calibration

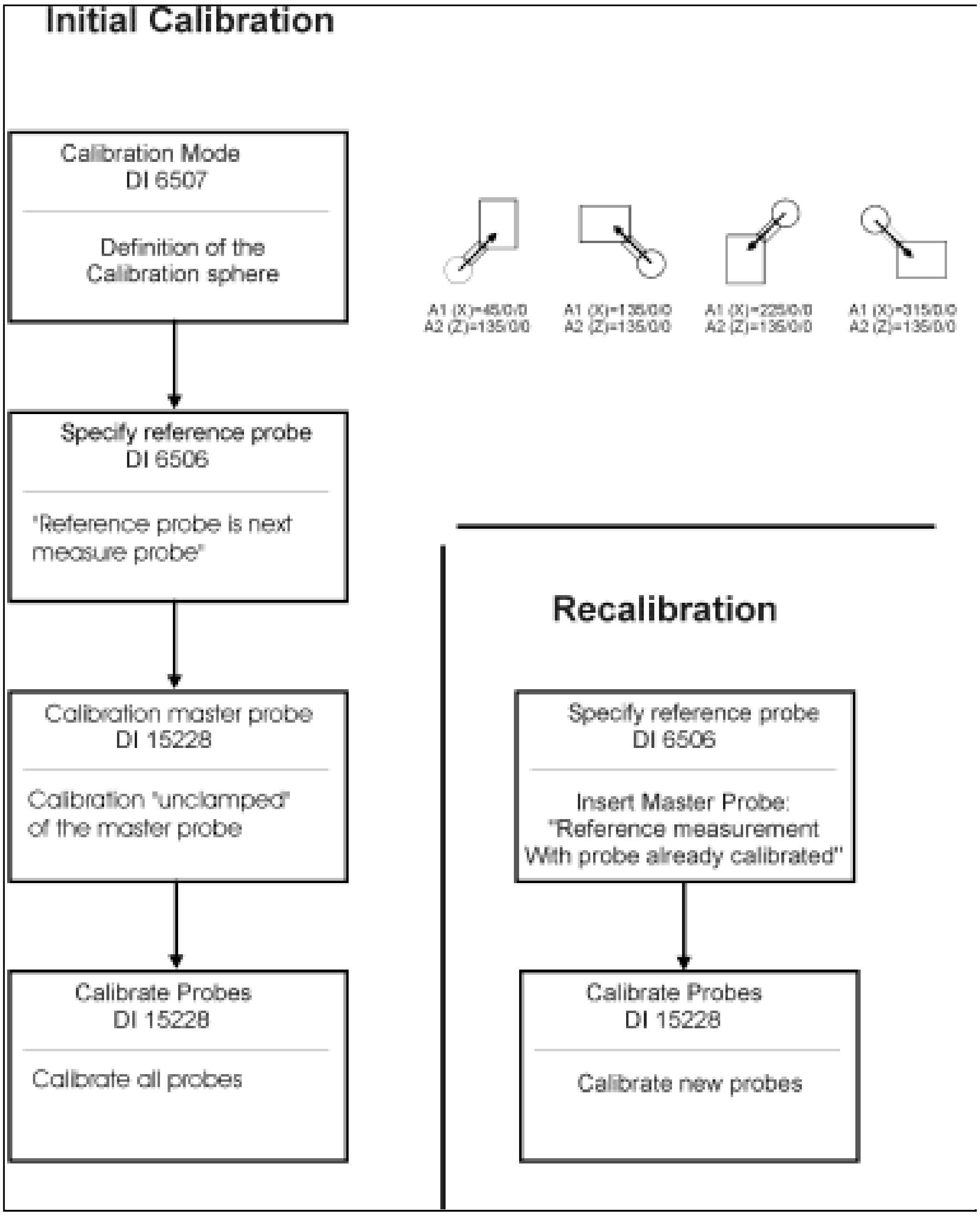
- Assemble the probe combination, taking into account the workpiece geometry and the later measurement.
- The probe arrangements with extensions must have adapted to the ambient temperature, particularly aluminium.
- Insert the master probe (reference probe) in the probe head.
- Define the position of the calibration sphere.
- Carry out the reference measurement with the master probe which has already been calibrated.
- Insert the configuration to be calibrated.
- Call the unclamped semi-automatic probe calibration.
- Carry out the calibration.
- Check the result (standard deviation S) and if necessary repeat the calibration.

Notes:

Worksheet 2: Calibration

Worksheet 2.1: General procedure for calibration

Measuring probe head



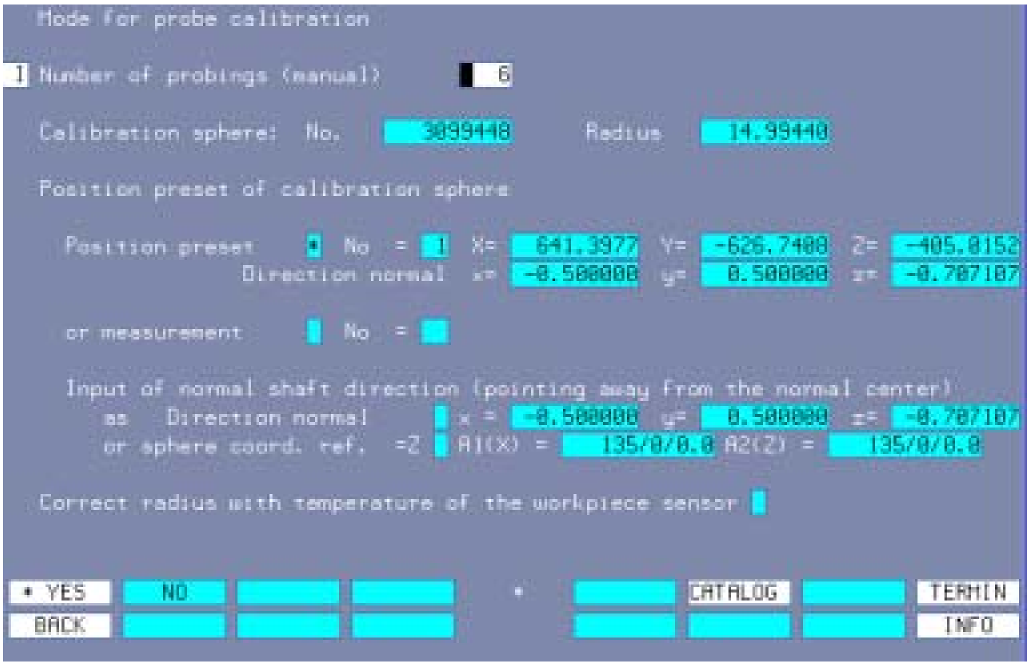
The individual steps:

Call up the calibration mode
Probe
↳ Mode
↳ for calibration

DI 6507

Complete the screen as shown above and give the value for A1(X) for sphere coordinates corresponding to the position of the calibration sphere.
End with TERMIN.

On the next page press AUTO CAL (F7). The following screen is displayed.

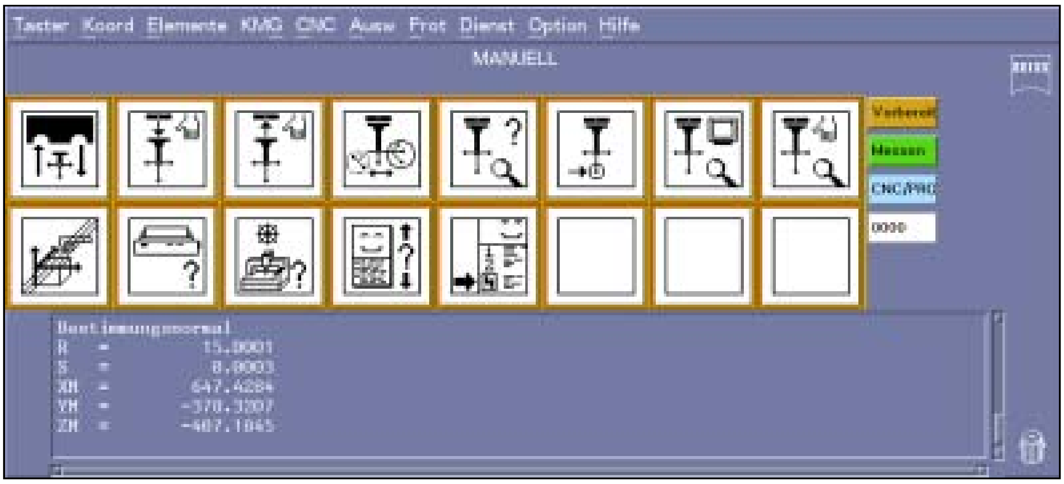


```
Mode for probe calibration

1 Number of probings (manual)        6

Calibration sphere:  No.   3099448      Radius   14.99440

Position preset of calibration sphere

  Position preset    *  No  =  1  X=  641.3977  Y=  -626.7400  Z=  -405.8152
                     Direction normal  x=  -0.500000  y=  0.500000  z=  -0.707107

  or measurement        No  =

  Input of normal shaft direction (pointing away from the normal center)
     as   Direction normal      x =  -0.500000  y=  0.500000  z=  -0.707107
     or sphere coord. ref.  =Z    A1(X) =  135/0/0.0  A2(Z) =  135/0/0.0

Correct radius with temperature of the workpiece sensor
```

```
Position meas. with master probe  Probing point   1

C Direct input
```

Here the calibration sphere must be probed in the direction of the master probe. The rest of the procedure follows automatically and you cannot influence this.

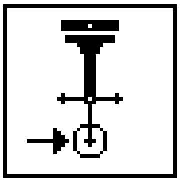
At the end, the position of the calibration sphere and the standard deviation of the measurement just carried out is displayed in the system window of the UMESS Main Menu:



```
Bestimmungsnormal
R   =       15.0001
S   =        0.0003
XM  =      647.4284
YM  =     -370.3207
ZM  =     -407.1845
```

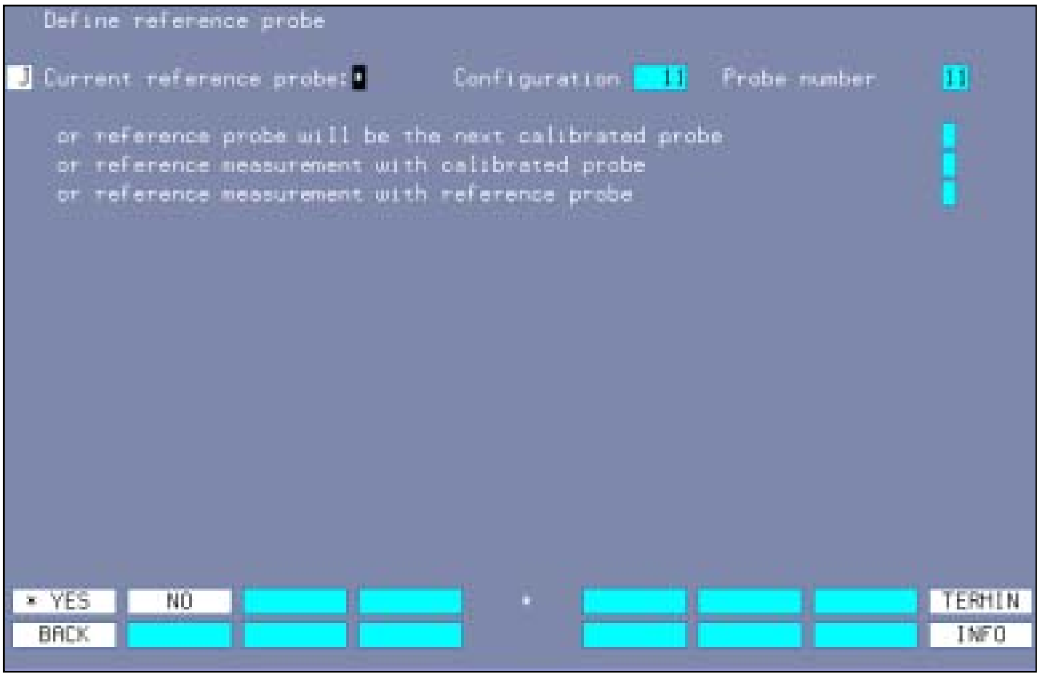
CAUTION: The standard deviation S should be smaller than 0.001 mm.

Next step: Input of a tensor calibrated reference probe:



DI 6506

Probe
↳ Mode
    ↳ Define reference probe



Define reference probe

☐ Current reference probe: Configuration 11 Probe number 11

or reference probe will be the next calibrated probe
or reference measurement with calibrated probe
or reference measurement with reference probe

End with TERMIN.

The next probe which is calibrated automatically becomes the reference probe for all other probes. This probe is also tensor calibrated which is of considerable importance for the accuracy of the calibration.

DI 15228

The actual calibration now takes place:

Probe
↳ Calibrate unclamped
  ↳ Semi automatically

The following screen must be completed:

```
  Probe and bend tensor determination for ball probe

  Probe :
I   Number              3
    New calibration     *     Or recalibration
    Radius of shaft      2.50

  Calibration standard
    Number                3099448        Radius       14.99448
```

Input of the shaft radius = Sphere radius for standard case.

The calibration now runs automatically.

Practical exercise:

A single probe is to be calibrated. The calibration sphere has been prepared.

Note:
The probe can have any axis direction.

To do | How to do it | What happens

Manual probe change

Call up
[Probe]
↳ **[change]**
↳ **[remove]**.
Time = Enter 5 seconds.
<TERMIN>

Caution !!
After the time entered has run out, the electromagnet is switched off. The probe in the probe head will then fall out.

Insert probe in the probe head

Call up
[Probe]
↳ **[change]**
↳ **[insert]**.
Enter Configuration no. = 1
<TERMIN>

After TERMIN, secure probe with your hand. After TERMIN the probe head is clamped and you will hear a "beep". The electromagnet is switched off for approx. 5 seconds. During this time you can insert the plate into the probe head.
If something goes wrong while inserting the probe, a corresponding message is displayed. Call up the insert procedure again. The probe data is saved as configuration 1.

Calibrate probes

[Probe]
↳ **[calibrate unclamped]**
↳ **[semi automatic]**

Complete screen

<TERMIN>

Select **probe**.

After prompt:
Probe the calibration sphere in the probe shaft direction.

The values are recorded after the tensor calibration has been made.

Measurement record

```
PROBE
                      R     2.4999
                      S     0.0001
                     XM     0.0009
                     YM    -0.0002
                     ZM    -2.9882
```

Explanation
The coordinates XM, YM, ZM show the distance to the reference probe. The standard deviation S should be < 0.001.

List data for Configuration 1

[Probe]
↳ **[data]**
↳ **[list]**

Measurement record
The data list for the current configuration 1 is output on the printer and in the protocol window on the screen.

This is the end of the practical exercise.

Worksheet 2: Calibration

Worksheet 2.2: Assembling a probe

A star probe is to be assembled for checking different dimensions on the practice cube.

The probe kit for this exercise contains:
- Probe plate
- Extension
- 3 probes with 5 mm tips
- 2 probes with 3 mm tips
- Tool

Probe
1: 5 mm
2: 5 mm
3: 3 mm
4: 5 mm
5: 3 mm

Worksheet 2: Calibrating a measuring probe head

2.3: Calibrating a probe

Practical exercise:

The reference for all probe arrangements to be calibrated is defined with a **semi-automatic measurement** and the master probe.

Note:
The same procedure should always be used if the position of the calibration sphere with regard to the machine zero point has been changed: The calibration sphere has been moved, the machine zero point traveled to again or there has been a change in temperature. If probe data is available, the reference measurement can be made with a probe which has already been calibrated.

To do	How to do it	What happens
Define position of the calibration sphere	Insert master probe Select **[Probe]** ↳ **[mode]** ↳ **[for calibration]** Complete screen: measurement * No. = 1 **<TERMIN>** Select **Probe 1** Select **<AUTCAL>** Probe the calibration sphere in –Z at the pole. After the automatic probings have been completed, end with **<TERMIN>**	**Protocol window** CALIBRATION SPHERE R 15.0001 S 0.0001 XM 233.8779 YM -864.7556 ZM -342.6216 **Explanation** XM, YM, ZM: Center point of the calibration sphere referring to the machine zero point. R: Radius of the calibration sphere. S: The standard deviation S should be smaller than 0.001.

IMPORTANT
Position 1 to which all probes to be calibrated refer has now been defined.
If the calibration sphere is moved, the machine switched ON/OFF, or if there is a greater change in temperature, this point must be redefined using the same procedure before each calibration or the displacement must be determined by a reference measurement with a probe which has already been calibrated.

This is the end of the practical exercise.

To do	How to do it	What happens
Enter reference probe	**[Probe]** ↳ **[Mode]** ↳ **[Define reference probe]** Complete screen Reference probe is the next probe to be measured: YES **<TERMIN>** Select **Probe 1**.	**Measurement record** PROBE R 3.9991 S 0.0001 XM 0.0009 YM -0.0002 ZM 0.0001 **Explanation** Probe data for the reference probe. The XM, YM, ZM coordinates must be zero (within the measuring uncertainty). The radius R should be 4 mm. The standard deviation S should be < 0.001.
	[Probe] ↳ **[calibrate unclamped]** **Complete screen with 4 mm shaft radius**	The input of the shaft radius influences the position of the probing points. Here shaft radius = probe tip radius is set (=4mm)
	After prompt: Probe the calibration sphere in –Z at the pole. The values are recorded after the tensor calibration has been made.	
List data for Configuration 1	**[Probe]** ↳ **[data]** ↳ **[list]**	Measurement record The data list of the current configuration 1 is output on the printer and in the protocol window on the screen.

This is the end of the practical exercise.

Practical exercise:

The five probes of a star probe are to be defined using the tensor calibration.

Note: The data will be saved as Configuration no. 2.

(For coordinate measuring machines with measuring probe head).

To do	How to do it	What happens
Remove probe	Call up **[Probe]** ↳ **[change]** ↳ **[remove]**. Enter Time = 5 seconds **<TERMIN>**	**Caution !!** After the time entered has run out, the electromagnet is switched off. The probe in the probe head will then fall out. After TERMIN secure probe with your hand.
Insert star probe in the probe head.	Call up **<Probe>** ↳ **[change]** ↳ **[insert]**. Configuration no.=2 **<TERMIN>**	After TERMIN you will hear a "beep". The electromagnet is switched off for approx. 5 seconds. During this time you can insert the plate into the probe head. If something goes wrong while inserting the probe, a corresponding message is displayed. Call up the insert procedure again. The probe data is saved as configuration no. 2.
Calibrate probes **Note:** The calibration sphere should be assembled so that the magnet switch points in +Y or the projection to the left at the front.	**[Probe]** ↳ **[calibrate unclamped]** ↳ **[semi automatic]** Complete screen **<TERMIN>** Select **Probe 1**. After prompt: Make search probing in the shaft direction at the pole. The values are recorded after the tensor calibration has been carried out.	**Monitor protocol** PROBE 1 R 2.5001 S 0.0003 XM 0.2348 YM -0.0702 ZM 65.2476 **Explanation** Probe data for probe 1. The XM, YM, ZM coordinates result from the difference in length to the reference point = center point of the master probe. The radius R should be 2.5 mm. The standard deviation S should be < 0.001.

Probes 2 and 3 are calibrated in the same way.

Important
Change probe! Standard deviation < 0.001 !

Now you have to calibrate probes 4 and 5.
Normally there are no problems with collision when the direction of the shaft is entered for the calibration sphere.

For the star probe used here, probe 1 runs the risk of colliding with the base of the calibration sphere. The machine only takes detour paths into consideration for the probe which is currently selected. Other detour paths are not taken into consideration.
For this reason we are looking at the most unfavorable situation here. The calibration sphere has to be rotated.
After the calibration sphere has been rotated its position must be redefined. This is done again with the master probe.

To do	**How to do it**	**What happens**
Rotate calibration sphere about 180°	Loosen the screw in the retaining plate and rotate the calibration sphere	
Manual probe change	**[PROBE]** ↳ **[change]** ↳ **[remove]** Enter Time = 5 seconds <TERMIN>	Caution! After the time entered has run out, the electromagnet is switched off. The probe in the probe head will then fall out. After TERMIN secure probe by hand.
Insert master probe in the probe head	**[PROBE]** ↳ **[change]** ↳ **[insert]** Configuration No. = 1 <TERMIN>	After TERMIN you will hear a "beep". The electromagnet is switched off for approx. 5 seconds. During this time you can insert the probe plate into the probe head. If something goes wrong while inserting the probe, a corresponding message is displayed. Call up the insert procedure again. The probe data is saved as configuration no. 2.
Redefine the position of the reference point	Select **[PROBE]** ↳ **[mode]** ↳ **[for calibration]** Complete screen. measurement: YES, No. 1. Sphere coordinates:YES, A1(X)= 225° A2(Z)= 135° Select **<AUTCAL>,** Probe in the shaft direction at the pole. End procedure with <TERMIN>.	Monitor protocol CALIBRATION SPHERE R 3.9991 S 0.0003 XM 250.8954 YM -466.2294 ZM -153.3946 **Explanation** XM, YM, ZM center point coordinates of the calibration sphere.
Manual probe change	**[PROBE]** ↳ **[change]** ↳ **[remove]** Enter Time = 5 seconds <TERMIN>	Caution! After the time entered has run out, the electromagnet is switched off. The probe in the probe head will then fall out. After TERMIN secure probe by hand.

To do	How to do it	What happens
Insert the star probe in the probe head again	[PROBE] ↳ [change] ↳ [insert] Configuration No. 2 <TERMIN>	After TERMIN you will hear a "beep". The electromagnet is switched off for approx. 5 seconds. During this time you can insert the probe plate into the probe head. If something goes wrong while inserting the probe, a corresponding message is displayed. Call up the insert procedure again.
Calibrate probes 4 and 5	[PROBE] ↳ [calibrate unclamped] ↳ [semi automatic] Complete screen Shaft radius = 2.5 mm <TERMIN> Select probe. After prompt: Make search probing in the direction of the shaft at the pole. The values are recorded after the tensor calibration has been made. List probe data.	**Monitor protocol** PROBE ..... R 2.5001 S 0.0003 XM .... YM .... ZM .... **Explanation** Probe data for the probe. The XM, YM, ZM coordinates result from the difference in length to the reference point = center point of the master probe. The radius R should be 2.5 mm. The standard deviation S should be < 0.001.
List probe data	[PROBE] ↳ [data] ↳ [list]	The configuration data is listed in the Measurement record. **Important:** The data is retained until a new calibration is carried out.

Worksheet 2: Calibration for trigger probe head

2.3: Calibrating a probe

Practical exercise:

The reference for all probe arrangements to be calibrated is defined with a **semi-automatic measurement** and the master probe.

Note:
The same procedure should always be used if the position of the calibration sphere with regard to the machine zero point has been changed: The calibration sphere has been moved, the machine zero point traveled to again or there has been a change in temperature. If probe data is available, the reference measurement can be made with a probe which has already been calibrated.

To do

Define the position of the calibration sphere

How to do it

Insert master probe
Select
[PROBE]
↳ **[mode]**
↳ **[for calibration]**

Complete screen:
measurement * No. = 1
<TERMIN>

Select **Probe 1**

Select **<AUT CAL>**

Probe the calibration sphere in –Z at the pole.
After the automatic probings have finished, end the measurement with **<TERMIN>**.

What happens

Protocol window

```
CALIBRATION SPHERE
        R     15.0001
        S      0.0001
        XM   233.8779
        YM  -864.7556
        ZM  -342.6216
```

Explanation

XM, YM, ZM	Center point of the calibration sphere referring to the machine zero point.
R	Radius of the calibration sphere.
S	The standard deviation S should be smaller than 0.001.

IMPORTANT
Position 1 to which all probes to be calibrated refer has now been defined.
If the calibration sphere is moved, the machine switched ON/OFF, or if there is a greater change in temperature, this point must be redefined using the same procedure before each calibration or the displacement must be determined by a reference measurement with a probe which has already been calibrated.

Practical exercise:

The five probes of a star probe are defined using the semi-automatic calibration.

Note:
The data is saved as Configuration no. 2.

(For coordinate measuring machines with trigger probe).

To do

Remove probe

Insert star probe in the probe head.

Calibrate probe 1

Note:
The calibration sphere should be assembled so that the magnet switch points in +Y or the projection to the left at the front.

How to do it

Call up
[PROBE]
↳ **[change]**
↳ **[remove]**.

Deflect probe by hand.

First insert the star probe, then

[PROBE]
↳ **[change]**
↳ **[insert]**
Configuration no.=2
<TERMIN>

[PROBE]
↳ **[calibrate clamped]**
↳ **[semi automatic]**

Select **Probe 1**.

After prompt:
Probe in the shaft direction at the pole.

The values are recorded after the semi-automatic calibration.

What happens

Caution !!
After the probe has been deflected, the electromagnet is switched off. The probe on the probe head will then fall out.
Therefore secure the probe by hand.

The probe is held straightaway by the electromagnet. During the probe change it is pulled up again (you will here a click).

If something goes wrong while inserting the probe, a corresponding message is displayed. Call up the insert procedure again. The probe data is saved as configuration no. 2

Measurement record
PROBE 1

R	2.5001
S	0.0003
XM	0.2348
YM	-0.0702
ZM	65.2476

Explanation
Probe data for probe 1.
The XM, YM, ZM coordinates result from the difference in length to the reference point.
The radius R should be 2.5 mm.
The standard deviation S should be < 0.001.

Probes 2 to 5 are calibrated in the same way.

Important
Change probe !
Standard deviation < 0.001 !

Continued overleaf.

To do	How to do it	What happens
List probe data	**[Probe]** ↳ **[data]** ↳ **[list]**	**Measurement record** The data list of the current configuration 2 is output on the printer and in the protocol window on the monitor.
Result	Data for configuration 2 is now defined. It is retained until overwritten by a new calibration.	

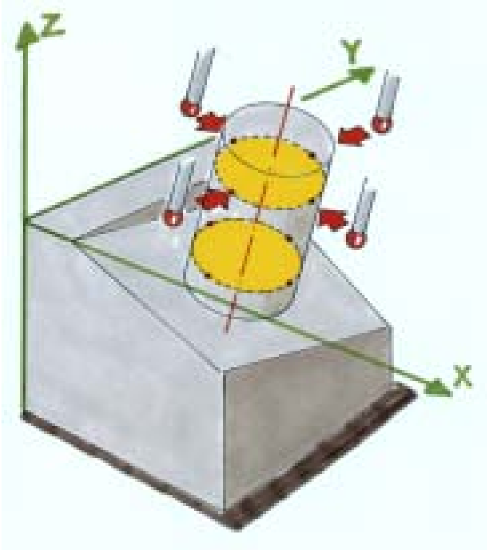
Measuring the workpiece

Generating data

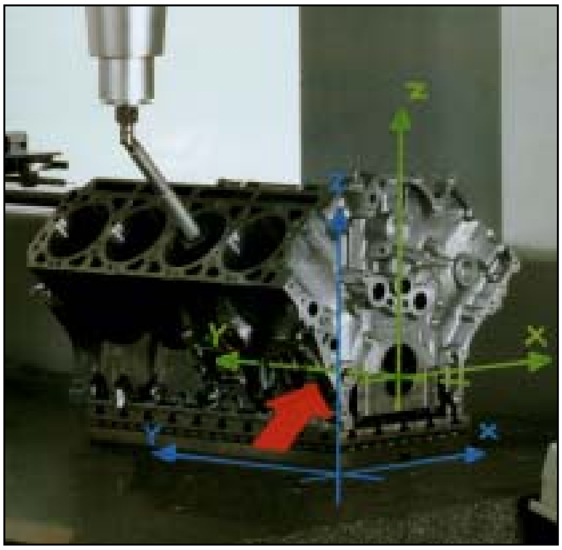
The entire measurement process is used to generate a mathematical model of the workpiece in order to gain the desired measurement results.

This section describes how you carry out probings, the steps you have to keep to during measurement and how you handle the results.

Because this section is so important, it is dealt with in detail and divided into several subsections to make the explanation clearer.



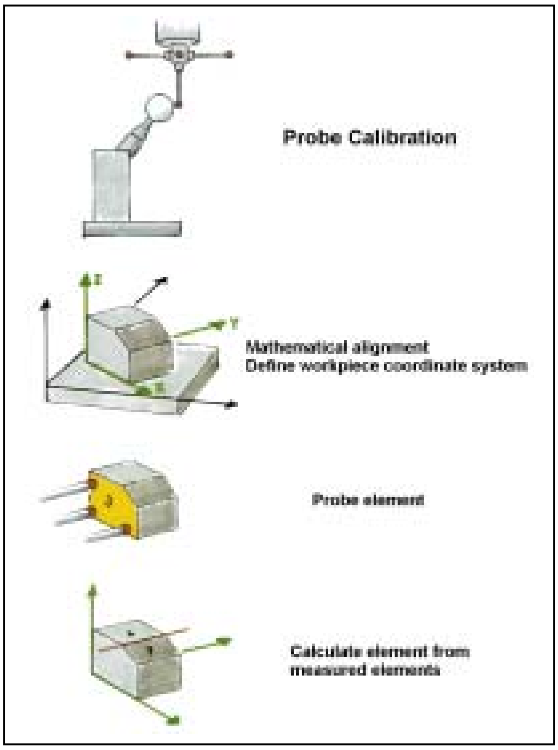
Probing the workpiece



You gain data by probing the workpiece with several probes. To measure the V shaped engine block shown on the right you would probe individual elements such as cylinder or coolant bores.

This section explains the basic principles of "Probing".

General measurement procedure



First we have to tell the computer which probes are to be used and to do this we use the probe calibration. Like the last time, we will use the star probe.

First the computer has to know the position of the workpiece on the CMM.
The workpiece does not have to be aligned exactly mechanically. The computer takes over the alignment, as we shall see.

The computer also has to know what is to be probed, e.g. a bore or a surface. To do this you call up the corresponding geometric element, here circle or surface.

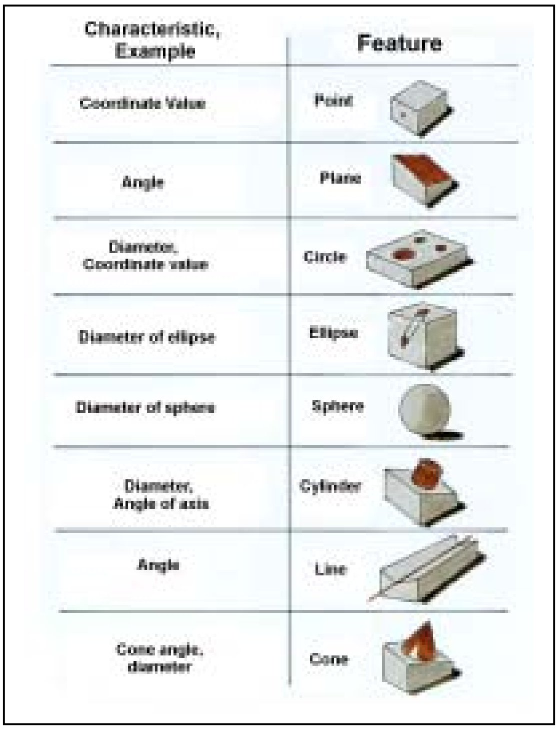
We can now probe the element on the workpiece. Data is then generated which can be compared to the dimensions in the manufacturing drawing. We define the sequence in which the elements are measured in the measuring run flowchart.

Not all the dimensions of a manufacturing drawing can be determined directly by probing specific elements, for example the edge of a cut. But this does not matter as the computer can also combine elements and calculate new ones. This can be done with elements which have just been defined or with elements from previous probings, as we shall see later.

Geometric elements

The computer has to know whether a bore, surface, sphere or bevel seat etc is being probed.

To do this you select the relevant geometric element before the probing. You have to decide which measurement results are of interest to you.



Characteristic, Example	Feature
Coordinate Value	Point
Angle	Plane
Diameter, Coordinate value	Circle
Diameter of ellipse	Ellipse
Diameter of sphere	Sphere
Diameter, Angle of axis	Cylinder
Angle	Line
Cone angle, diameter	Cone

Control panels

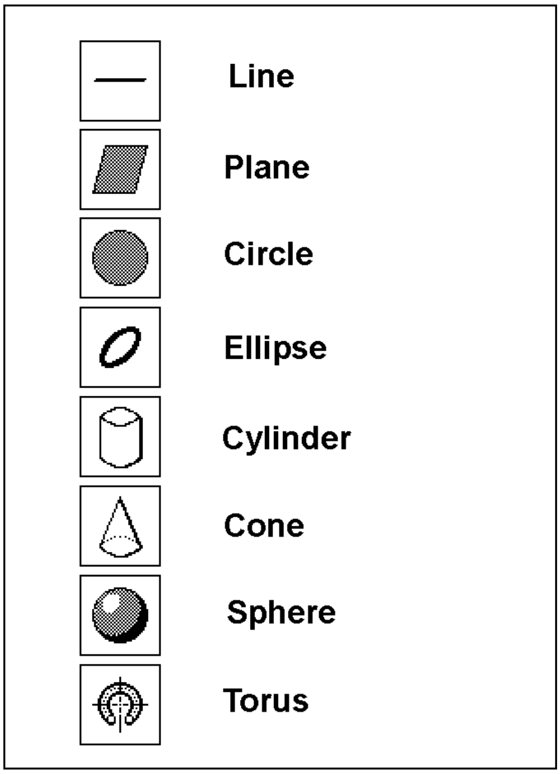
There is a button on the control panel for each geometric element. Your coordinate measuring machine is equipped with one of the following control panels:

- Standard control panel for trigger probe head
- Standard control panel for measuring probe head
- Alphanumeric panel
- Dynalog control panel

The operating procedure for measurement

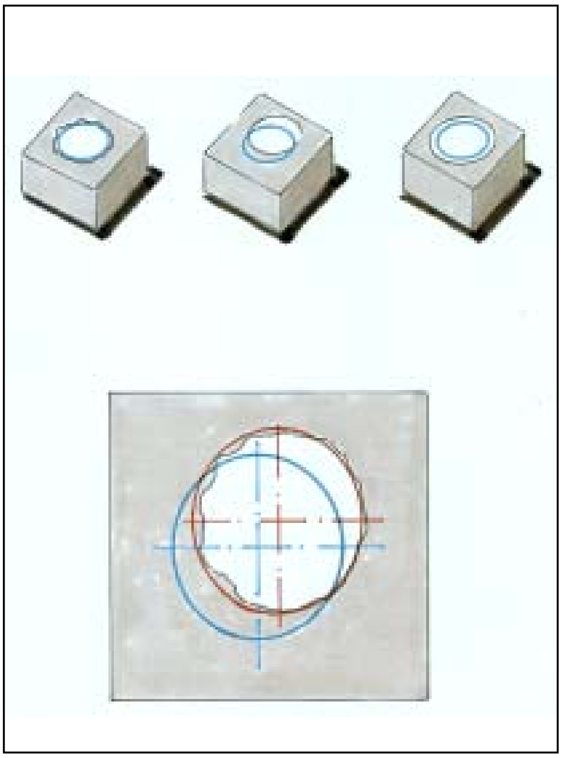
When you measure an element, you must keep to a defined operating procedure:

- Select element:
  - Pictogram
  - DI
  - Pulldown menu
- Probe element
- Press "TERMIN" key



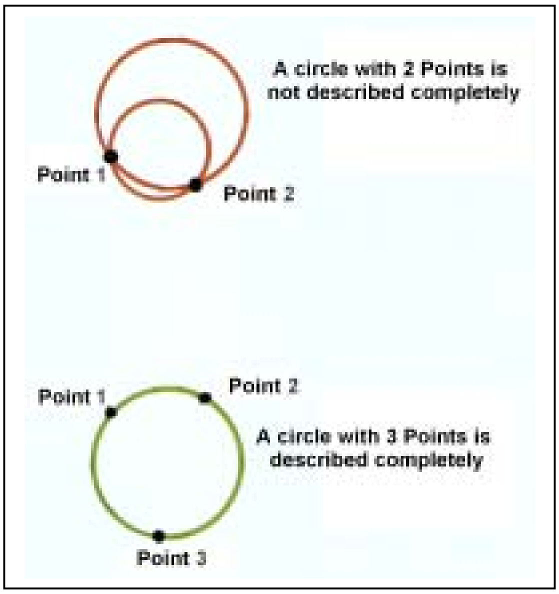
Ideal and actual form and substitute form

When designing a workpiece, we assume the form is geometrically ideal, that its bores are true to dimension, circular and correctly positioned. The real part however has dimension, form and position errors. All these deviations can be measured using multi-coordinate metrology.
To determine the value of these deviations, the corresponding elements (e.g. the bore) are probed. From the points probed the computer determines the substitute form. The substitute form consists of geometrically ideal substitute elements. Here for example the substitute element is a circle.
The values the computer supplies state how far the dimension and position deviations of the substitute element deviate from the dimension and position given in the drawing and how big the form deviation is with reference to the geometrically ideal substitute element.



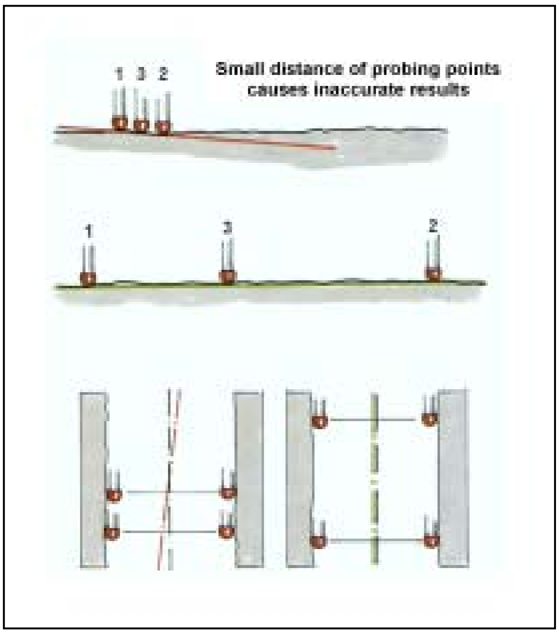
Minimum number of probings

To calculate the geometric elements, the computer needs the (mathematically required) minimum number of probings. The computer monitors whether this minimum number has been probed.

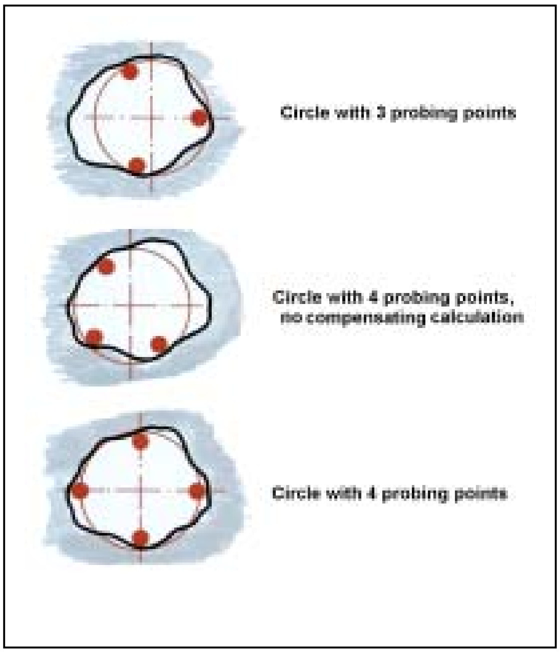


Minimizing the measuring uncertainty by favorable probing

As we know, workpieces do not have an ideal form but form deviations occur as a result of manufacture.
If you limit yourself to the minimum number of probings and distribute these unfavorably with regard to position, different measurement results may occur. It is therefore important to carry out the probings as accurately as possible distributed over the entire element to be measured.



Minimizing the measuring uncertainty with more probings



So that the geometrically ideal substitute element is defined as accurately as possible in form and position by the computer, you should probe more times than is required mathematically. The computer evaluates the probings and determines with a compensating calculation the best fit substitute element.

