Teaching Material

PT 105 Dimensional Metrology I:
Training Kit 5

Teaching Material

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This manual must be kept by the unit.

Before operating the unit:
- Read this manual.
- All participants must be instructed on handling of the unit and, where appropriate, on the necessary safety precautions.

Version 1.1

Subject to technical alterations

Table of Contents

1 Introduction

1.1 Subject, target group and learning objectives

The **PT 105** training kit is part of the G.U.N.T. learning concept for dimensional metrology. The training kit includes various items of test equipment and test objects. A shaft is used as an example to perform, document and evaluate measuring exercises.

The main application of the training kit is in the training of specialist technicians.

The learning content includes:

- Familiarisation with the various measuring instruments
- Measurement of specified lengths, diameters and radii
- Dimensional checks using slip gauges
- Keeping a measurement log
- Estimating measuring variations
- Identifying typical errors

1.2 Didactic information for the tutor

This teaching material is designed to assist you in preparing your lessons. You can put together sections of the material as information for your students and use them in their lessons.

The teaching material also includes prepared worksheets for the students, along with the corresponding solutions.

To support your teaching, we also provide this material in PDF format on a CD. We grant you unrestricted rights to reproduce the teaching material for the purposes of your teaching work.

1.3 Structure of teaching material

Chapter 2 – Safety

This chapter contains safety information, which must be taken into account when using the **PT 105** training kit.

Chapter 3 – Principles of metrology

Explains the difference between testing, measuring and gauging, and between calibration, adjustment and official calibration. Systematic and random measuring variations and actions to avoid these are also dealt with in this chapter.

Chapter 4 – Dimension check with the training kit PT 105

The components of the **PT 105** training kit are outlined here. It outlines the structure of the measuring instruments and how to read off measured values. A dimension drawing illustrates the dimensions that can be measured on the test objects. There is an explanation of how the dimensions are recorded on the test objects using measuring instruments.

Chapter 5 – Tasks

This chapter contains worksheets for the students. These include questions on metrology and exercises in measuring and gauging using the test equipment and test objects in the **PT 105** training kit.

Chapter 6 – Solutions

This chapter contains the solutions to the exercises for the teacher.

2 Safety

2.1 Intended use

The unit is to be used only for teaching purposes.

2.2 Structure of the safety instructions

The signal words DANGER, WARNING or CAUTION indicate the probability and potential severity of injury.

An additional symbol indicates the nature of the hazard or a required action.

Signal word	Explanation
⚠ DANGER	Indicates a situation which, if not avoided, **will** result in **death or serious injury**.
⚠ WARNING	Indicates a situation which, if not avoided, **may** result in **death or serious injury**.
⚠ CAUTION	Indicates a situation which, if not avoided, may result in **minor or moderately serious injury**.
NOTICE	Indicates a situation which may result in **damage to equipment**, or provides instructions on **operation of the equipment**.

Symbol	Explanation
	Notice

2.3 Safety instructions

NOTICE

Test equipment and test objects are sensitive.

- Handle all components of the **PT 105** training kit with great care.

3 Principles of metrology

3.1 Testing – measuring – gauging

In general, testing means comparing an actual value with a set or specified value. We can differentiate between testing, measuring and gauging.

Testing

Testing involves using **test equipment** to establish whether a **test object** meets the specified requirements.

Measuring

Measuring involves using a measuring instrument with a scale, on which the measured variable can be **read off**.

The **measuring instrument** has a scale. It can be fixed (solid measure, e.g. ruler) or adjustable (indicating measuring instrument, e.g. calliper gauge).

The result is a **measured value**, consisting of a numerical value and a unit.

Examples:

- Calliper gauge
- Micrometer
- Dial gauge

Gauging

Gauging involves **comparing** a dimension or shape with a gauge that has the specified dimension or shape.

The **gauge** represents the negative shape, i.e. it is the counterpart to the test object. It is fixed, has no scale and, in general, no moving parts. There are dimension gauges, form gauges and limit gauges.

The result is a **conclusion** as to whether the test object lies within specified limits.

Examples:

- Radius gauge
- Taper gauge

3.2 Calibration – adjustment – official calibration

Operational or legal regulations may stipulate that test equipment has to be compared with a reference. We differentiate between calibration, adjustment and official calibration depending on the test equipment and the activity.

Calibration

Comparison of the values measured using an item of test equipment (measuring instrument or gauge) with a reference.

This identifies the level of variation between two values (measuring instrument) or whether the variation between two values lies within certain limits (gauge).

This variation is noted.

Calibration does not involve any modification of the test equipment.

Adjustment

Changing the display on a measuring instrument due to a variation identified during calibration.

Gauges cannot be adjusted.

Official calibration

Calibration and adjustment of a measuring instrument by a **statutory body**, for example the state calibration authority.

Examples:

- A calliper gauge is calibrated by measuring and noting the difference from a reference.
- An example of adjustment would be changing the zero indicator on a pressure gauge so that it corresponds to the zero indicator on a reference pressure gauge.
- Equipment such as scales used in food shops are officially calibrated. The statutory body thus confirms that adjustment has been carried out in accordance with the regulations.

In general, all objects that have a greater accuracy than the test equipment can be used as a reference.

3.3 Measuring variations

3.3.1 Systematic measuring variations

Systematic measuring variations can be identified by calibration. The measured value is then corrected by the amount of the variation to give the measuring result.

Measuring result = Measured value ± Variation

The sign is crucial here.

Significant systematic measuring variations include:

- Reference temperature

  The reference temperature for test equipment and test objects is 20°C, i.e. test equipment and test objects should have this temperature.

  If the temperatures differ from this, the measured length must be corrected using the temperature and material-specific coefficient of linear expansion.

- Abbe's comparator principle for measuring instruments

  This principle was established in 1893 by Ernst Abbe, the former owner of the Carl Zeiss company (optical industry). It states that the length to be measured and the scale of the measuring instrument must be positioned flush to one another.

The micrometer conforms to this principle.

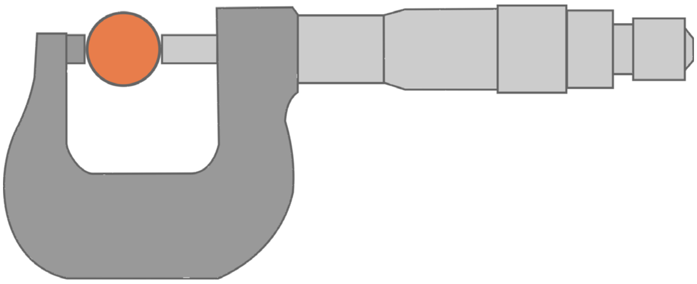


Fig. 3.1 Measuring instrument in line with Abbe’s comparator principle

The calliper gauge does not conform to Abbe's comparator principle – as the scale and the measuring object do not lie on an axis. Therefore, measuring errors can occur by tilting the gauge (see Fig. 3.2).

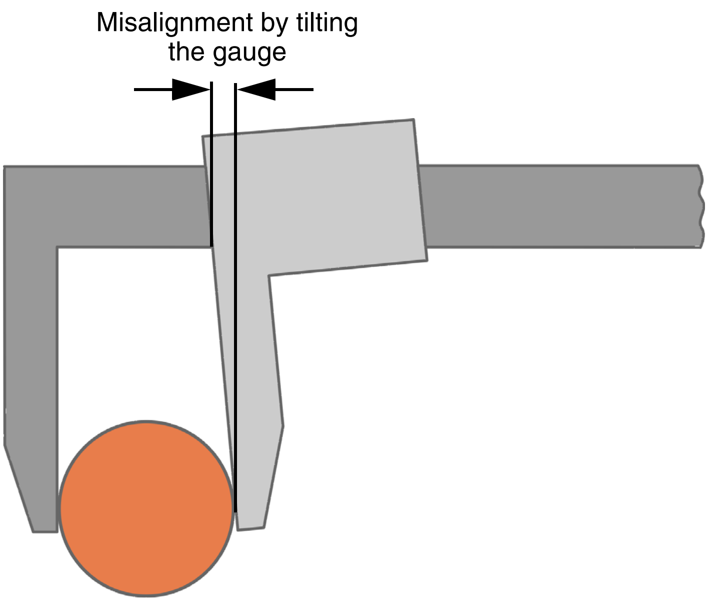


Fig. 3.2 Measuring error by tilting the gauge

3.3.2 Random measuring variations

Random measuring variations are different for each measurement. They cannot be identified by calibration and thus cannot be corrected.

Examples of random measuring variations include:

- Contamination

  Test equipment must always be stored separately from test objects. In the laboratory or workshop, test equipment is stored in particular locations where they will be protected from contamination, severe temperature fluctuations and moisture.

- Reading error due to parallax

  Look at the scale from a right angle when reading the measured value. An inclined view can falsify the reading.