The following applies:
The more probings, the more reliable the result, and the more reliably it can be repeated.
(As the measurement cannot take forever, a compromise has to be reached.) In the record, the computer outputs the values determined and the absolute deviations from the substitute element.

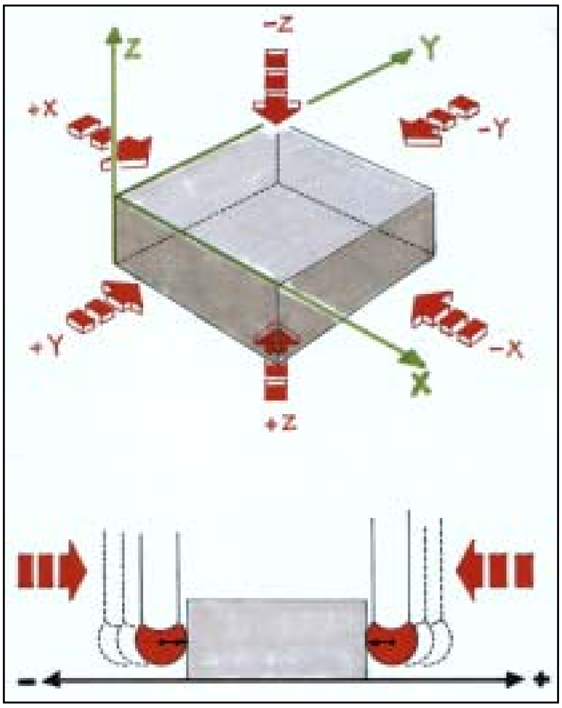
What is important for those who have used conventional methods up till now is that: "More probings" means: more probing points, distributed evenly over the element to be measured. It does not mean probing on the same spot several times and forming a mean value like on a measuring table, as the advantages of the compensating calculation are not used in this way.

Notes:

Measured elements

The Point element

Point probing on a surface parallel to one of the coordinate planes

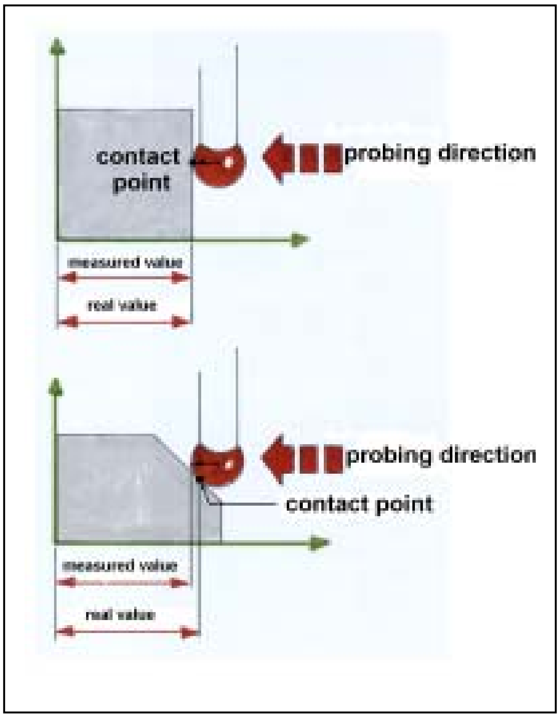


With the Point element, coordinates of individual points on the workpiece can be determined, e.g. for determining dimensions. (Naturally no compensating calculation is made for the Point element.)

During the probing the coordinate is output in the direction of the probing.
This means, the contact point and the coordinate printed only coincide if the surface probed lies parallel to the X/Y, X/Z or Y/Z plane of the workpiece coordinate system.

Probing strategy
Number of probings: 1
What you should be aware of: The greatest measuring uncertainty results when probing at less than 45° to the coordinate axes.

Point probing on an inclined surface

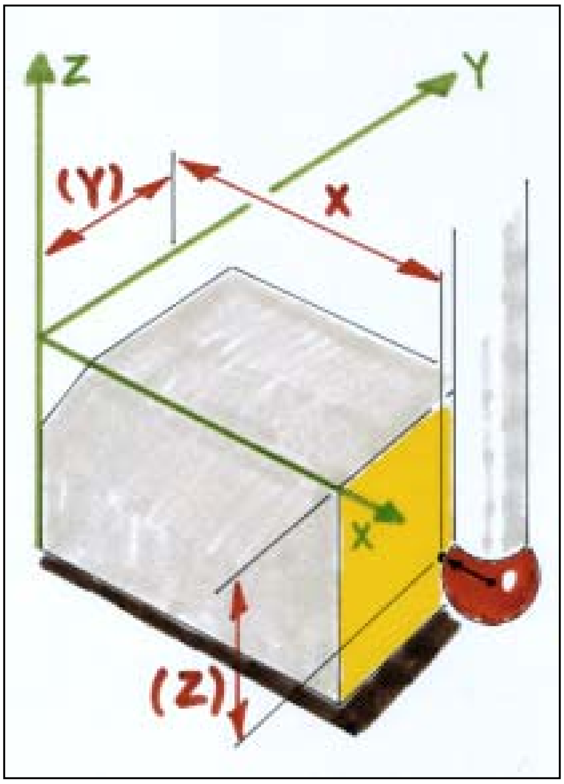


If you are probing a surface which is inclined to the coordinate planes, the coordinate which is output is different to that of the point of contact.

The single point should therefore only be used for measurements under certain conditions.

Meaning of the data in the measurement record

After the probing, the computer prints the result in the measurement record.



Example:
The probing direction parallel to the X axis

X	X coordinate of the contact point

Supplementary coordinates
Y and Z coordinate of the sphere center point

The supplementary coordinates are not printed but can be called up when required.

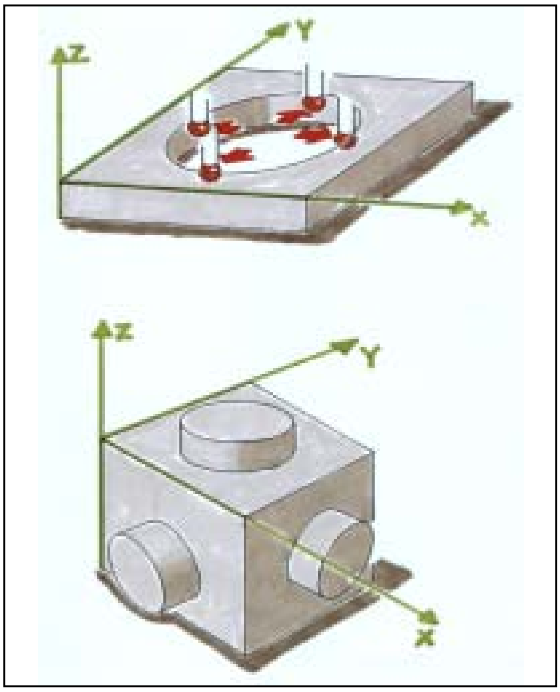
The same applies correspondingly for the other probing directions.

The Circle element

With this program you can measure bores or plugs with circular cross section whose axes have a negligibly small parallelism deviation to the workpiece coordinate axes.

The computer differentiates automatically between bores and plugs, i.e. between inner and outer diameters.

The minimum number of probings is 3.



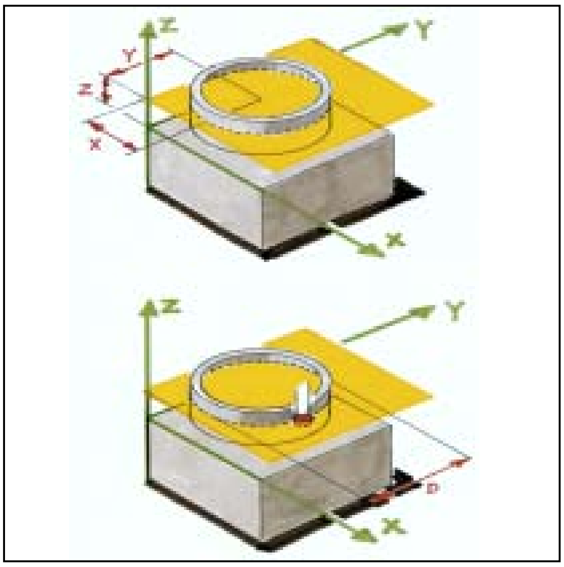
Probing strategy:
Recommended number of probings: 4.
Probing sequence: Distribute the probing points as evenly as possible.

Meaning of the data in the record

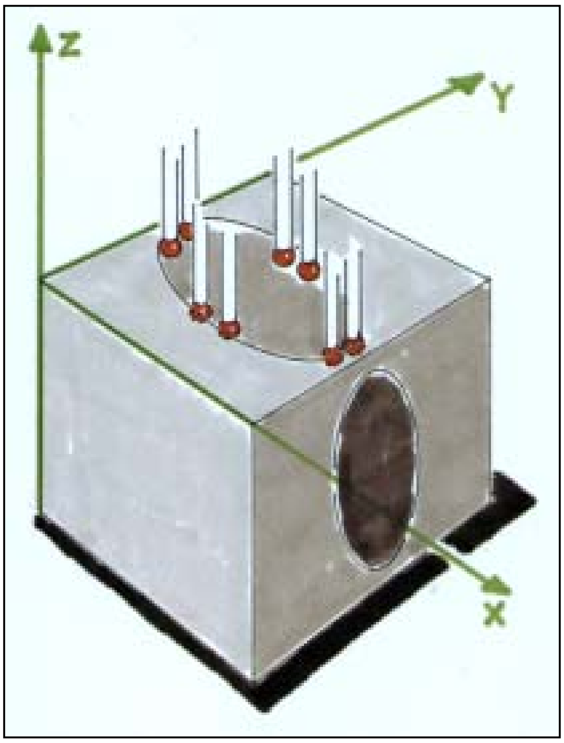
X	Center point coordinate
Y	Center point coordinate
D	Diameter
4P	Number of probings (here 4)

S/MIN/MAX
Standard deviation, minimum and maximum value referring to the best fit substitute element (is calculated automatically if more than the minimum number of probings have been made – here therefore more than 3 probings).

Supplementary coordinate:
If the circle probed lies in the X,Y plane for example, the 3rd coordinate is Z.



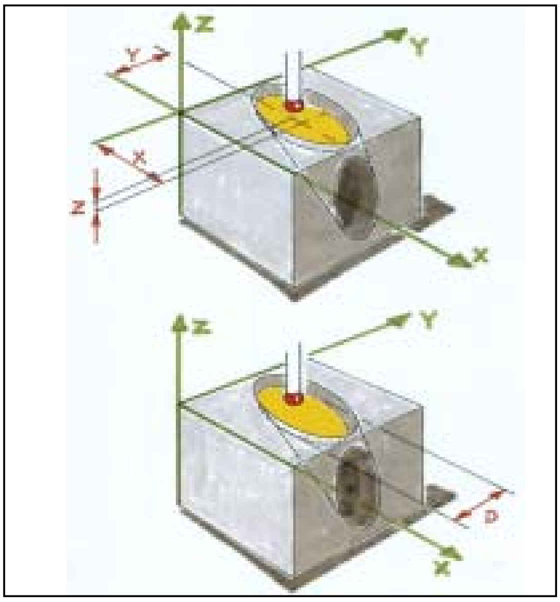
The Ellipse element



With this program you can measure bores or plugs with circular cross section whose axes do not lie parallel to the workpiece coordinate axes and of course also "real" ellipses.
The computer differentiates automatically between bores and plugs, i.e. between inner and outer diameters
The minimum number of probings is 5.

<u>Probing strategy</u>
Recommended number of probings: 8.
Probing sequence: All the points must be probed in one plane, the CMM therefore must not travel in the 3rd axis during the measurement.
What to be aware of: see Circle element.

Meaning of the data in the record



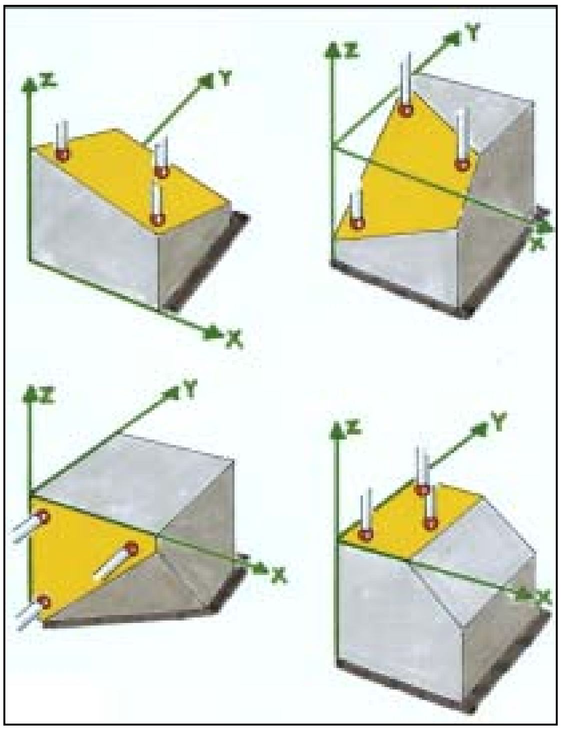
X	Center point coordinate
Y	Center point coordinate
D	Diameter
8P	Number of probings (here 8}

S/MIN/MAX
Standard deviation, minimum and maximum value referring to the best fit substitute element (is calculated automatically if more than the minimum number of probings have been made – here therefore more than 5 probings).

Supplementary coordinate:
The position of the measuring plane. If the ellipse probed lies in the X, Y plane for example, the 3rd coordinate is Z.

The Surface element

With the Surface element, you can determine the position and inclination of surfaces. Any probing direction is possible, but should not be changed.
The minimum number of probings is 3.



Probing strategy
Recommended number of probings: 4
Probing sequence: as vertical to the surface as possible
What to be aware of: see Circle element.

Meaning of the data in the record

Z Coordinate of the point where the reference axis Z pierces the surface

X/Z A1 Angle between the reference axis Z and Y/Z A2 the "shadow" (=projection) of the normal in the X/Y or Y/Z plane

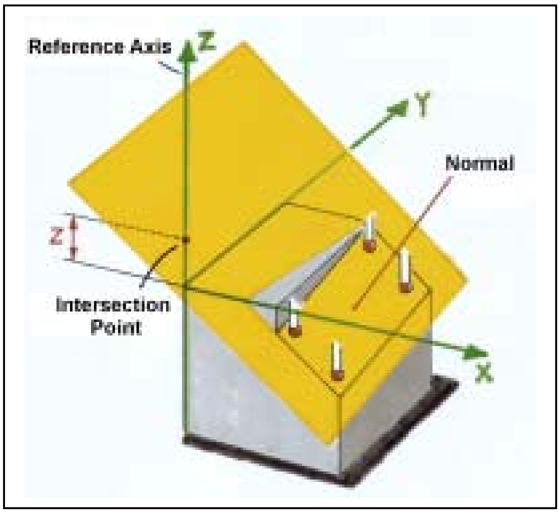
5P Number of probings (here 5)

S/MIN/MAX
Standard deviation, minimum and maximum value referring to the best fit substitute element (is calculated automatically if more than the minimum number of probings have been made – here therefore more than 5 probings).

Supplementary coordinates
Further coordinates for the piercing point (here always 0)

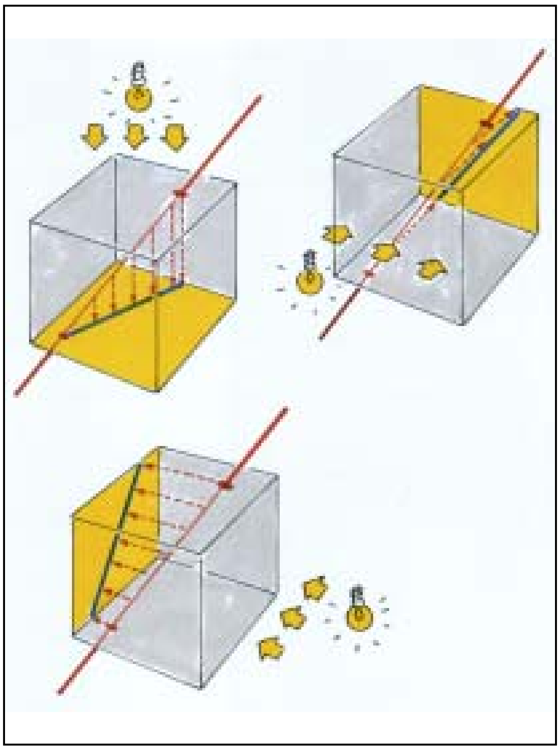
Reference axis, normal and piercing point

The flat surface of the workpiece to be defined is inclined. How far it is inclined can be printed out in various ways. Here it is a question of the inclination of the surface normals referring to a coordinate axis, the reference axis. The point at which the reference axis pierces the surface is given in the record.



3D display of the projection angle

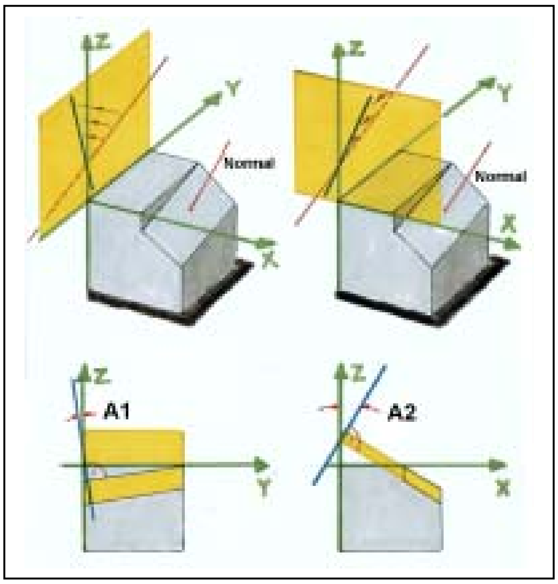
By specifying 2 angles in the measurement record, the inclination of the surface can be clearly defined. How is the angle data to be understood ? The figure on the left would result for the projection angle if it were possible to view the normal of the inclined surface in a see-through cube.



Projection angle A1
If you look in the direction opposite the Y axis to the X/Z plane, you will see the inclination of the surface projected in this plane.

The projection (=shadow) of the normal in the X/Z plane encloses the projection angle A1 with the reference axis Z.

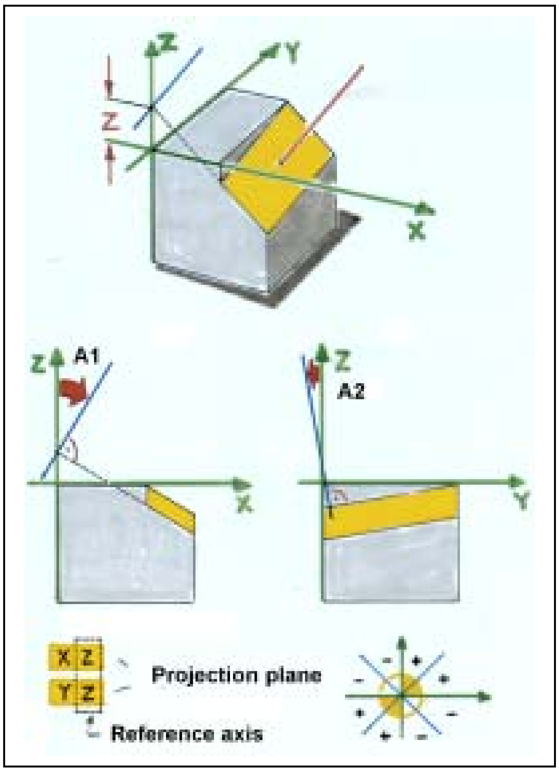
Projection angle A2
And this is what it looks like in the Y/Z plane. The projection (=shadow) of the normal in the Y/Z plane encloses the projection angle A2 with the reference axis Z.



The computer always selects the reference axis so that the angles resulting are always smaller than 45°.

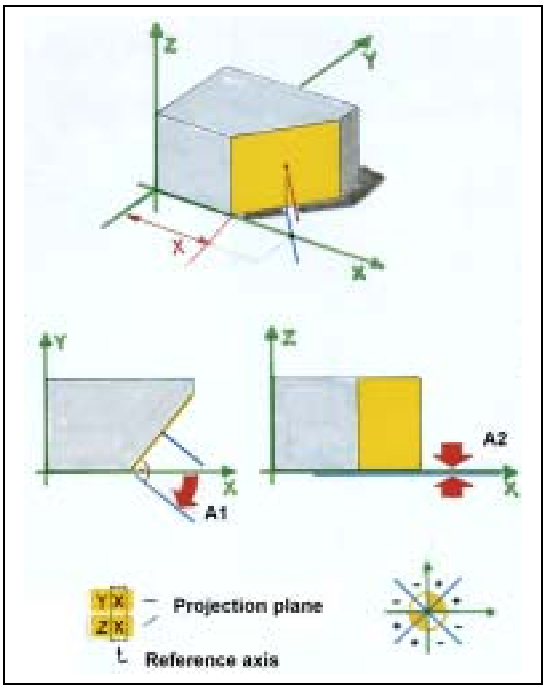
Projection planes for the Z reference axis

In the measurement record, the projection planes and the corresponding reference axis are specified for the projection angle. The coordinate axis with which the projected normal encloses the specified projection angle is called the reference axes. It is selected so that a projection smaller than 45° results. Here the reference axis is the Z axis.
Therefore the projection planes are the X/Z and the Y/Z plane.
See the graphics in the figure on the right for the +/- signs for A1/A2.



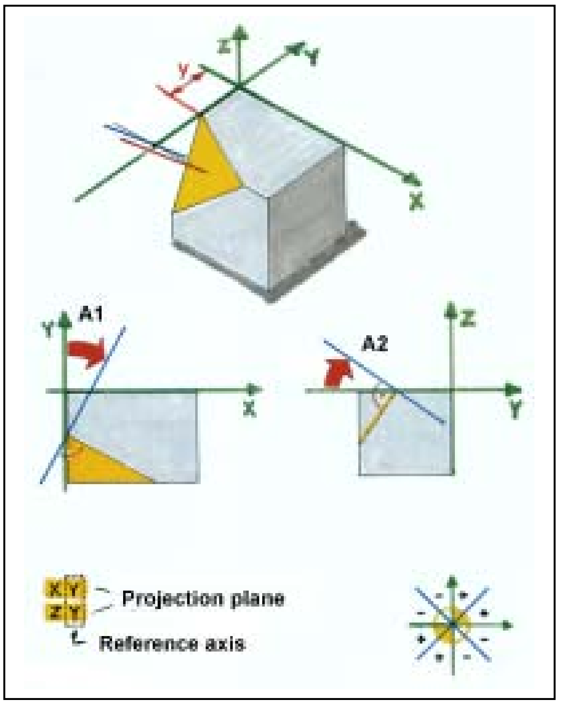
Projection planes for the X reference axis

As above, only here the reference axis is the X axis. Therefore the projection planes are the Y/X and Z/X plane.
See the graphics in the figure on the right for the +/- signs for A1/A2.

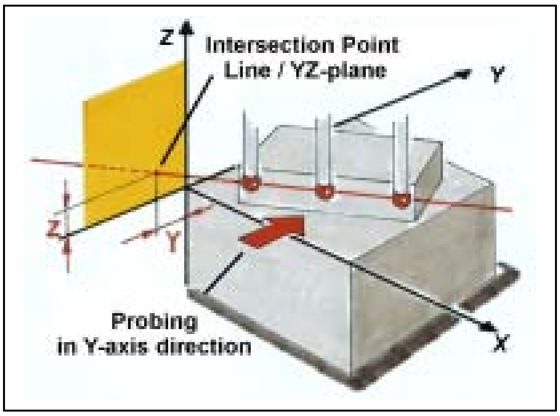


Projection planes for the Y reference axis

As above, only here the reference axis is the Y axis. Therefore the projection planes are the X/Y and Z/Y plane.
See the graphics in the figure on the right for the +/- signs for A1/A2.



The Line element



The Line element is used for defining lines in any plane of the workpiece. Direct probing is more a theoretical case (except for self-centering scanning with measuring probe head). The Line element is mostly used for linkings, more about this later.
The minimum number of probings is 2.

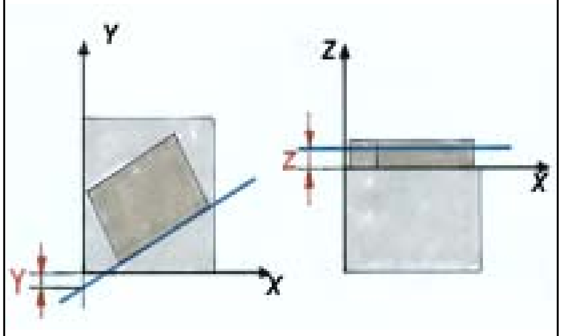
Probing strategy:
Recommended number of probings: 3.
Probing sequence: Distribute the probing points as evenly as possible.
What to be aware of: see Circle element.

Meaning of the data in the record

Y	Coordinates of the piercing
Z	point of the line, here through the Y/Z plane
Y/X A1	Projection angle between the
Z/X A2	reference axis X and the projections of the line
3P	Number of probings (here 3)
S/MIN/MAX	Standard deviation, minimum and maximum value referring to the best fit substitute element (is calculated automatically if more than the minimum number of probings has been made, i.e. here more than 2 probings).
Supplementary coordinate:	3rd coordinate of the piercing point (is always 0)

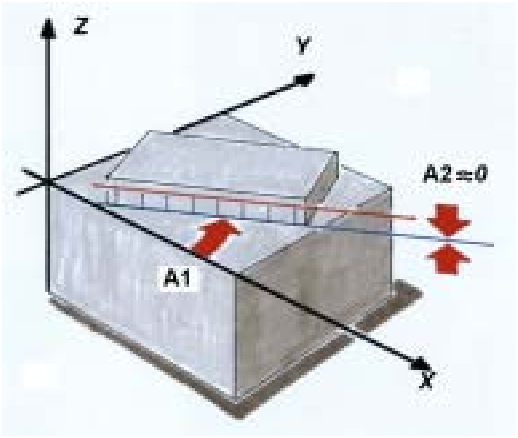
Coordinates of the piercing point

The coordinates of the point at which the line pierces the X/Y, X/Z or Y/Z plane are given in the measurement record. This is dependent on the reference axis for the projection angle: here e.g. Y and Z are given because the reference axis is the X axis.



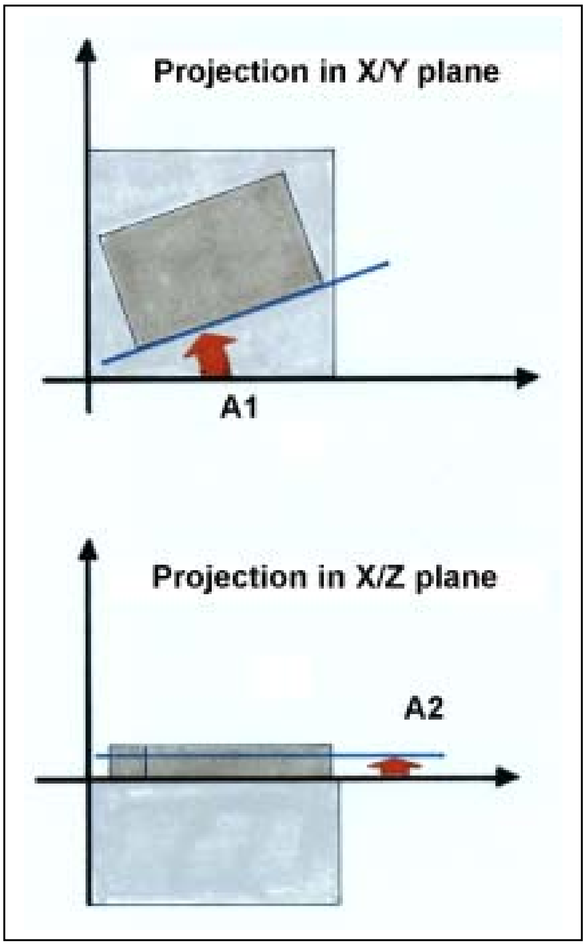
3D representation of the projection angle

This figure results for the projection angle for a 3D view.



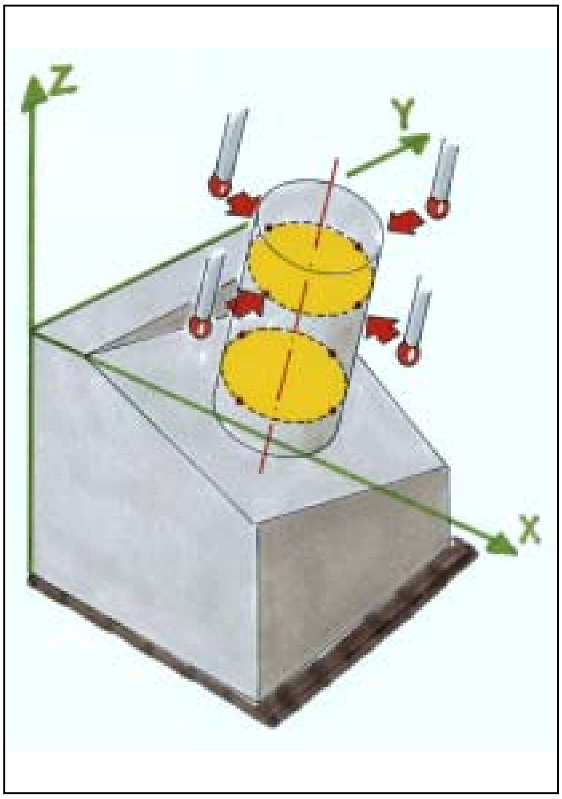
Projection angle A1
If you look in the opposite direction to the Z axis onto the X/Y plane you will see the angle A1 between the X reference axis and the projection (=shadow) of the line.

Projection angle A2
If you look in the opposite direction to the Y axis onto the X/Z plane you will see the angle A2 between the X reference axis and the projection (=shadow) of the line.



The Cylinder element

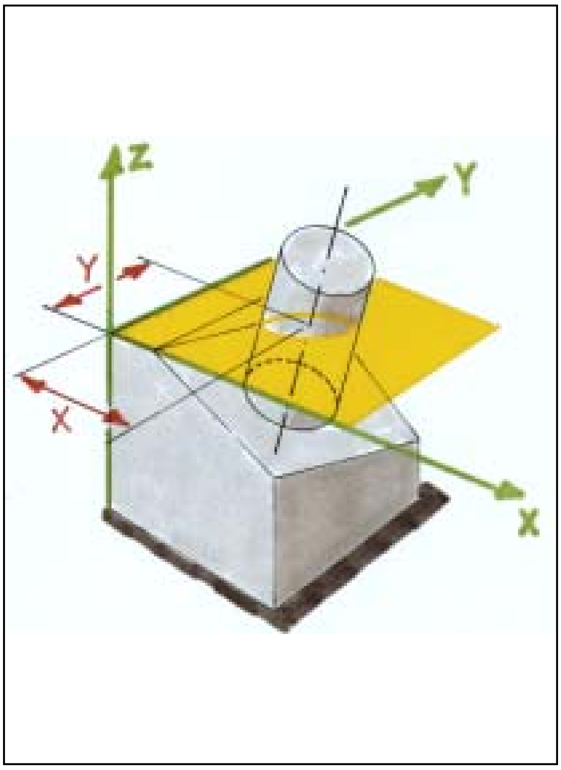
The Cylinder element is used for defining the diameter as well as the axis direction and position of circular plugs and bores. The computer differentiates automatically between inner and outer diameters, that is between bore and plug. The minimum number of probings is 5.



Probing strategy:
Recommended number of probings: 8.
Try to distribute the probing points as far as possible on cross sections, i.e. 4 points on each "circular section".
What to be aware of: see Circle element.

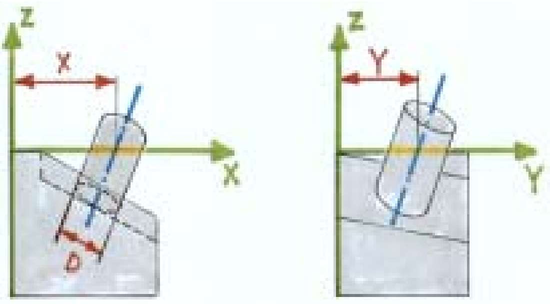
Meaning of the data in the record

X or Y	Coordinates of the piercing point of the cylinder axis, here through the XY plane
D	Cylinder diameter
X/Z A1 or Y/Z A2	Angle between the Z reference axis and the projection of the cylinder axis.
8P	Number of probings (here 8)
S/MIN/MAX	Standard deviation, minimum and maximum value referring to the best fit substitute element (is calculated automatically if more than the minimum number of probings has been made – i.e. here more than 5 probings).
Supplementary coordinate:	3rd coordinate of the piercing point (is always 0)



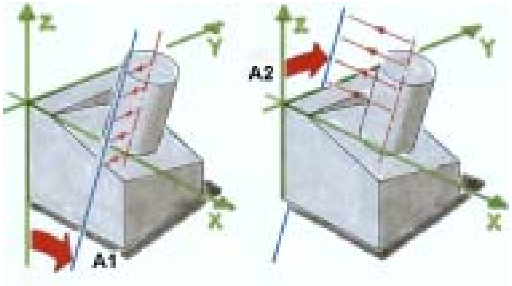
Coordinates of the piercing point

In the record, the coordinates of the point are given where the cylinder axis pierces the X/Y, X/Z or Y/Z plane. Here for example X and Y are given because the X/Y plane is vertical to the Z reference plane of the projection angle.



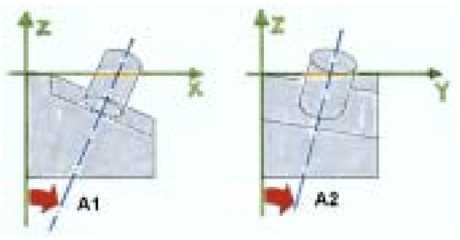
3D representation of the projection angle

This figure results for a 3D view of the projection angle.



Projection angle A1

If you look in the opposite direction to the Y axis onto the X/Z plane you will see the angle A1 between the Z reference axis and the projection of the cylinder axis in this plane.

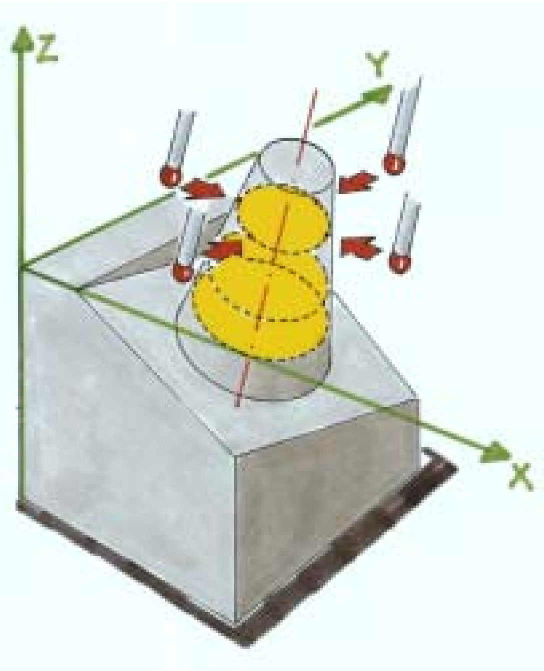


Projection angle A2

If you look in the opposite direction to the X axis onto the Y/Z plane you will see the angle A1 between the Z reference axis and the projection of the cylinder axis in this plane.

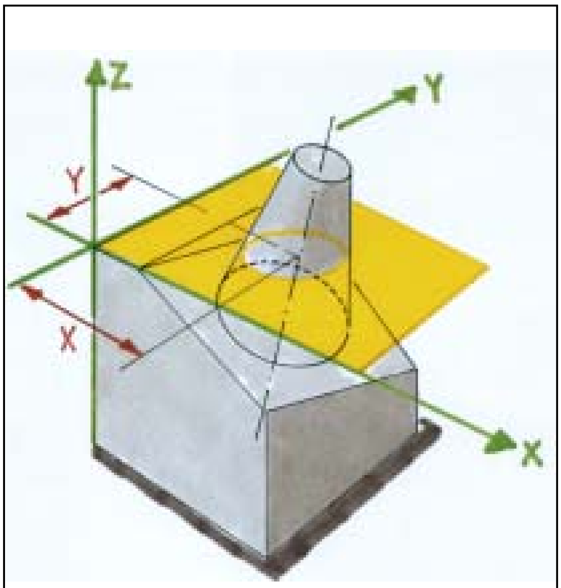
The Cone element

The Cone element is used for defining the following parameters for a cone or a truncated cone:
Position and direction of the cone axis, cone diameter at the piercing point (vertical to the axis direction) and generating angle of the cone.
The computer differentiates automatically between inner and outer diameter, that is between conical bores or plugs.
The minimum number of probings is 6.



Probing strategy:
Recommended number of probings: 12.
Probing sequence: Try to distribute the probing points as far as possible on cross sections, i.e. 4 points on each "circular section".
In unfavorable situations, e.g. only one small cone section, the cone surface lines should also be probed.
What to be aware of: see Circle element.

Meaning of the data in the record

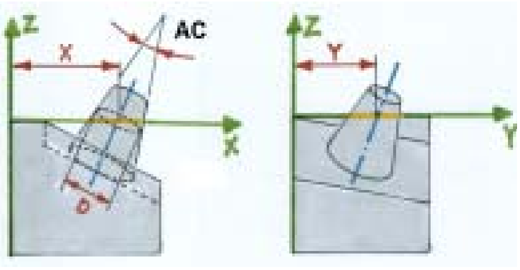


X or Y	Coordinates of the piercing point of the cone axis, here through the X/Y plane
D	Cone diameter at the piercing point
X/Z A1 or Y/Z A2	Angle between the projection of the cone axis and the Z reference axis
AC	Generating angle of the cone
12P	Number of probings (here 12)
S/MIN/MAX	Standard deviation, minimum and maximum value referring to the best fit substitute element (calculated automatically if more than the minimum number of probings has been made – i.e. here more than 6 probings).

Supplementary coordinate:
3rd coordinate of the piercing point (always 0)

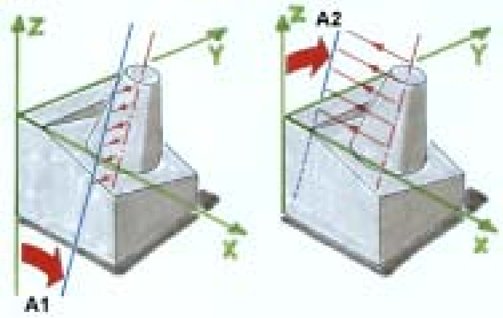
Coordinates of the piercing point

In the record, the coordinates of the point are given where the cylinder axis pierces the X/Y, X/Z or Y/Z plane. Here for example X and Y are given because the X/Y plane is vertical to the Z reference plane.



3D representation of the projection angle

This figure results for a 3D view of the projection angle.

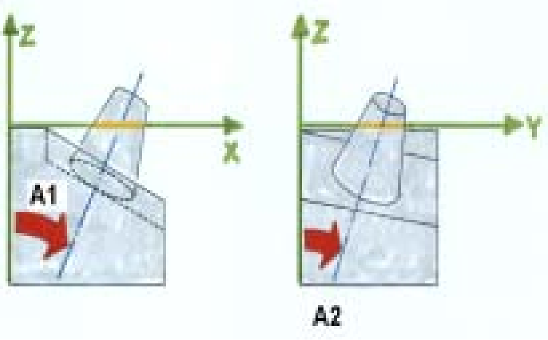


Projection angle A1

If you look in the opposite direction to the Y axis onto the X/Z plane you will see the angle A1 between the Z reference axis and the projection of the cone axis in this plane.

Projection angle A2

If you look in the opposite direction to the X axis onto the Y/Z plane you will see the angle A2 between the Z reference axis and the projection of the cone axis in this plane.

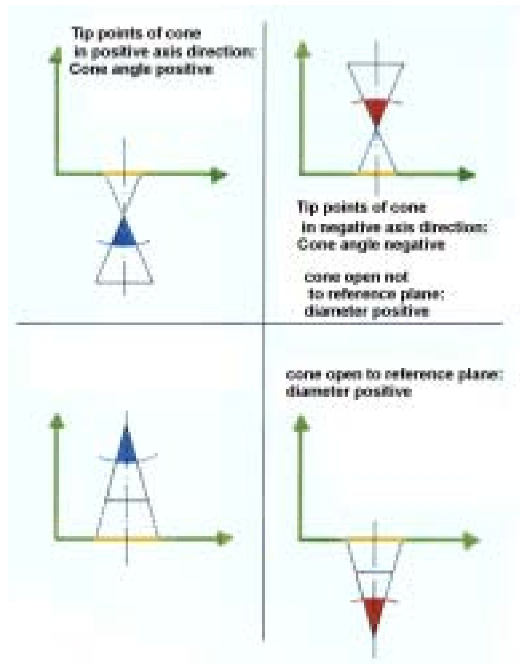


+/- sign for the diameter and generating angle

AC is the generating angle for the cone.
D is the cone diameter at the height where the cone axis pierces the coordinate plane.

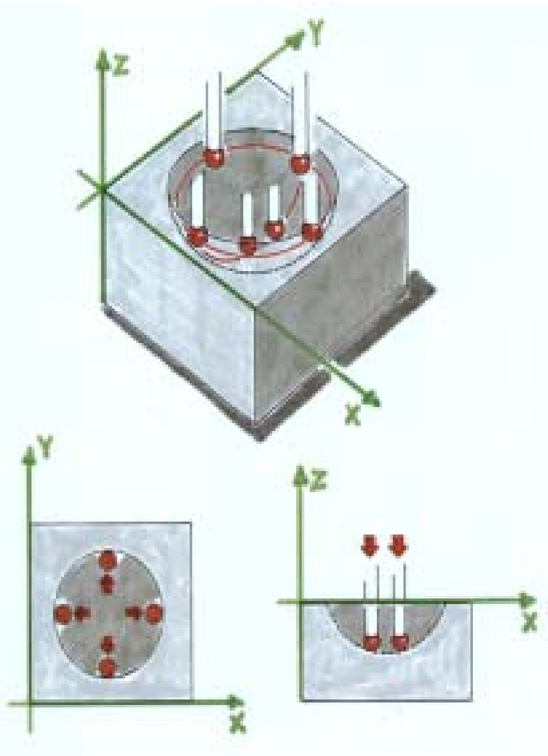
The following applies for the AC angle:
Tip (of the real cone) points in the direction of the reference axis, sign is positive (+).
Tip points in the opposite direction to the reference axis, sign negative (-).

The following applies for the +/- sign for D:
D on the side of the real cone, sign positive (+), D on the side of the cone which is not real, sign negative (-).



The Sphere element

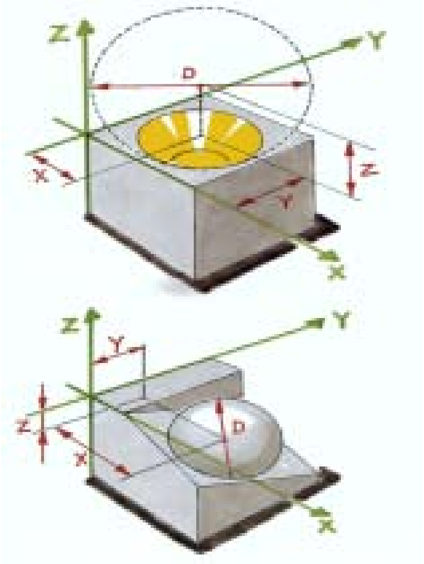
The Sphere element is used for measuring the center coordinates and diameter of spheres or spherical segments.
The minimum number of probings is 4.



Probing strategy:
Recommended number of probings: 6.
Probing sequence: Two points near the pole, four further points distributed equally around the equator.

Meaning of the data in the measurement record

X, Y, Z	Coordinates of the sphere center points
D	Sphere diameter
6P	Number of probings (here 6)
S/MIN/MAX	Standard deviation, minimum and maximum value referring to the best fit substitute element (calculated automatically if more than the minimum number of probings has been made – i.e. here more than 4 probings).

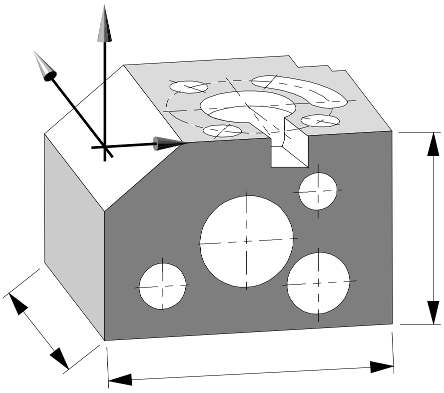


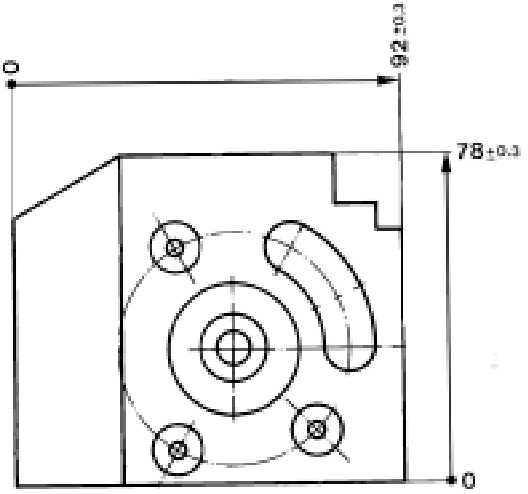
Summary of geometric elements

DI	Element program	Number of probing points		Result
		minimum	recommended	e.g.
1101	Point	1	–	1 coordinate of the contact point X
1104	Circle	3	4	2 coordinates of the center point X,Y in the measuring plane Diameter D
1108	Ellipse	5	8	2 coordinates of the center point in the measuring plane X,Y Small diameter D1 Angle A1
1103	Surface	3	4	1 coordinate of the piercing point Z 2 projection angles X/Z A1 Y/Z A2
1102	Line	2	3	2 coordinates of the piercing point X,Y 2 projection angles X/Z A1 Y/Z A2
1106	Cylinder	5	2 x 4	2 coordinates of the piercing point X,Y Diameter D 2 projection angles X/Z A1 Y/Z A2
1107	Cone	6	3 x 4	2 coordinates of the piercing point X,Y Diameter at the piercing point D 2 projection angles X/Z , Y/Z A1,A2 Generating angle of the cone AC
1105	Sphere	4	2 x 3	3 coordinates of the sphere center point X,Y,Z Sphere diameter D
1109	Torus	7	4 x 3	3 coordinates of the center point X,Y,Z Center circle - Diameter D1 2 projection angles X/Z , Y/Z A1,A2 Ring diameter D2

Worksheet 3: Measured elements

3.1 Test feature: Coordinate value
Element: Point





```
===============================================================================
 ADR|REC | TASK   | IDF |SY| ACTUAL  | NOMINAL  | U.TOL | L.TOL | DEV  | EXC
============================================================================


   1      POINT         Z     -0.0124

   2      POINT         X      0.0044

   3      POINT         Y      0.0019

   4      POINT         Z    -62.9169

   5      POINT         X     91.9747

   6      POINT         Y     77.9207
```

Practical exercise :

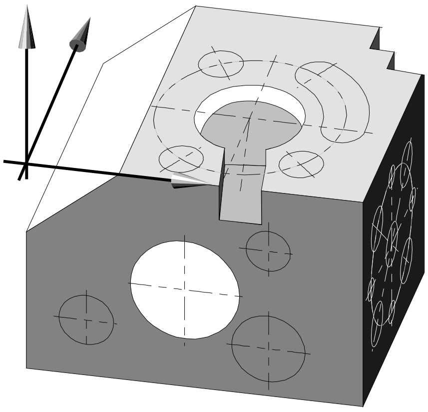
With the **POINT** element program you gain the length, width and height dimensions.

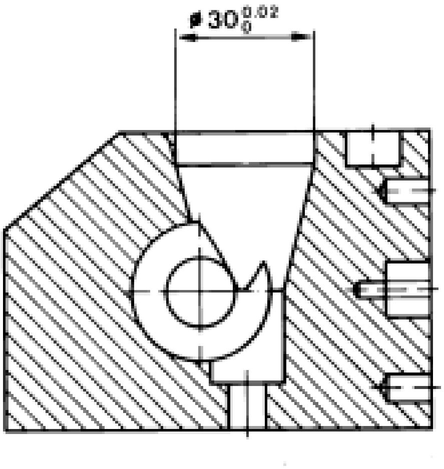
To do	How to do it	What happens
Define the coordinate system	Proceed as described in practical exercise 16 (see Section 4.1 "Mathematical alignment of the workpiece").	The workpiece coordinate system is now in the front upper left corner of the workpiece (address 1 to 8).
Measure length	Select **Probe 5** Probe the right side of the cube with probe 5.	**Measurement record** 9 POINT X 91.811 **Explanation** X Coordinate of the contact point. The result corresponds to the length of the cube
Measure width	Select **Probe 4** Probe the rear of the cube with probe 4.	**Measurement record** 10 POINT Y 77.948 **Explanation** Y Coordinate of the contact point. The result corresponds to the width of the cube
Measure height	Select **Probe 2** Probe the underneath of the cube with probe 2.	**Measurement record** 11 POINT Z -62.833 **Explanation** Z Coordinate of the contact point. The result corresponds to the height of the cube
Result comparison	Compare the measurement results with the data in the manufacturing drawing.	

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.2 Test feature: Diameter
Element: Circle





```
================================================================================
ADR|REC | TASK   | IDF |SY| ACTUAL  | NOMINAL  | U.TOL | L.TOL | DEV   | EXC
============================================================================
   8      CIRCLE I       Z    -32.9680
                         X     41.8952
                         D     29.9457
       4P S/MIN/MAX              .0040        (3)  -.0023     (1)   .0020
```

Practical exercise:

The large bores on the top of the cube and the front of the cube are to be measured with the **CIRCLE** element.

To do

How to do it

What happens

Measure top circle

Call up
[Elements]
↳ **[Geometric elements]**
↳ **[Circle]**.

Select **Probe 1**.
Move this into the hole in the center.

Probe the side of the hole in +X, -X, +Y and -Y
Press the **<TERMIN>** key.

Measurement record

```
CIRCLE_1
12    CIRCLE I    X     51.829
                  Y     32.047
                  D     30.058
      4P S/MIN/MAX        0.005   (4) -0.003   (2) 0.002
```

Explanation

X, Y	Center point coordinates
D	Diameter
S/MIN/MAX	Standard deviation, minimum and maximum value

Measure the front circle

[Elements]
↳ **[Geometric elements]**
↳ **[Circle]**

<Macro selection>
Select **<36 points Circle>**
Press **<Measure macro>**

Select **Probe 2**.
Position the probe in front of the hole then
press the <I-POS> button.

Probe the side of the hole twice in +Z near the top arc of the circle.
After the measurement has been made automatically
press the **<TERMIN>** key.

Measurement record

```
CIRCLE_2
13    CIRCLE I    Z    -33.067
                  X     41.867
                  D     30.003
      36P S/MIN/MAX              0.001        (4) -0.002
      (2) 0.002
```

Explanation

Z, X	Center point coordinates
D	Diameter
S/MIN/MAX	Standard deviation, minimum and maximum value

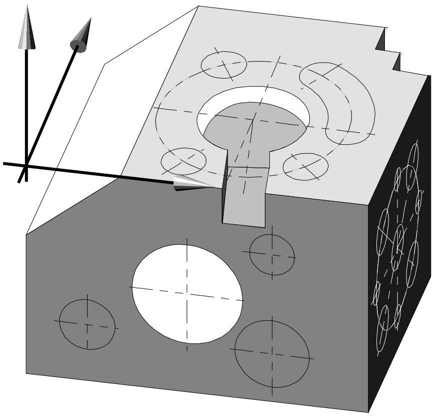
Result comparison

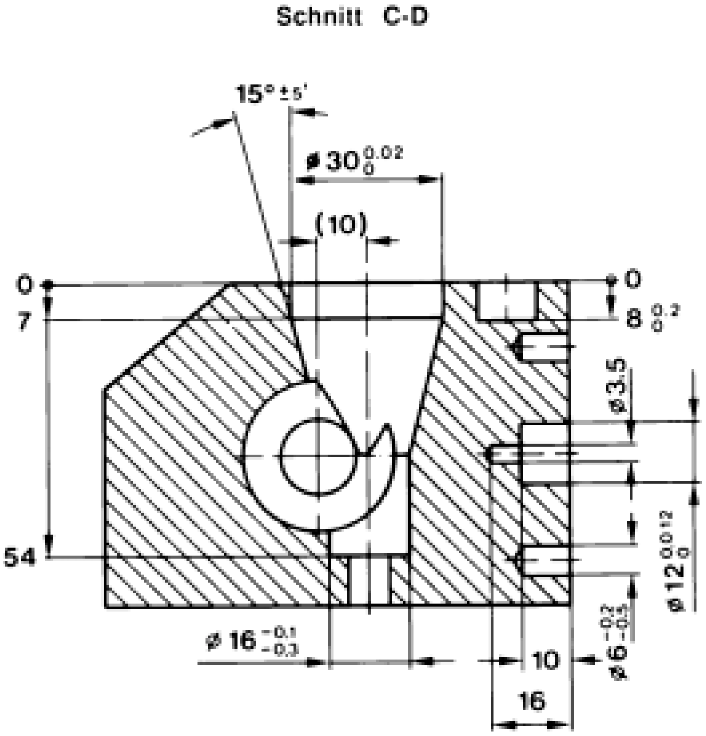
Compare the measurement results with the data in the manufacturing drawing.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.3 Test feature: Position
Element: Ellipse





```
==============================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
==============================================================================


   9      ELLIP I       X      51.8922
                        Y      32.0511
                        D1     29.9883
              Y/X       A1      8.4907
                        D2     30.0023
       8P S/MIN/MAX              .0017        (4)  -.0015     (5)   .0014
```

Practical exercise :

With the **ELLIPSE** element program, the center coordinates, angle position as well as large and small diameter of the ellipse at the front of the cube are gained.

Note:
We will view the large hole at the front as a special type of ellipse. The two diameters D1 and D2 are therefore approximately the same.

To do

How to do it

What happens

Measure ellipse

[Elements]
↳ **[Geometric elements]**
↳ **[Ellipse]**

Select **Probe 2**

Move this roughly to the center of the hole.

Measure 8 points as recommended for the probing strategy.

Press the **<TERMIN>** key.

Measurement record

```
ELLIP_1
14      ELLIP I          Z     -33.067
                         X      41.861
                        D1      29.999
                        A1      15.455
                        D2      30.005
        8P S/MIN/MAX             0.001   (4) -0.000    (2) 0.001
```

Explanation

X, Z	Center point coordinates
D1	Small
D2	Large ellipse diameter
A1	Angle between small ellipse axis and reference axis

Output meas. depth

[Evaluation]
↳ **[Additions]**
↳ **[XYZ supplement]**

Measurement record

```
                         Y       2.576
```

Explanation

Y	Measurement depth

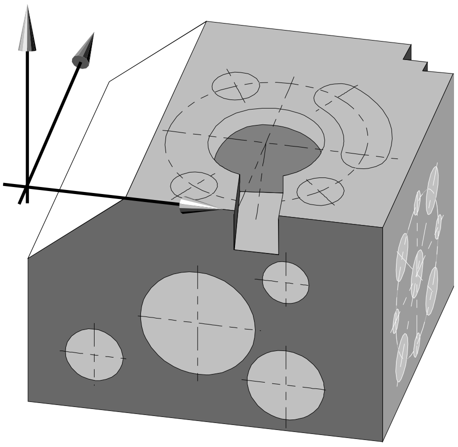
Result comparison

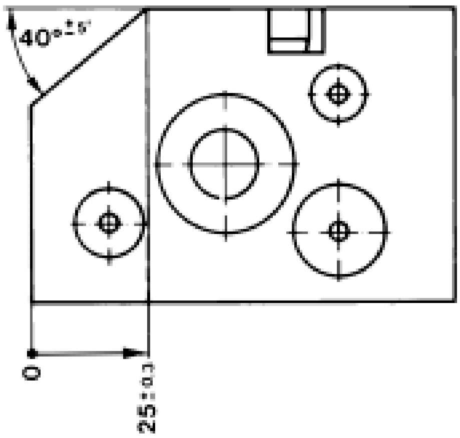
Compare the measurement results to those from practical exercise 8.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.4 Test feature: Inclination
Element: Surface





```
=================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
=================================================================================

  10      SURFACE        Z    -20.9237
              X/Z        A1   -40.1276
              Y/Z        A2     0.0174
       4P S/MIN/MAX              .0031        (3)  -.0016     (4)   .0016
```

Practical exercise :

With the **SURFACE** element program, the inclination angle and the position of flat surfaces referring to the workpiece coordinate system are determined.

To do

How to do it

What happens

Measure surface

[Elements]
↳ **[Geometric elements]**
↳ **[Surface]**

Using **Probe 1** probe the four corner points of the inclined surface.

After the measurement has finished, carry out the calculation with **<TERMIN>.**

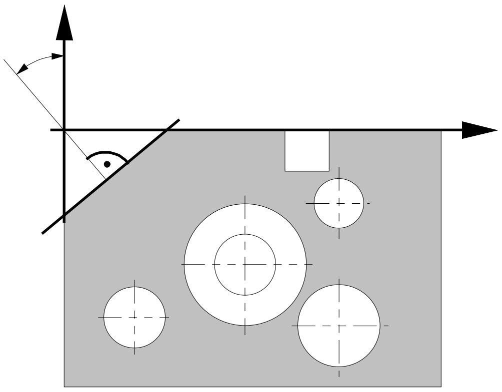
Measurement record

```
SUR_3
15     SURFACE     Z      -20.787
       X/Z         A1     -40.059
       Y/Z         A2       0.139
       4P S/MIN/MAX         0.002   (4) -0.003    (2) 0.002
```

Explanation

Z		Coordinate of the point at which the Z reference axis pierces the inclined surface
X/Z	A1	Angle between the Z reference axis and the projections of the surface normals in the X/Z or Y/Z plane
Y/Z	A2	

See figure below:



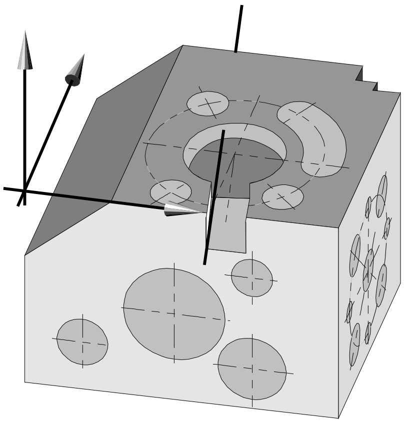
Result comparison

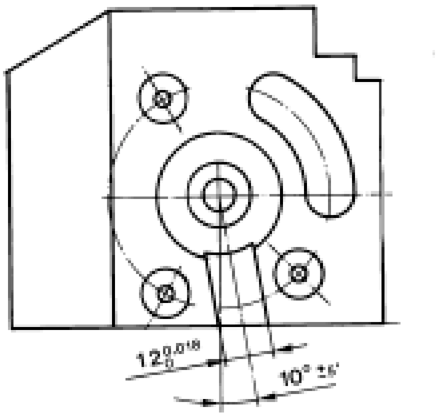
Compare the measurement results with values from the drawing.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.5 Test feature: Angle of a groove
Element: Line





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL  | U.TOL | L.TOL | DEV    | EXC
================================================================================

  11       LINE        Z     -2.0987
                       X     51.3921
             Z/Y       A1    -0.0143
             X/Y       A2    -9.9000
```

Practical exercise :

The position and angle is determined using the **LINE** element program.

Note:
The Line element can always be used if the workpiece is too thin for a surface measurement.

To do

How to do it

What happens

Measure line

[Elements]
↳ **[Geometric elements]**
↳ **[Line]**

Select **Probe 1**.

Move probe 1 into the groove and probe 3 points on the left side.

Press the **<TERMIN>** key.

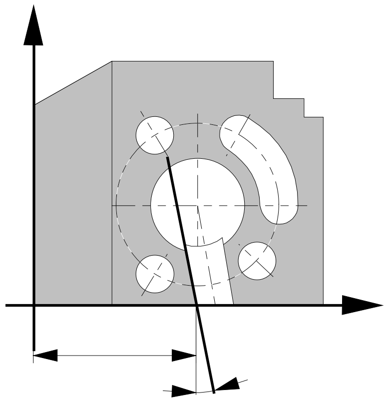
Measurement record

```
LIN_1
16     LINE          Z       -5.512
                     X       51.406
       Z/Y          A1       -0.124
       X/Y          A2       -9.936
        3P S/MIN/MAX          0.005   (1)  0.003    (2) 0.002
```

Explanation

Z X		Coordinates of the point at which the line pierces the X/Z plane.
Z/Y X/Y	A1 A2	Projected angle between the Y axis and the projections of the line in the Z/Y or X/Y plane.

See figure below:



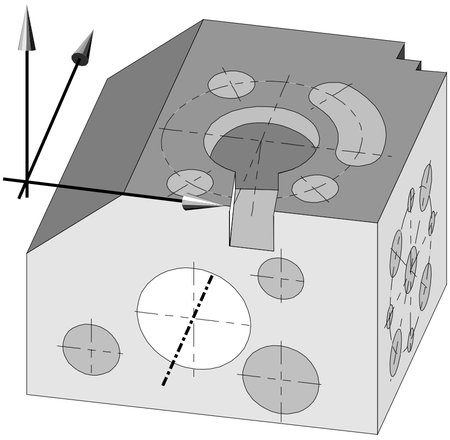
Result comparison

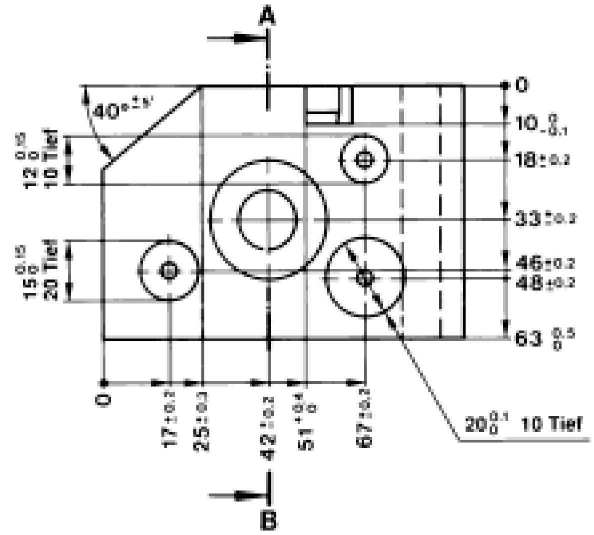
Compare measurement results with values from the drawing.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.6 **Test feature:** Direction of a cylinder axis
Element: Cylinder





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
================================================================================

  12      CYL   I       Z    -32.9681
                        X     41.8929
                        D     29.9468
            Z/Y         A1     0.0056
            X/Y         A2     0.0612
     8P S/MIN/MAX               .0033        (3)  -.0024     (6)   .0026
```

Practical exercise :

The **CYLINDER** element program will be used to measure the position deviation, the direction and the diameter of the large hole at the front of the cube.

Note:
Avoid faulty probings because of the cone. Pay attention to the standard deviation. Point correction if necessary.

To do

How to do it

What happens

Measure cylinder

[Elements]
↳ **[Geometric elements]**
↳ **[Cylinder]**

<Macro selection>
Select **<2 x 4 cylinder>**
<Measure macro>

Select **Probe 2**
Position the probe in front of the hole, press the <I POS> key
Carry out the search probings with this probe.

End the measurement with **<TERMIN>**

Measurement record

```
CYL_1
17      CYLINDER I  Z     -33.064
                    X      41.856
                    D      30.003
        Z/Y        A1      -0.102
        X/Y        A2       0.068
        8P S/MIN/MAX        0.001   (1) -0.001    (2) 0.001
```

Explanation

Z X		Coordinate of the point at which the cylinder axis pierces the X/Z plane.
D		Diameter
Z/Y X/Y	A1 A2	Projected angle between the Y axis and the projections of the cylinder axis in the Z/Y or X/Y plane

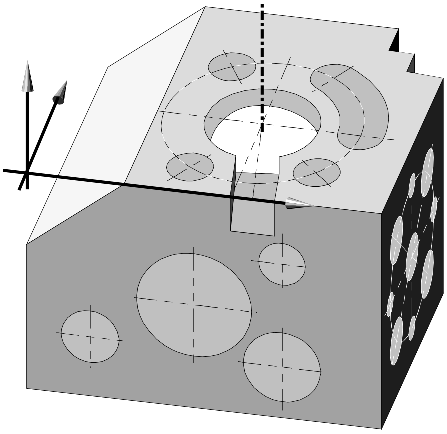
Result comparison

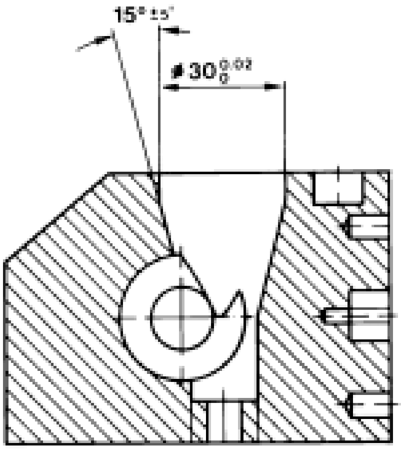
Compare the measurement results with values from the manufacturing drawing and with exercise numbers 8 and 9.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.7 **Test feature:** Cone angle
Element: Cone





```
===============================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
===============================================================================

  13       CONE I       X     51.8965
                        Y     32.0525
                        D     33.7636
             X/Z        A1     0.0471
             Y/Z        A2     0.0275
                        AC   -29.9455
     11P S/MIN/MAX              .0071        (1)  -.0065     (7)   .0072
```

Practical exercise :

With the **CONE** program, the center coordinates, size, cone angle as well as the direction of the cone axis are determined.

Note:
Pay attention to the probing strategy and do not make any wrong probings.

To do

How to do it

What happens

Measure cone

[Elements]
↳ **[Geometric elements]**
↳ **[Cone]**

Select **Probe 1**

Move probe 1 to the cone. As with the recommended probing strategy, probe 3 x 4 points on 3 circle sections.

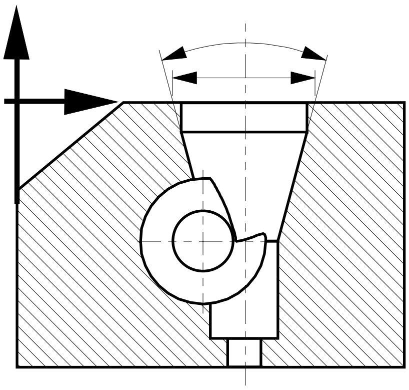
Press the **<TERMIN>** key.

Measurement record

```
CONE_1
18     CONE  I       X      51.837
                     Y      32.053
                     D      33.755
       X/Z          A1       0.009
       Y/Z          A2       0.066
                    AC     -29.914
       12P S/MIN/MAX                  0.002        (1) -0.003
       (2) 0.002
```

Explanation

X, Y		Coordinates of the point at which the -cone axis pierces the Y/X plane.
D		Diameter of the cone at this point
X/Z	A1	Projected angle between the Z axis and the projections of the cone axis in
Y/Z	A2	the X/Z or Y/Z plane.
AC		Cone angle



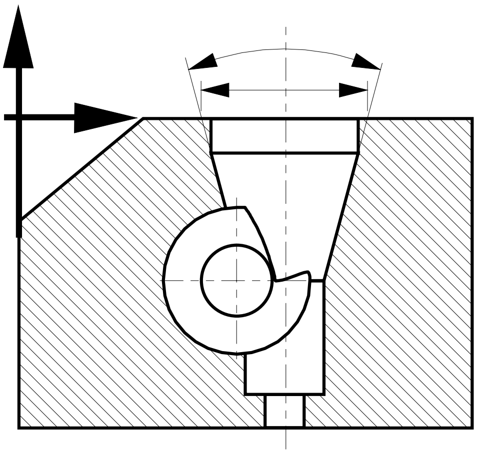
Result comparison

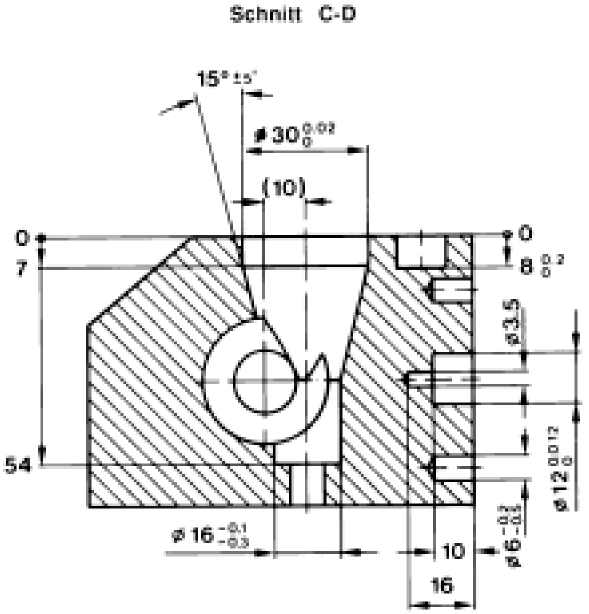
Compare the measurement results with the values from the manufacturing drawing.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.8 **Test feature:** Diameter
Element: Cone





```
================================================================================
ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
================================================================================

          INTERS. HEIGHT  H   -7.0000
  14      CON DIA       D     30.0194


          DIAMETER      D     30.0000
  15      CON CO        X     51.8907
                        Y     32.0492
                        Z     -7.0363
```

Practical exercise:

With the **ADD CON** calculation program, either the cone diameter at a specific height can be defined or the height at a given diameter.

To do

How to do it

What happens

Calculate diameter

[Evaluation]
↳ **[Additions]**
↳ **[Add.cone prog.]**

Calculate diameter ?
<YES>

Confirm page for element name
<TERMIN>

Height= -7 <RETURN>
O.K. ? <YES>

Measurement record

```
ADDCON_1 (CONE_1)
INTERS.HEIGHT      H       -7.000
19       CONDIA.   D       30.011
```

Explanation

H	Height at which the diameter is to be calculated.
D	Calculated diameter

Calculate height

[Evaluation]
↳ **[Additions]**
↳ **[Add.cone prog.]**

Calculate diameter ?
<NO>

Confirm page for element name
<TERMIN>

DIAMETER = 30
<RETURN>
O.K. ? <YES>

Measurement record

```
ADDCON _2 (CONE_1)
DIAMETER           D       30.000
20       CON CO.   X       51.834
                   Y       32.045
                   Z       -7.000
```

Explanation

D	Input diameter.
X, Y, Z	Coordinates calculated for which this diameter occurs. The Z value is the height looked for.

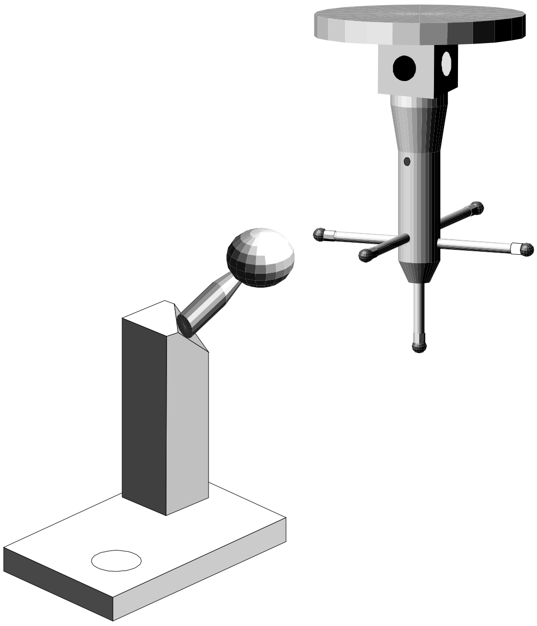
Result comparison

Compare measurement results with the values from the manufacturing drawing.

This is the end of the practical exercise.

Worksheet 3: Measured elements

3.9 **Test feature:** Diameter
Element: Sphere



```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL   | NOMINAL   | U.TOL | L.TOL | DEV    | EXC
================================================================================

  16      SPHERE A      X     51.0803
                        Y    232.7574
                        Z     90.3622
                        D     30.0002
       6P S/MIN/MAX             .0006        (6)  -.0005     (5)   .0005
```

Practical exercise:

With the **SPHERE** element program, the center point coordinates and the diameter of the calibration sphere are determined.

Note:
By repeating the measurement with all the other probes, the accuracy of the calibration can be tested here.

To do

How to do it

What happens

Measure sphere

[Elements]
↳ **[Geometric elements]**
↳ **[Sphere]**

<Macro selection>
Select **<Standard Sphere>**
<Measure macro>

Select **Probe 1**

With this probe carry out the search probings at the "POLE".

End the measurement with **<TERMIN>**

Measurement record

```
SPHERE_1
21     SPHERE A    X     154.091
                   Y     230.514
                   Z      89.620
                   D      30.000
       6P S/MIN/MAX        0.000   (5) -0.000    (4) 0.000
```

Explanation

Z, Y, Z	Sphere center point coordinates
D	Sphere diameter
S/MIN/MAX	Standard deviation, minimum and maximum value

Position zero point in the center of the sphere

[Coordinates]
↳ **[zero point]**
↳ **[define]**

Measurement record

```
NPNT_4
22       ZEROP X        154.091
               Y        230.514
               Z        89.620
```

Explanation

Z, Y, Z	Coordinates around which the zero point is moved.

Check probe values

Carry out the sphere measurement with each probe.

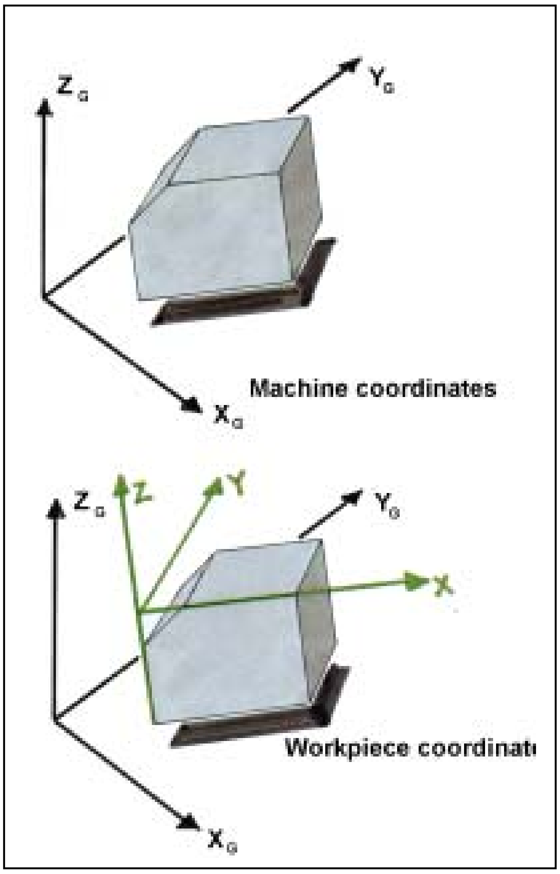
Measurement record

Zero and the same sphere diameter (within the measuring uncertainty) should result for the X, Y and Z coordinates for the individual addresses.

This is the end of the practical exercise.

4. Alignment and recalls

4.1 Alignment



Why alignment ?

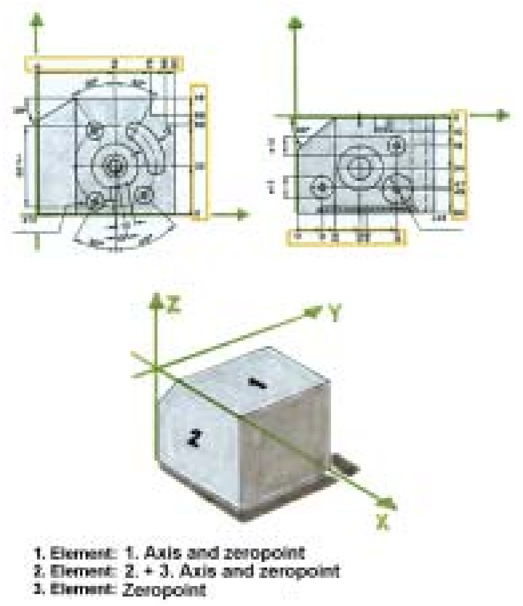
The workpiece is only aligned "by eye" on the CMM table.
If no alignment has been made, i.e. after switching on or after entering a new record header, all measurement results refer to the machine coordinate system.
These measurement results therefore cannot be compared directly with the dimensions given in the manufacturing drawing as the dimensions in the drawing refer to surfaces, axes, circles etc. of the workpiece. Or the dimensions refer to a workpiece coordinate system (especially for parts which were produced on CNC machine tools).

Mathematical alignment
Due to the clamping, the workpiece surfaces do not lie straight in the CMM coordinate system.
To remedy this, either the workpiece has to be aligned to the machine coordinate system or a coordinate system has to be generated which refers to the workpiece. This is what happens with the mathematical alignment: a coordinate system is generated for the workpiece with its own elements – this is called the workpiece coordinate system.
And what is important to know: the mathematical alignment is quicker and more exact than the mechanical alignment.

Selecting the geometric elements to be used for the alignment

You can recognize the elements which define the coordinate axes from the manufacturing drawing. However you have to look closely as these elements result only from the function the workpiece has. These could be for example cylinder axes for a drive, or graduated circles for a flange, or as here surfaces vertical to one another.

For our example we will choose two workpieces surfaces which are vertical to one another, 1 and 2.



Procedure for the alignment

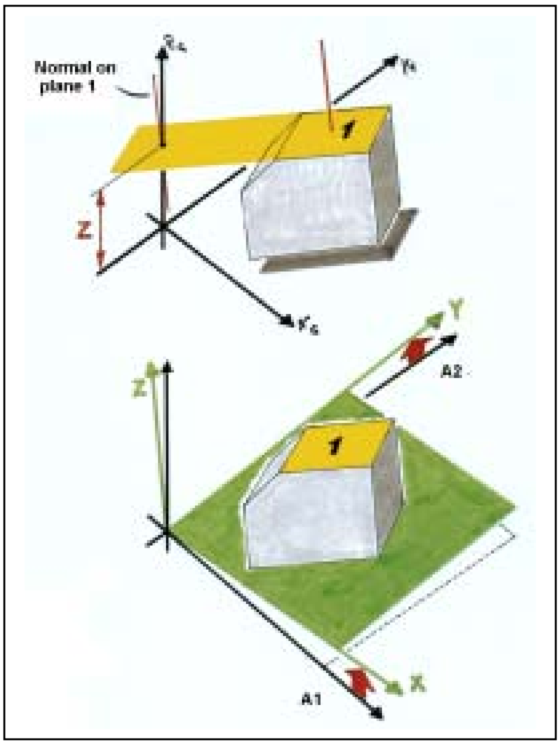
What do we need to generate a workpiece coordinate system?
Answer: 3 axes and a spatially defined zero point.
The basic procedure for alignment is as follows:

Probe first element	1st axis of the workpiece = 3D axis
Probe second element	2nd and 3rd axis of the workpiece
Probe more elements	zero point position

If you start from the coordinate planes, the first axis results in the first coordinate plane. This is known as the main or primary reference. The second axis results in the second coordinate plane, the auxiliary or secondary reference. The zero point in the third axis is the tertiary reference.