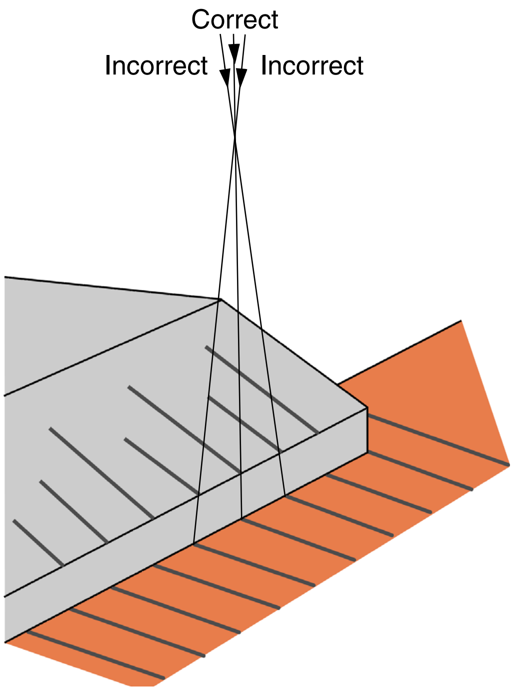


Fig. 3.3 Reading error due to parallax

Random measuring variations are reduced by:

- Careful and calm working
- Multiple measurements

  Measure each dimension several times, if possible with the measuring object at different positions. For example, measure round measuring objects three times, turning the object by 120° each time.

  Then calculate the mean value of your measurements.

4 Dimension check with the training kit PT 105

4.1 Components

Item	Designation	Measuring range	Additional specifications
1	Depth calliper gauge	0...150 mm	Reading accuracy: 0,05 mm
2	Calliper gauge	0...200 mm	Reading accuracy: 0,05 mm
3	Slip gauge 10mm	–	Tolerance class 2 in line with DIN EN ISO 3650
4	Slip gauge 50mm	–	
5	Slip gauge 90mm	–	
6, 8	Shafts 01 to 10	–	Manufacturing dimensions: See Chapter 4.3, Page 24
7	Radius gauge, concave and convex	R1...R7mm	Graduation: 1,0 to 3,0mm: 0,25mm 3,0...7,0mm: 0,50mm
9	External micrometer	0...25 mm	Reading accuracy: 0,01 mm
10	External micrometer	25...50 mm	Reading accuracy: 0,01 mm

Fig. 4.1 Practice kit PT 105

4.2 Test equipment

4.2.1 Calliper gauge

Because of its versatility for different measuring tasks, ease of use and handling, the calliper gauge is the most important length measuring instrument in metalworking. The **PT 104** training kit includes:

- a calliper gauge for external and internal measurements
- a depth calliper gauge for depth measurements.

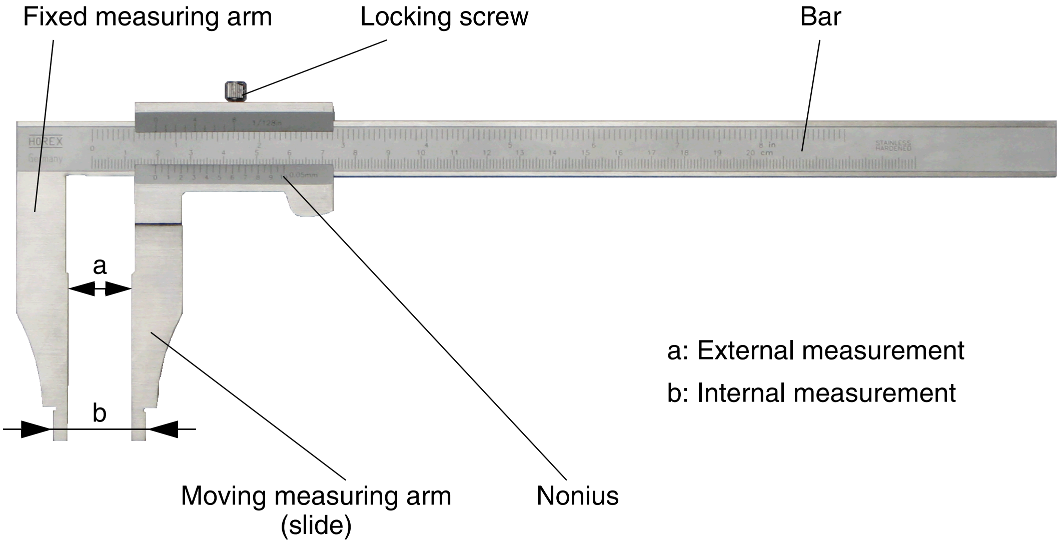
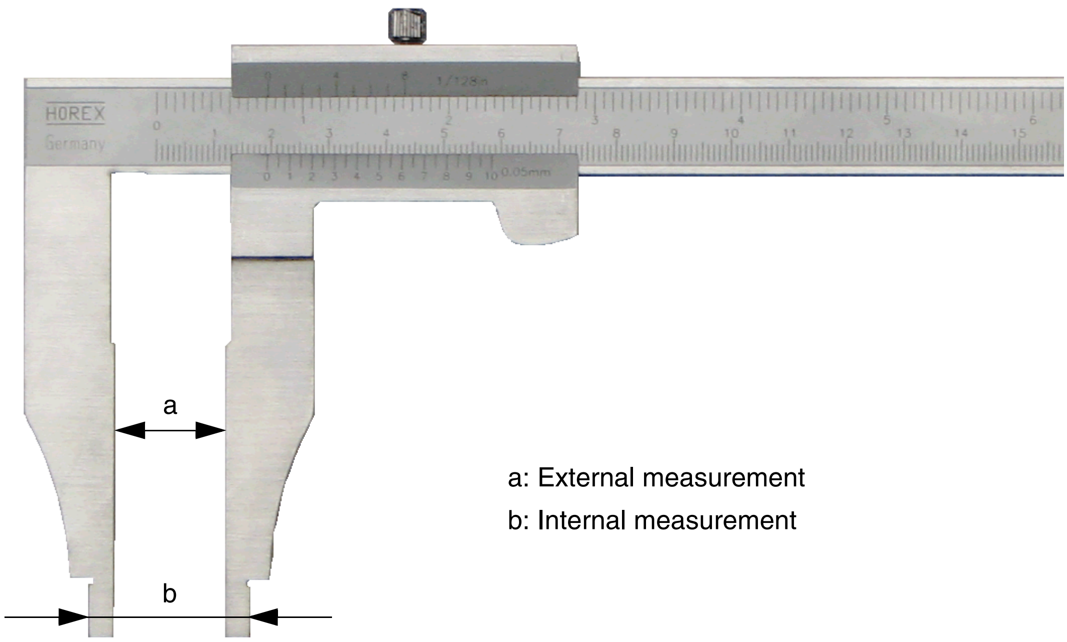


Fig. 4.2 Calliper gauge

The calliper gauge consists of a bar with millimetre graduations and a fixed measuring arm, which makes a right angle with the bar. The moving measuring arm or slider also has a scale, known as the nonius.

The calliper gauge shown in Fig. 4.2 can be used to perform the following measurements:

- External measurement using inner sides of measuring arm.
- Internal measurement using outer sides of measuring arm. In this case, 10mm (length of two measuring arms) must be added to the measured dimension.



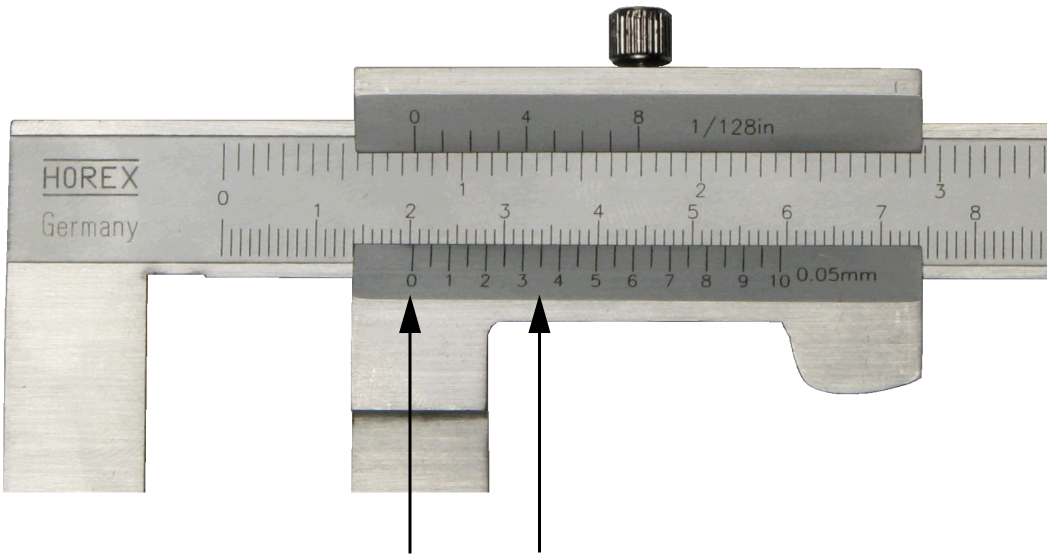
a: External measurement
b: Internal measurement

Fig. 4.3 External and internal measurement with calliper gauge

The locking screw also allows the calliper gauge to be used as an adjustable gauge.

The calliper gauge is read as follows:

- View the zero line of the nonius as the decimal point. Read off the full millimetres at the zero line of the nonius.
- Then look to the right of the zero line for the graduation on the nonius that coincides with a graduation on the scale. Read off the tenths of millimetres there.