Probing surface 1 and meaning of the data in the measurement record

After calling up the surface element and probing surface 1 (you must probe more than 3 points as this surface is the reference for all other measurements), the following is output in the measurement record:

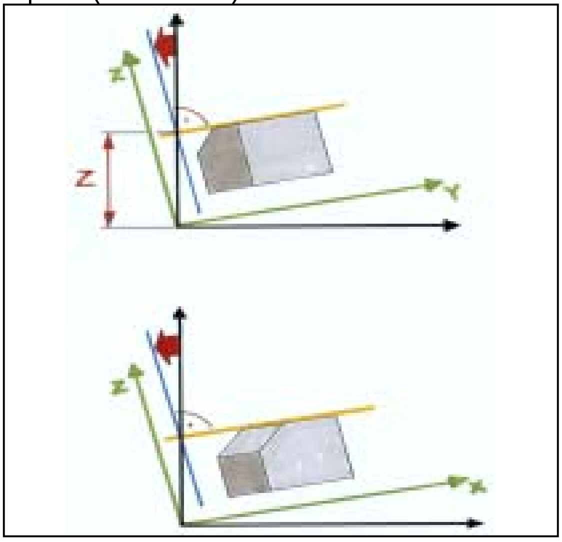


Z	Coordinate of the piercing point of the Z reference axis through plane 1
X/Z A1 or Y/Z A2	Angle between the Z reference axis and the projections of the normal in the X/Z or Y/Z plane.

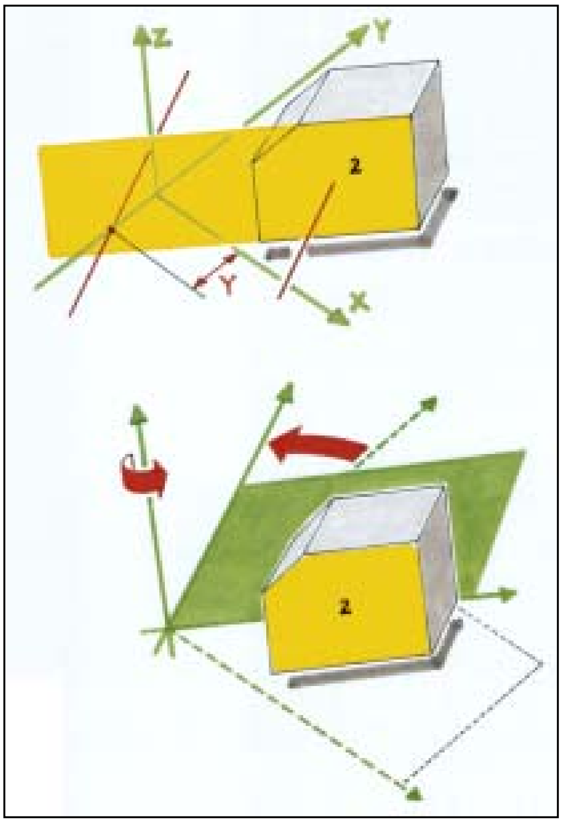
3D Transformation (3D Rotation)

After probing surface 1 we call up the Rotate Space (3D rotation) function. The 3D axis of the new workpiece coordinate system is given the direction of the normal on surface 1 or in other words:

The computer tilts the workpiece coordinate system around the A1 and A2 projection angles. In our case, the Z axis is the 3D axis of the workpiece coordinate system. The first step for the alignment has been made.



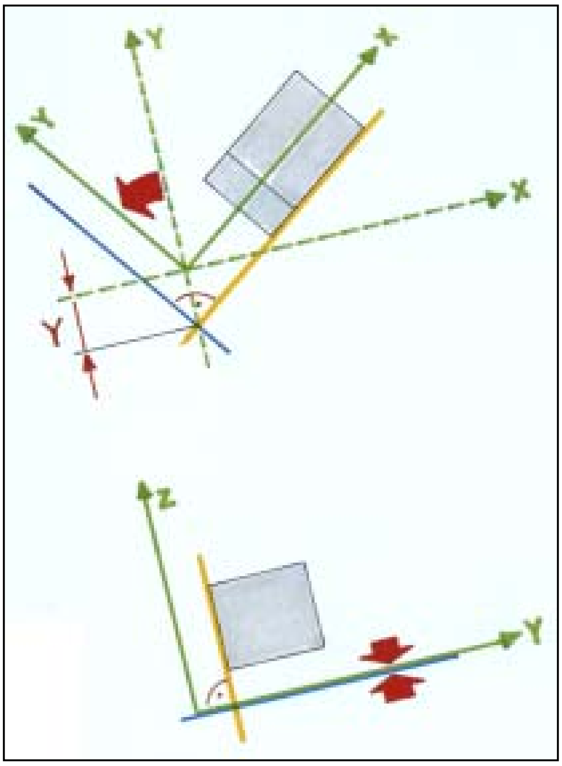
Probing surface 2 and meaning of the data in the measurement record



After calling up the surface element and probing surface 2 (you must probe more than 3 points as this surface is reference for all other measurements) the following is output in the measurement record:

Y	Coordinate of the piercing point of the reference axis of the new coordinate system (here the Y axis)
X/Y A1 or Z/Y A2	Angle between the new reference axis Y and the projections of the normal in the X/Y or Z/Y plane

2D Transformation (Rotate plane)

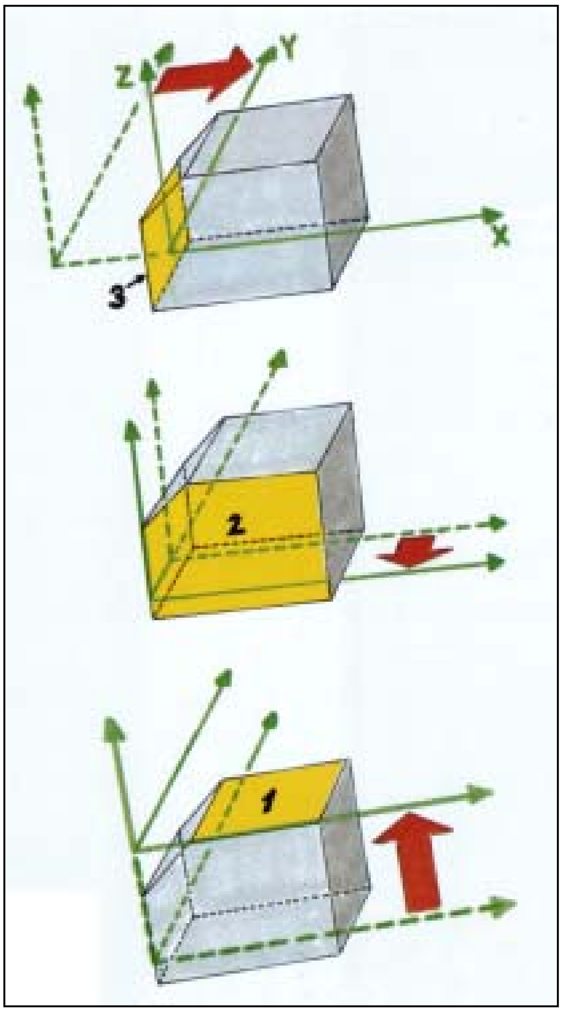


The computer now has to know how the workpiece is rotated around the 3D axis of the new coordinate system.
After probing surface 2, we call up the Transformation Plane program.

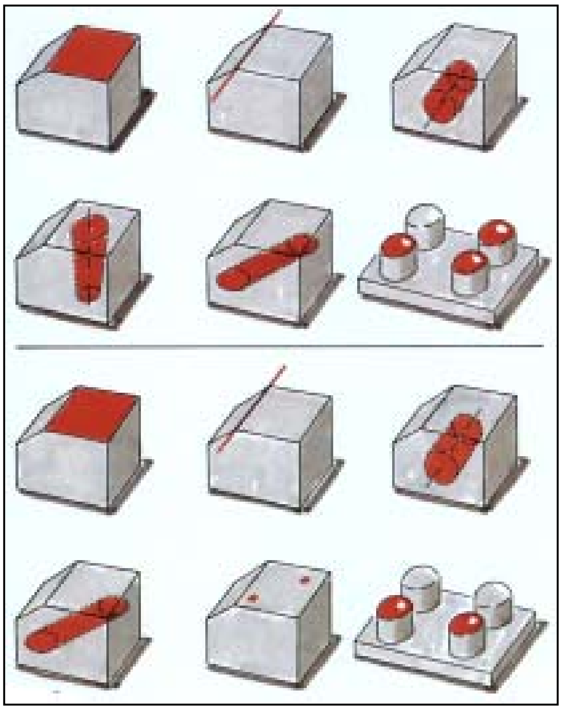
The Y axis of the new coordinate system is given the direction of the normal on surface 2. Or in other words: The coordinate plane X/Y is rotated until the Y axis lies parallel to the projections (shadow) of the normals. For 3D elements, only that angle is used which lies parallel to the 3D axis in the coordinate plane. The X axis or the workpiece coordinate system is then also automatically defined because it has to be vertical to the Y and Z axis.
Now the second step for the alignment is finished.

Sensible position for the zero point

The position of the zero point has not yet changed. It is still in the machine zero point. We select the zero point of the workpiece coordinate system so that as many measured values as possible can be compared directly with the dimensions in the manufacturing drawing.
As we have seen, most dimensions in our example originate from the upper left front corner. That is why we will set the zero point there.
To set the zero point, we could probe a point in each of the coordinate planes in which the zero point is to lie. However it is easier if we use the elements we used for the 3D alignment for setting the zero point as well. We then only have to measure another element for defining the third zero point coordinate.



Geometric elements for the alignment



Of course we could also use other reference elements for the 3D rotation and 2D rotation than the surfaces shown. Then you have to be aware that

- 3D rotation needs reference elements which are defined with <u>two</u> projection angles. 2D rotation only needs <u>one</u> projection angle.
- that 3D rotation is always carried out <u>before</u> the 2D rotation.

<u>Possible elements for 3D rotation</u>

SURFACE

Linking LINE

CYLINDER

CONE

ELLIPSE/ELLIPSE

SPHERE/SPHERE

<u>Possible elements for 2D rotation</u>

SURFACE

CYLINDER

Linking LINE

ELLIPSE/ELLIPSE

CIRCLE/CIRCLE

SPHERE/SPHERE

POINT/POINT

General procedure for the mathematical alignment and setting of the zero point

When we are probing elements for Rotate Space (3D rotation) and Rotate Plane (2D rotation) which are to lie in one coordinate system, we can set the zero point at the same time. We will discuss this in more detail in the following exercises. A general procedure results for the alignment.

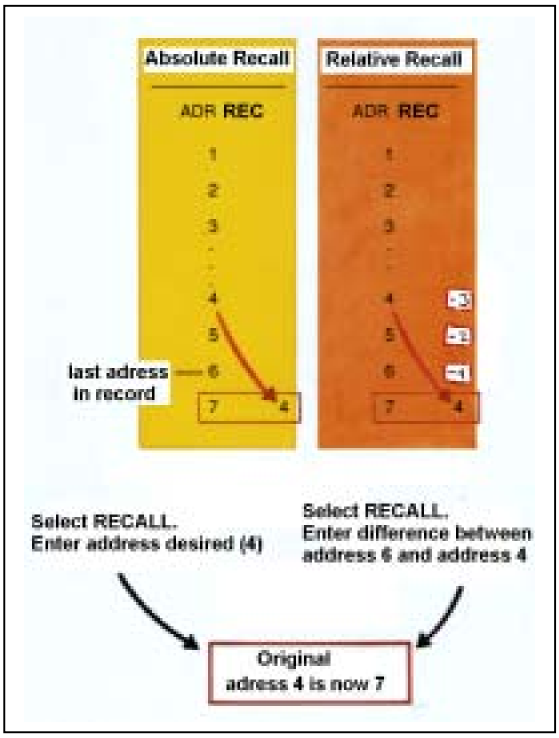
- If necessary, set the initial status
- Select (at least 2) metrologically suitable elements
- Probe element 1 (e.g. surface 1)
- Call up Rotate Space
- Set the zero point
- Probe element 2 (e.g. surface 2, which is vertical to surface 1)
- Call up Rotate Plane
- Set zero point
- Probe element 3 (e.g. surface 3, which is vertical to surface 1 and 2)
- Set zero point

4.2 Recalls

Absolute and relative recall

Each printed geometric element gained by probing or linkings is given an address. The computer saves the element under this address.
The element can be reprinted and used again if it is recalled. This is important, for example, in order to link an element at a previous position in the protocol with a later element (as we shall see in the exercises).
There are two ways of making a recall:

- Absolute recall, by specifying the address of the element desired or
- Relative recall, by specifying the difference between the address just printed and the desired address.



Recall of a coordinate system to change the alignment

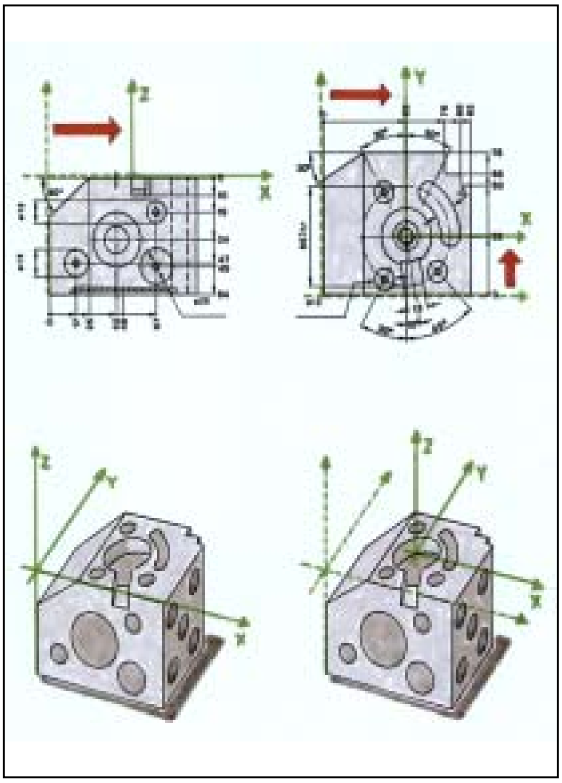
In most cases, the dimensions given in manufacturing drawings refer to different elements. E.g. most of the dimensions of our workpiece refer to surfaces 1, 2 and 3, however there are also elements whose dimensions refer to the large hole.

To gain suitable measurement results from these elements, we recommend the position of the workpiece coordinate system be changed and that you change the alignment.

If now the first coordinate system is to be generated, this can be recalled.

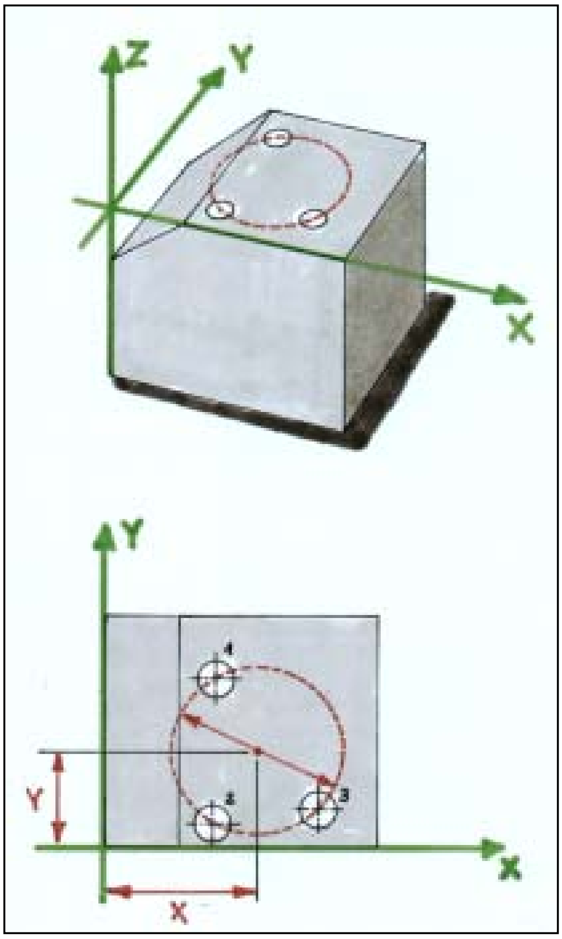
This happens by recalling the <u>last</u> operation of the alignment (usually the last zero point).

If the last zero point was address 20, then all measurement results now refer to the workpiece coordinate system as for address 20.



Recalling several elements for generating a new element

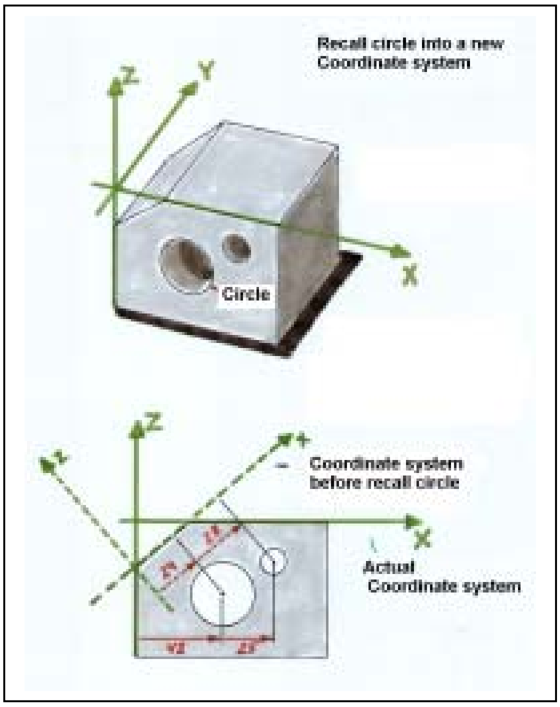
Several elements lying in a common coordinate system can be linked to a new element by using the recall.
Example: Circles 1, 2 and 3 have been measured. Now the graduated circle on which they lie can be defined using the recall.



Recalling an element after alignment

This recall is always necessary if elements which have been used for the mathematical alignment are also to supply measurement results in the current coordinate system.
Example: Circles 1 and 2 were used for the alignment for Rotate Plane. These circles must be brought to the current coordinate system by recall.

Now the coordinate values no longer refer to the original coordinate system but to the current one.



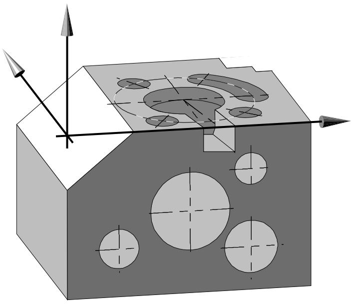
Worksheet 4: Alignment

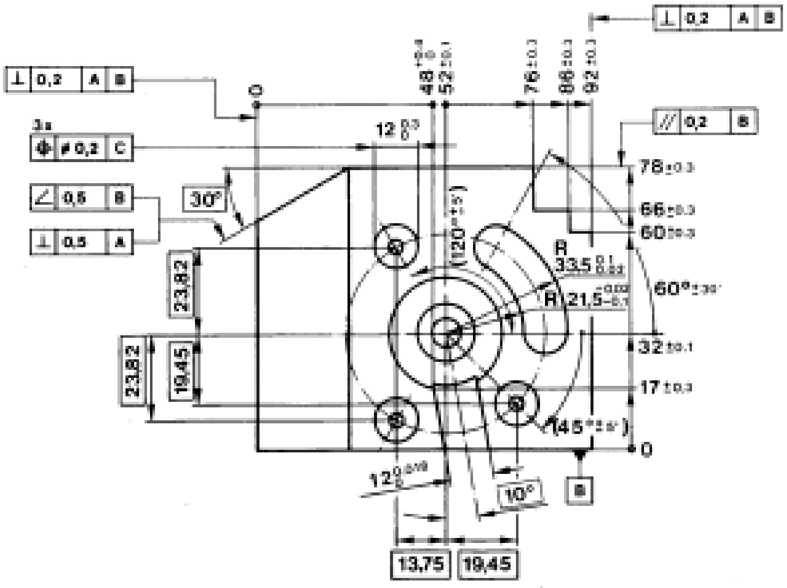
4.2.1 Alignment with three surfaces

⊥

Test feature: DIN Rectangularity

Elements: Surface 1, Surface 2, Surface 3





The workpiece coordinate system is placed in the top left front corner.
The alignment is made over three surfaces.
The sequence for the alignment is 1 - 2 – 3.

DIN Rectangularity must be defined for surfaces 2 and 3.

```
14      DIN-REC t                 0.0656            0.2000            ++
                       L1                   60.0000
                       L2                   40.0000
```

Practical exercise:

The workpiece coordinate system is placed in the top left front corner.

The alignment is made over three surfaces.

The sequence of the alignment is 1 - 2 - 3.

To do	How to do it	What happens
Bring the machine to its initial status	Call up **[Coordinates]** ↳ **[Preparation]** ↳ **[Initial status]**	The machine coordinate system is active, i.e. all old workpiece coordinate systems are deleted. The address counter is set to 1. **Note:** Before starting to measure a new workpiece, the new initial status should be set.
Define the main plane of the workpiece	Call up **[Elements]** ↳ **[Geometric elements]** ↳ **[Surface]**. Select **Probe 1** With **Probe 1**, probe four points on the surface. Carry out calculation with **<TERMIN>**.	**Measurement record** SUR_1 1 SURFACE Z -454.321 X/Z A1 -0.094 Y/Z A2 0.047 4P S/MIN/MAX 0.048 (4) -0.027 (2) 0.029 **Explanation** Z — Coordinate of the points at which the reference axis (machine axis Z) pierces surface 1. X/Z A1 — Angle between the reference axis Z and the projections Y/Z A2 — of the surface normals into the X/Z or Y/Z plane.
Define the first axis of the workpiece coordinate system	Call up **[Coordinates]** ↳ **[Space axis]** ↳ **[define]**	**Measurement record** RTSPAC_1 2 RT SPAC A -0.1048 **Explanation** A — 3D angle between the machine axis in this case Z and the surface normals of surface 1. The workpiece coordinate system is tilted around this angle so that the new Z axis, at the same time 3D axis, is parallel to the normals of surface 1.

To do

How to do it

What happens

Place zero position in surface 1

Call up
[Coordinates]
↳ **[Zero point]**
↳ **[define]**.

Measurement record

```
ZPNT_1
3      ZEROP       Z   -454.321
```

Explanation

Z	Value about which the coordinate system is moved. The coordinate defined last is set to zero. The workpiece coordinate system is moved down to surface 1.

The Z axis of the workpiece coordinate system and the Y/X coordinate plane (parallel to surface 1) is now defined. The coordinate system still has to be rotated (about the space axis) and moved (in X and Y).

Define secondary plane of the workpiece

Call up
[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**.

Select **Probe 2**

Using **probe 2**, probe four points on surface 2.

Carry out calculation with **<TERMIN>**.

Measurement record

```
SUR_2
4      SURFACE   Y   -391.929
       Z/Y          A1       0.078
       X/Y          A2       1.234
       4P S/MIN/MAX        0.002   (4) -0.001   (2) 0.002
```

Explanation

Y		Coordinate of the point at which the reference axis Y pierces surface 2
Z/Y	A1	Angle between the reference axis Y and the
X/Y	A2	projections of the surface normals into the Z/Y or X/Y plane.

Define the second and third axis of the workpiece coordinate system

Call up
[Coordinates>]
↳ **[2D Transformation]**
↳ **[Rotate Plane]**

Measurement record

```
RTPLAN_1
5      ROT PLANEA        1.234   ABOUT SPACE AX Z
```

Explanation

A	Plane angle between the new coordinate axis, in this case Y and the projection of the surface normals of surface 2 into the X/Y coordinate plane. The workpiece coordinate system is rotated about the Z axis until the Y axis is parallel to the projection of the surface normals of surface 2.

All axis directions of the workpiece coordinate system have now been defined, as the X axis has to lie vertical to the Y axis. The workpiece coordinate system lies in surface 1 and is partly parallel to surface 2. It now only has to be moved in X and Y into the corresponding surfaces.

Continued overleaf.

To do

How to do it

What happens

Place zero position in surface 2

Call up
[Coordinates]
↳ **[Zero point]**
↳ **[define]**.

Measurement record

```
NPNT_2
6       ZEROP       Y   -391.938
```

Explanation

Y	Value around which the coordinate system is moved. The coordinate defined last is set to zero. The workpiece coordinate system is moved forwards to surface 2.

Define the position of the third zero point

Call up
[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**.

Select **Probe 3**

Using **Probe 3**, probe four points on surface 3.

Carry out calculation with **<TERMIN>**.

Measurement record

```
SUR_3
7       SURFACE   X    389.485
        Y/X          A1     -0.014
        Z/X          A2     -0.106
        4P S/MIN/MAX               0.001         (4) -0.001
        (2) 0.000
```

Explanation

X		Coordinate of the point at which the Reference axis X pierces surface 3.
Y/X	A1	Angle between the reference axis X and the projections of the surface
Z/X	A2	normals in the Y/X or Z/X plane.

Place the zero position in surface 3

Call up
[Coordinates]
↳ **[Zero point]**
↳ **[define]**.

Measurement record

```
NPNT_3
8       ZEROP       X    389.485
```

Explanation

X	Value around which the coordinate system is moved. The coordinate defined last is set to zero The workpiece coordinate system is moved to the right up to surface 3.

The workpiece coordinate system has now been defined completely:

- the Z axis is vertical to surface 1, the Y/X plane is parallel to this,
- the Z zero point lies in surface 1.
- The Y axis is vertical in the X direction to surface 2, the X/Z plane is parallel in this direction,
- the Y zero point lies in surface 2.
- The X axis is now vertical to the Z or Y axis,
- The zero point lies in surface 3.

This is the end of the practical exercise.

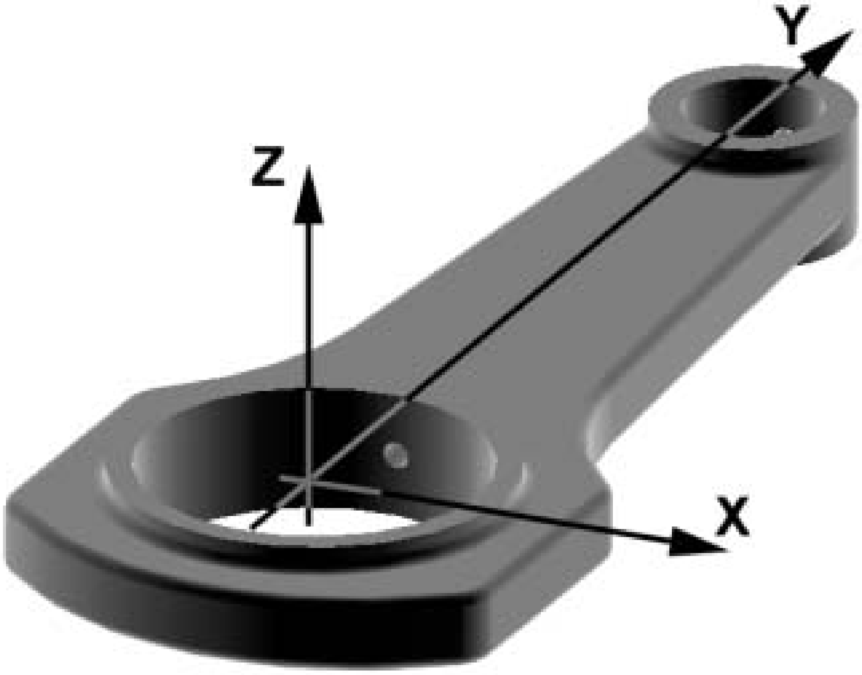
Worksheet 4: Alignment

//

4.2.2 Aligning a connecting rod

Test feature: DIN Parallelism

Elements: Cylinder, circle, surface



The alignment is made using the large hole, the small hole and the contact surface.
The zero point lies in the large hole.
The DIN parallelism is to be determined for the two cylinder axes.

```
================================================================================
 ADR|REC | TASK | IDF |SY| ACTUAL   |NOMINAL   | U.TOL | L.TOL | DEV   | EXC
================================================================================

13      DIN-PAR       tx      0.0000     0.0500                          +-
                      tz      0.0031     0.5000                          +
                      L      10.0000
```

The workpiece coordinate system is placed in the center of the bore with 55 mm diameter and the surface.

Note:
The primary reference is placed above the bore with 55 mm diameter, the secondary reference above an axis which goes through the holes with the 55 mm diameter and 22 mm diameter. The holes must be measured as cylinder for the later parallelism evaluation.

To do / How to do it / What happens

Bring the machine to its initial status

[Coordinates]
↳ **[Preparation]**
↳ **[Initial status]**

The machine coordinate system is active.

Measure a cylinder

[Elements]
↳ **[Geometry elements]**
↳ **[Cylinder]**

With Probe 1 measure the cylinder (macro or probe).

Measurement record

```
CYL_1
1       CYL I           Z   -501.255
                        X    457.317
                        D     22.012
        Y/Z           A1       0.003
        X/Y           A2       1.225
        8P S/MIN/MAX                   0.005        (1) -0.003
        (2) 0.002
```

First coordinate axis (space axis)

[Coordinates]
↳ **[space axis]**
↳ **[define]**

Measurement record

```
RTSPAC_1
2       RT SPACE  A      1.2247
```

Place the zero position in the cylinder axis

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

Measurement record

```
NPNT_1
3       ZEROP           Z   -501.255
                        X    427.213
```

Define the position of the third zero point

[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**

Using **Probe 2**, probe surface 2 with four points.

Measurement record

```
SUR_1
4       SURFACE   Y   -392.267
        Z/Y           A1       0.038
        X/Y           A2       0.001
        4P S/MIN/MAX           0.002   (4) -0.001   (2) 0.001
```

Continued overleaf.

To do — How to do it — What happens

Place the zero position in surface 2.

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

```
Measurement record
NPNT_2
5       ZEROP       Y   -392.267
```

Measure bore with 22 mm diameter

[Elements]
↳ **[Geometry elements]**
↳ **[Cylinder]**

Measure cylinder with probe 2 (macro or probe)

```
Measurement record
CYL_2
6       CYL I           Z     30.013
                        X     -0.004
                        D     12.009
        Y/Z            A1     -0.003
        X/Y            A2      0.041
        8P S/MIN/MAX                    0.003         (1) -0.003
        (2) 0.002
```

Generate secondary plane

[Coordinates]
↳ **[2D transformation]**
↳ **[Zero pnt & 1 Element]**

```
Measurement record
RTNPNT_1
7       RT. (OP+1)  A     -0.0077   ABOUT SPACE AXIS
Y
```

Explanation:

A — Angle around which the coordinate system is rotated around the space axis Y.

The temporary coordinate axis Z is rotated about the zero point of the hole with 30 mm diameter until it runs through the center of the hole with 12 mm diameter.

.

Evaluation of parallelism

[Evaluation]
↳ **[Position]**
↳ **[Parallelism]**
[AX/AX]

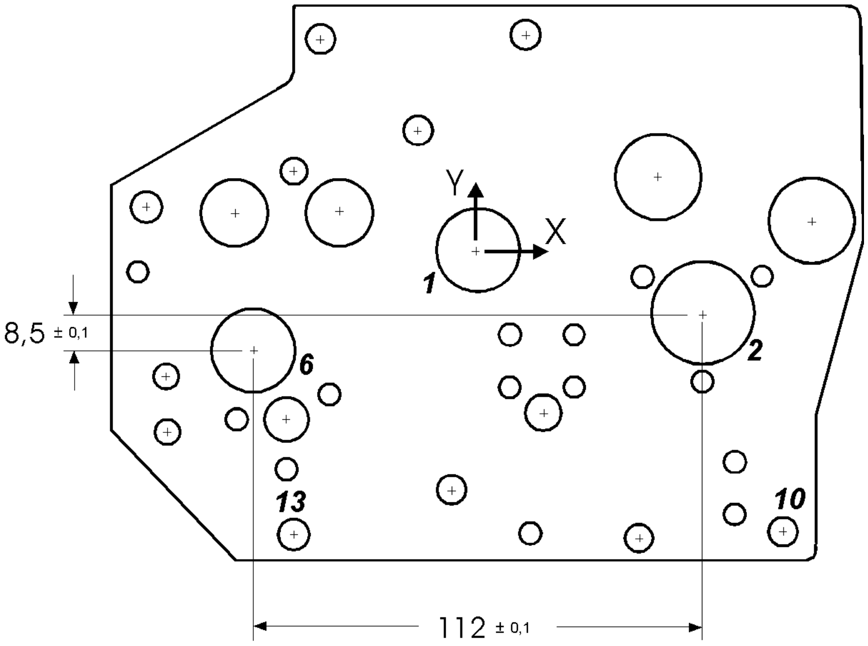
```
Measurement record
13    DIN-PAR       tx    0.0000  0.0500
                    tz    0.0031  0.5000
                    L     10.0000
```

Worksheet 4: Alignment

4.2.3 Aligning a hole plate

Test feature: Distance between two circles

Elements: Surface, circles



Aligning the hole plate :

Zero point in bore 1.
3D alignment with surface.
2D rotation above holes
10 and 13.

The distance between holes
2 and 6 is to be checked.

```
================================================================================
 ADR|REC | TASK | IDF |SY| ACTUAL   |NOMINAL   | U.TOL | L.TOL | DEV    | EXC
================================================================================

  29   6! CIRCLE I      X    -56.1116
                        Y    -24.0592
                        D     20.0176
                        S       .0091      FORM    .0101

  30   2! CIRCLE I      X     55.9158
                        Y    -15.5462
                        D     47.0335
                        S       .0258      FORM    .0272



  31   29 DIST 30       X    112.0273   112.0000  0.1000 -0.1000  0.0273   ++
                        Y      8.5130     8.5000  0.1000 -0.1000  0.0130   +
```

Practical exercise:

The workpiece system is placed in hole 1.
The Y axis is to run through holes no. 10 and 13 of the hole plate.

The primary plane is defined by the surface, the secondary plane by the two holes 10 and 13, the zero point by hole 1 and top surface.

To do / How to do it / What happens

Bring machine to initial status

[Coordinates]
↳ **[Preparation]**
↳ **[Initial status]**

The machine coordinate system is active.

Define main plane of the workpiece

[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**

With **Probe 1**, measure four points on surface 1.

Measurement record

```
SUR_1
1       SURFACE   Z   -453.276
        X/Z      A1      0.005
        Y/Z      A2     -0.001
        4P S/MIN/MAX     0.000   (4) -0.000   (2) 0.000
```

Define space axis

[Coordinates]
↳ **[Space axis]**
↳ **[define]**

Measurement record

```
RTSPAC_1
2       RT SPACE  S     0.0075
```

Place zero position in surface 1

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

Measurement record

```
NPNT_1
3       ZEROP       Z  --453.276
```

Measure hole 1

[Elements]
↳ **[Geometry elements]**
↳ **[Circle]**

Using **Probe 1**, measure the circle with four points.

Measurement record

```
CIRCLE_1
4       CIRCLE I    X    434.450
                    Y   -369.655
                    D     29.652
        4P S/MIN/MAX     0.004   (4) -0.003   (2) 0.002
```

Place zero position in the hole

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

Measurement record

```
NPNT_1
5       ZEROP       X    434.450
                    Y   -369.655
```

Explanation
The workpiece coordinate system lies in the hole with 30 mm diameter.

Continued overleaf.

To do

How to do it

What happens

Measure the first hole (10)

[Elements]
↳ **[Geometry elements]**
↳ **[Circle]**

With **Probe 1**, measure the circle with four points.

```
Measurement record
CIRCLE_2
6       CIRCLE I    X   -56.1116
                    Y   -54.0592
                    D      6.629
        4P S/MIN/MAX       0.001   (4) -0.001   (2) 0.000
```

Measure the second hole (13)

[Elements]
↳ **[Geometry elements]**
↳ **[Circle]**

With **Probe 1**, measure the circle with four points.

```
Measurement record
CIRCLE_3
7       CIRCLE I    X    55.9158
                    Y   -15.5462
                    D      6.604
        4P S/MIN/MAX       0.001   (4) -0.001   (2) 0.001
```

Define the second and third axis of the workpiece coordinate system

Call up
[Coordinates]
↳ **[2D Transformation]**
↳ **[Rotate Plane]**

```
Measurement record
RTPLAN_1
8       RT PLANE   A      1.2538   ABOUT SPACE AXIS
Z
```

Explanation

A — A line is placed through the centers of the two holes. The coordinate system is then rotated about the space axis Z until the X axis is parallel to this line. The rotation is made around the zero point which is defined by the hole and the surface.

Evaluation of the distance recall of the holes

[Elements]
↳ **[Recall]**
Adr. ...

[Elements]
↳ **[Recall]**
Adr. ...

[Eval]
↳ **[Distance]**
↳ **[Cartesian]**

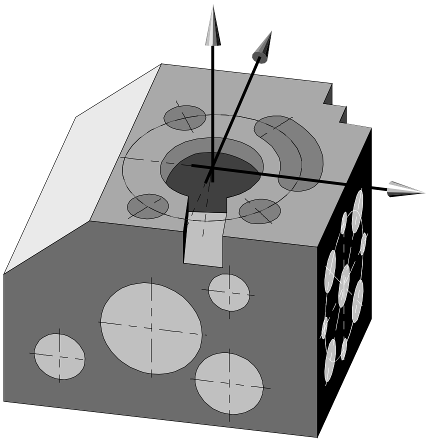
```
Measurement record

31   29 DIST 30      X    112.0273
                     Y      8.5130
```

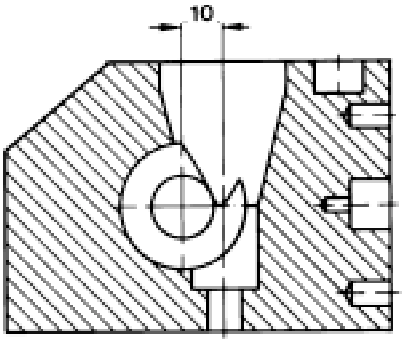
This is the end of the practical exercise.

Worksheet 4: Alignment

4.2.4 Aligning a gearbox case

Test feature: Perpendicular-distance
Elements: Cone, cylinder





The workpiece coordinate system is placed in the center of the cone hole, parallel to the axis of the cylinder in the front surface and in the top surface.

The primary reference is defined using the cone axis, the secondary reference using the axis of the front cylinder, the zero position using cone and surface.

The Perpendicular-distance test feature is then to be evaluated between cone and cylinder.

```
================================================================================
 ADR|REC | TASK | IDF |SY| ACTUAL  |NOMINAL  | U.TOL | L.TOL | DEV   | EXC
================================================================================

  13      PERP CYL      Y     -0.0000
                        Z    -33.1226
                        D     10.0248
            Y/X         A1    -0.0000
            Z/X         A2     0.0000
```

Practical exercise:

The workpiece coordinate system is placed in the center of the cone hole, parallel to the axis of the cylinder in the front surface and in the top surface.

Note:
The primary reference is defined using the cone axis, the secondary reference using the axis of the front cylinder, the zero position using cone and surface.
The sequence is then cone – cylinder – surface 1.

To do | How to do it | What happens

Bring machine to initial status

Call up
[Coordinates]
↳ **[Preparation]**
↳ **[Initial status]**

The machine coordinate system is active.

Measure cone

[Elements]
↳ **[Geometry elements]**
↳ **[Cone]**

Select **Probe 1**.
Probe points as per probing strategy

Press the **<TERMIN>** key.

Measurement record

```
CONE_1
1       CONE  I     X    434.493
                    Y   -369.467
                    D    275.983
        X/Z        A1      0.010
        Y/Z        A2      0.018
                   AC    -29.923
12P S/MIN/MAX       S      0.005   (1) -0.003   (2) 0.002
```

Define the first axis of the workpiece coordinate system

Call up
[Coordinates]
↳ **[Space axis]**
↳ **[define]**

Measurement record

```
RTSPAC_1
2       RT SPACE  A     -0.0205
```

Explanation

A — The workpiece coordinate system is tilted around this angle so that the new Z axis (space axis) is parallel with the cone axis.

Place zero position in the cone axis

Call up
[Coordinates]
↳ **[Zero point]**
↳ **[define]**.