Reading at the zero line of the nonius
Value: 20

Reading at the graduation on the nonius that coincides with a graduation on the scale
Value: 0,35

Value read: 20,35 mm

Fig. 4.4 Reading a calliper gauge

4.2.2 Micrometers

The **PT 105** training kit contains two micrometers.

With a micrometer, the rotational movement of the scale barrel creates a longitudinal movement.

The measuring accuracy and measuring range are specified on the insulating plate. The measuring accuracy of the micrometer is normally greater than that of a calliper gauge. However, the measuring range of the micrometer is smaller than that of a calliper gauge.

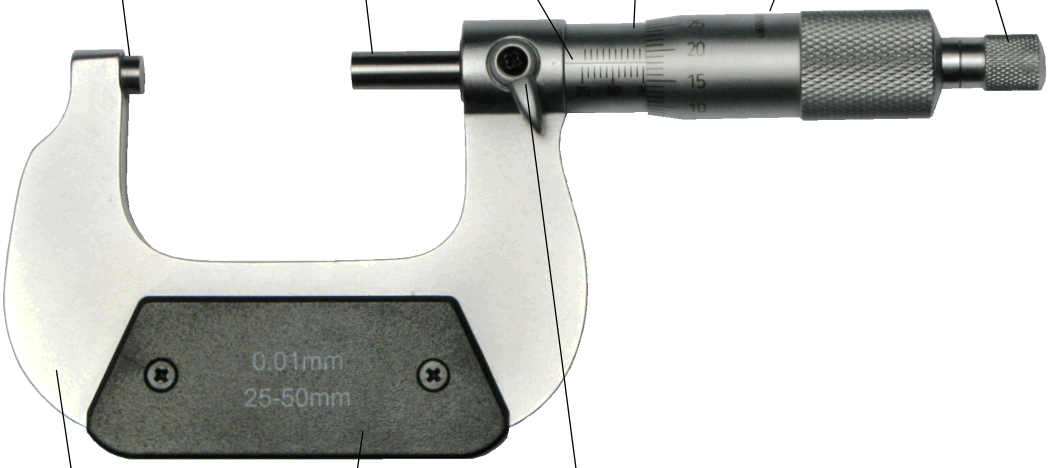


Fig. 4.5 External micrometer

A micrometer should be held by the insulating plate where possible. This prevents temperature changes from being transferred to the instrument, thus reducing the possibility of variations caused by temperature.

The test object is positioned between the anvil and the spindle. The coupling (ratchet) limits the pressure applied to the test object via the thread, thus preventing deformation and measuring variations.

The locking lever allows the micrometer to be fixed and used as a gauge.

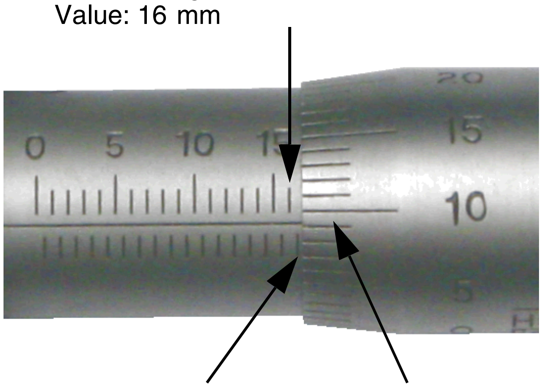
The spindle thread normally has a pitch of 0,5 mm, i.e. a complete rotation moves the spindle 0,5 mm in a longitudinal direction. The scale barrel is divided into 50 equal intervals by graduation marks. Rotation from one graduation mark to another corresponds to spindle longitudinal movement of

$$\frac{0{,}5\,\text{mm pitch}}{50\ \text{graduation}} = 0{,}01\ \text{mm}$$

Reading the micrometer:

- Read the full millimetres from the scale on the scale sleeve with numbers (first reading).
- Decimal places:
  - On the scale on the barrel that does not have numbers, each graduation mark divides the full millimetre scale into 0,5mm. If no graduation mark on this scale is visible between the edge of the barrel and the graduation mark read for the full millimetres, the value is 0,0mm (second reading). If a graduation mark is visible, the value is 0,5mm.
  - Each graduation mark on the scale barrel represents 0,01mm. Read off this value at the reference line (third reading).
  - Add the values from the second and third reading, which give the tenths and hundredths of millimetres respectively.

First reading on scale sleeve
Value: 16 mm



Second reading on scale sleeve
Graduation mark visible
Value: 0,5 mm

Third reading on scale sleeve / reference line
Value: 0,09 mm

Value read: 16,59 mm

Fig. 4.6 Reading a micrometer

4.2.3 Radius gauge

Radius gauges are used to test convex and concave curves. The curves on the test object are compared with different radius gauges and thus classified.

The measuring range is specified on each set of radius gauges. The relevant radius is specified on each individual radius gauge.

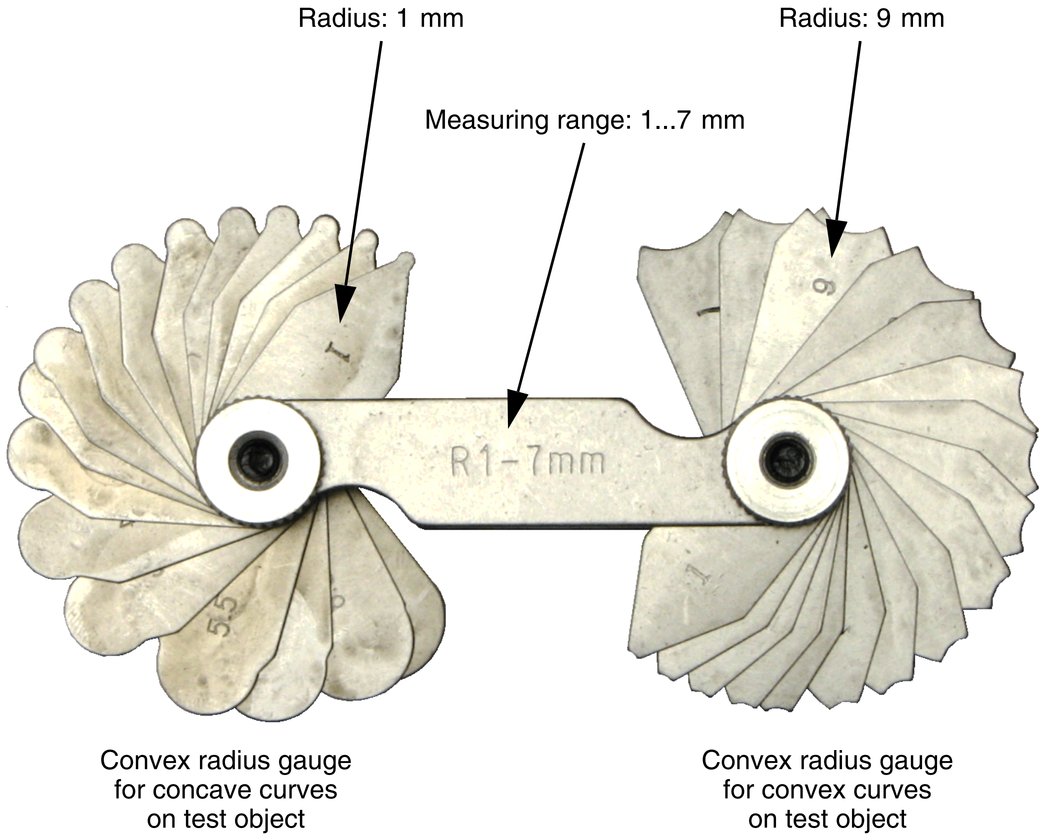


Fig. 4.7 Radius gauges

4.2.4 Slip gauges

Slip gauges are small blocks with a high length accuracy, and are used for calibrating measuring instruments.

They are made of steel, carbide or ceramic and have two completely flat, polished measuring surfaces parallel to one another. Because of their surface quality, they can be slid together and are held together by the adhesion force (known as "wringing”).

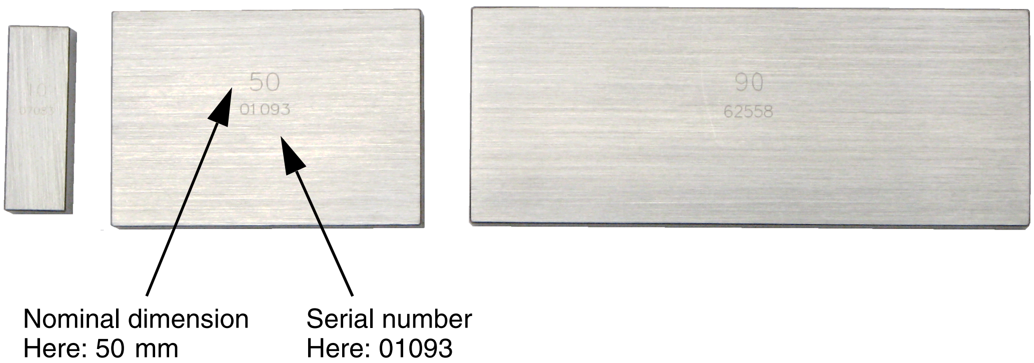


Fig. 4.8 Slip gauges

NOTICE

Slip gauges should not remain joined together for long periods. They should be detached after a maximum of 8 hours as they have a tendency towards cold shutting. Cold shut slip gauges are destroyed when detached.

Slip gauges of different lengths are joined in sets, allowing as many lengths as possible to be produced by combining a series of slip gauges.

Each slip gauge is identified by a nominal dimension and serial number.

Slip gauges are classified in tolerance classes in DIN EN ISO 3650 and assigned to different applications.

Tolerance class	Application
Calibration class K	Reference standard slip gauge set for calibration of other gauge blocks
Tolerance class 0	Factory standard slip gauge set for calibration of gauges and measuring instruments in a climate controlled laboratory
Tolerance class 1	Working standard slip gauge set for calibration of gauges and measuring instruments in a laboratory
Tolerance class 2	Working standard slip gauge set for calibration of gauges and measuring instruments in a workshop

Tab. 4.1 Tolerance classes from DIN EN ISO 3650

The 10mm, 50mm and 90mm slip gauges can be used to calibrate the calliper gauge, the depth calliper gauge, the 0...25mm micrometer and the 25...50mm micrometer. The slip gauges – individually or wrung together – are used as a reference.

The micrometers can also be calibrated in a different way.

- On the micrometer 0...25mm, this is done by fully closing the spindle, so that it is positioned on the anvil. The measured value should then be 0,00mm.
- On the micrometer 25...50mm, the spindle cannot be fully closed. It is calibrated using the reference supplied (cylinder of length 25,00mm), and the measured value should be 25,00mm.

The result of the calibration – the difference in length between the test equipment and the reference – is documented in a calibration report.

For measurements with multiple references, the measured results are also plotted in a calibration curve. With the **PT 105** training kit, a calibration curve can only be produced for the calliper gauge. The micrometers can only be calibrated using one reference, which means that calibration curves cannot be plotted for them.

4.3 Test objects

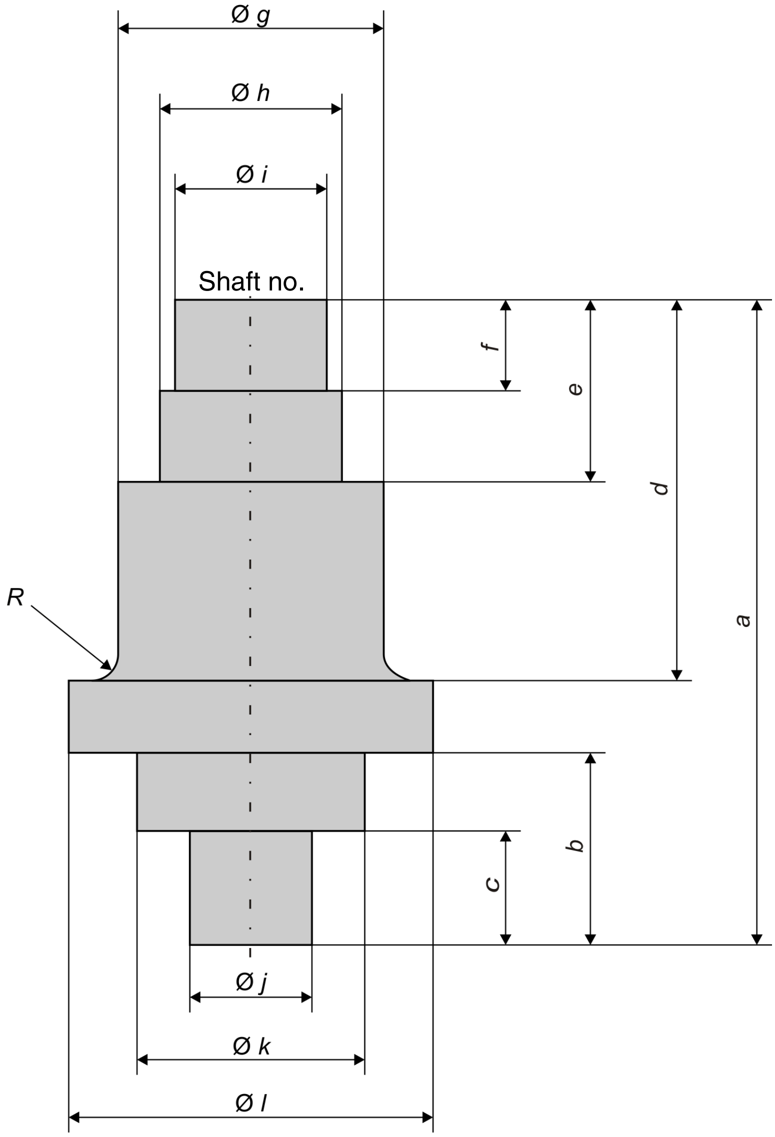


Fig. 4.9 Dimension drawing of shafts, scale 1 : 1

Ten shafts are used as test objects. They are produced to the accuracy of CNC parts and differ due to slight variations in the manufacturing dimensions.

Dimension name	Tolerance	Shaft 01	02	03	04	05	06	07	08	09	10
Lengths in mm											
a	**A**	85,0	84,1	84,8	84,5	85,7	85,7	84,3	84,0	85,5	85,0
b	**A**	25,3	24,1	25,0	24,3	25,5	25,2	24,0	24,6	25,5	25,0
c	**A**	15,0	14,0	15,0	14,5	15,4	15,0	14,1	14,5	15,7	15,1
d	**A**	50,2	50,0	50,1	49,8	50,3	50,0	50,1	49,5	50,0	50,0
e	**A**	24,0	25,0	24,5	24,9	25,0	25,3	25,0	24,8	25,2	25,3
f	**A**	12,0	12,2	11,8	12,1	12,0	12,0	12,2	12,0	11,8	11,9
Diameter in mm											
Ø *g*	**B**	35,10	35,00	35,00	35,02	34,96	35,00	35,00	35,02	34,95	34,96
Ø h	**B**	24,00	23,93	23,98	24,01	24,00	24,02	24,03	24,01	24,00	23,99
Ø *i*	**B**	20,00	20,05	19,98	20,01	20,00	20,02	19,95	20,03	20,05	20,04
Ø *j*	**B**	16,10	16,20	16,00	16,00	15,92	15,20	16,00	16,15	16,00	15,98
Ø *k*	**B**	30,00	30,00	30,02	29,98	30,00	29,95	30,10	30,00	30,03	30,01
Ø *l*	**B**	48,02	48,04	47,95	48,08	48,06	48,09	48,06	47,98	48,12	48,04
Radii in mm											
R	**B**	3,50	3,00	4,00	3,00	3,50	4,00	3,50	3,50	4,00	3,50

Tab. 4.2 Selected shaft dimensions
Tolerance A: General tolerances complying with ISO 2768-1 medium, production tolerance
Tolerance B: ± 0.02 mm, production tolerance

4.4 Examples for testing the test objects

The **PT 105** training kit contains various items of length measuring equipment for testing the lengths and diameters of the shafts specified in Fig. 4.9. Some lengths can be tested using various instruments, others with just one instrument.

Fig. 4.10 to Fig. 4.13 examples of measurement and gauging on a shaft.