Measurement record

```
NPNT_1
3       ZEROP       X    434.493
                    Y   -369.467
```

Explanation

X, Y — Values around which the coordinate system is moved.
The workpiece coordinate system lies in the cone axis.

The space axis Z of the workpiece coordinate system now lies in the cone axis (the Y/X coordinate plane vertical). The coordinate system now only has to be rotated (about the space axis) and moved (in X and Y).

Continued overleaf.

To do

How to do it

What happens

Measure cylinder

Call up
[Elements]
↳ **[Geometry elements]**
↳ **[Cylinder]**.

<MACRO SELECTION>
Select **<2 x 4 cylinder>**
<MEASURE MACRO>

Select **Probe 2**

Carry out the search probings with this probe.

End the measurement with **<TERMIN>.**

Measurement record

```
CYL_1
4      CYL I        Z   -486.305
                    X     -9.985
                    D     30.028
       Z/Y         A1      0.009
       X/Y         A2      1.246
       8P S/MIN/MAX               0.005       (1) -0.003
       (2) 0.002
```

Explanation

Z		Coordinate of the point at which the
X		cylinder axis pierces the X/Z plane
D		Diameter
Z/Y	A1	projected angle between the Y axis
X/Y	A2	and the projections of the cylinder axis into the Z/Y and X/Y plane.

Define the second and third axis of the workpiece coordinate system

Call up
[Coordinates]
↳ **[2D transformation]**
↳ **[Rotate Plane]**

Measurement record

```
RTPLAN_1
5      RT PLANE   A       1.246   ABOUT SPACE AXIS
Z
```

Explanation

A	2D angle between the temporary coordinate axis, in this case Y and the projection of the cylinder axis into the Y/X coordinate plane. The workpiece coordinate. system is rotated around the Z axis until the Y axis is parallel to the projection of the cylinder axis.

All the axis directions of the workpiece coordinate system have now been defined, as the X axis has to lie vertical to the Y axis. The workpiece coordinate system lies in the cone axis and partly parallel to the cylinder axis. It only has to be moved in Z into the corresponding surface.

Define the position of the third zero point

Call up
[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**.

Select **Probe 1**

Using **Probe 1** probe four points on surface 1.

Calculation with **<TERMIN>**.

Measurement record

```
SUR_1
6      SURFACE   Z   -453.384
       X/Z         A1     -0.001
       Y/Z         A2     -0.023
       4P S/MIN/MAX       0.002   (4) -0.001   (2) 0.002
```

Explanation

Z		Coordinate of the point at which the reference axis Z pierces surface 1
X/Z	A1	Angle between the reference axis Z and the projections
Y/Z	A2	of the surface normals in the X/Z or Y/Z plane.

To do

Continued overleaf.

This is the end of the practical exercise

How to do it

What happens

Place the zero position in surface 1

Call up
[Coordinates]
↳ **[Zero point]**
↳ **[define]**.

Measurement record

```
NPNT_2
7       ZEROP       Z   -453.384
```

Explanation

Z Value around which the coordinate system is moved.

The coordinate defined last is set to zero.

The workpiece coordinate system is moved down to surface 1.

The workpiece coordinate system is now completely defined:
- The space axis Z is in the cone axis, the Y/X plane is vertical to this,
- the X and Y zero point lies in the cone axis.
- The Y axis is partly parallel to the cylinder axis, the X/Z plane is partly parallel in this direction.
- The X axis is only vertical on the Z or Y axis.
- The Z zero point lies in surface 1.

Recall of the cone and cylinder

Elements]
↳ **[Recall]**
Address 1
in current coordinate system: YES

Measurement record

```
CONE_1
1       I              X     434.493
                       Y    -369.467
                       D     275.983
        X/Z           A1       0.010
        Y/Z           A2       0.018
                      AC     -29.923
12P S/MIN/MAX          S       0.005   (1) -0.003    (2) 0.002
```

[Elements]
↳ **[Recall]**
Address 4
in current coordinate system: YES

```
ZYL_1
4       ZYL I          Z    -486.305
                       X      -9.985
                       D      30.028
        Z/Y           A1       0.009
        X/Y           A2       1.246
          8P S/MIN/MAX            0.005    (1) -0.003
          (2) 0.002
```

[Evaluation]
↳ **[Distance]**
↳ **[Perp cylinder]**

Measurement record

```
13      PERP-CY     Y    -0.0000
                   Z   -33.1226
                   D    10.0248
          Y/X     A1   -0.0000
          Z/X     A2    0.0000
```

Explanation

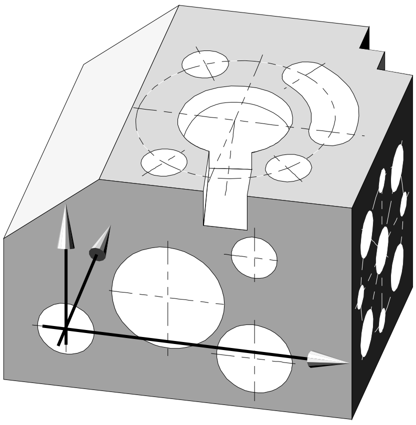
The distance is the space between the two axes.

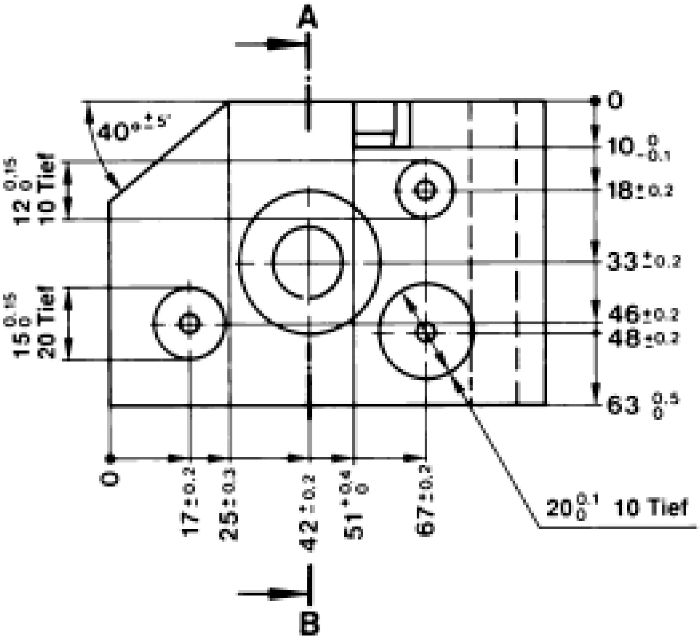
Worksheet 4: Alignment

4.2.6 Aligning a gearbox flange or support

Test feature: Position

Elements: Circle, surface





The alignment with Rotate Distance and Rotate about angle is first carried out on the practice cube.

Practical exercise:

This exercise deals with
- how a coordinate system is rotated around a preset angle
- and how a coordinate system is set to a Cartesian default value.

Note:
The primary reference is placed over surface 2, the secondary reference over the hole with 20 mm diameter and the hole with 15 mm diameter at the front.

.

To do

How to do it

What happens

Bring machine to its initial status

[Coordinates]
↳ **[Preparation]**
↳ **[Initial status]**

The machine coordinate system is active.

Measure surface 2

[Elements]
↳ **[Geometry elements]**
↳ **[Surface]**

Measure surface 2 with probe 2.

```
Measurement record
SUR_1
1       SURFACE I Y   -392.575
        Z/Y         A1       0.038
        X/Y         A2       1.236
        4P S/MIN/MAX              0.002        (1) -0.002
        (2) 0.02
```

First coordinate axis (space axis)

[Coordinates]
↳ **[Space axis]**
↳ **[define]**

```
Measurement record
RTSPAC_1
2       RT SPACE   A      1.2363
```

Place zero position in surface 2

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

```
Measurement record
NPNT_1
3       ZEROP       Y   -392.484
```

Measure the first alignment circle hole with 15 mm diameter

[Elements]
↳ **[Geometry elements]**
↳ **[CIRCLE]**

Using **Probe 2**, measure hole with 15 mm diameter with four points.

```
Measurement record
CIRCLE_1
4       CIRCLE I     Z   -499.009
                     X    407.290
                     D     15.143
        4P S/MIN/MAX              0.005        (4) -0.003
        (2) 0.002
```

Place zero position in the hole with 15 mm diameter

[Coordinates]
↳ **[Zero point]**
↳ **[define]**

```
Measurement record
NPNT_2
5       ZEROP        Z   -499.009
                     Z    407.290
```

Continued overleaf.

To do	How to do it	What happens
Measure the second alignment circle, hole with 20 mm diameter	**[Elements]** ↳ **[Geometry elements]** ↳ **[CIRCLE]** Measure hole with 20 mm diameter with **Probe 2** using four points.	**Measurement record** CIRCLE_2 6 CIRCLE I Z -2.006 X 49.999 D 19.939 4P S/MIN/MAX 0.005 (4) -0.003 (2) 0.003

From here, generation of the workpiece coordinate system can continue as follows:

Case 1: Setting of the nominal angle for the secondary plane
Case 2: Rotation of the coordinate system so that the Z value of the hole with the 20 mm diameter has that of the nominal coordinate
Case 3: Setting of the X value for the 20 mm hole

Note:
In the exercise, all three versions are carried out one after the other, in order to show the differences of the individual workpiece coordinate systems. In practice only one of the rotations has to be carried out as per drawing or as arranged. To check, the 20 mm bore is recalled after the rotation. The individual cases always start from this address.

To do	How to do it	What happens
Case 1: **Define the temporary secondary axis**	**[Coordinates]** ↳ **[2D transf.]** ↳ **[Zero pt & 1 Element]**	**Measurement record** RTNPNT_1 7 ROT (OP+1)A 2.2969 **Explanation**: First the X axis is placed through the centers of the 15 mm and 20 mm hole.
Rerotate secondary plane	**[Coordinates]** ↳ **[2D transf.]** ↳ **[rerotate]** Enter rerotation angle **A = -2.2906**	**Measurement record** RRTANGL_1 8 REROTATE A -2.2906 **Explanation**: The coordinate system is rerotated around the nominal angle entered around the space axis Y.
Check **recall of 20 mm hole**	**[Elements]** ↳ **[Recall]** Enter address **Address = 6** **Transformation ?** **<YES>**	**Measurement record** RECALL_1 9 6! CIRCLE I Z -2.000 X 49.999 D 19.934 **Explanation**: The coordinate values are converted to the new coordinate system.

This is the end of case 1.
The following rerotation angle should result from the calculation of the angle from the two coordinates:
A = atn (Z/X) = atn (2 / 50) = 2.2906, i.e. the 20 mm hole lies exactly around the angle A under the x axis.

Continued overleaf.

To do	How to do it	What happens
Case 2: **Set secondary value to the Z value**	**[Coordinates]** ↳ **[2D transf.]** ↳ **[Distance]** Enter distance **Z = -2**	**Measurement record** RRTLIN_1 10 ROTATE Z -2.000 ABOUT SPACE AXIS Y A 0.000 **Explanation:** The coordinate system is rotated so that the 20 mm hole lies exactly 2 mm under the X axis.
Check **Recall of 20 mm hole**	**[Elements]** ↳ **[Recall]** Enter address **Address = 6** **Transformation ?** **<YES>**	**Measurement record** RECALL_2 11 6! CIRCLE I Z -2.000 X 49.999 D 19.934 **Explanation**: The coordinate values are converted to the new coordinate system.

This is the end of case 2.
The value Z = 2.000 must be the exact result when address 6 is recalled.

Fall 3: **Set the secondary plane to the X value**	**[Coordinates]** ↳ **[2D transf.]** ↳ **[Distance]** Enter distance **X = 50**	**Measurement record** RRTLIN_2 12 ROTATE X 50.000 ABOUT SPACE AXIS Y A 0.009 **Explanation:** The coordinate system is rotated until the 20 mm hole lies exactly 50 mm to the right of the Z axis.
Check **Recall of 20 mm hole**	**[Elements]** ↳ **[Recall]** Enter address **Address = 6** **Transformation ?** **<YES>**	**Measurement record** RECALL_3 13 6! CIRCLE I Z -1.992 X 50.000 D 19.934 **Explanation**: Coordinate values are converted to the new coordinate system.

This is the end of case 3.
The value Z = 2.000 must be the exact result when address 6 is recalled.

This is the end of the practical exercise.

Rotate distance to another workpiece

Test feature: Position

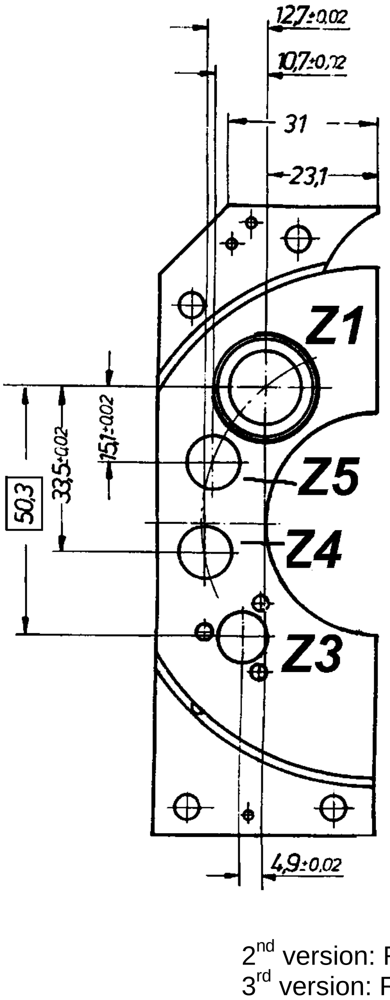
Elements: Circles, surface

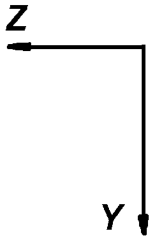
The same exercise is to be carried out on the support as was carried out on the practice cube.

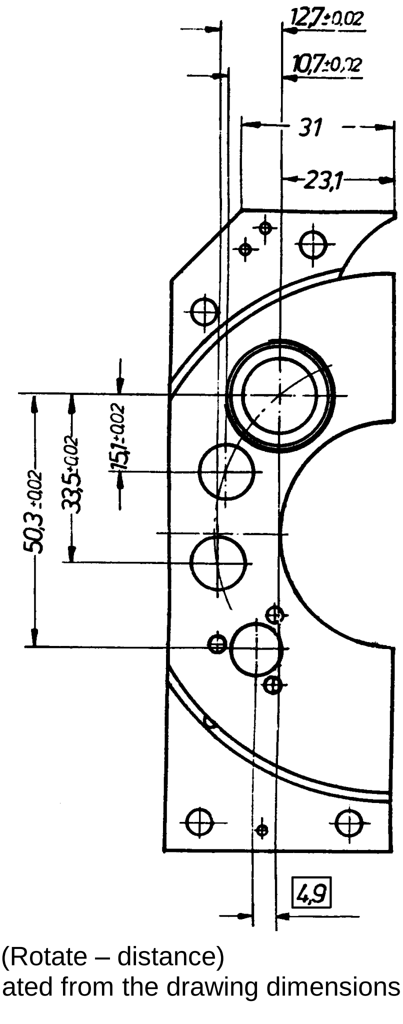
Alignment of the workpiece in 3 versions:

The following applies for each version:

Space alignment and zero point (Y,Z) in Z1.
Surface 1 for zero point in X.
Plane rotation:
1st version: Rotation of Z3 to a Y value of 50.3 (Rotate – distance)







2nd version: Rotation of Z3 to a Z value of 4.9. (Rotate – distance)
3rd version: Rotation to a nominal angle, calculated from the drawing dimensions 4.9 and 50.3.

$$W = \arctan\left(\frac{Z}{Y}\right) = \arctan\left(\frac{4.9}{50.3}\right) = 5.5639^{0}$$

Caution: Please be careful with the +/- sign of the direction of rotation!

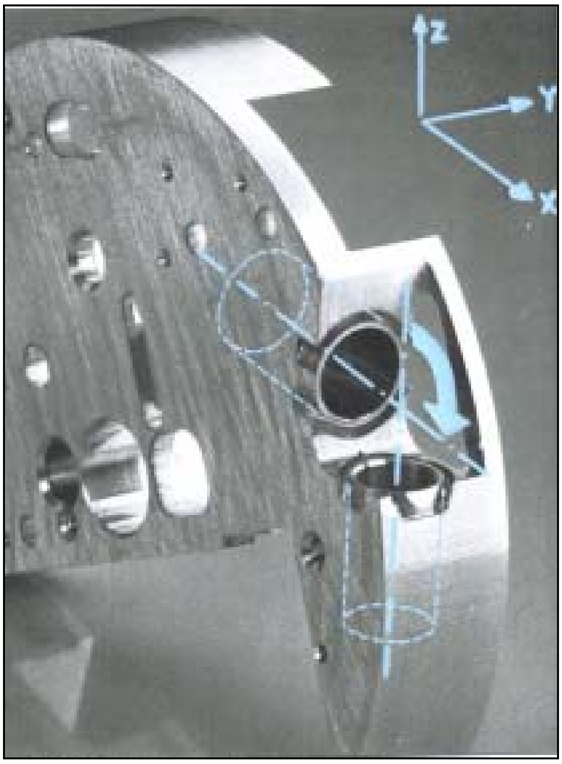
Notes:

5. Linkings

"Invisible elements"

Sometimes it is not possible to define values directly. The intersection point of the two hole axes in the figure on the right for example cannot be measured directly. However by linking measurement results which are already available, values for such "invisible" elements can be calculated.

This chapter describes what you should be aware of.

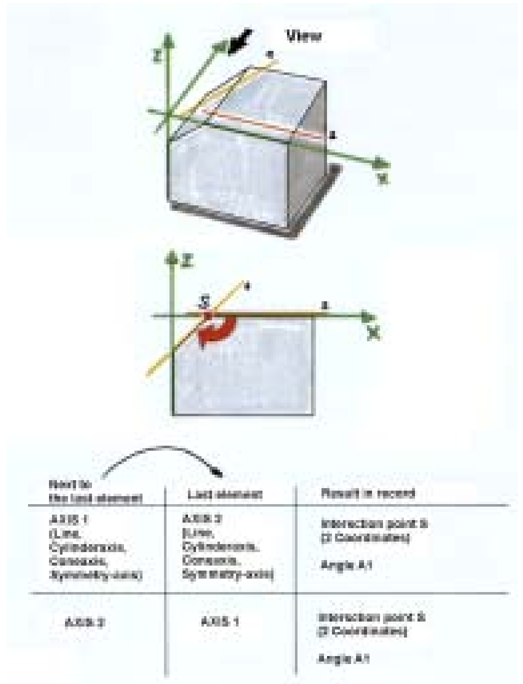


Linking 2 elements by using an intersection

It is not always possible to probe the elements you want, e.g. lines which are the result of the intersection of two surfaces. We can link these two surfaces with the intersection function and as result will get an intersection line. The intersection function always links the two elements output last in the protocol. Important: For cylinders and cones the intersection function only links their axes (in the following too and also for symmetry, perpendicular etc. only their axes, the surfaces are not of importance). This is why we call the intersection of cylinder axes, cone axis and also lines just the intersection of axes.
In the following we will discuss the possible uses for the intersection.

Intersection of 2 axes

The intersection point which results when the two axes are projected into a common plane is calculated here.
The reference side for the angle between the two projected axes is always the next to last geometric element.
If the angle is to be checked, you have to be careful with the sequence of the axes.
The sign of the angle is positive when the rotation direction is counterclockwise. You always look from the positive into the negative axis direction. If it is a question of the XZ plane, then you have to look at this from the rear of the coordinate measuring machine.
Generally the following applies:
The direction of view is always opposite the 3rd axis which is vertical to the projection plane.



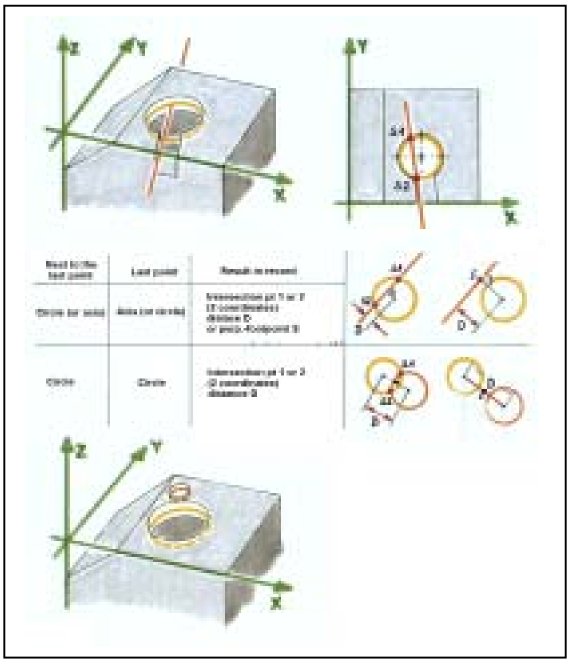
Next to the last element	Last element	Result in record
AXIS 1 (Line, Cylinderaxis, Coneaxis, Symmetry-axis)	AXIS 2 (Line, Cylinderaxis, Coneaxis, Symmetry-axis)	Intersection point S (2 Coordinates) Angle A1
AXIS 2	AXIS 1	Intersection point S (2 Coordinates) Angle A1

Intersection of circle/axis or circle/circle

The intersection point calculated is the one which results if both elements are projected into a common plane.
If two intersection points result, one can be selected on the computer. Exception: The distance D between the circle center point and the axis is always the same as the circle radius. If no intersection point results, this is noted in the protocol.

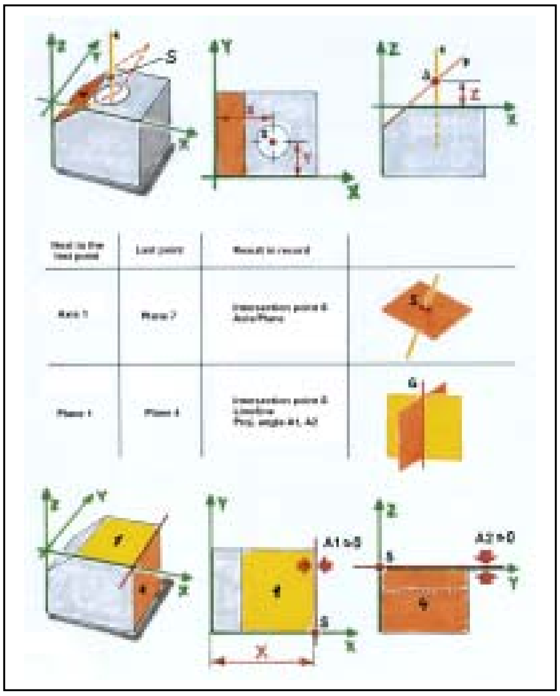
No intersection point: 2 coordinates of the perpendicular for point are output as well as distance D.

With intersection of circle/circle



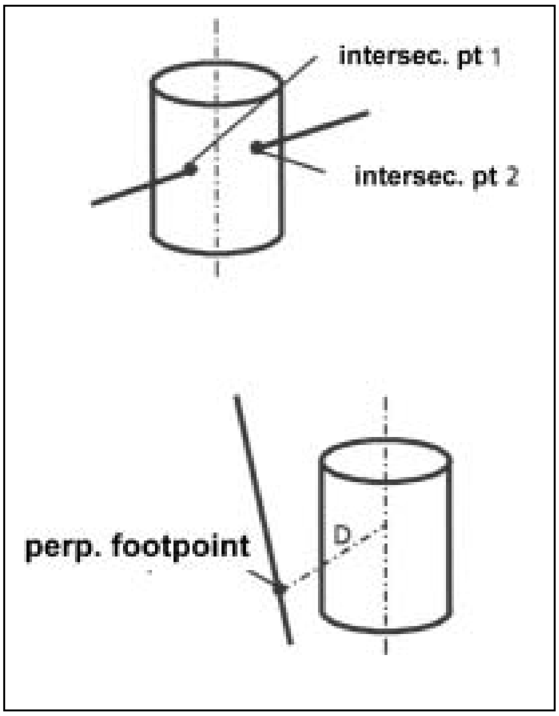
Intersection of axis/surface or surface/surface

With the intersection of the axis and surface, the three coordinates of the piercing point of the axis through the surface is calculated.
With the intersection of two surfaces, one intersection line results as spatially defined element.



Surface section

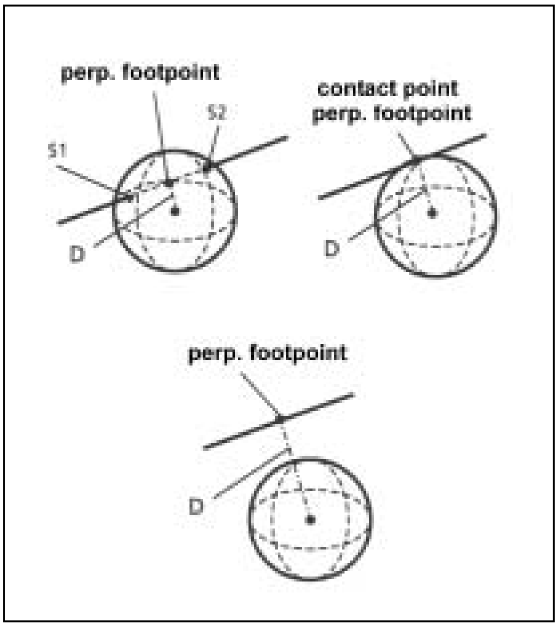
Intersection of cylinder and axis



Here the intersection points of an axis with the cylinder are calculated. What is important is that it is not the cylinder axis which is evaluated for the intersection point but the outer surface.
Two points are calculated, you select the one you want.

In this way it is possible to calculate the intersection of two cylinders. You now have to specify which element represents the axis and which the curved surface.
If no intersection is made, we are given the perpendicular foot point and the shortest distance between the two axes.

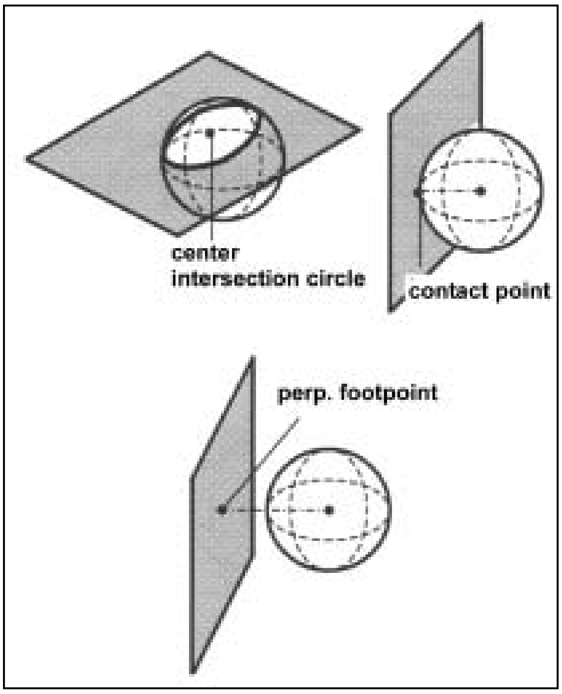
Intersection of sphere and axis



As for the above example, there are either two intersection points or no intersection point at all. The distance of the axis to the sphere center point is output under D. No intersection point means no output of the perpendicular foot point.

Intersection of sphere and surface

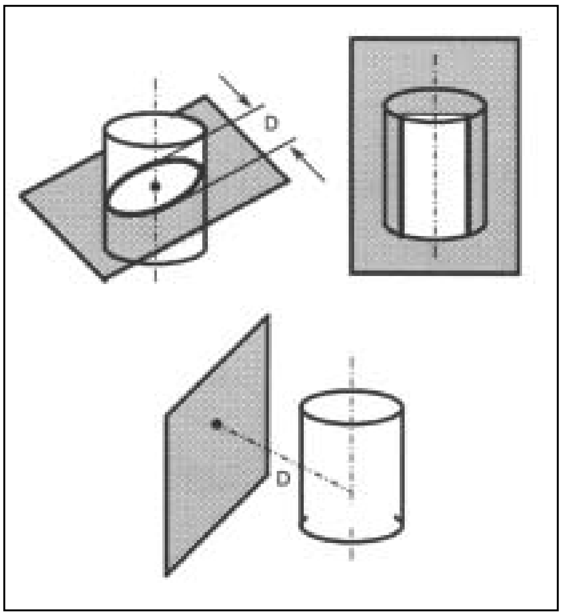
The result here– for a real intersection is always a circle. This intersection circle is shown in the measurement record as a "normal" circle. The diameter of the intersection circle is shown with D. If no intersection takes place D is equal to zero.



Intersection of cylinder and surface

The result here is always an ellipse, outer surface and cylinder are absolutely parallel to one another.
In keeping with reality, the evaluation of two intersection lines can be carried out with angle differences smaller than 3°.

You have to run through a special dialog in which different reference lengths have to be entered. The result is then a line.

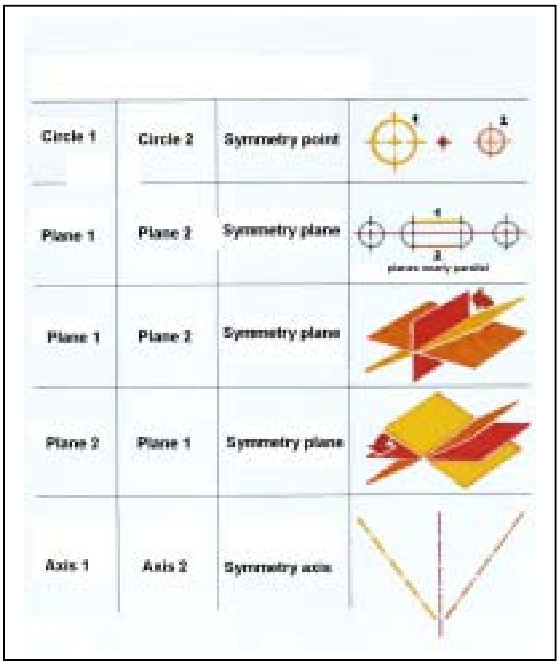


Symmetry

Linking 2 elements with symmetry

As for intersection elements, symmetry elements cannot be probed, e.g. the symmetry of two hole center points. We can link these holes using the Symmetry function and the result we will get is the symmetry point.

The symmetry function always <u>links the last two elements output in the measurement record</u>. The calculation is made for the coordinates which are common to both elements, for example:
If 2 circle center points are given with the X and Y coordinate, X and Y are also calculated for the symmetry point. The symmetry element calculated can be linked with any other element.



Circle 1	Circle 2	Symmetry point
Plane 1	Plane 2	Symmetry plane
Plane 1	Plane 2	Symmetry plane
Plane 2	Plane 1	Symmetry plane
Axis 1	Axis 2	Symmetry axis

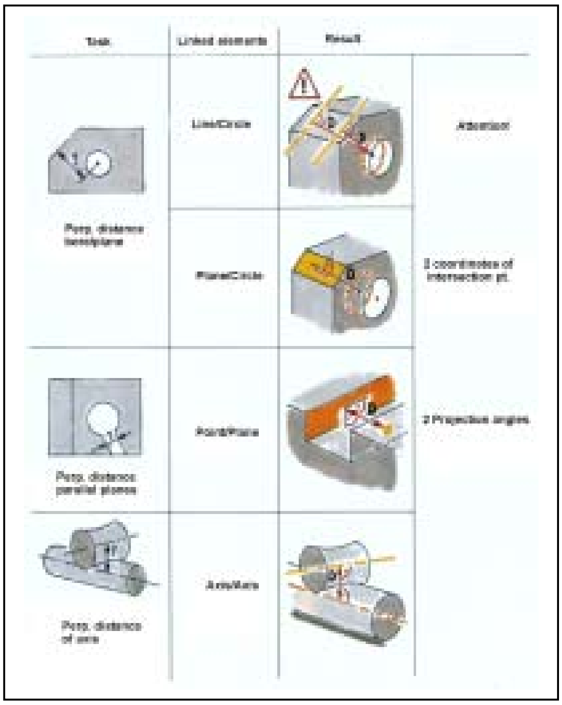
Applications for symmetry

In the following we will discuss possible uses for the symmetry function.

Perpendicular and perpendicular cylinder

Linking 2 elements using the perpendicular

The perpendicular can be used for defining the shortest distance between two geometric elements in space.
The program always links the last two elements output in the measurement record.
One of the two elements must be defined in space, e.g. a line, surface, cylinder or cone axis. Because the perpendicular is vertical to this element, the direction of the perpendicular results. If both elements are defined in space, the last element defines the perpendicular direction.
If the sequence is changed for two spatially defined elements, different results emerge.
The perpendicular is not clearly defined by the direction alone, we also need a point on the perpendicular. This point is supplied by the other element which has not been used for defining the direction, e.g. elements such as point, circle, surface, line, cylinder or cone axis.



Perpendicular cylinder

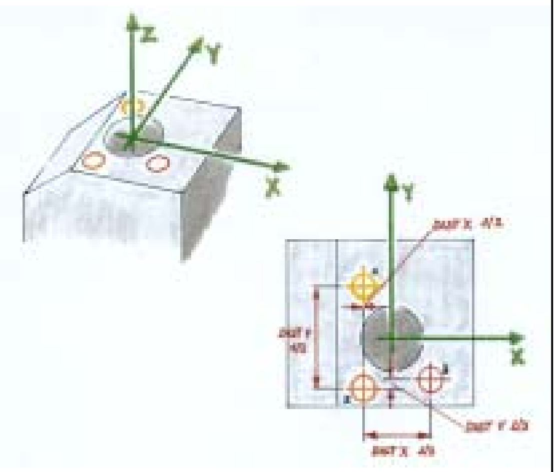
Output of the perpendicular as a line. The line element has two coordinates of the piercing point, two projected angles as well as the diameter. The perpendicular cylinder uses these identifications, only here D is the distance.

Applications for the Perpendicular program

In the following we will discuss possible applications for the Perpendicular program.

Distance

Distance between 2 elements by the Cartesian distance



Till now, the measurement results for geometric elements always referred to the zero point of the workpiece coordinate system. Using this it is not always possible to read the distance between the elements.
With the Cartesian distance function, the distance between two geometric elements can be defined and output in perpendicular (Cartesian) coordinates.

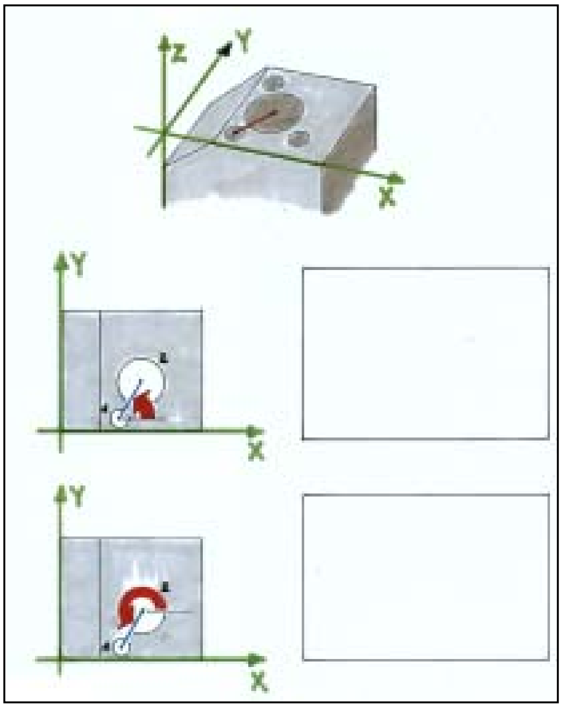
The Cartesian distance function always links the last two elements output in the measurement record.

The Cartesian distance between the two elements is calculated by subtracting the coordinates as follows:

Distance = Coordinates of the next to last element minus coordinates of
the last element

The sign of the "coordinates" calculated is always output positive.

Conversion of the coordinates by polar distance 2D



With the polar distance 2D function, perpendicular (Cartesian) coordinates can be converted to polar coordinates, i.e. radius and polar angle. The angle value output lies between 0 and 360°.
Before the polar distance 2D function is called, there must be a pair of coordinates in the last address.
The result of the conversion depends on <u>what was output last in the measurement record</u>.

- If a geometric element was output, the distance to the zero point is calculated in polar coordinates.
- If the Cartesian distance of two elements was output, the shortest distance (polar distance) is calculated. This however depends on the sequence of the geometric elements as we shall see.

Sequence of the geometric elements for the Polar Distance 2D function

The sequence of the two geometric elements in the measurement record which are used for the Cartesian distance influence the angle output.
The rotation direction of the angle is positive when viewed from the positive direction of the 3rd coordinate axis and counterclockwise.

Reference axis for polar angles:

X/Y plane	X axis
Y/Z plane	Y axis
Z/X plane	Z axis

The Angle function

Last address in record		Angle	depends on	Reference axis
2 Points		2D angle	Probing direction	perp. to probing direction
2 Spacepoints		2 projection angles		Z-axis
2 Elements in 1 plane		D>R: 2D angle D<R: projection angle	Position of plane	———
2 Elements in different planes		D>R: 2D angle D<R: projection angle	Position of plane	reference axis for angle <90°
1 spatial element (plane, cylinder, cone)		Inclination- and rotation angle	Position of plane	ref. axis for A1: in proj.-plane ref. axis for A2: coordinate axis

Calculation of the angle when linking different elements

Here is a summary for the Angle function:

Case 1:
The last two addresses in the measurement record before the angle function is called up are two points. The 2D angle is calculated which forms the connecting line of the two points with a coordinate axis. The output of the angle value in the measurement record depends on the probing direction.

Case 2:
The last two addresses before the angle function is called are two circles or ellipses **in one plane**. The 2D angle is calculated which forms the projection of the connecting line in the coordinate plane of the elements with a coordinate axis. The distance D between the two center points must be greater than the radius of the last circle (or greater than the small semi-axis of the last ellipse).
Otherwise two projection angles are output (see case 3).

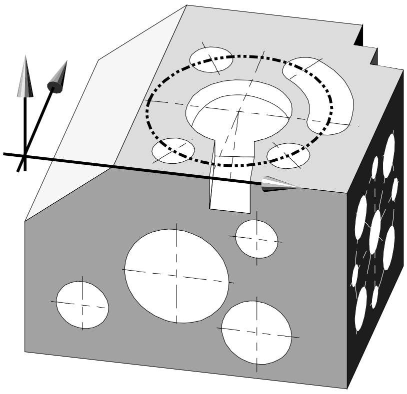
Case 3:
The last two addresses before the angle function is called up are two circles or ellipses lying in different planes.
The two projection angles are calculated which form the two projections of the connecting line with the reference axis.
The distance D of the two center points must be smaller than the radius of the last circle (or smaller than the small semi-axis of the last ellipse).
Otherwise the 2D angle is output (see case 2).

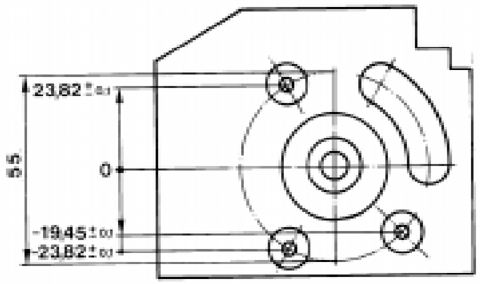
Case 4:
A spatially defined element (surface, cylinder etc.) is saved under the last address before the angle function is called up.
The rotation and tilt angle of the normal or the axis are calculated. The **tilt angle** is the 3D angle which the axis or normal forms with a coordinate axis. The **rotation angle** results from the projection of the positive section of the axis or normal in the plane vertical to a coordinate axis.

Worksheet 5: Measuring tasks

5.2.1 Diameter of a hole pattern

Test feature: Graduated circle measurement
Element: Circle





```
================================================================================
 ADR|REC | TASK   | IDF |SY| ACTUAL   |NOMINAL   | U.TOL | L.TOL | DEV   |
================================================================================


From address: 4     To address: 6     Step width: 1
  15    * CIRCLE        X     51.9806
                        Y     32.0843
                        D     55.0086
```

Practical exercise:

The graduated circle in the top surface is to be defined.