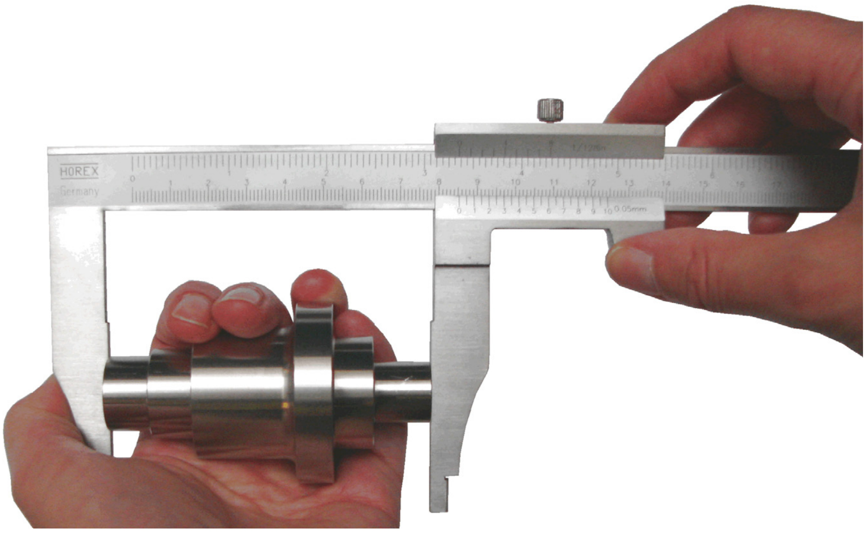


Fig. 4.10 Measuring a length with the calliper gauge

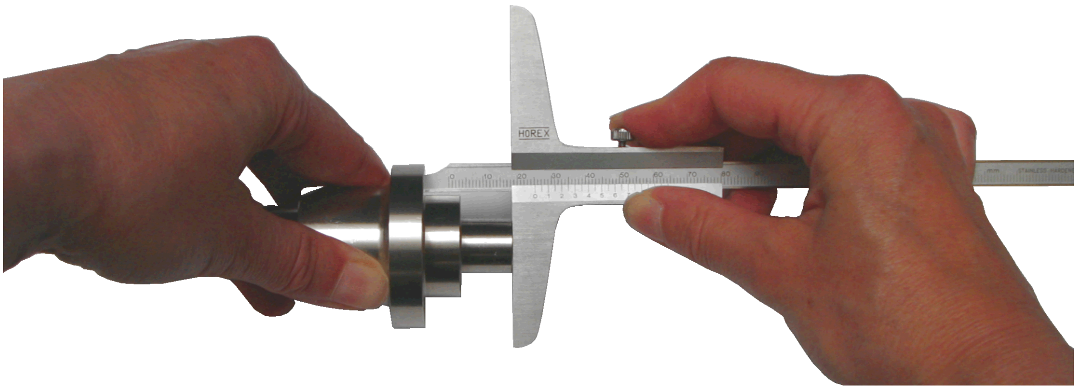


Fig. 4.11 Measuring a length with the depth calliper gauge

Fig. 4.12 Measuring a diameter with the micrometer 0...25 mm

Fig. 4.13 Gauging a radius with the convex radius gauge

5 Tasks

Questions	Worksheet A – Metrology	Page 29
	Worksheet B – Micrometer	Page 30
Exercises	Worksheet C – Calliper gauge calibration	Page 31
	Worksheet D – Performing measurements on a shaft	Page 33
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5.1 Worksheet A – Metrology

Page 1

1. What do you understand by the term “testing”?

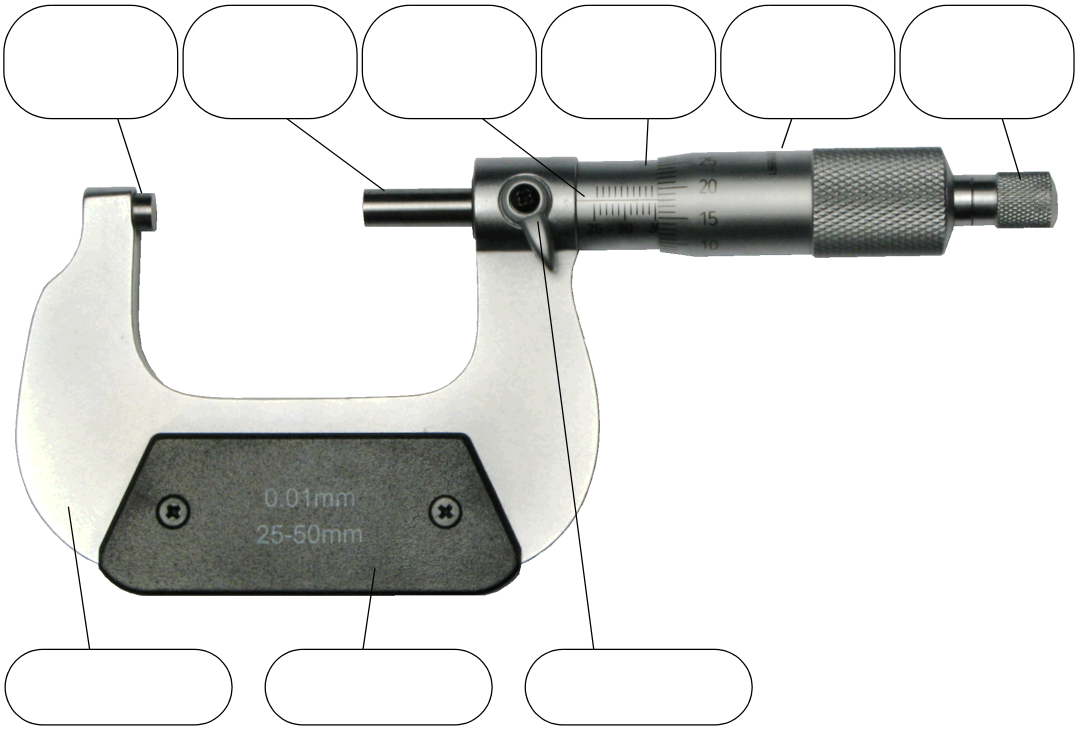
2. What is the difference between measuring instruments and gauges?

3. In theory, you need to calibrate and adjust a length measuring instrument. How would you do this?

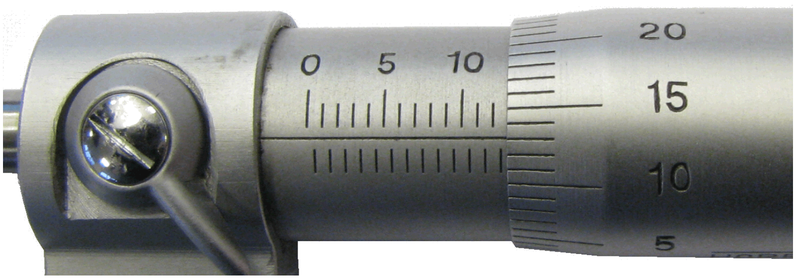
5.2 Worksheet B – Micrometer

Page 1

1. Name the parts of the micrometer.



2. Read off the measured value on the micrometer and note it..



Measured value: mm

5.3 Worksheet C – Calliper gauge calibration

Page 1

1. Calibrate the calliper gauge using the slip gauges and enter the measured values in the calibration report.

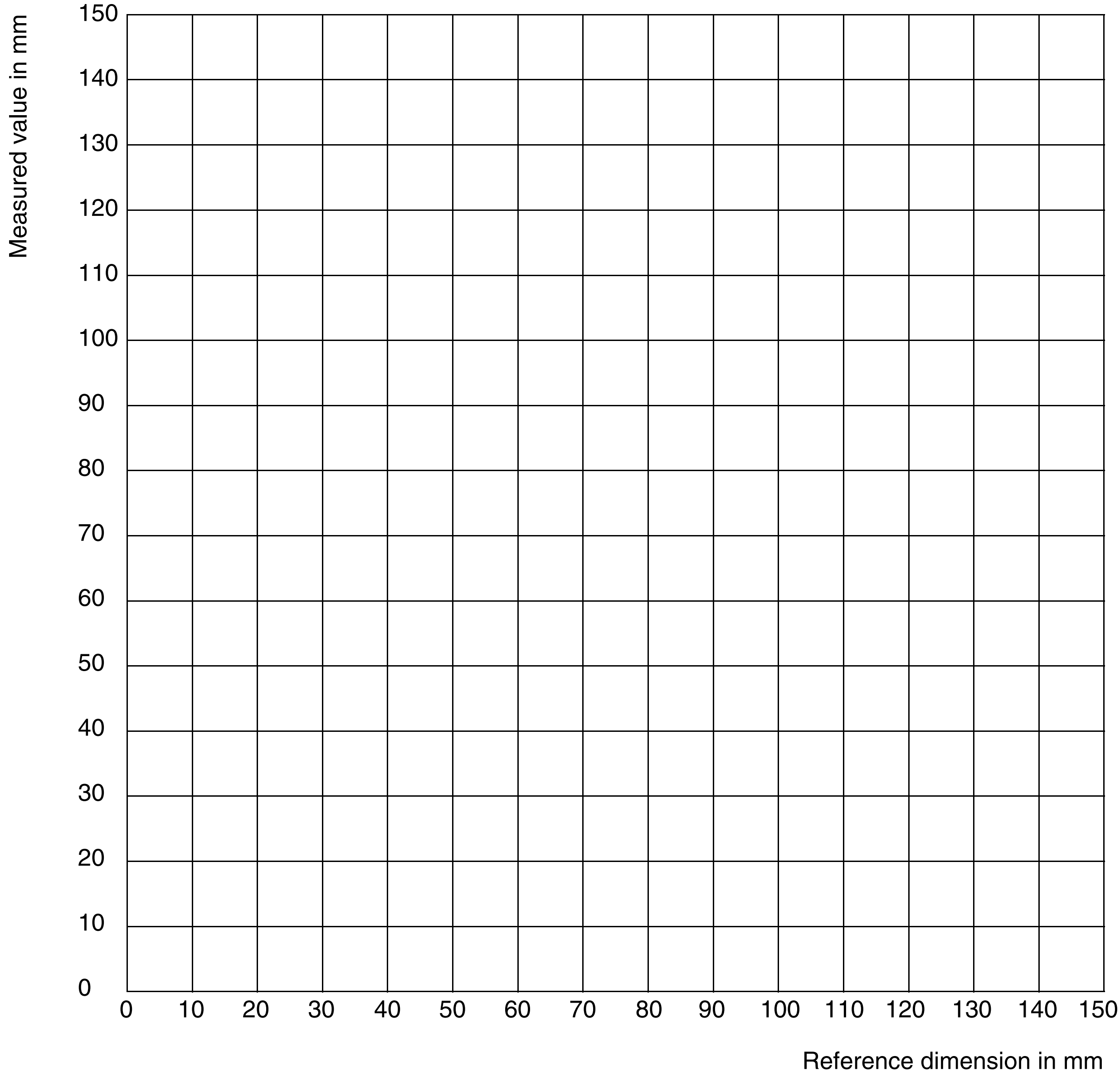
   Calculate the variation.