Note:
A workpiece coordinate system has to be generated first.

To do	How to do it	What happens

Define coordinate system

Proceed as described in worksheet 4.1.

The workpiece coordinate system is now located in the front left upper corner of the workpiece (address 1 to 8).

Measure 1st circle

Select **Probe 1**

Measure circle 1 with four points

Measurement record

```
CIRCLE_1
9       CIRCLE I    X     38.134
                    Y     55.797
                    D     12.114
        4PS/MIN/MAX        0.003   (2) -0.001   (1) 0.001
```

Measure 2nd circle

Select **Probe 1**

Measure circle 2 with four points

Measurement record

```
CIRCLE_2
10      CIRCLE I    X     38.139
                    Y      8.160
                    D     12.105
        4PS/MIN/MAX        0.002   (4) -0.001   (1) 0.001
```

Measure 3rd circle

Select **Probe 1**

Measure circle 3 with four points

Measurement record

```
CIRCLE_3
11      CIRCLE I    X     71.337
                    Y     12.532
                    D     12.099
        4PS/MIN/MAX        0.003   (3) -0.002   (2) 0.002
```

The circles have now been measured and they are known to the computer. The graduated circle can now be calculated.

Continued overleaf.

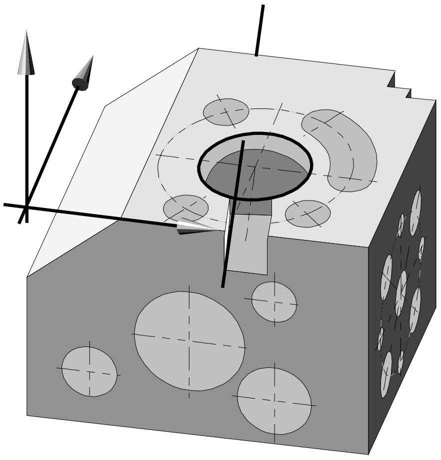
To do	How to do it	What happens
Calculate graduated circle	**[Elements]** ↳ **[Geometry elements]** ↳ **[Circle]** **<Action>** **<Recall>** ADR 9 to 11 step 1 (absolute) or ADR -1 to -3 step 1 (relative) **<TERMIN>**	**Measurement record** From address: -1 To address: -3 Step width: 1 CIRCLE_4 12 * CIRCLE X 51.889 Y 31.979 D 55.007 **Explanation** * Element calculated X, Y Center point coordinates D Graduated circle diameter S/MIN/MAX Cannot be calculated with only three points.
Result comparison	Compare the measurement results with the data in the manufacturing drawing.	

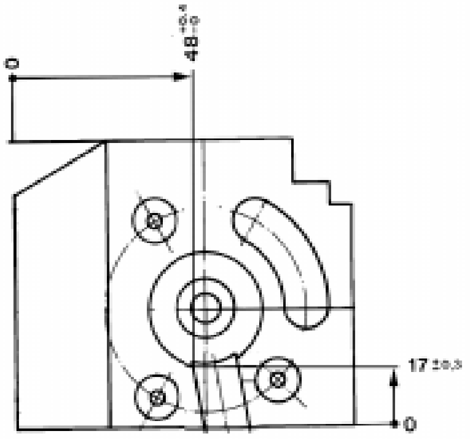
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.2 Intersection point between hole and groove

Test feature: Intersection point
Elements: Circle, line





```
==============================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
==============================================================================



  20      I-P-2 CL      X     48.4695
                        Y     17.4642
                        Z     -1.6713
```

Practical exercise:

The transition of the line to the circle is to be defined.
To do this, the 2D intersection (projection into a coordinate plane) is calculated in the first part, and in the second part the 3D intersection (piercing).

Note:
The workpiece coordinate system is again at the front upper left.

To do

How to do it

What happens

Measure 30 mm hole

Select **Probe 1**

Measure Circle 1 with four points

```
Measurement record
CIRCLE_5
18    CIRCLE I    X     51.853
                  Y     32.024
                  D     30.058
      4PS/MIN/MAX        0.007   (1) -0.004   (4) 0.003
```

Measure left flank of groove

Select **Probe 1**

Measure line with three points

```
Measurement record
LIN_1
19    LINE        Z     -1.899
                  X     51.423
      Z/Y        A1     -0.127
      X/Y        A2     -9.977
      3PS/MIN/MAX        0.004   (1) 0.002    (2) 0.003
```

The intersection point can now be calculated.

Define intersection point

[Evaluation]
↳ **[Intersection]**
↳ **[Intersection]**

```
Screen
Inters. point no:1     X = 48.361  Y = 17.406
Inters. point no:2     X = 43.582  Y = 44.573
No intersection point is saved if '0'!
```

Select intersection point

Select the front intersection point with X or Y.

Accept inters. point 1 ?
<YES>

```
Measurement record
SECT_1 (CIRCLE_5, LIN_1)
20    I-P-1 CL    X     48.361
                  Y     17.406
                  D      5.972
Text              Inters. point 1, CIRCLE / LINE
X, Y              Coordinates of the intersection point
```

Result comparison

Compare the intersection point coordinates with the entry in the manufacturing drawing.

Continued overleaf.

To do | How to do it | What happens

Measure hole as cylinder

Measure cylinder with 8 points

```
Measurement record
CYL_1
21      CYL I          X     51.845
                       Z     32.026
                       D     30.052
        Z/Y           A1     -0.154
        X/Y           A2      0.071
        8PS/MIN/MAX           0.009   (1) -0.009   (7) 0.006
```

Recall line

[Elements]
↳ **[Recall]**

Address = 19

```
Measurement record
LIN_1
22 19* LINE            Z     -1.899
                       X     51.423
        Z/Y           A1     -0.127
        X/Y           A2     -9.977
```

Explanation
There is no prompt after the transformation as the workpiece coordinate system has not been changed.

The intersection point can now be calculated.

Define intersection point

[Evaluation]
↳ **[Inters.]**
↳ **[Surface sections]**

```
Screen
Inters. point no:1     X = 43.582   Y = 44.573 Z = -1.989
Inters. point no:2      X = 48.359  Y = 17.414 Z = -1.938
```

Select intersection point

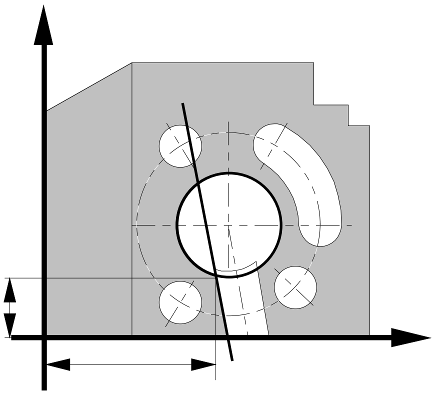
Select the front intersection point with X or Y.

Accept inters. point 1?
<NO>

```
Measurement record
SSECT_1 (CYL_1, RECALL_5)
23      I-P-2 CL       X     48.359
                       Y     17.414
                       Z      -1.938
Text                   Surface intersection cylinder / line
X, Y, Z                Coordinates of the intersection point
```

Result comparison

Compare the intersection point coordinates with the previous intersection point.

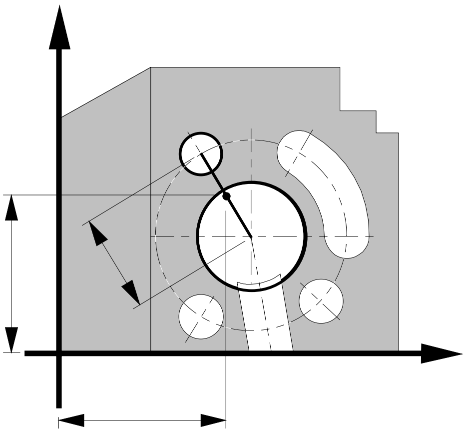


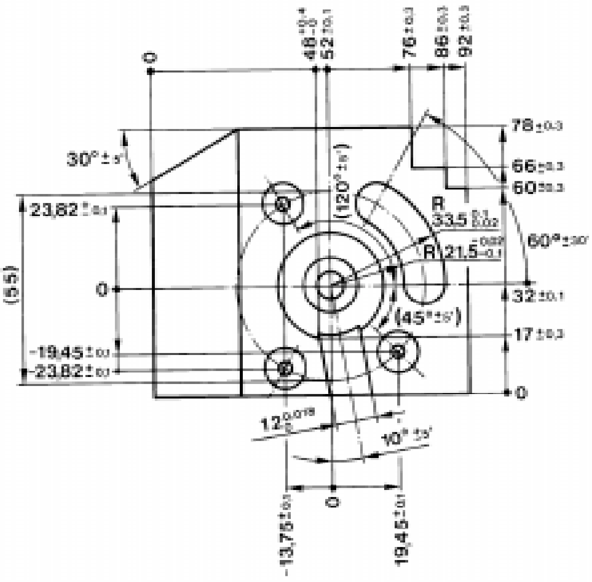
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.3 Intersection point between two holes

Test feature: Intersection point
Element: Circle





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
================================================================================


  16      I-P-0 CC      X     44.5892
                        Y     43.9799
                        D     27.5247
```

Practical exercise:

Although the two circles do not intersect, you can use the measurement result when the intersection program is applied.

The coordinate system remains at the upper front left.

To do / How to do it / What happens

Recall the large circle

[Elements]
↳ **[Recall]**

Address = 18

Measurement record

```
RECALL_6
24 18* CIRCLE I   X     51.853
                  Y     32.024
                  D     30.058
```

Recall the small circle

[Elements]
↳ **[Recall]**

Address = 9

Measurement record

```
RECALL_7
25 9! CIRCLE I    X     38.135
                  Y     55.797
                  D     12.114
```

The intersection point can now be calculated.

Define intersection point

[Evaluation]
↳ **[Inters.]**
↳ **[Inters.]**

Screen
There is no prompt as the solution is clear.

Measurement record

```
SECT_2 (RECALL_6, RECALL_7)
26    I-P-0 CC    X     44.994
                  Y     43.910
                  D     27.447
```

Explanation

Text	Inters. CIRCLE / CIRCLE
X, Y	Coordinates of the symmetry point
D	Distance between the center points

Result comparison

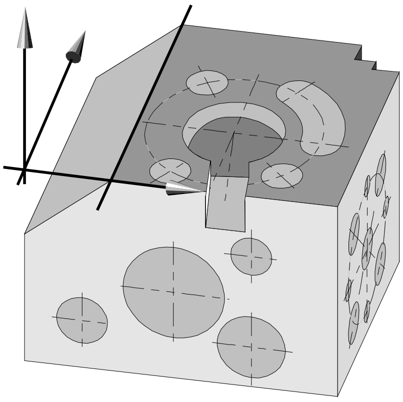
Compare the distance with the data in the manufacturing drawing.

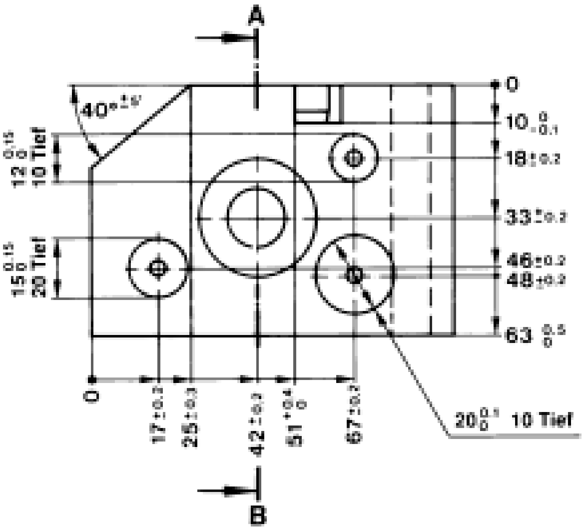
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.4 Direction and position of an edge of cut

Test feature: Coordinate of an intersection line
Elements: Surfaces





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
================================================================================


  15      I-L    SS       Z       0.0000
                          X      24.8923
              Z/Y         A1      0.0000
              X/Y         A2      0.0461
```

Practical exercise:

The INTERSECTION program defines the distance of the edge from the zero point.

The workpiece coordinate system remains at the front upper left.

To do

How to do it

What happens

Measure inclined surface

Measure inclined surface with 4 points

Measurement record

```
SURF_4
27      SURFACE   Z     -20.760
        X/Z         A1  -40.005
        Y/Z         A2    0.164
        4PS/MIN/MAX       0.008   (2) -0.005   (3) 0.004
```

Recall top surface

[Elements]
↳ **[Recall]**

ADR = 1 (absolute) or

ADR = -xx (relative)
Transf. to new coord.?
<YES>

Measurement record

```
RECALL_8
28 1!  SURFACE   Z       0.000
       X/Z         A1    0.000
       Y/Z         A2    0.000
```

Explanation
The surface is output in the new coordinate system.
This is why all values have to be zero.
28 Address 28 is the old Address 1.
! It has been converted.

The two surfaces are the last addresses in the memory. The calculation now follows.

Carry out intersection

[Evaluation]
↳ **[Inters.]**
↳ **[Inters.]**

Measurement record

```
SECT_3 (SURF_4, RECALL_8)
29      I-L SS      Z     0.000
                    X    24.724
        Z/Y         A1    0.000
        X/Y         A2    0.196
```

Explanation
The result is the intersection line

Text		Inters. line surface / surface
Z, X		Piercing point, X is the value looked for
Z/Y	A1	Projected angle
X/Y	A2	

Result comparison

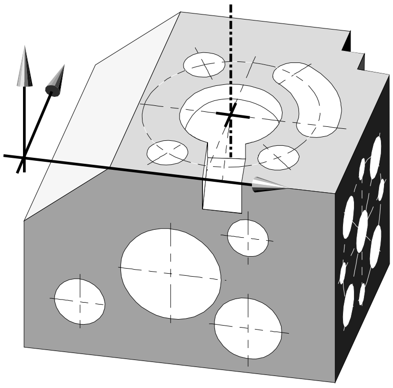
Compare the measurement results with the manufacturing drawing.

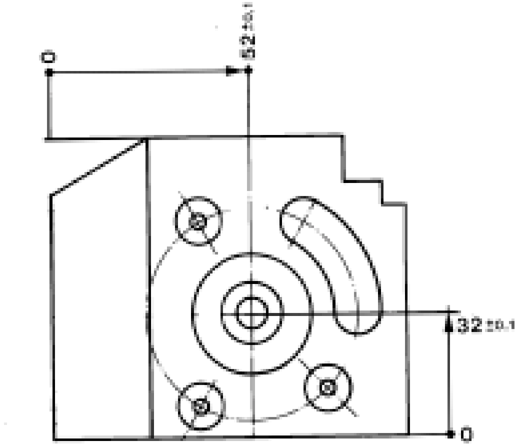
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.5 Piercing point of an axis through a surface

Test feature: Intersection point
Elements: Cone, surface





```
==================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
==================================================================================


  15      I-PNT SL       X      51.9876
                         Y      32.0745
                         Z       0.0000
```

Practical exercise:

The piercing point of the cone axis through surface 1 is calculated.

The coordinate system remains at the upper front left.

To do | How to do it | What happens

Recall surface 1

[Elements]
↳ **[Recall]**

Address = 1

```
Measurement record
RECALL_9
30 1!  SURFACE   Z      0.000
       X/Z       A1     0.000
       Y/Z       A2     0.000
```

Define cone axis

[Elements]
↳ **[Geometric elements]**
↳ **[Cone]**

3 Intersection circles, each with 4 points

```
Measurement record
CONE_1
31     CONE I     X     51.853
                  Y     32.026
                  D     33.748
       Y/Z       A1     -0.016
       X/Z       A2      0.072
                 AC    -29.996
       12PS/MIN/MAX      0.003   (5) -0.004   (7) 0.003
```

The intersection point can now be calculated.

Define intersection point

[Evaluation]
↳ **[Inters.]**
↳ **[Inters.]**

```
Measurement record
SECT_4 (RECALL_9, CONE_1)
32     I-PNT SC   X     51.853
                  Y     32.026
                  Z      0.000
```

Explanation

Text	Inters. point surface / cone axis
X, Y, Z	Coordinates of the intersection point

Result comparison

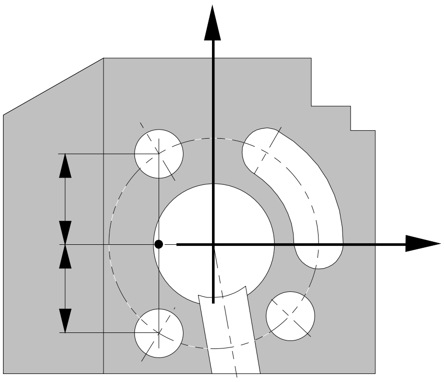
Compare the intersection point coordinates with the data in the manufacturing drawing.

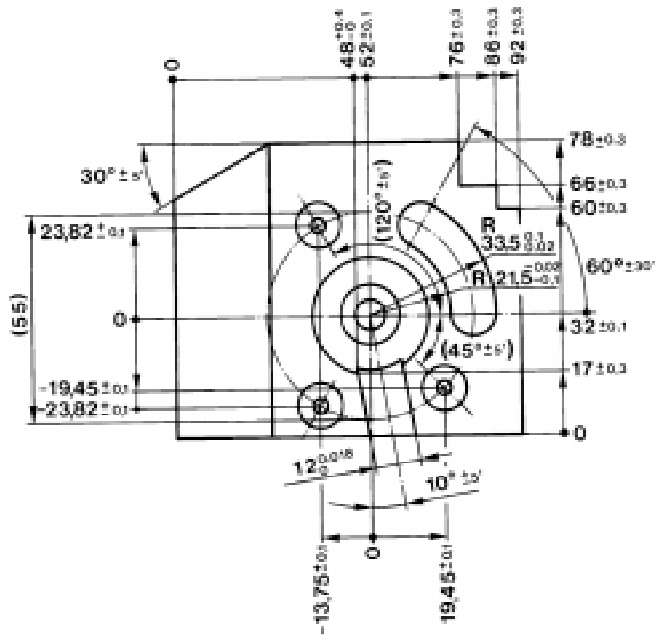
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.6 Position between two holes

Test feature: Symmetry point
Element: Circle





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
================================================================================



  16   14 SY-P 15       X     -13.7538
                        Y      -0.0202
```

Practical exercise:

We will check whether the two 12 mm holes on the left of the hole pattern in the top surface lie symmetrical to the graduated circle center.

To do this the coordinate system is moved to the graduated circle center.

To do

How to do it

What happens

Recall coordinate system

[Elements]
↳ **[Recall]**

Address = 13

```
Measurement record
RECALL_10
33      13* COORD. SYSTEM AS FOR ADR. 13
```

Recall 1st hole

[Elements]
↳ **[Recall]**

Address = 9
Transformation ? <YES>

```
Measurement record
RECALL_11
34 9!  CIRCLE I     X    -13.754
                    Y     23.817
                    D     12.114
```

Recall 2nd hole

[Elements]
↳ **[Recall]**

Address = 10
Transformation ? <YES>

```
Measurement record
CIRCLE
35 10! CIRCLE I     X    -13.750
                    Y    -23.819
                    D     12.105
```

The symmetry point can now be calculated.

Symmetry point

[Evaluation]
↳ **[Symmetry element]**

End prompt with
<TERMIN>

```
Measurement record
SYMME_1 (RECALL_11, RECALL_12)
36      34 SY-P 35  X    -13.752
                    Y     -0.001
```

Explanation

Text	Symmetry CIRCLE / CIRCLE
X, Y	Coordinates of the symmetry point

Result comparison

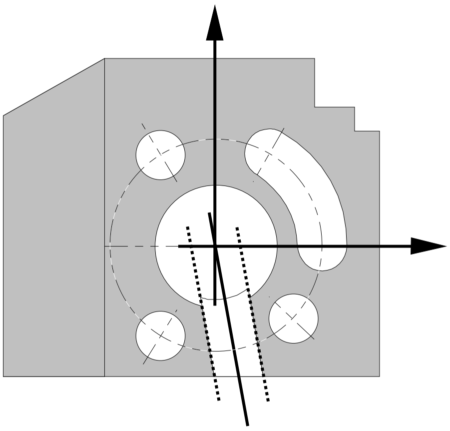
Compare the coordinates of the symmetry point with the data in the manufacturing drawing.

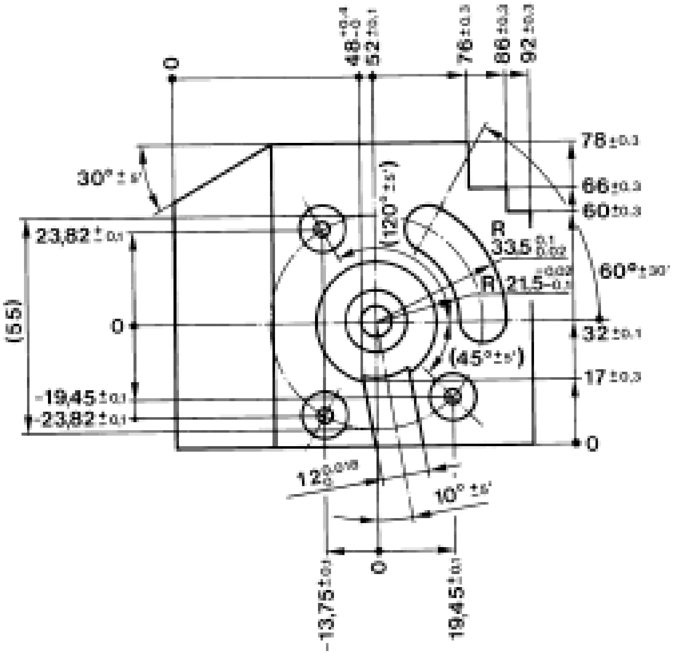
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.7 Direction and position of a groove

Test feature: Symmetry axis
Element: Line





```
===============================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV   |
===============================================================================


18        SYMM-A        Z      -2.7025
                        X      -0.0104
              Z/Y       A1     -0.0718
              X/Y       A2    -10.0747
```

Practical exercise:

You can use the SYMMETRY program to check whether the groove runs symmetrical to the graduated circle center.

The coordinate system remains in the graduated circle center.

To do	How to do it	What happens

Recall the line on the left side

[Elements]
↳ **[Recall]**

Address = 19

Measurement record

```
RECALL_13
37 19! LINE        Z    -1.9702
                   X     -6.092
     Z/Y          A1     -0.127
     X/Y          A2     -9.977
```

Measure the line on the right side

[Elements]
↳ **[Geometric elements]**
↳ **[LINE]**

Measure with three points

Measurement record

```
LIN_2
38   LINE          Z     -4.194
                   X      6.104
     Z/Y          A1     -0.138
     X/Y          A2     -9.991
     3PS/MIN/MAX          0.004   (3) 0.001    (2) 0.003
```

The symmetry line can now be calculated.

Calculate symmetry line

[Evaluation]
↳ **[Symmetry element]**

<TERMIN>

Measurement record

```
SYMME_2 (RECALL_13, LIN_2)
39   SYMM-A        Z     -3.082
                   X      0.006
     Z/Y          A1     -0.133
     X/Z          A2     -9.984
```

Explanation

Text	Symmetry axis LINE / LINE
Z, X	Coordinates where the symmetry axis pierces the coordinate plane
Z/Y A1 X/Y A2	Projected angle of the symmetry axis

Result comparison

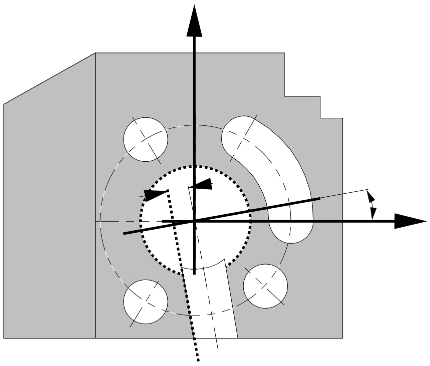
Compare the coordinates of the symmetry axis with the data in the manufacturing drawing.

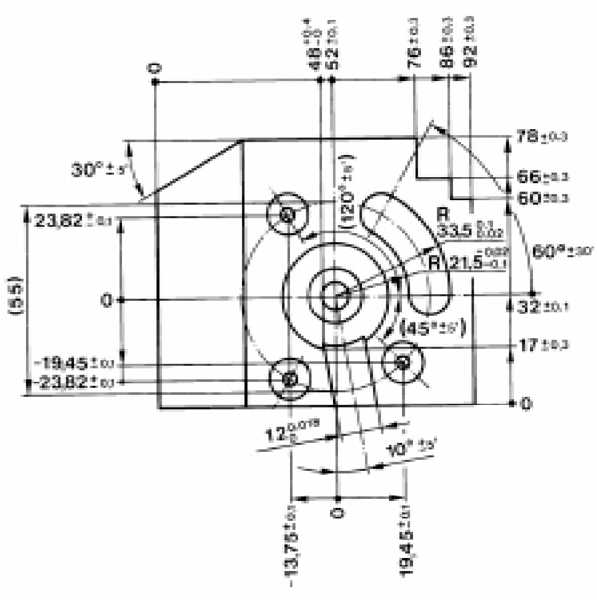
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.8 Position of a surface

Test feature: Perpendicular
Elements: Circle, surface





```
==================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
==================================================================================


17      PERP CYL        Y      -0.0000
                        Z      -1.3898
                        D       6.0192
              Y/X       A1     10.0628
              Z/X       A2      0.0674
```

Practical exercise:

With the PERPENDICULAR evaluation program the distance of the left side of the groove from the 30 mm hole is defined.

The coordinate system remains in the graduated circle center.

To do

How to do it

What happens

Measure left side of groove

[Elements]
↳ **[Geometric elements]**
↳ **[Surface]**

Measure with four points

Measurement record

```
SURF_5
40     SURFACE   X      -6.097
       Y/X       A1      9.984
       Z/X       A2      0.049
       4PS/MIN/MAX       0.000   (3) -0.000   (4) 0.000
```

Recall 30 mm hole

[Elements]
↳ **[Recall]**

Address = 18
Transformation ? <YES>

Measurement record

```
RECALL_14
41 18! CIRCLE I  X      -0.036
                 Y       0.048
                 D      30.058
```

The PERP can now be calculated.

Calculate perpendicular

[Evaluation]
↳ **[Distance]**
↳ **[Perp-cylinder]**

<TERMIN>

Measurement record

```
PERPCYL_1 (SURF_5, RECALL_14)
42     PERCYL      Y       0.051
                   Z      -1.725
                   D       5.975
       Y/X        A1       9.984
       Z/X        A2       0.049
```

Explanation

Text		Perp-cylinder circle / surface
Z, X		Coordinates of the piercing point
D		Distance
Y/X	A1	Projected angle of the perp-cylinder
Z/X	A2	

Result comparison

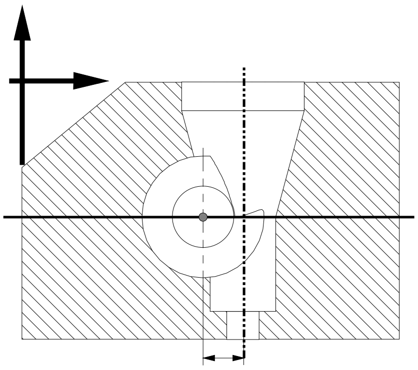
Compare distance with the data in the manufacturing drawing.

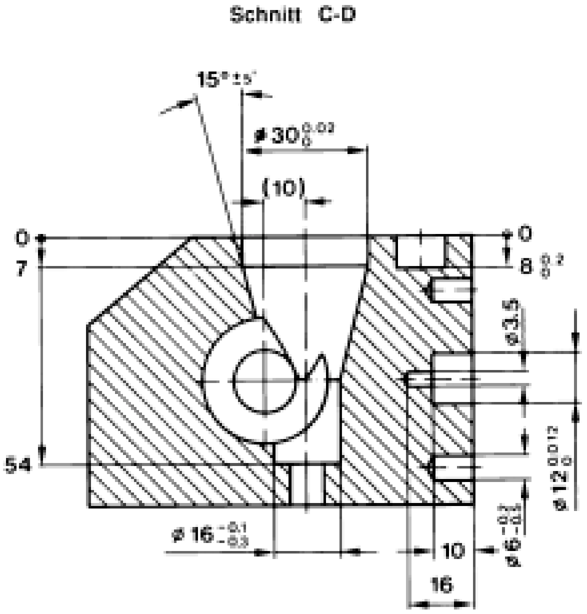
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.9 Distance between two axes

Test feature: Perpendicular
Elements: Cone, cylinder





```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
================================================================================


  16      PERP CYL        Y      31.9993
                        Z    -32.9469
                        D     10.0516
            Y/X       A1     0.0278
            Z/X       A2    -0.0194
```

Practical exercise:

The PERPENDICULAR evaluation program defines the distance between the cone axis and the 30 mm hole axis (front side).

The coordinate system can remain in the graduated circle center.

To do / How to do it / What happens

Recall cone

[Elements]
↳ **[Recall]**

Address = 31
Transformation ? <YES>

```
Measurement record
RECALL_15
43 31! CONE I     X      -0.036
                  Y       0.046
                  D      33.748
      X/Z        A1      -0.016
      Y/Z        A2       0.072
                 AC     -29.996
```

Recall 30 mm hole

[Elements]
↳ **[Geometric elements]**
↳ **[Cylinder]**

Measure 8 points for cylinder

```
Measurement record
CYL_2
44    CYL I       Z     -33.086
                  X      -9.971
                  D      30.002
      Y/X        A1      -0.109
      Z/X        A2       0.066
      8PS/MIN/MAX         0.001   (3) -0.001   (7) 0.001
```

You can now calculate the perpendicular.

Calculate perpendicular

[Evaluation]
↳ **[Distance]**
↳ **[Perp-cylinder]**

<TERMIN>

```
Measurement record
PERP_CYL_2 (RECALL_15, CYL_2)
45    PERP CYL  Y      0.0048
                Z     -33.084
                D       9.944
      Y/X      A1      -0.066
      Z/X      A2       0.016
```

Explanation

Text		Perp-cylinder cone / cylinder
Z, X		Coordinates of the piercing point
D		Shortest distance
Y/X	A1	Projected angle of the line which
Z/X	A2	is vertical to the two axes.

Result comparison

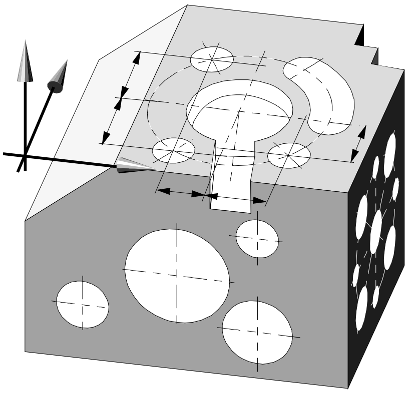
Compare with the manufacturing drawing.

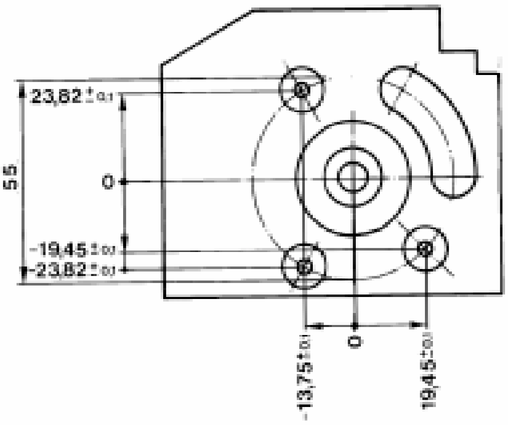
This is the end of the practical exercise.

Worksheet 5: Measuring tasks

5.2.11 Distance of holes to the graduated circle center

Test feature: Cartesian distance
Elements: Circle





```
==============================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
==============================================================================


  18   16 DIST 17       X     13.7893
                        Y     23.7980

  21   19 DIST 20       X     13.7220
                        Y     23.8368

  24   22 DIST 23       X     19.4614
                        Y     19.4356
```

Practical exercise:

The distance of the holes to the graduated circle center point are to be defined.

Note:
The workpiece coordinate system is again at the front upper left.

To do | How to do it | What happens

Recall coordinate system

[Elements]
↳ **[Recall]**

Address = 8

```
Measurement record
RECALL_16
46      8 *COORD. SYSTEM AS FOR ADR.   8
```

Recall Circle 1

[Elements]
↳ **[Recall]**

Address = 9
Transformation ? <YES>

```
Measurement record
RECALL_17
47 9! CIRCLE I    X     38.135
                  Y     55.797
                  D     12.114
```

Recall graduated circle

[Elements]
↳ **[Recall]**

Address = 12
Transformation ? <YES>

```
Measurement record
RECALL_18
48 12! CIRCLE I   X     51.889
                  Y     31.979
                  D     55.007
```

The distance can now be calculated.

Calculate distance

[Evaluation]
↳ **[Distance]**
↳ **[Cartesian]**

```
Measurement record
DIST_1 (RECALL_17, RECALL_18)
49      47 DIST 48  X     13.754
                    Y     23.817

Text            Distance circle / circle
X, Y            Absolute Cartesian distance of the
                        circles
```

The distance for the first hole has now been calculated. Now the distance of hole 2 to the graduated circle will be calculated.

Continued overleaf.

To do	How to do it	What happens
Recall Circle 2	**[Elements]** ↳ **[Recall]** Address = 10 Transformation ? <YES>	**Measurement record** RECALL_19 50 10! CIRCLE I X 38.139 Y 8.160 D 12.105

The hole distance can be calculated as the distance result is skipped.

To do	How to do it	What happens
Distance of circle 2 to the graduated circle center point	**[Evaluation]** ↳ **[Distance]** ↳ **[Cartesian]**	**Measurement record** DIST_2 (RECALL_18, RECALL _19) 51 48 DIST 50 X 13.750 Y 23.819 **Explanation** Text Distance circle / circle X, Y Absolute Cartesian distance of the circles
Recall Circle 3	**[Elements]** ↳ **[Recall]** Address = 11 Transformation ? <YES>	**Measurement record** RECALL_20 52 11! CIRCLE I X 71.337 Y 12.532 D 12.099
Recall graduated circle	**[Elements]** ↳ **[Recall]** Address = 12 Transformation ? <YES>	**Measurement record** RECALL_21 53 12! CIRCLE I X 51.889 Y 31.979 D 55.007

The distance can now be calculated.

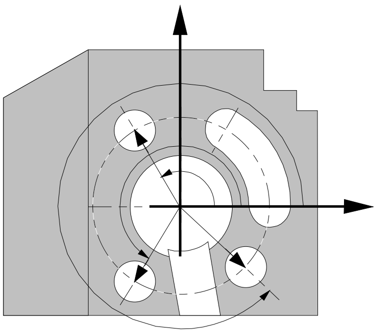
To do	How to do it	What happens
Calculate distance	**[Evaluation]** ↳ **[Distance]** ↳ **[Cartesian]**	**Measurement record** DIST_3 (RECALL_20, RECALL_21) 54 52 DIST 53 X 19.484 Y 19.493 Text Distance circle / circle X, Y Absolute Cartesian distance of the circles
Result comparison	Compare the distances with the entries in the manufacturing drawing.	

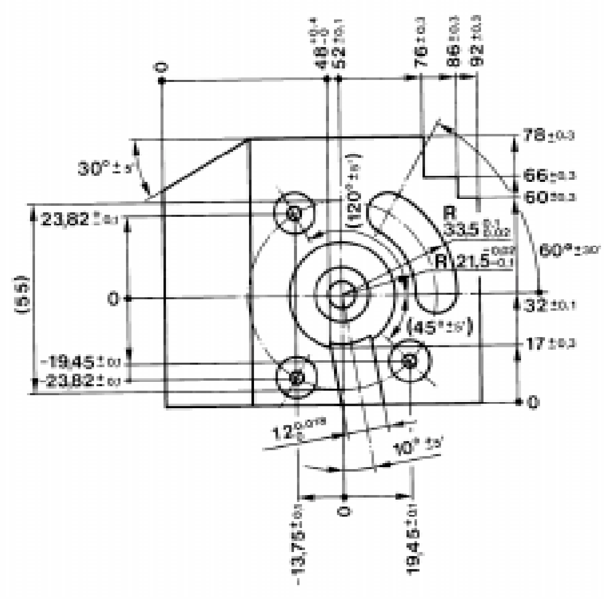
This is the end of the practical exercise.

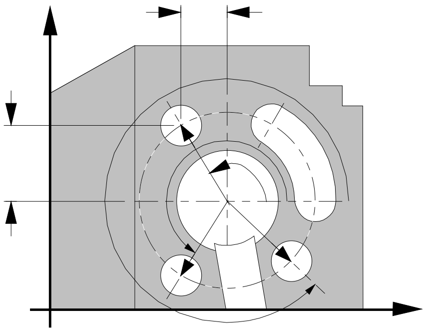
Worksheet 5: Measuring tasks

5.2.12 Distance of the holes to the graduated circle center

Test feature: Polar distance
Elements: Circle







```
================================================================================
 ADR|REC | TASK    | IDF |SY| ACTUAL    |NOMINAL    | U.TOL | L.TOL | DEV    |
================================================================================

  16      POLAR         R     27.5043
              Y/X       A1   120.0894

  18      POLAR         R     27.5043
              Y/X       A1   240.0726

  20      POLAR         R     27.5043
              Y/X       A1   315.0381


  27   38 DIST 39       X     13.7893
                        Y     23.7980

  28      POLAR         R     27.5043
              Y/X       A1   120.0894


  31   30 DIST 31       X     13.7220
                        Y     23.8368

  32      POLAR         R     27.5043
              Y/X       A1   240.0726


  35   34 DIST 35       X     19.4614
                        Y     19.4356

  36      POLAR         R     27.5043
              Y/X       A1   315.0381
```

Practical exercise:

The polar angles of the hole pattern are to be evaluated in decimal degrees and degrees/minutes/seconds.

First the workpiece coordinate system is moved to the graduated circle center. Then the holes individually converted to the new workpiece coordinate system.

To do	How to do it	What happens
Move the zero position to the graduated circle center	**[Elements]** ↳ **[Recall]** Address = 13	**Measurement record** RECALL_22 55 13 * COORD.-SYSTEM AS FOR ADR. 13 **Explanation** To update the coordinate system, you simply recall the address with the zero point.
Recall 1st hole	**[Elements]** ↳ **[Recall]** ADR = 9 (absolute) or ADR = -xx (relative) Transf. to new coord.? <YES>	**Measurement record** RECALL_23 56 9! CIRCLE X -13.742 Y 23.817 D 12.114 **Explanation** The circle center point is output in the new coordinate system. 9 Address 56 is the old Address 9. ! It has been converted.
Convert the 1st hole to polar coordinates	**[Evaluation]** ↳ **[Distance]** ↳ **[Polar]**	**Measurement record** POL2D_1 (RECALL_23) 60 POLAR R 27.503 Y/X A1 120.006 **Explanation** The Cartesian coordinates are converted to cylinder coordinates. R Radius Y/X A1 Polar angle in decimal degrees.

Now we just need the conversion in degrees/minutes/seconds.

Continued overleaf.

To do

How to do it

What happens

Conversion to degrees

[Evaluation]
↳ **[Angle]**
↳ **[Output º/ ' / "]**

```
Measurement record
                         A1120 DEGR   0 MIN    25.11 SEC
```

Recall 2nd hole

[Elements]
↳ **[Recall]**

ADR = 10 (absolute) or

ADR = -xx
Transf. to new coord.?
<YES>

```
Measurement record
RECALL_24
58 10! CIRCLE     X    -13.750
                  Y    -23.819
                  D     12.105
```

Convert 2nd hole to polar coordinates

[Evaluation]
↳ **[Distance]**
↳ **[Polar]**

```
Measurement record
POL2D_2(RECALL_24)
59      POLAR       R      27.504
        Y/X        A1     240.003
```

Conversion to degrees

[Evaluation]
↳ **[Angle]**
↳ **[Output º/ ' / "]**

```
Measurement record
                         A1240 DEGR   0 MIN     12.51 SEC
```

Recall 3rd hole

[Elements]
↳ **[Recall]**

ADR = 11 (absolute) or

ADR = -xx
Transf- to new coord.?
<YES>

```
Measurement record
RECALL_25
60 11! CIRCLE     X     19.448
                  Y    -19.448
                  D     12.099
```

Convert 3rd hole to polar coordinates

[Evaluation]
↳ **[Distance]**
↳ **[Polar]**

```
Measurement record
POL2D_3 (RECALL_25)
61      POLAR       R      27.504
        Y/X        A1     314.999
```

Conversion to degrees

[Evaluation]
↳ **[Angle]**
↳ **[Output º/ ' / "]**

```
Measurement record
                         A1314 DEGR   59 MIN    58.67 SEC
```

Result comparison

Compare angles to the data in the manufacturing drawing.

This is the end of the practical exercise.

Practical exercise:

The hole pattern can also be evaluated if the coordinate system is not located in the graduated circle center.

To do

How to do it

What happens

Move zero position to the front left corner

[Elements]
↳ **[Recall]**

Address = 8

Measurement record

```
RECALL_26
62   8  *COORD.-SYSTEM AS FOR ADR.  8
```

Explanation
To update the coordinate system, you simply recall the address with the zero point.

Recall graduated circle center

[Elements]
↳ **[Recall]**

ADR = 12 (absolute) or

ADR = -xx (relative)
Transf. to new coord.?
<YES>

Measurement record

```
RECALL_27
63 12! CIRCLE      X      51,889
                   Y      31.979
                   D      55.007
```

Explanation
The graduated circle center point is output in the new coordinate system.

12 Address 63 is the old Address 12.
! It has been converted.

Recall 1st hole

[Elements]
↳ **[Recall]**

ADR = 9 (absolute) or

ADR = -xx (relative)
Transf. to new coord.?
<YES>

Measurement record

```
RECALL_28
64 9!  CIRCLE      X      38.135
                   Y      55.797
                   D      12.114
```

Calculate distance

[Evaluation]
↳ **[Distance]**
↳ **[Cartesian]**

Measurement record

```
DIST_4  (RECALL_27, RECALL_28)
65     63 DIST 64  X      13.754
                   Y      23.817
```

Continued overleaf.

To do	How to do it	What happens
1 Convert 1st hole to polar coordinates	**[Evaluation]** ↳ **[Distance]** ↳ **[Polar]**	**Measurement record** POL2_2D (DIST_4) 66 POLAR R 27.504 Y/X A1 120.006
Conversion to degrees	**[Evaluation]** ↳ **[Angle]** ↳ **[Output º/ ' / "]**	**Measurement record** A1120 DEGR 0 MIN 25.66 SEC

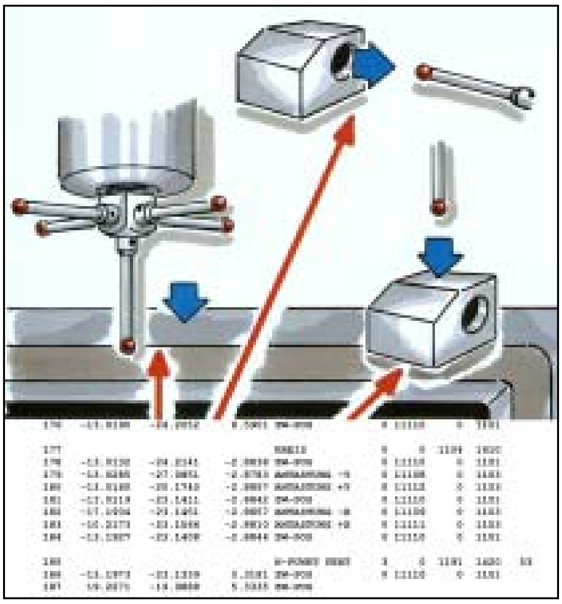
Note
Holes 2 and 3 are evaluated in the same way. To do this, see practical exercise 34.

Worksheet 6: CNC Programming

6.1 Introduction

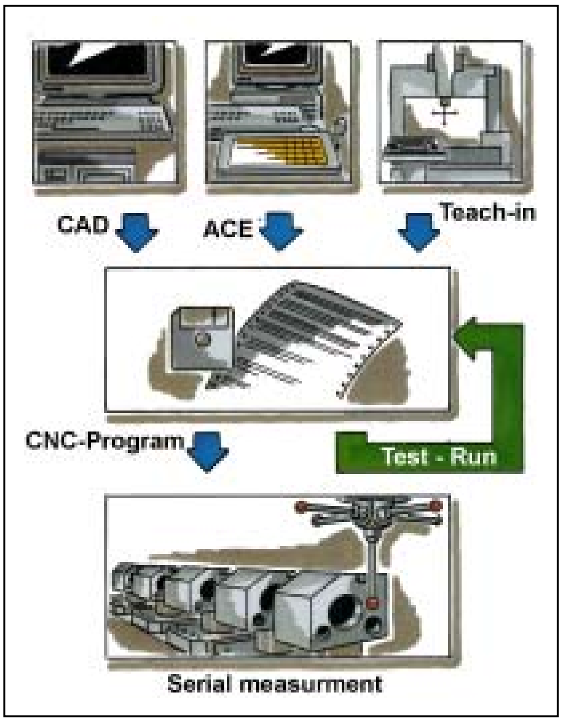
Automatic, CNC controlled measuring run

Till now we have been measuring manually with the machine. However our goal is: The measurement procedure should be carried out automatically. To do this, the CMM needs a CNC program. This program must contain all instructions on how the measurement should run. This includes for example, the travel paths, the elements to be probed, the calculations and lastly the output.



How a CNC program is generated

We can create a CNC program with offline parts programming (ACE), by transferring the CNC program or by self-teach programming.
At the moment self-teach (or learn programming) is most often used and we can take this as an example for explaining the general steps for programming. This is why in this seminar we will only be dealing with learn programming.
During learn programming, the measurement of the first workpiece in a production batch is carried out manually. The computer saves all the program call ups, key activations, general steps parallel to the manual measuring run and creates the CNC program from this. After the test run, in which any errors made are recognized and then corrected, the CMM can measure all the remaining parts in the batch automatically.



Planning the measuring run

To achieve an optimum CNC run as quickly as possible, we have to think through the run carefully and plan it beforehand. We can use forms to help us with the planning of the run, such as

- probe plan
- workpiece position plan
- measuring run plan.

In these we can note the various steps required. The individual forms and their layout are explained in the following and then filled in.

Probe plan, selecting the probes

The type of probe and its arrangement is defined depending on the workpiece and the measuring task. Generally the machine is equipped with a probe changer, so we have to consider which probe goes on which plate. You have to observe the permissible limiting values for the individual plates

- weight (mass)
- number of buckling points
- minimum probe ball diameter.
- maximum extensions

These are described in the machine manual.
Check beforehand whether you can use an existing configuration.

The assembly is recorded in the **probe plan**. All the data is entered there, such as e.g. diameter, length, components, etc, so that the probe arrangement can be assembled straightaway at a later date.
At the same time we enter the number of the intended probe configuration, combination and probe. Later the numbers are used to identify the probe in the measuring run plan.

Example: see documentation

Note:
As at the moment UMESS UX does not have a catalog function for the probe data, these probe plans are our documentation for the configurations which already exist.

Workpiece position plan, selecting the clamping

In order to avoid incorrect measurements, the workpiece should

- be thoroughly cleaned,
- be accessible from all sides and be aligned by eye in order to avoid probings with the shaft of the probe.
- It should be firmly clamped, where necessary in a mounting device
- but you must make sure the workpiece is not deformed by the clamping.

Generally, five sides can always be reached for probing, with a suitable clamping device six as well. To ensure a collision-free run, follow-on parts should be clamped in a similar way.
This is why the clamping device, the components required and the general conditions are entered in the **workpiece position plan**.
The next section deals with how the control coordinate system is defined on various workpieces.

Measuring run plan and structured programming

This shows the flow diagram of a CNC program.
Extensive programs always need a measuring run plan before the actual coding of the CNC program takes place on the coordinate measuring machine or ACE station.

The programming

- is more structured,
- is made in a fraction of the time
- is easy to correct

and therefore as a whole more cost-effective.

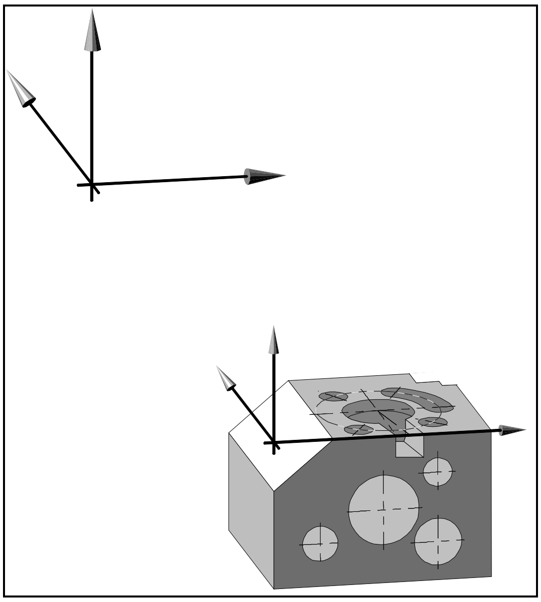
After the probes, the workpiece clamping and the control coordinate system have been defined, we can start creating the measuring run. With this measuring run plan, the program can be converted more quickly on the CMM so that the machine is not blocked unnecessarily.
We recommend a structured, block by block programming:

- Define the machine mode, output mode and other special functions
- Define the exact workpiece coordinate system
- Definition of the exact control coordinate system from the exact workpiece coordinate system
- Block or section by section programming of the actual measurement of the workpiece
- Set the machine to the normal status, i.e. programs which have a long-term effect should be reset.

The programs and steps required for this are then defined in the measuring run plan.
(Example of a measuring run plan in worksheet 7.)

DI 1710

6.2 Control coordinate system for the CNC measuring run



Till now we have carried out the probe travel paths using the joysticks. The travel paths of the probe which is active refer to a previously defined control coordinate system during the learn programming and later in the CNC run.
Yet another coordinate system! Therefore to remind you: We have

- the machine coordinate system. Its zero point lies in one of the positions in the measuring volume defined by the hardware and software. Its axes are parallel to the machine axis. As a result of the alignment we gain
- the workpiece coordinate system. We have positioned its axes and zero point as deemed suitable by the manufacturing drawing. The values measured can then be compared directly with the data in the manufacturing drawing.
- The current workpiece coordinate system is saved on the hard disk as control coordinate system by the program WP No. X.

All standard travel movements during programming and the run refer to this control coordinate system.
In keeping with the program, the control coordinate system (CCS) is also known for short as W-Position.

Defining the control coordinate system

The CCS system is defined by manual probing. The position of the CCS and the steps required for defining it are entered in the **W-Position plan**.
Example: See documentation in next section

Defining the CCS for simple workpieces

We recommend this method for workpieces where the mathematical alignment can be made with only a few probings.

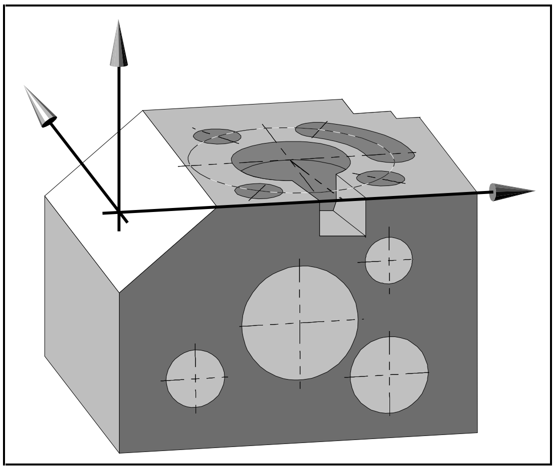
- Manual definition of the workpiece coordinate system:
  - Surface
  - Transformation space
  - Zero point
  - Circle
  - Zero point
  - Cylinder
  - Transformation Plane
- By calling up the program Coordinates
  - ↳ Control system WP
    - ↳ WP No. x ...

  we save the current WPS as control coordinate system.

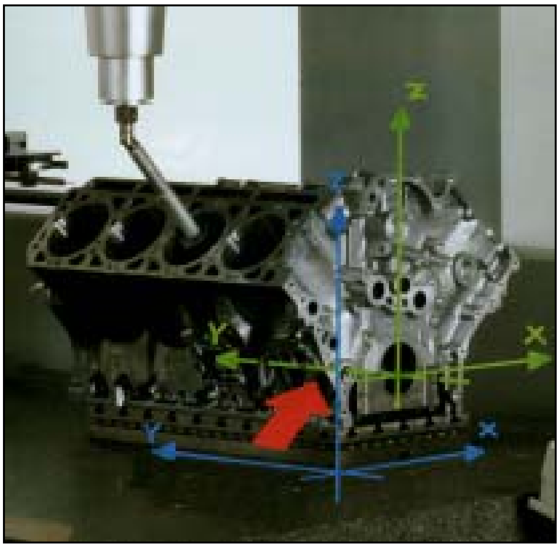
Defining the CCS of another simple workpiece

Procedure as above:

- Complete the W-Position plan
- Define the CCS with manual probing
- save the CCS with the program WP No. x ...



Defining the CCS for complex workpieces



The manual definition of the CCS should not take up much time. We recommend the following procedure for workpieces

- for which definition of the CCS is relatively complicated (long travel paths, many linkings) and
- for workpieces on pallets or clamping devices.

You define a **temporary control coordinate system** with just a few probings. This is then replaced in the CNC run with the **exact control coordinate system** which belongs to the respective workpiece.

How to proceed:

- Carry out the alignment according to characteristic elements which are easily accessible e.g. of the workpiece or the clamping device.
- Call up program WP No. x ...
  Enter the steps in the W-Position plan

The CCS has now been defined so that by probing in the CNC run, the workpiece is found and a new exact workpiece coordinate system can be defined. This WPS can be defined to an exact control coordinate system by programming in the W-Position. Now both coordinate systems are identical again.

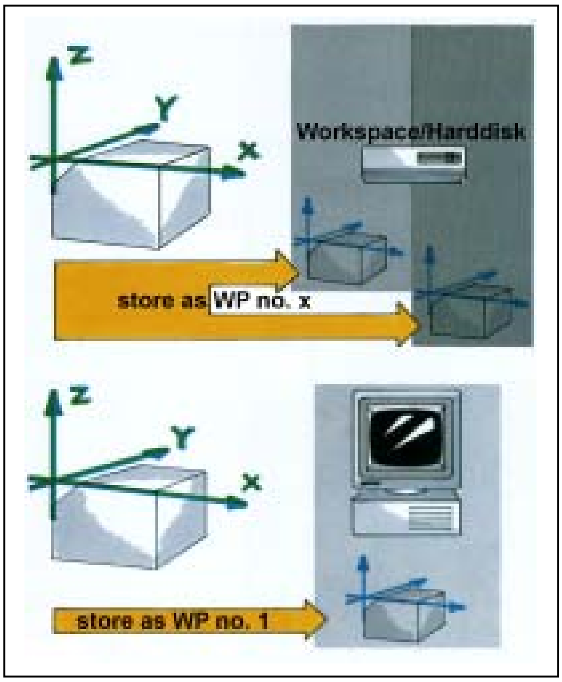
Defining the CCS of another complicated workpiece

Procedure as before:

- Complete W-Position plan
- Define CCS by manual probing
- Save using the program WP No. x ...

The exact definition of the CCS is made in the CNC run.

Inputs in the program WP No. x ...



DI 1710

As you later want the CCS to be available straightaway, in order to start the CNC run, it is saved under a number with a maximum of four digits. So that the number is easier to assign to a workpiece, you can enter a comment for each CCS.
To make sure you do not overwrite an existing CCS, you can

- list the W-Positions which already exist by pressing the <CATALOG> function, or
- leave the default "Overwrite W-Pos?" as NO. If there is already a CCS under this number, a message will be displayed. You can then look for a free number using the catalog.
  If you change the default to YES, the existing CCS is overwritten.

After pressing <TERMIN>, the CCS is saved in the computer and on the hard disk.

Computer-internal control coordinate systems

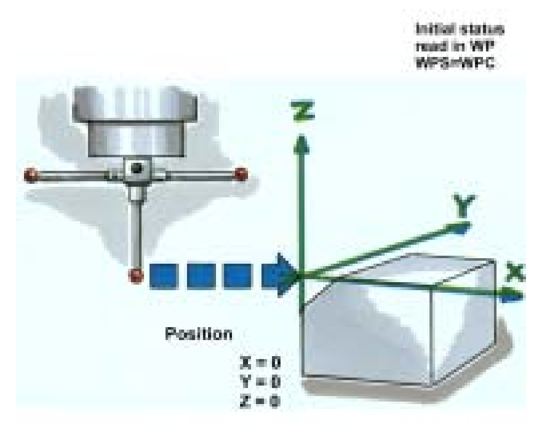
DI 1708

You define the exact control coordinate system within the CNC run. This can also be saved under a number.
So that the contents of the W-Position catalog remain easy to identify, and you often need several exact control coordinate systems for complicated workpieces, we recommend you keep the program-internal CCS only in the computer.
To do this, use

↳ Control system WP
    ↳ WP No. 1

This CCS is only found in the computer, is however automatically generated or adapted by the CNC run.

Access options to specific control coordinate systems



How can we find out whether a saved CCS has been completely defined. You can find out the position of the CCS using the following steps:

- Coordinates
  ↳Preparation
  ↳Initial status
  All alignments are deleted.

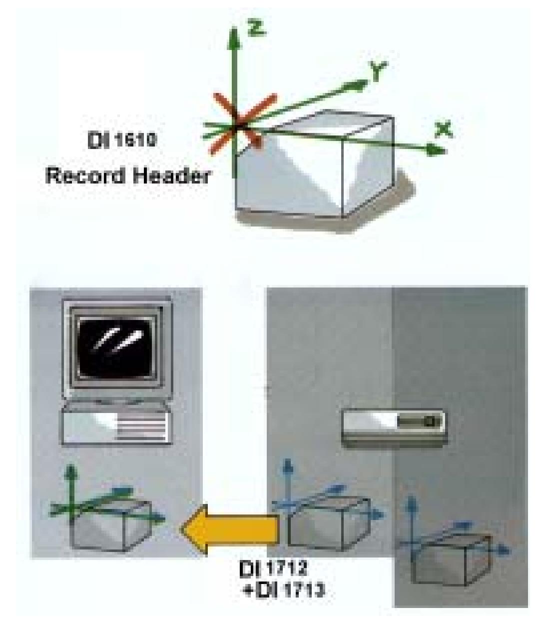
- Coordinates
  ↳Preparation
  ↳Read WP
  After entering the W-Position number and pressing <TERMIN>, the CCS selected is loaded to the computer.

- Coordinates
  ↳ Preparation
  ↳WPS = WPOS
  A workpiece coordinate system is formed again from the CCS.

- CMM
  ↳Travel commands
  ↳Position
  with probing NO
  Rough position Yes
  And input of the value zero for X, Y and Z and <TERMIN>

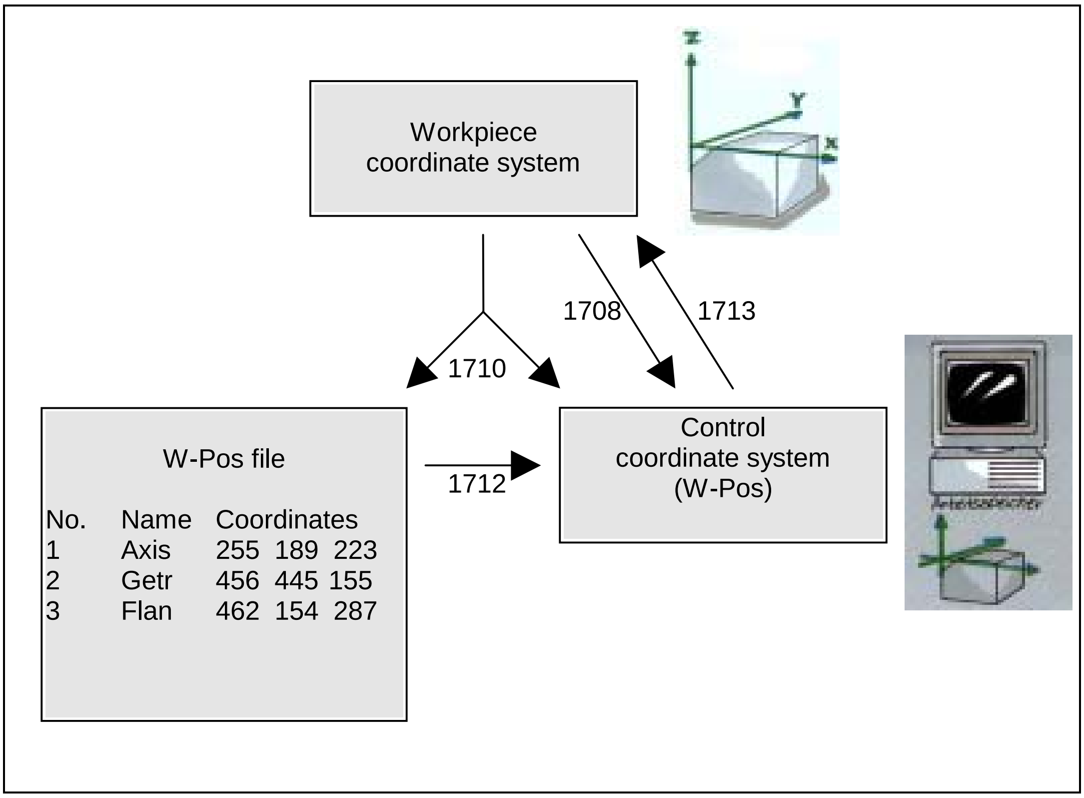
the probe which is active moves to the zero point. If there is a corner, the probe radius must be taken into consideration in one axis direction.

Further use for the program WPS=WPOS



After calling up the record header or setting the initial status, the workpiece coordinate system is deleted. The control coordinate system in the computer is however retained. Using this program we gain an initial, if somewhat approximate, workpiece coordinate system.
We will see its use in the CNC program later.

Overview of the functions for W-Position



No.	Name	Coordinates
1	Axis	255 189 223
2	Getr	456 445 155
3	Flan	462 154 287

DI 1708: Temporary W-Pos in the computer

- Coordinates
  - ↳Control system WP
    - ↳ WP No. 1

DI 1710: W-Position in the computer and save to hard disk (W-Pos file)

- Coordinates
  - ↳ Control system WP
    - ↳ WP No. x

DI 1712: Read in the W-Pos from the W-Position file to the computer

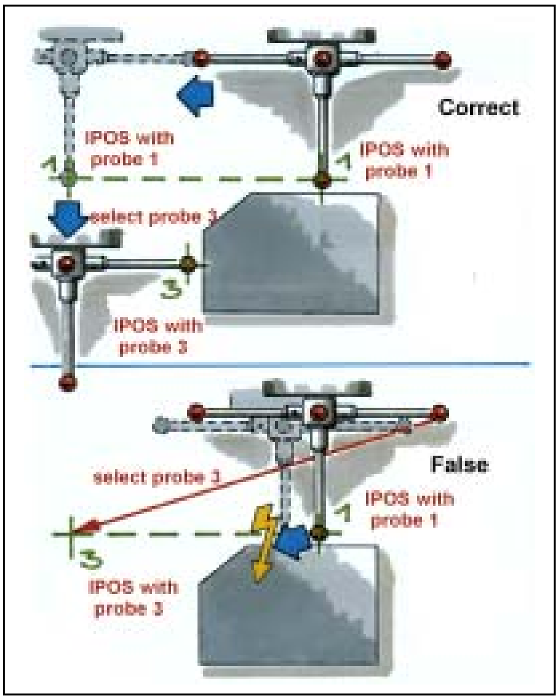
- Coordinates
  - ↳Preparation
    - ↳ Read WPOS

DI 1713: Generate a WCS from the W-Position in the computer

- Coordinates
  - ↳Preparation
    - ↳ WPS = WPOS

6.3 Intermediate positions and nominals

Defining the intermediate positions



This is where the control coordinate system is used. So that the probe can move from one probing to the next without causing a collision, we have to define probing detours. This is done as follows:

- Move the probe to the desired location
- Press the I-POS key on the CMM control panel

The X, Y and Z values referring to the active probe are saved.

Notes:

- The start and end point are usually placed above the workpiece so that the probe can move from one workpiece to the next (e.g. pallet measurement).
- The detour points lie outside the element. The last detour point before travelling to the section height or measurement position should be before the element is called.
- All the other intermediate points should lie within a measuring element and be assigned to it by the structure.
- If you forget any IPOS points you can edit them later.
- Too many IPOS points slow up the CNC run. Intermediate points are not entered in the measuring run plan as otherwise it would become too long and unclear.

Entering the nominals

−−−+++

DI 1452

The nominals and tolerances are taken from the manufacturing drawing and entered in the measuring run plan.

- The nominals are entered straightaway during programming. Input is always made before measurement of the element or before calculation of a result using linkings.

  You will find both cases under
    - Nom/Act
      - enter

- If elements are to be toleranced straightaway, the nominal input can be made after the probing has been carried out using the NOM/ACT button.

- With PCM macros, the nominal input is made within the input mask.

Summary: Planning the measuring run

Before programming

- Select the probes and create probe plan.
- Select the clamping, define the control coordinate system, create W-position plan.
- Create the measuring run plan.

Subsequently on the machine

- Define the control coordinate system with manual probing.
- Save the control coordinate system under a number with WP No. x ...
- Learn programming as per measuring run plan.

6.4 Exercise with control data editor

The following CNC run has been programmed but has 2 defects:
1. An intermediate position has been forgotten
2. The tolerances for a hole have not be given

These corrections have to be made.

The measurement record and the control data of the program "CNC1":

```
================================================================================
                         MEASURING RECORD    ZEISS  UMESS

Cube                                          CNC RUN
====
DRAWING NO         | ORDER NO          | SUPPLIER/CUSTOMER | OPERATION
1234567            |522/700            |daimler            |050

OPERATOR          | DATE        | PART NO       |
OPERATOR          | 15.10.1997  | 10
================================================================================
 ADR|REC | TASK   | IDF |SY| ACTUAL   | NOMINAL  | U.TOL | L.TOL | DEV   | EXC
================================================================================
   1   WP same as WPOS  X      0.0000
                        Y      0.0000
                        Z      0.0000

   2      SURFACE       Z      0.2079
              X/Z       A1     0.0394
              Y/Z       A2     0.0045
       4P S/MIN/MAX             .0011       (2)  -.0007     (3)   .0007

   3      ROTATE SPACE  A      -.0397

   4      ZERO PT       Z      0.2079

   5      POINT         Y      0.1365

   6      POINT         Y     -0.4212

   7      ROTATE PLANE  A      -.5630  ABOUT SPACE AXIS Z

   8      ZERO PT       Y     -0.7102

   9      POINT         X      0.3868

  10      ZERO PT       X      0.3868

  11      CIRCLE I      X     52.0434
                        Y     31.9375
                        D     30.0050
       4P S/MIN/MAX             .0007       (3)  -.0004     (2)   .0004

  12      CIRCLE I      X     38.3192
                        Y     55.7556
                        D     11.9709
       4P S/MIN/MAX             .0041       (4)  -.0022     (1)   .0025

  13      CIRCLE I      X     38.2854
                        Y      8.1066
                        D     11.9736
       4P S/MIN/MAX             .0036       (1)  -.0019     (3)   .0021

  14      CIRCLE I      X     71.4768
                        Y     12.4476
                        D     11.9716    12.0000  0.1000 -0.1000 -0.0284   --
       4P S/MIN/MAX             .0041       (1)  -.0021     (3)   .0022
================================================================================
                                  CNC - END
================================================================================
```

```
================================================================================

                      CONTROL DATA LIST    ZEISS  UMESS

WORKPIECE NAME:   CNC1_Exercise Control data
FILE NAME:  CNC________42B
CONTROL DATA LINES:   100            NOMINAL LINES:     0
================================================================================
    |     X    |     Y    |     Z    |            |     |     |     |     |
 NO |--------------------------------|  Function  | SC2 | SC1 | PCN | CCN | ADR
    |            Dialog              |
   Snr  | Record type                | Idf  |Sy  |Nominal  | U.Tol | L.Tol
   Snr  |                  |MEadr|   | Idf  |Sy  |   t     |(M)|    A   |(M)
================================================================================
   1  1001   3   0     0.0000  1.0000 P_PARAM          2     7     0  1500
   2  2001   3   0     0.0000  0.0000  DL P_PARAM      2     0     0  1911
   3  1020   3   0     0.0000  0.0400  DL F_PARAM      1     0     0  1911
   4  2000   3   0     0.0050  0.0000 MEAS_FORCE       3     0     0  1911
   5  1004   3   0     0.0000  5.5000  DL F_PARAM      1     0     0  1911
   6  1001   3   0     0.0000 75.0000  DL F_PARAM      1     0     0  1911
   7  1014   3   0     0.0000 1000.00 LDL F_PARAM      1     0     0  1919
   8     1   1   1 10  0.0000  0.0000 REC DEF          0     1  1665     0
   9     2   1   1 10  0.0000  0.0000 REC DEF          0     1  1665     0
  10                                  PRINTER ON       0     0  1614     0
  11                                  TERMINAL EIN     0     0  1615     0
  12 Wuerfel                          RECORD HEAD      0     8  1610  1650
  13 1234567            |              DL R-HEAD       0     0  9911     0
  14 522/700            |              DL R-HEAD       0     0  9911     0
  15 daimler            |              DL R-HEAD       0     0  9911     0
  16 050                               DL R-HEAD       0     0  9911     0
  17                                   DL R-HEAD       0     0  9911     0
  18                                  LDL R-HEAD       0     0  9919     0
  19         55                       WPOS F DISK      0     1  1712  1610
  20                                  WPOS TO WSYS     0     0  1713  1640    1
  21    27.8869     9.1506    92.2804 I-POS            0 11110     0  1101

  22                                  SURFACE          0     0  1103  1410
  23    29.9492     9.1510     9.9095 I-POS            0 11110     0  1101
  24    29.9538     9.1511     2.6871 PROBING -Z       0 11107     0  1103
  25    29.9565    64.6270     9.6796 I-POS            0 11110     0  1101
  26    29.9570    64.6300     2.6816 PROBING -Z       0 11107     0  1103
  27    68.2331    64.6295    12.9405 I-POS            0 11110     0  1101
  28    68.2372    64.6296     2.6565 PROBING -Z       0 11107     0  1103
  29    86.1817     8.8798    10.3344 I-POS            0 11110     0  1101
  30    86.1823     8.8809     2.6475 PROBING -Z       0 11107     0  1103

  31                                  N POINT TERM     3     0  1191  1420    2
  32                                  ROTATE SPACE     0     0  1706  1640    3
  33                                  ZERO POINT       0     0  1701  1640    4
  34    86.1827     8.8778     7.9625 I-POS            0 11110     0  1101
  35    86.1816   -12.6223     7.9622 I-POS            0 11110     0  1101
  36    86.1822   -12.6137    -5.4633 I-POS            0 11110     0  1101

  37                                  POINT            0     0  1101  1410
  38    86.1818    -2.3639    -5.4666 PROBING +Y       0 11112     0  1103

  39                                  N POINT TERM     2     0  1191  1420    5
  40    29.4192   -12.5065    -5.4667 I-POS            0 11110     0  1101

  41                                  POINT            0     0  1101  1410
  42    29.4183    -2.9216    -5.4666 PROBING +Y       0 11112     0  1103

  43                                  N POINT TERM     2     0  1191  1420    6
  44    29.4172   -12.1000    -5.4667 I-POS            0 11110     0  1101
  45          3   359.4370            TR PLANE         0     1  1702  1640    7
  46                                  ZERO POINT       0     0  1701  1640    8
  47   -12.3389   -12.0991    -5.4668 I-POS            0 11110     0  1101
  48   -12.3281     6.3603   -27.4729 I-POS            0 11110     0  1101

  49                                  POINT            0     0  1101  1410
  50    -2.1948     6.3616   -27.4723 PROBING +X       0 11111     0  1103

  51                                  N POINT TERM     1     0  1191  1420    9
  52    -9.4276     6.3597   -27.4723 I-POS            0 11110     0  1101
  53                                  ZERO POINT       0     0  1701  1640   10
  54                                  W-POS            0     0  1708  1610
  55    -9.7694     7.1608    27.6043 I-POS            0 11110     0  1101
  56    51.8518    33.4457    12.9251 I-POS            0 11110     0  1101

  57                                  CIRCLE           0     0  1104  1410
  58    51.8622    33.4469    -2.0903 I-POS            0 11110     0  1101
  59    64.4693    33.3224    -2.0817 PROBING +X       0 11111     0  1103
  60    39.6470    33.5661    -2.0987 PROBING -X       0 11109     0  1103
  61    52.8696    33.4370    -2.0896 I-POS            0 11110     0  1101
  62    52.9789    44.4046    -2.0887 PROBING +Y       0 11112     0  1103
  63    46.9754    20.5087    -2.0947 PROBING -Y       0 11108     0  1103
  64    52.1543    33.3010    -2.0901 I-POS            0 11110     0  1101

  65                                  N POINT TERM     3     0  1191  1420   11
  66    52.1423    33.2996    15.8998 I-POS            0 11110     0  1101
  67    38.6974    55.7409     7.5044 I-POS            0 11110     0  1101

  68                                  CIRCLE           0     0  1104  1410
  69    38.7037    55.7401    -1.6171 I-POS            0 11110     0  1101
  70    38.7379    59.2184    -1.6173 PROBING +Y       0 11112     0  1103
  71    38.6697    52.2864    -1.6179 PROBING -Y       0 11108     0  1103
  72    38.7130    56.6876    -1.6180 I-POS            0 11110     0  1101
  73    34.9727    56.7239    -1.6206 PROBING -X       0 11109     0  1103
  74    41.6838    56.6568    -1.6150 PROBING +X       0 11111     0  1103
  75    38.1010    56.6941    -1.6174 I-POS            0 11110     0  1101

  76                                  N POINT TERM     3     0  1191  1420   12
  77    38.0910    56.6927     9.1660 I-POS            0 11110     0  1101
  78    38.5723     8.8225     9.4839 I-POS            0 11110     0  1101

  79                                  CIRCLE           0     0  1104  1410
  80    38.5814     8.8228    -1.5270 I-POS            0 11110     0  1101
  81    41.7022     8.7926    -1.5249 PROBING +X       0 11111     0  1103
  82    34.8827     8.8597    -1.5320 PROBING -X       0 11109     0  1103
  83    38.5014     8.8241    -1.5286 I-POS            0 11110     0  1101
  84    38.5296    11.5869    -1.5283 PROBING +Y       0 11112     0  1103
  85    38.4621     4.6229    -1.5289 PROBING -Y       0 11108     0  1103
  86    38.5023     8.7121    -1.5286 I-POS            0 11110     0  1101

  87                                  N POINT TERM     3     0  1191  1420   13
  88    71.5377    12.7352    10.7829 I-POS            0 11110     0  1101

  89                                  CIRCLE           0     0  1104  1410
```

```
  90    71.5478    12.7366    -1.5970 I-POS            0 11110     0  1101
  91    74.9510    12.7036    -1.5947 PROBING +X       0 11111     0  1103
  92    68.0080    12.7715    -1.5999 PROBING -X       0 11109     0  1103
  93    71.6723    12.7364    -1.5974 I-POS            0 11110     0  1101
  94    71.7041    15.9282    -1.5971 PROBING +Y       0 11112     0  1103
  95    71.6362     8.9636    -1.5978 PROBING -Y       0 11108     0  1103
  96    71.6731    12.7189    -1.5974 I-POS            0 11110     0  1101
  97    71.6629    12.7202    13.8310 I-POS            0 11110     0  1101

  98                                  N POINT TERM     3     0  1191  1420   14
  99    49.7195    53.5170   136.8430 I-POS            0 11110     0  1101
 100                                  P-END
```

Program section with correction:

```
  78    38.5723     8.8225     9.4839 I-POS           0 11110     0  1101

  79                                  CIRCLE          0     0  1104  1410
  80    38.5814     8.8228    -1.5270 I-POS           0 11110     0  1101
  81    41.7022     8.7926    -1.5249 PROBING +X      0 11111     0  1103
  82    34.8827     8.8597    -1.5320 PROBING -X      0 11109     0  1103
  83    38.5014     8.8241    -1.5286 I-POS           0 11110     0  1101
  84    38.5296    11.5869    -1.5283 PROBING +Y      0 11112     0  1103
  85    38.4621     4.6229    -1.5289 PROBING -Y      0 11108     0  1103
  86    38.5023     8.7121    -1.5286 I-POS           0 11110     0  1101
  87    38.5023     8.7121    10.8000 I-POS           0 11110     0  1101

  88                                  N POINT TERM    3     0  1191  1420   13
  89    71.5377    12.7352    10.7829 I-POS           0 11110     0  1101
  90 D               1  0   0   0   0 NOMINALS SN     0     2  1459     0
  91        12.0000   0.1000  -0.1000 LDL NOM V SN    1     0  9919     0
  92                 0  0   0   0   0 NOMINALS SN     0     2  1459     0
  93                  0.0000   0.0000 LDL NOM V SN    0     0  9919     0

  94                                  CIRCLE          0     0  1104  1410
  95    71.5478    12.7366    -1.5970 I-POS           0 11110     0  1101
  96    74.9510    12.7036    -1.5947 PROBING +X      0 11111     0  1103
  97    68.0080    12.7715    -1.5999 PROBING -X      0 11109     0  1103
  98    71.6723    12.7364    -1.5974 I-POS           0 11110     0  1101
  99    71.7041    15.9282    -1.5971 PROBING +Y      0 11112     0  1103
 100    71.6362     8.9636    -1.5978 PROBING -Y      0 11108     0  1103
 101    71.6731    12.7189    -1.5974 I-POS           0 11110     0  1101
 102    71.6629    12.7202    13.8310 I-POS           0 11110     0  1101