Calibration report			
Date: ________________			
Test equipment:Calliper gauge			
Reference	**Length of reference / references in mm**	**Measured length on test equipment in mm**	**Variation in mm**
Slip gauge	10		
Slip gauge	50		
Slip gauge	90		
Slip gauge	60		
Slip gauge	100		
Slip gauge	140		
Slip gauge	150		

Worksheet C – Calliper gauge calibration

Page 2

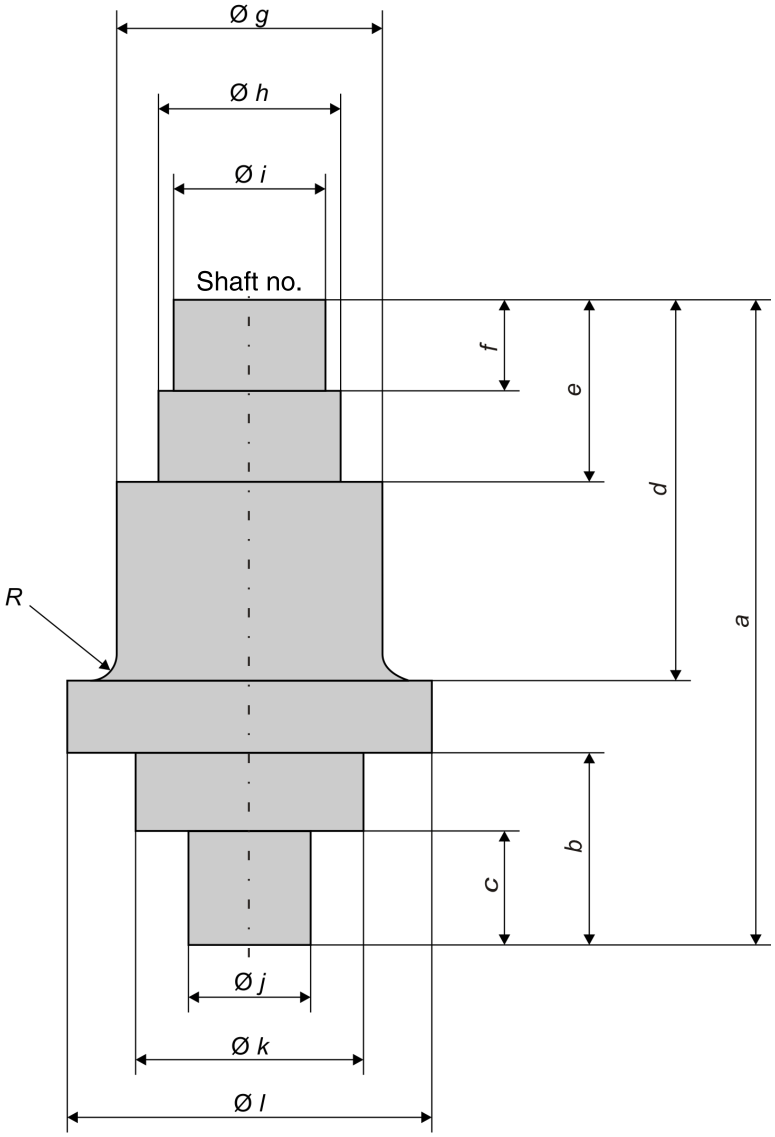
2. Represent the lengths of the reference and the measured dimensions as points and a calibration curve.



5.4 Worksheet D – Performing measurements on a shaft

Page 1

1. Determine the dimensions of a shaft and enter the measured values in the test report.



Worksheet D – Performing measurements on a shaft

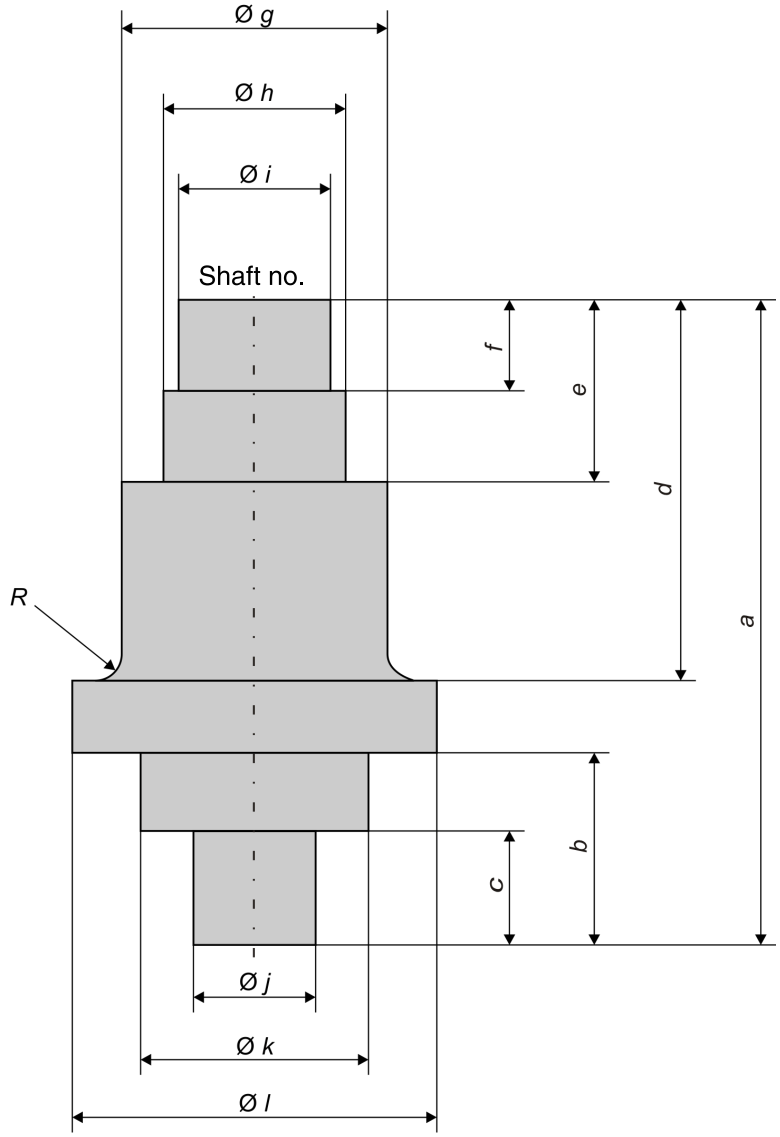
Page 2

Test report		
Test object: Shaft ______		
Date: ________________		
Dimension name	**Measured dimension in mm**	**Measuring instrument or gauge**
Lengths		
a		
b		
c		
d		
e		
f		
Diameter		
Ø *g*		
Ø *h*		
Ø *i*		
Ø *j*		
Ø *k*		
Ø *l*		
Radii		
R		

5.5 Worksheet E – Determining measuring accuracy

Page 1

1. Measure the dimensions *g*, *h*, *i*, *j* and *l* on a shaft with the calliper gauge and the micrometers and enter the measured values in the test report.



Worksheet E – Determining measuring accuracy

Page 2

Test report		
Test object: Shaft _______		
Date: _________________		
Dimension name	**Measured dimension in mm** **Measuring instrument: Calliper gauge**	**Measured dimension in mm** **Measuring instrument: External micrometer**
Diameter		
Ø *g*		
Ø *h*		
Ø *i*		
Ø *j*		
Ø *l*		

2. You have to test a workpiece with a length of 37 mm and a length tolerance of 0,025 mm. What measuring instruments do you use?

____

____

____

____

6 Solutions

6.1 Worksheet A – Metrology

Page 1

1. What do you understand by the term “testing”?

   Testing involves using test equipment to establish whether a test object meets the specified requirements.

2. What is the difference between measuring instruments and gauges?

   - On measuring instruments, a measured value is read on a scale.
   - Gauging involves comparing a dimension or shape of the test object with a gauge that has the specified dimensions or shape. Where: A gauge is the negative form, i.e. the counterpart to the test object. It identifies whether the test object falls within certain limits.

3. In theory, you need to calibrate and adjust a length measuring instrument. How would you do this?

   Calibration:

   Measure the length of a reference with the length measuring instrument. Compare the measured value with the known length of the reference, and note the variation.

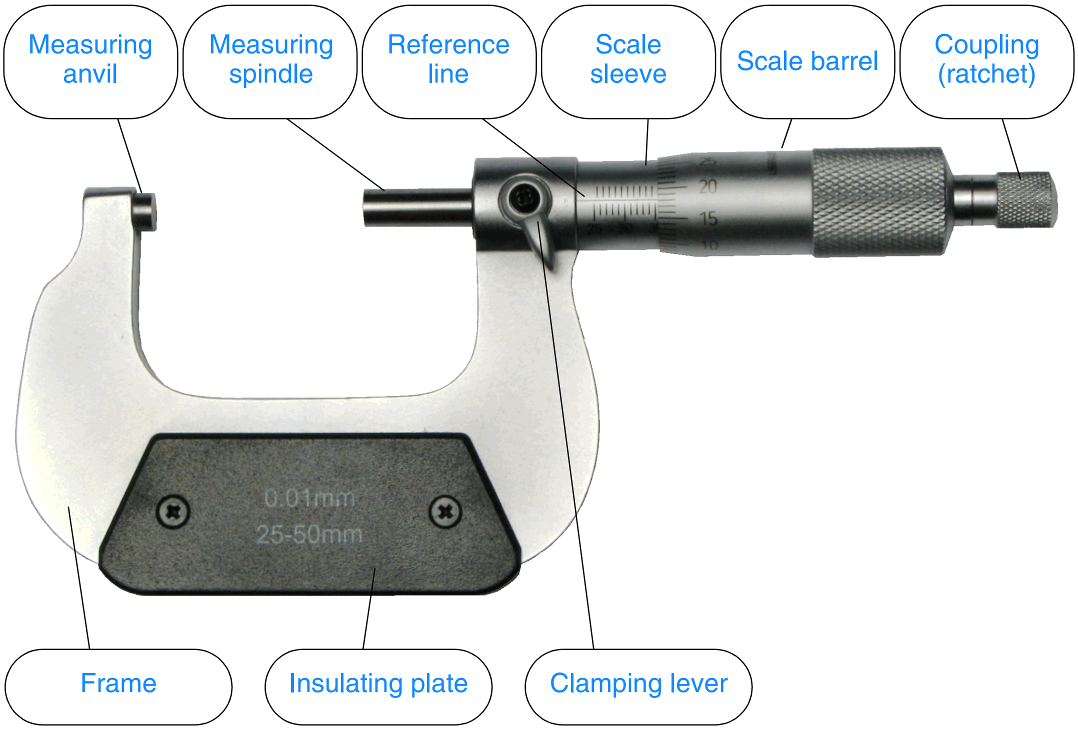
   Adjustment:

   Adjust the length measuring instrument to the length of the reference, so that the new variation is zero.

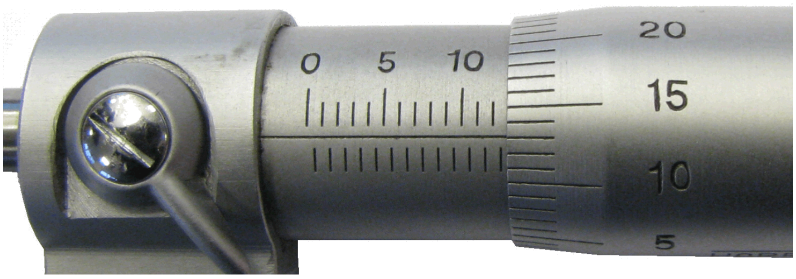
6.2 Worksheet B – Micrometer

Page 1

1. Name the parts of the micrometer.



2. Read off the measured value on the micrometer and note it.



Measured value: 12,63 mm

6.3 Worksheet C – Calliper gauge calibration

Page 1

1. Calibrate the calliper gauge using the slip gauges and enter the measured values in the calibration report.

   Calculate the variation.

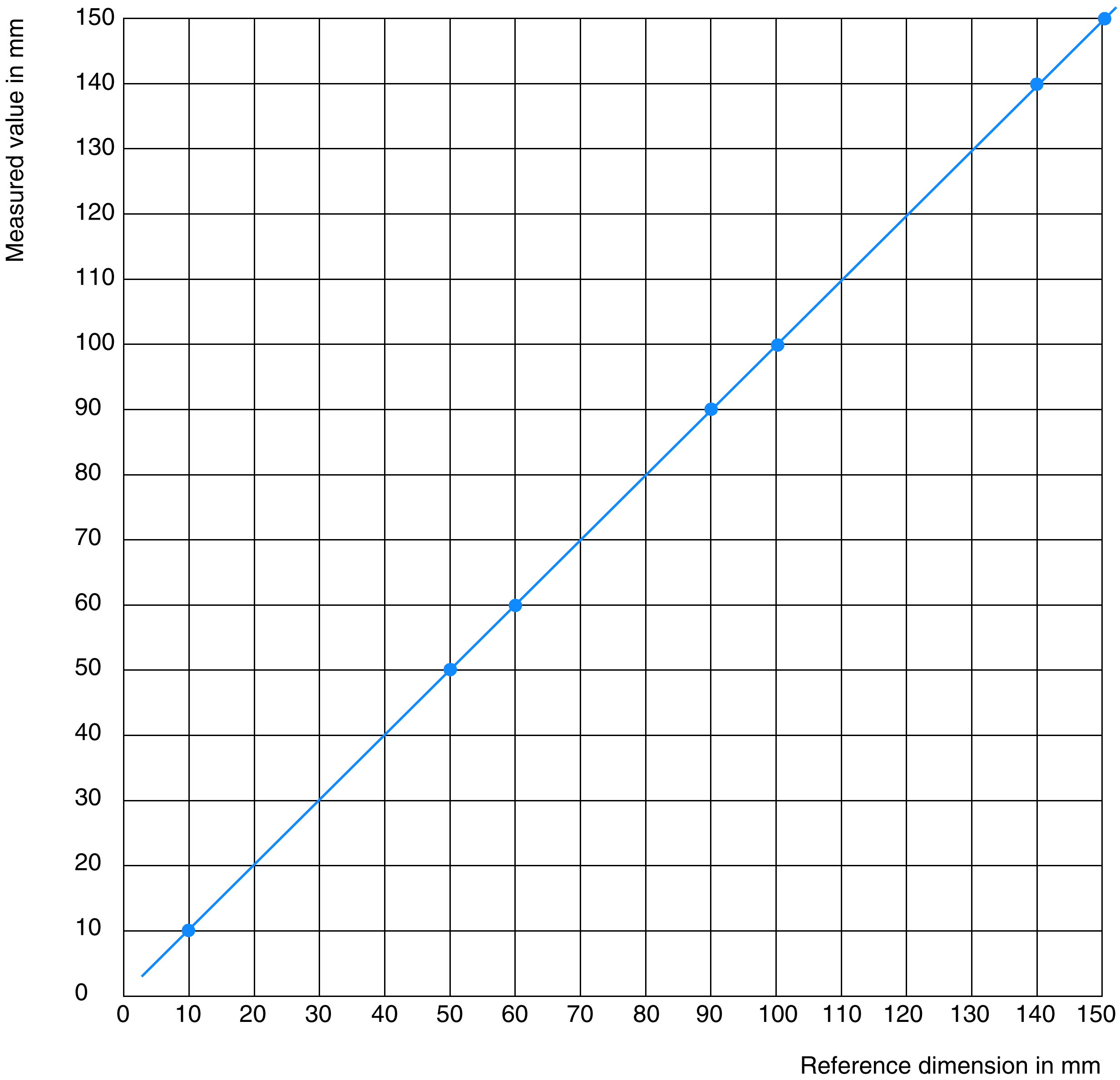
Calibration report			
Date: ________________			
Test equipment:Calliper gauge			
Reference	**Length of reference / references in mm**	**Measured length on test equipment in mm**	**Variation in mm**
Slip gauge	10	*	*
Slip gauge	50	*	*
Slip gauge	90	*	*
Slip gauge	60	*	*
Slip gauge	100	*	*
Slip gauge	140	*	*
Slip gauge	150	*	*

* Information for the teacher: The values depend on the calliper gauge and are therefore not specified.

Worksheet C – Calliper gauge calibration

Page 2

2. Represent the lengths of the reference and the measured dimensions as points and a calibration curve.

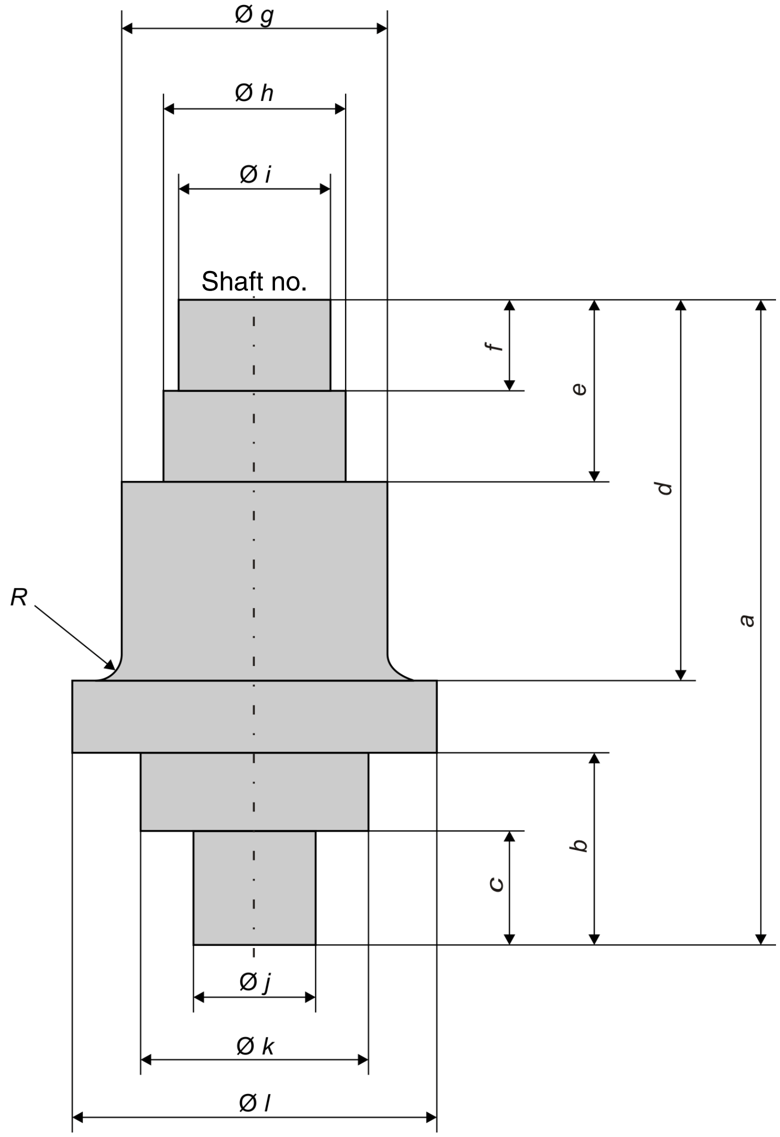


Information for the teacher: The measuring points and the calibration curve represent ideal values.