 103                                  N POINT TERM     3     0  1191  1420   14
 104    49.7195    53.5170   136.8430 I-POS           0 11110     0  1101
 105                                  P-END           0     0  9999  1999
```

Worksheet 6: Example of a CNC run

Overview

Preparations

1.	Define the workpiece clamping	
2.	Select the probes, assemble, calibrate	15228
3.	Define the W-position, measure and save	1710
4.	Define the measuring run	
5.	Create a measuring run flowchart, probe plan and W-position plan.	

Learn programming

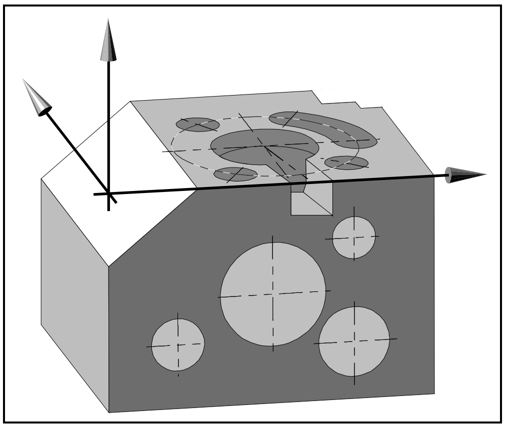
1.	Call up the learn programming	1639
2.	Define the control mode	1661
3.	Define the output mode	1662
4.	Measuring probe head mode	1502
5.	Switch on printer	1614
6.	Switch off printer	1615
7.	Print record header	1610
8.	Read in W-position	1712
9.	WPS = WPOS	1713
10.	Automatic probe change	1553
11.	Measure and save "Fine W-Pos"	1708
12.	Carry out measurements on the workpiece	
13.	Reset control mode	1661
14.	Reset output mode	1662
15.	Switch off printer	1615
16.	End learn programming	1632

6.1 Task

This section describes the CNC programming of a run on the practice cube. An alignment and three surfaces are to be programmed, and then the evaluation of the hole pattern of the 12mm holes on the top of the workpiece. Finally the evaluation of the circular groove on the top.

The "circle segment" function is used for this.

Elements
- ↳ Special elements
  - ↳ Circle segment



All the steps in the measuring run flowchart are explained in the following.

To program runs quickly which are free of error requires good documentation, the measuring run flowchart in this example is very detailed. However, correction with the control data editor is almost always necessary, for example in order to insert intermediate positions which have been forgotten, or nominals or other functions or to delete them.

Preferably you should program a specific part of the program and then test it. For example you can program the alignment and then test is as CNC run for any errors. If this is done satisfactorily, you can continue programming by calling up Programming Start.

CNC
- ↳ Prog.
  - ↳ Start

The last control data line in the current program offered. If the test run was successful, the address counter, the intermediate positions as well as the alignment are in the correct position.

DI 1639

The individual steps in detail:

Control probing mode DI 1661
The general conditions for the measurement are defined. The settings are saved and can be adapted where necessary by editing.

Output mode DI 1662
Using this program you define which results are to be output where and how. Normally on the printer the output is reduced, whereas on the monitor everything is displayed.

MPH mode DI 1502
Activate the vectorial probing

Printer on DI 1614

Terminal on DI 1615
One of the functions is masked, test or measurement, as necessary.

Name allocation DI 1663
Deactivate name allocation. It can be activated when necessary.

Other programs can be planned where necessary.

Record header DI 1610
You can now enter the workpiece-specific codes in the record header. It is output updated for each CNC run.

Read W-Position DI 1712
The control coordinate system required for the measurement is read from the memory.

WPS = CCS DI 1713
In order for the first measurement results to be output straightaway to a known workpiece coordinate system, a temporary workpiece coordinate system is formed from the control coordinate system. The machine coordinate system which the record header has generated is replaced by a temporary workpiece coordinate system.

Probe change DI 1553
The probe configuration required for the measurement is inserted at the start. This is necessary as we cannot assume that the correct configuration is in the probe head at the start of the program.

Defining the alignment elements
In this section, the elements required for generating the workpiece coordinate systems are defined. Normally more points are probed for defining the surfaces, but due to time we will limit ourselves here to four points. No alignment takes place within the measurement so that the workpiece coordinate system is retained.

Generating the WPS required
The elements required are made available via a relative recall and the coordinate transformations required are programmed.

W-POS =1 DI 1708
After an exact alignment has been made within the CNC run, the temporary control coordinate system can be replaced by the exact control coordinate system. This does not need to be recorded in the W-positions catalog, this is why DI 1708 is used instead of DI 1710.

TEXT DI 1676

Headings and notes should be inserted in the record for clarification and for comments.

RESULT COUNTER DI 1690

So that you can later insert forgotten results, the address counter should have gaps in it. If DI 1690 is programmed, this structure is retained even with an automatic new addressing.

CIRCLE DI 1104

With the MACRO, the first evaluation measured is the center hole with a diameter of 30 mm. As the measuring area is not continuous, the parameters have to be entered. After the macro run the element window remains open. The nominals are now entered.

CONE DI 1107

Measurement of the cone with tolerance.

Zero point DI 1701

The zero point is placed in the cone axis.

W-POS = 1 DI 1708

The hole pattern in the top surface is completely dimensioned to this center. So that the same coordinates are in the control data, the control coordinate system is moved to this point.

TEXT DI 1676

So that it is clear that the next evaluation block is the graduated circle, a comment line is output.

CIRCLE DI 1104

The holes of the graduated circle are required using normal probings and intermediate positions.

REC Circle

The graduated circle is defined by recall from the last three elements. The position is toleranced using a standard nominal/actual comparison. The graduated circle diameter should be output again for checking. As there is no tolerance, the lower and upper tolerance is set to open.

ZERO POINT DI 1701

The position of the individual graduated circle holes is to be evaluated to the graduated circle center. This is why the graduated circle center is set to zero.

Evaluation of the position of graduated circle holes

The individual holes are transformed to the current evaluation coordinate system by using a relative recall. As a nominal/actual comparison has been programmed previously, the representation required results in the protocol.

TEXT DI 1676

Comment on the radii check of the circular groove.

RESULT COUNTER DI 1690
So that you can later insert forgotten results, the address counter should have gaps in it. If DI 1690 is programmed, this structure is retained even with an automatic new addressing.

CIRCLE
Defining the start of the groove at zero.

TRANS PLANE ZERO POINT + 1 ELEMENT
The start of the groove can now lie below or above the X axis. So that the angle calculation for the end starts at zero degrees, the X axis is rotated to the start.

W-POS = 1 DI 1708
Rotation of the control coordinate system to the workpiece coordinate system which is now valid.

CIRCLE
Definition of the end of the groove.

POLAR
Conversion of the Cartesian coordinates to polar coordinates.

DEGR/MIN/SEC
The nominal/actual comparison of the angle looked for is not to be made in decimal. The output required can be achieved with this program. First the input of the nominals takes place.

CIRCLE SEGMENT DI 1114
The circle segment is started from the Special Elements menu. The start point is the center of the graduated circle. It is preassigned as fixed input with zero. Due to the four probings, the output of four individual results with nominal/actual comparison is made.

At the end of a CNC program, an initial status should be set for manual measurements. The extent depends on the changes which have been made within the program. The output and control mode is listed here as example.

6.2 Measuring run flowchart

W-Name: Practice cube						Drawing no.:				Date: 02.02.1994			Page 1 / 3
Probes			Addresses		WPS	Step		Nominal					Additional notes/ Travel commands
Cf.:	Cb.:	No.:	ADR	REC	CCS	Prog/Task	Name	SYM	IDF	nom	U-T	L-T	
						DI 1661							Control probing mode
						DI 1662							Output mode
						DI 1502							MPH mode
						Printer on							
						Terminal on							masked
						DI 1663							Name allocation off
						Protocol header DI 1610							Cube data
						DI 1712							Read in W-POS=55
			1			DI 1713							WPS=CCS
						DI 1553							Probe change no.:2
2	1	1	2			Surface							Top surface 4Pnt
2	1	2	3			Surface							Front surface 4Pnt
2	1	3	4			Surface							Left surface 4Pnt
			5	-3		REC Surface							
			6			TR SPACE							Primary reference = Z
			7			Zero point							Z=0
			8	-5		REC Surface							
			9			TR EBENE							Y,X defined
			10			Zero point							Y=0
			11	-7		REC Surface							
			12			Zero point							X=0
						DI 1708							New CCS
						TEXT							CENTER HOLE TOP
						DI 1690							ADDRESS COUNTER=50

Measuring run plan

W-Name: Practice cube | Drawing no.: | Date: 02.02.1994 | Page 2 / 3

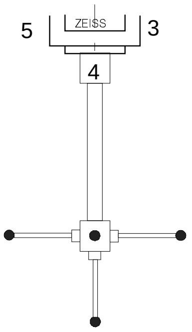
Probes			Addresses		WKS	Step		Nominal					Additional notes/ Travel commands
Cf.:	Cb.:	No.:	ADR	REC	SKS	Prog/Task	Name	SYM	UDF	NOM	U-T	L-T	
2	1	1	50			Circle	KR_1	X	M1	52	0.2	-0.2	Macro Define start angle, angle Range and other inputs.
								Y	M2	32	0.2	-0.2	
								D	M3	30	0.08	0	
			51			Cone	KE_1	X	M4	52	0.2	-0.2	Measure cone manually or with macro
								Y	M5	32	0.2	-0.2	
								WK	M6	30	0/5/0	-0/5/0	
			52			Zero point							Zero point
						DI 1708							Control zero point in the center
						TEXT							GRADUATED CIRCLE TOP
2	1	1	53			Circle	KR_2						Measurement of the 3 holes with 12 mm diameter
2	1	1	54			Circle	KR_3						
2	1	1	55			Circle	KR_4						
			56	-1/-3/1		REC Circle	TK_1	X	M7	0	0.2	-0.2	Calculate graduated circle
								Y	M8	0	0.2	-0.2	
								D	M9	55	open	open	
			57			Zero point							Zero point in graduated circle
			58	-5		REC Circle	RKR_2	X	M10	13.75	0.1	-0.1	Hole pattern top cart.
								Y	M11	23.82	0.1	-0.1	
								D	M12	12	0.3	0	
			59	-5		REC Circle	RKR_3	X	M13	13.75	0.2	-0.2	
								Y	M14	23.82	0.2	-0.2	
								D	M15	12	0.3	0	
			60	-5	K1	REC Circle	RKR_4	X	M16	19.45	0.2	-0.2	
								Y	M17	19.45	0.2	-0.2	
								D	M18	12	0.3	0	
						TEXT							Sector angle circular groove TOP

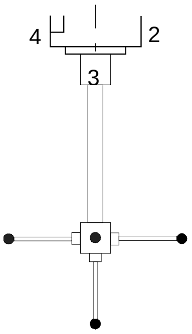
Measuring run plan

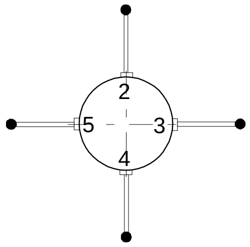
W-Name: Practice cube						Drawing no.:				Date: 02.02.1994			Page 3 / 3
Probe			Addresses		WPS	Step		Nominal					Additional notes/ Travel commands
Cf.:	Cb.:	No.:	ADR	REC	CCS	Prog/Task	Name	SYM	IDF	NOM	U-T	L-T	
						DI 1690							Address counter=100
2	1	1	100			Circle	KR_5						Circle in groove at 0 degrees
			101			TE NP & 1E							WPS by KR_5
						DI 1708							CCS by KR_5
2	1	1	102			Circle	KR_5						Circle in groove at 60 degrees
			103			Polar	POL_1						Polar evaluation
						Deg/Min/Sec			M19	60/0/0	0/30/	-0/30/	Tolerance Deg/Min/Sec
						Circle segm							Evaluation as circle and radius table
													Input: Center point X=0, Y=0
						Terminal on							
						DI 1661							Control probing mode
						DI 1662							Output mode

6.3 Probe plan

W-Code: 10		W-Name: cube		Date: 06.10.97	Page: 1 / 1
Drawing no.: ---		Comment: Training		Operator: I-ED/Hke	
Customer: ---		Operation: Demo			
W-Pos No.: 1		Comment: ---		Grid: 3 / 2	Start line:
With PCH:	without PCH:	Configuration: 2	Rack: B	Measuring room temperature: 20	



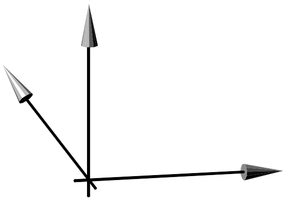


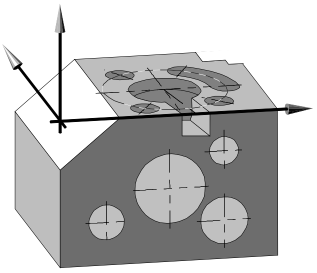


Probes							Connecting elements (dia. in [mm] / ∠ in [°])				
No.	Cf.:	Cb.:	No.:	Type	dk	Length [mm]	Adapter	Extension	Joint	Cube	Swivel
1	2	1		600341-8425				Dia. 20 x 40			
2	2	1		602030-8362						20	
3	2	1	1	600342-8022	5	53					
4	2	1	2		5						
5	2	1	3	600342-8021	3	58					
6	2	1	4		5						
7	2	1	5		3						

6.4 W-Position plan

W-Code: 10		W-Name: Cube		Date: 06.10.97	Page: 1 / 1
Drawing no.:		Comment: Training		Operator: I-ED/HKe	
Customer:		Operation:			
W-Pos No.: 1		Comment:		Grid: 3 / 2	Start line: 1
with PCH: X	Without PCH:	Configuration: 2	Rack: B	Measuring room temperature: 20	





Clamping device
Grid bore

Clamping device no.:

Notes on the clamping:

Quill before the start:

Probes			Addresses					Additional notes
Cf.:	Cb.:	No.:	ADR	REC	CCS	Prog/task	Name	
2	1	1	1			Surface		Top surface
			2			TR Space		
			3			Zero point		
2	1	1	4			Point		Surface front left
2	1	1	5			Point		Surface front right
			6			TE Plane		
			7			Zero point		
2	1	1	8			Point		Surface left
			9			Zero point		
						DI 1710		W-Pos = 1

6.5 Measurement record

```
================================================================================
                         MEASUREMENT RECORD    ZEISS  UMESS

Cube                                          CNC-RUN
=======
DRAWING NO         | ORDER NO           | SUPPLIER/CUSTOMER | OPERATION
123-456            |                    |                   | Training

OPERATOR          | DATE         | PART NO        |
OPERATOR          |  7.10.1997   | 6              |

================================================================================
 ADR|   NAME  / IDF   |SY| ACTUAL    | NOMINAL | U.TOL | L.TOL | DEV   | EXC
================================================================================
   1                    WP same as WPOS
                        X    192.7310
                        Y   -609.2077
                        Z   -487.4798
                        SPACE
                        A      0.0380
                        PLANE
                        A     -0.0908   ABOUT SPACE AXIS   Z

   2                    SURFACE
                        Z      0.0163
                    X/Z A1     0.0127
                    Y/Z A2    -0.0154
       4P S/MIN/MAX             .0278        (1)  -.0171     (2)   .0151

   3                    SURFACE
                        Y     -0.0070
                    Z/Y A1     0.0290
                    X/Y A2    -0.0051
       4P S/MIN/MAX             .0012        (4)  -.0007     (3)   .0007

   4                    SURFACE
                        X      0.0761
                    Y/X A1     0.0077
                    Z/X A2    -0.0626
       4P S/MIN/MAX             .0025        (3)  -.0013     (2)   .0013

   5                    SURFACE RECALL (   2) WITHOUT TRANSFORMATION
                        Z      0.0163
                    X/Z A1     0.0127
                    Y/Z A2    -0.0154
                        S       .0278      FORM    .0321

   6                    ROTATE SPACE
                        A       -.0578

   7                    ZERO POINT
                        Z      0.0163

   8                    SURFACE RECALL (   3) WITH TRANSFORMATION
                        Y     -0.0070
                    Z/Y A1     0.0136
                    X/Y A2    -0.0959
                        S       .0012      FORM    .0014

   9                    ROTATE PLANE  ABOUT SPACE AXIS Z
                        A       -.0959

  10                    ZERO POINT
                        Y     -0.0070

  11                    SURFACE RECALL (   4) WITH TRANSFORMATION
                        X      0.0762
                    Y/X A1     0.0026
                    Z/X A2    -0.0499
                        S       .0025      FORM    .0025

  12                    ZERO POINT
                        X      0.0762

Center holes top
----------------

  50                    CIRCLE I
     M1                 X     52.1390    52.0000  0.2000 -0.2000  0.1390   +++
     M2                 Y     32.1878    32.0000  0.2000 -0.2000  0.1878  ++++
     M3                 D     30.0775    30.0000  0.0200  0.0000  0.0775  0.0575
       4P S/MIN/MAX             .0002        (1)  -.0001     (4)   .0001

  51                    CONE I
     M4                 X     52.1427    52.0000  0.2000 -0.2000  0.1427   +++
     M5                 Y     32.2036    32.0000  0.2000 -0.2000  0.2036  0.0036
                        D     33.8622
                    X/Z A1     0.0285
                    Y/Z A2     0.0877
     M6                 AC   -30.0293    30.0000  0.0833 -0.0833  0.0293   ++
      12P S/MIN/MAX             .0086        (5)  -.0111    (11)   .0073
```

```
Graduated circle top
--------------------

  52                    CIRCLE I
                        X     38.3217
                        Y     56.0135
                        D     12.0368
       4P S/MIN/MAX             .0001        (4)   .0000     (2)   .0000

  53                    CIRCLE I
                        X     38.2947
                        Y      8.3721
                        D     12.0449
       4P S/MIN/MAX             .0007        (4)  -.0004     (2)   .0004

  54                    CIRCLE I
                        X     71.4925
                        Y     12.7290
                        D     12.0396
       4P S/MIN/MAX             .0014        (1)  -.0008     (3)   .0008

  55                    CIRCLE RECALL OF ELEMENTS
     M7                 X     52.0543    52.0000  0.2000 -0.2000  0.0543   ++
     M8                 Y     32.1850    32.0000  0.2000 -0.2000  0.1850   ++++
     M9                 D     55.0048    55.0000                  0.0048
Hole pattern top
----------------

  56                    ZERO POINT
                        X     52.0543
                        Y     32.1850

  57                    CIRCLE I RECALL (  52) WITH TRANSFORMATION
     M10                X    -13.7326    13.7500  0.2000 -0.2000 -0.0174   -
     M11                Y     23.8285    23.8200  0.2000 -0.2000  0.0085   +
     M12                D     12.0368    12.0000  0.3000  0.0000  0.0368   ----
                        S       .0001      FORM    .0001

  58                    CIRCLE I RECALL (  53) WITH TRANSFORMATION
     M13                X    -13.7596    13.7500  0.2000 -0.2000  0.0096   +
     M14                Y    -23.8129    23.8200  0.2000 -0.2000 -0.0071   -
     M15                D     12.0449    12.0000  0.3000  0.0000  0.0449   ---
                        S       .0007      FORM    .0008

  59                    CIRCLE I RECALL (  54) WITH TRANSFORMATION
     M16                X     19.4382    19.4500  0.2000 -0.2000 -0.0118   -
     M17                Y    -19.4560    19.4500  0.2000 -0.2000  0.0060   +
     M18                D     12.0396    12.0000  0.3000  0.0000  0.0396   ---
                        S       .0014      FORM    .0015
Sector angle circular groove top
--------------------------------

 100                    CIRCLE I
                        X     27.5075
                        Y     -0.0081
                        D     12.0117

 101                    ROTATE (0P+1) ABOUT SPACE AXIS Z
                        W       -.0169

 102                    CIRCLE I
                        X     13.7490
                        Y     23.8193
                        D     11.9851

 103                    POLAR
                        R     27.5027
                    Y/X A1    60.0055

          DEG     M19   A1    60.0000    60.0000  0.0000  0.0000  0.0000
          MIN     M19   A1     0.0000     0.0000 30.0000-30.0000  0.0000   +
          SEC     M19   A1    19.9000     0.0000  0.0000  0.0000 19.9000
```

```
Fixed value input: XY

 104                   CIRCLE-SEGMENT I
                       X      0.0000
                       Y      0.0000
                       D     67.0082
       7P S/MIN/MAX             .0032        (7)  -.0043     (1)   .0057

 105                   RADMEAS
                       R     33.5098
                   Y/X A1   359.9912

 106                   RADMEAS
                       R     33.5050
                   Y/X W1    10.0027

 107                   RADMEAS
                       R     33.5059
                   Y/X A1    20.0070

 108                   RADMEAS
                       R     33.5032
                   Y/X A1    30.0047

Measured value output on printer : Default without restriction
                                   Standard deviation output and texts

Measured value output on terminal: Default without restriction
                                   Standard deviation output and texts

================================================================================
CNC - END
================================================================================
```

Measuring run plan

W-Name:						Drawing no.:				Date:			Page
Probes			Addresses		WPS	Step		Nominal					Additional notes / Travel commands
Cf.:	Cb.:	No.:	ADR	REC	CCS	Prog/Task	Name	SYM	IDF	NOM	U-T	L-T	

Probe plan

W-Code:		W-Name:		Date:	Page:
Drawing no.:		Comment:		Operator:	
Customer:		Operation:			
W-Pos No.:		Comment:		Grid:	Start line:
With PCH:	Without PCH:	Configuration:	Rack:	Measuring room temperature:	

Probes							Connecting elements (dia in [mm] / ∠ in [°])				
No.:	Cf.:	Cb.:	No.:	Type	dk	Length [mm]	Adapter	Extension	Joint	Cube	Swivel

W-Position plan

W-Code:		W-Name:		Date:	Page:
Drawing no.:		Comment:		Operator:	
Customer:		Operation:			
W-Pos No.:		Comment:		Grid:	Start line:
With PCH: X	Without PCH:	Configuration:	Rack:	Measuring room temperature:	

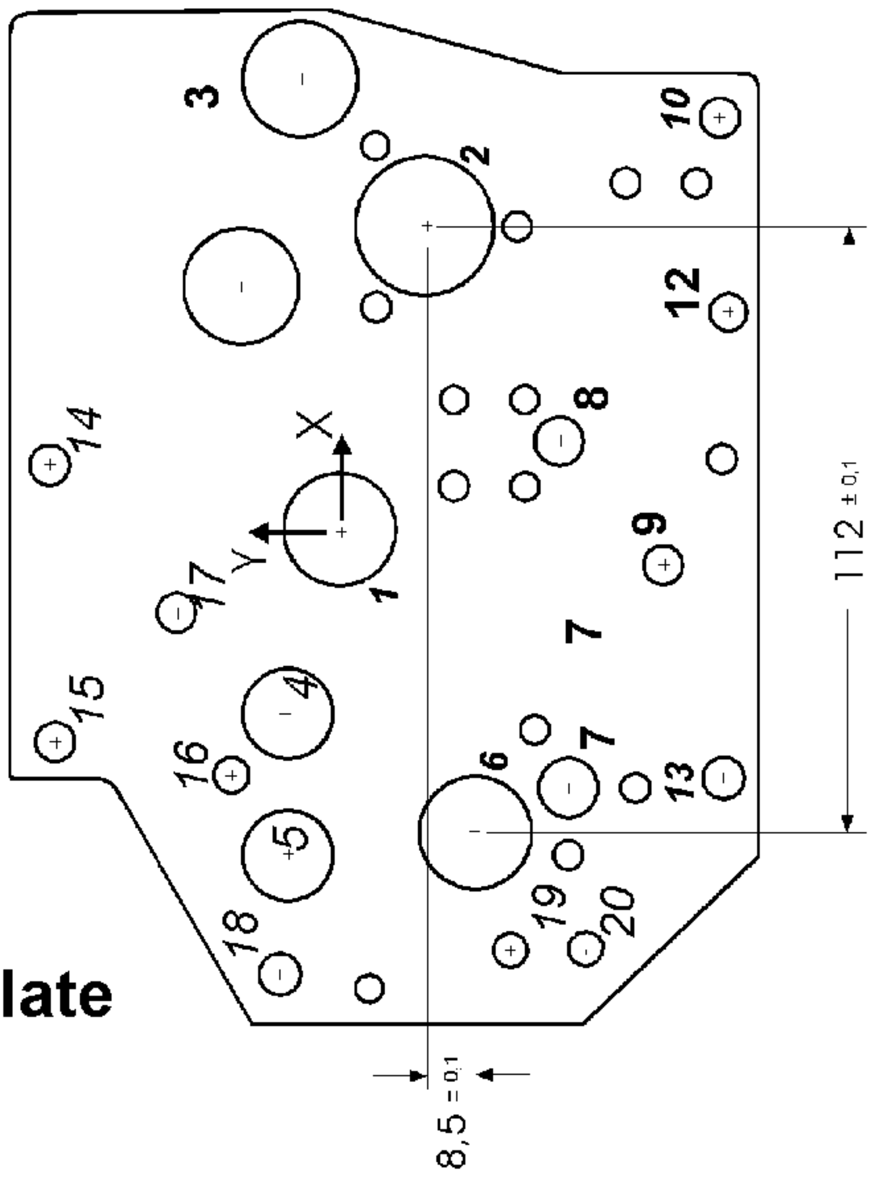
Clamping device
Grid bore

Clamping device no.:

Notes on clamping:

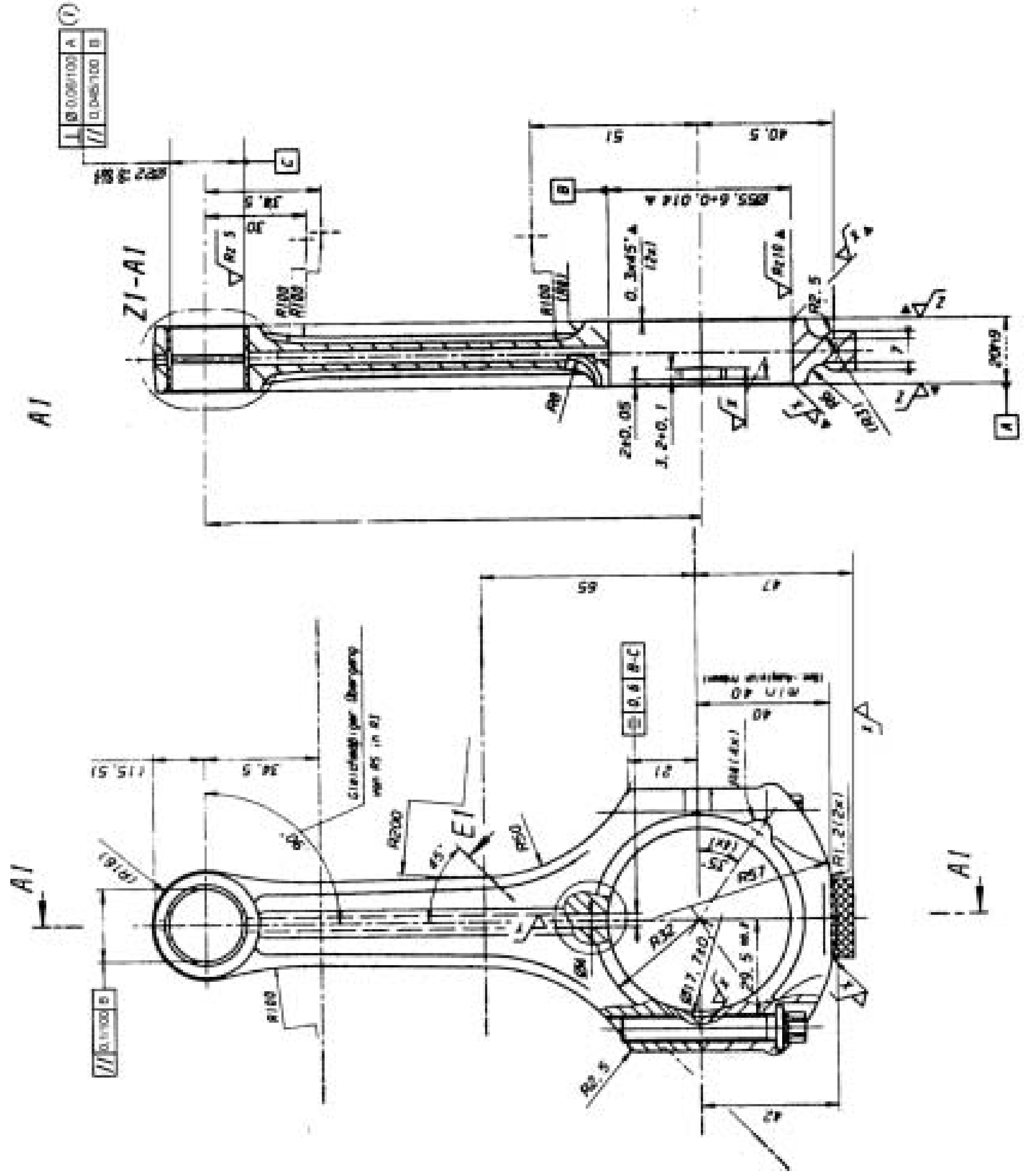
Quill before the start:

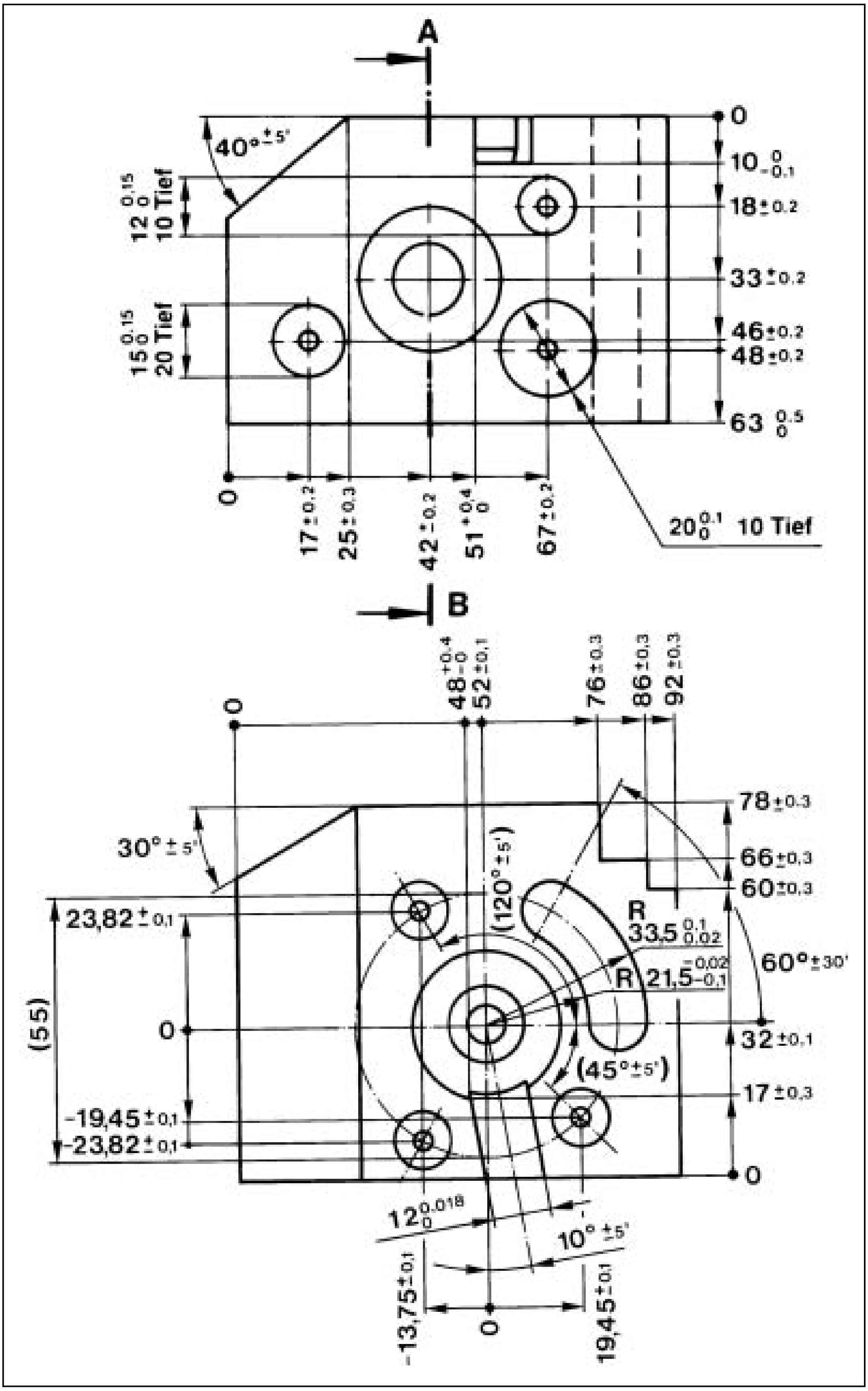
Probes			Addresses					Additional notes
Cf.:	Cb.:	Nor.:	ADR	REC	CCS	Prog/Task	Name	

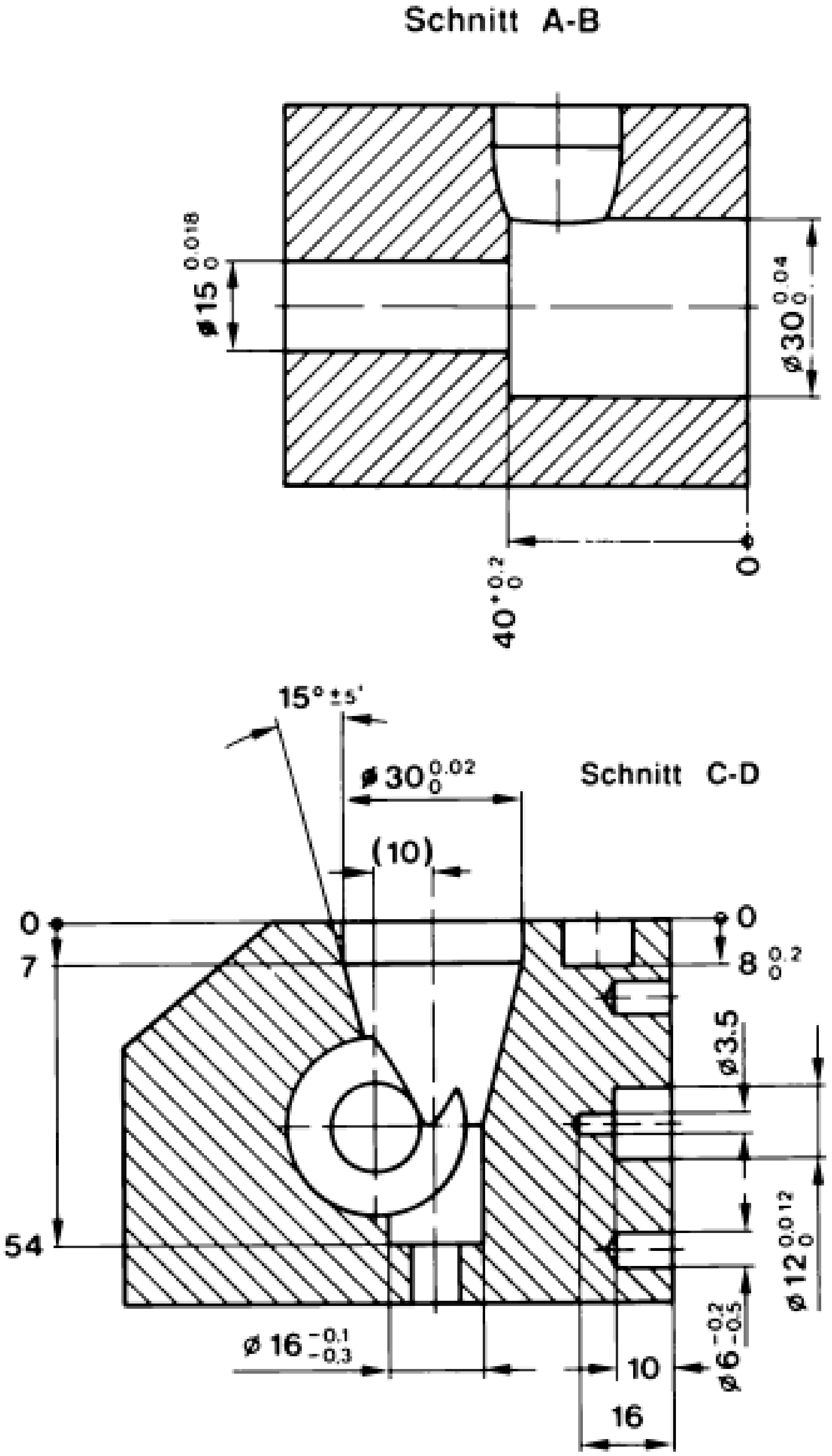


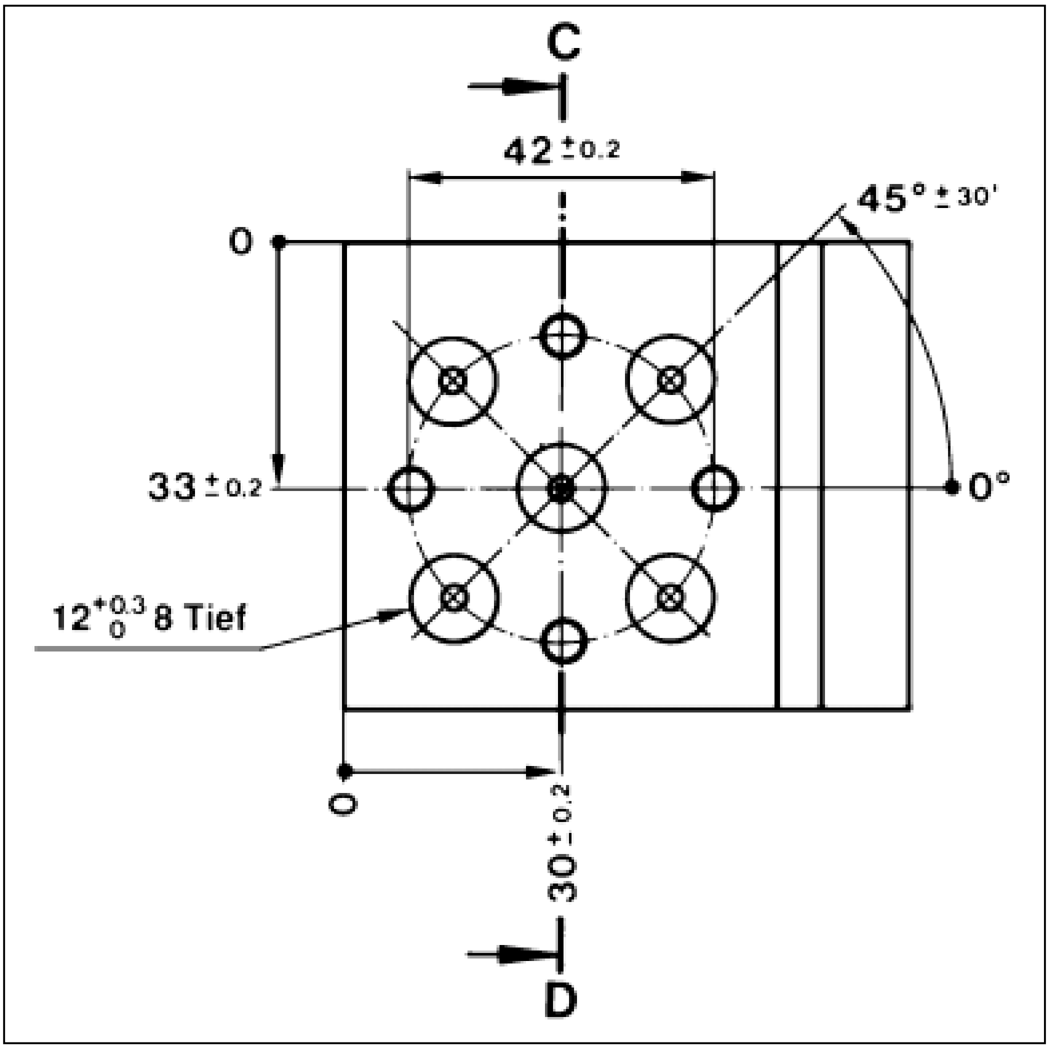
Boreplate

Connecting rod




A
B
0
10 -0,1 0
18±0.2
33±0.2
46±0.2
48±0.2
63 0.5 0
40°±5'
12 0.15 0 10 Tief
15 0.15 0 20 Tief
17±0.2
25±0.3
42±0.2
51 +0.4 0
67±0.2
20 0.1 0 10 Tief
48 +0.4 -0
52±0,1
76±0,3
86±0,3
92±0,3
78±0.3
66±0,3
60±0,3
30°±5'
23,82±0,1
(120°±5')
R 33,5 0,1 0,02
R 21,5 -0,02 -0,1
60°±30'
(55)
32±0,1
(45°±5')
17±0,3
-19,45±0,1
-23,82±0,1
12 0,018 0
10°±5'
-13,75±0,1
19,45±0,1


Schnitt A-B
ø15 0.018 0
ø30 0.04 0
40 +0.2 0
0
15° ±5'
ø30 0.02 0
Schnitt C-D
(10)
0
7
54
0
8 0.2 0
ø3.5
ø12 0.012 0
ø16 -0.1 -0.3
10
ø6 -0.2 -0.5
16


C
42 ± 0.2
45° ± 30'
0
33 ± 0.2
0°
12 +0.3/0 8 Tief
0
30 ± 0.2
D