6.4 Worksheet D – Performing measurements on a shaft

Page 1

1. Determine the dimensions of a shaft and enter the measured values in the test report.



Worksheet D – Performing measurements on a shaft

Page 2

Test report		
Test object: Shaft _______		
Date: ________________		
Dimension name	**Measured dimension in mm**	**Measuring instrument or gauge**
Lengths		
a	*	Calliper gauge
b	*	Depth calliper gauge
c	*	Depth calliper gauge
d	*	Depth calliper gauge
e	*	Depth calliper gauge
f	*	Depth calliper gauge
Diameter		
Ø *g*	*	Calliper gauge or micrometer
Ø *h*	*	Calliper gauge or micrometer
Ø *i*	*	Calliper gauge or micrometer
Ø *j*	*	Calliper gauge or micrometer
Ø *k*	*	Calliper gauge
Ø *l*	*	Calliper gauge or micrometer
Radii		
R	*	Radius gauge

* Information for the teacher: The values depend on the shaft and the test equipment and are therefore not specified here. For comparison, the manufacturing dimensions of all shafts are specified in a table on the next page.

Worksheet D – Performing measurements on a shaft

Page 3

For the teacher only

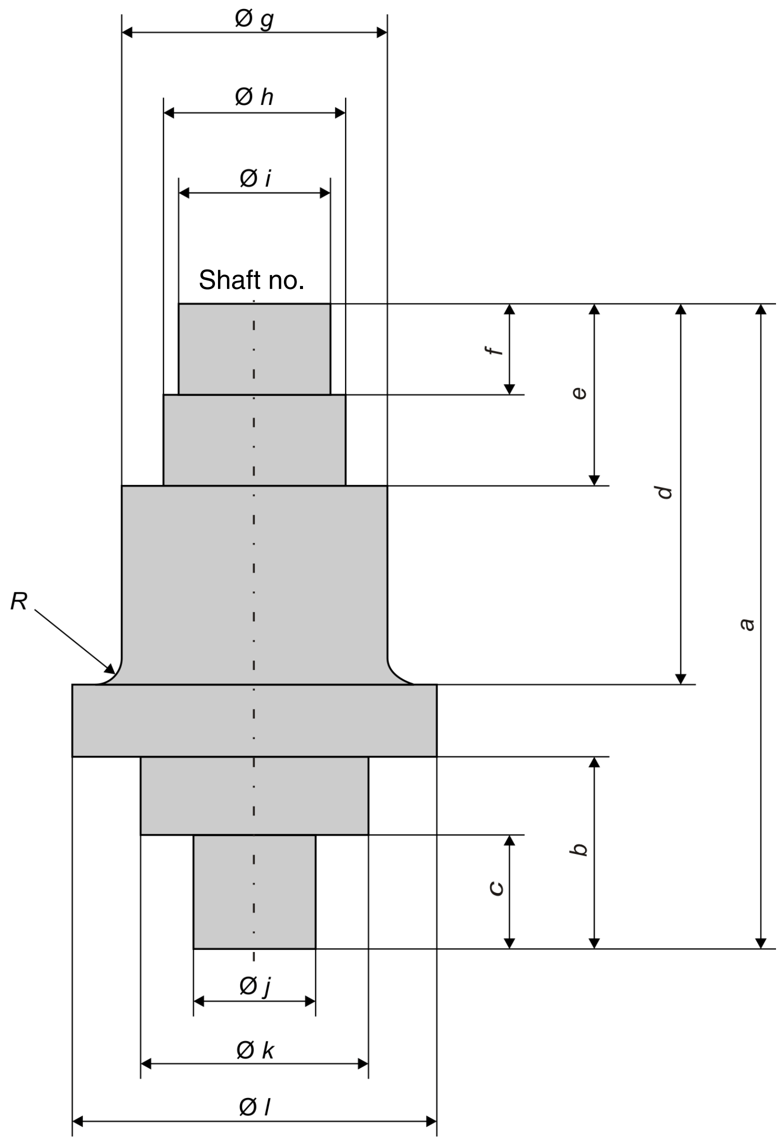
Dimension name	Tolerance	Shaft 01	02	03	04	05	06	07	08	09	10
Lengths in mm											
a	**A**	85,0	84,1	84,8	84,5	85,7	85,7	84,3	84,0	85,5	85,0
b	**A**	25,3	24,1	25,0	24,3	25,5	25,2	24,0	24,6	25,5	25,0
c	**A**	15,0	14,0	15,0	14,5	15,4	15,0	14,1	14,5	15,7	15,1
d	**A**	50,2	50,0	50,1	49,8	50,3	50,0	50,1	49,5	50,0	50,0
e	**A**	24,0	25,0	24,5	24,9	25,0	25,3	25,0	24,8	25,2	25,3
f	**A**	12,0	12,2	11,8	12,1	12,0	12,0	12,2	12,0	11,8	11,9
Diameter in mm											
Ø *g*	**B**	35,10	35,00	35,00	35,02	34,96	35,00	35,00	35,02	34,95	34,96
Ø h	**B**	24,00	23,93	23,98	24,01	24,00	24,02	24,03	24,01	24,00	23,99
Ø *i*	**B**	20,00	20,05	19,98	20,01	20,00	20,02	19,95	20,03	20,05	20,04
Ø *j*	**B**	16,10	16,20	16,00	16,00	15,92	15,20	16,00	16,15	16,00	15,98
Ø *k*	**B**	30,00	30,00	30,02	29,98	30,00	29,95	30,10	30,00	30,03	30,01
Ø *l*	**B**	48,02	48,04	47,95	48,08	48,06	48,09	48,06	47,98	48,12	48,04
Radii in mm											
R	**B**	3,50	3,00	4,00	3,00	3,50	4,00	3,50	3,50	4,00	3,50

Tab. 6.1 Selected shaft dimensions
Tolerance A: General tolerances complying with ISO 2768-1 medium, production tolerance
Tolerance B: ± 0,02 mm, production tolerance

6.5 Worksheet E – Determining measuring accuracy

Page 1

1. Measure the dimensions *g*, *h*, *i*, *j* and *l* on a shaft with the calliper gauge and the micrometers and enter the measured values in the test report.



Worksheet E – Determining measuring accuracy

Page 2

Test report		
Test object: Shaft ______		
Date: _______________		
Dimension name	**Measured dimension in mm** **Measuring instrument: Calliper gauge**	**Measured dimension in mm** **Measuring instrument: External micrometer**
Diameter		
Ø *g*	*	*
Ø *h*	*	*
Ø *i*	*	*
Ø *j*	*	*
Ø *l*	*	*

* Information for the teacher: The values depend on the shaft and the test equipment and are therefore not specified here. For comparison, the required manufacturing dimensions of all shafts are specified in a table on the next page.

2. You have to test a workpiece with a length of 37 mm and a length tolerance of 0,025 mm. What measuring instruments do you use?

   The micrometer 25...50 mm must be used.
   This is the only instrument with the correct measuring range and with sufficient measuring accuracy.

Worksheet E – Determining measuring accuracy

Page 3

For the teacher only

Dimension name	Tolerance	Shaft 01	02	03	04	05	06	07	08	09	10
Diameter in mm											
Ø *g*	B	35,10	35,00	35,00	35,02	34,96	35,00	35,00	35,02	34,95	34,96
Ø h	B	24,00	23,93	23,98	24,01	24,00	24,02	24,03	24,01	24,00	23,99
Ø *i*	B	20,00	20,05	19,98	20,01	20,00	20,02	19,95	20,03	20,05	20,04
Ø *j*	B	16,10	16,20	16,00	16,00	15,92	15,20	16,00	16,15	16,00	15,98
Ø *l*	B	48,02	48,04	47,95	48,08	48,06	48,09	48,06	47,98	48,12	48,04

Tab. 6.2 Selected shaft dimensions
Tolerance B: ± 0,02 mm, production tolerance