

# **Textbook for Vocational Training – Test Technique**



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# Textbook for Vocational Training – Test Technique

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## Preface

The present manual imparts knowledge of measuring and testing. It is meant for learners going into a trade in the field of metal working.

On the basis of concrete examples, the learner is provided with a simple, clear and brief survey of the workshop means and methods of "Measuring" and "Testing".

Only those measuring and testing instruments were described in respect to structure, function and use which the learner will need in his practical work very often.

Due to extensive illustrations, the manual is comprehensible, vivid and practice-linked.

The manual will enable the learner to choose and use in a correct way the appropriate instruments of measuring and testing for the respective required accuracy.

Furthermore, his attention is drawn to doing quality work and to treating and tending the measuring and testing instruments properly.

Summaries and instructions are oriented to essential focal points (marked by a vertical line at the side of the text). The questions asked in the text serve the testing of acquired knowledge.

The correctness of the answers can be tested with the help of the solutions given at the end of the manual.

## 1. Measuring and testing

The need of high-grade, long-life commodities, machines and appliances is constantly increasing. Anywhere in every-day life we have to do with them and use them for various reasons. From the abundance of machines which we employ to make our work easier the compressor shown in Fig. 1/1 is a random choice.

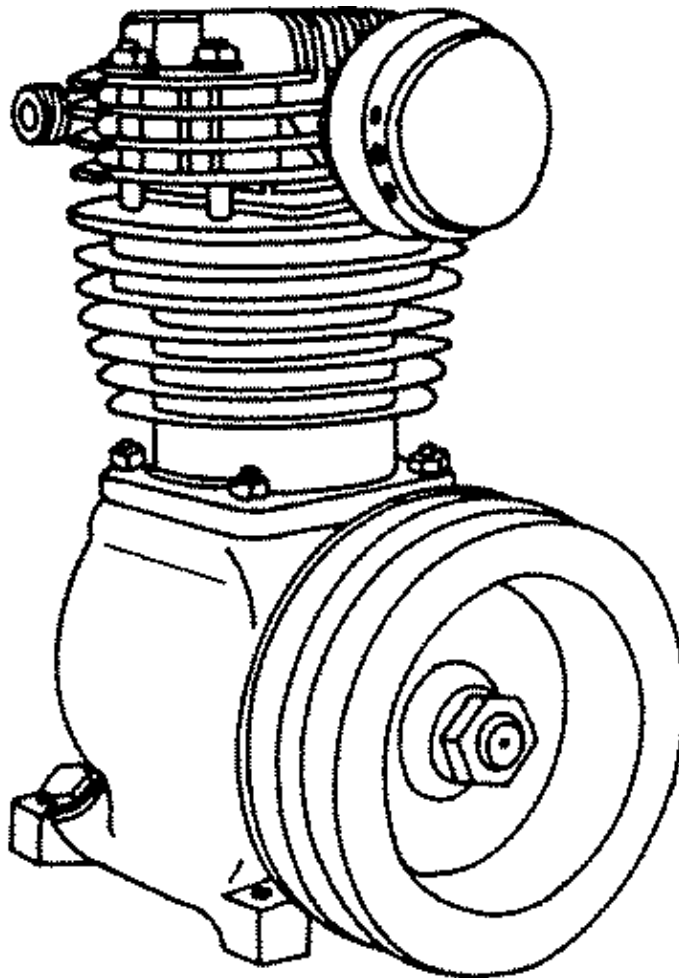


Fig. 1/1 Compressor

Three technical basic notions shall be explained on the basis of this example:

A machine is a construction to make use of natural powers or to carry out certain works. Each machine can carry out only those works for which it is constructed.

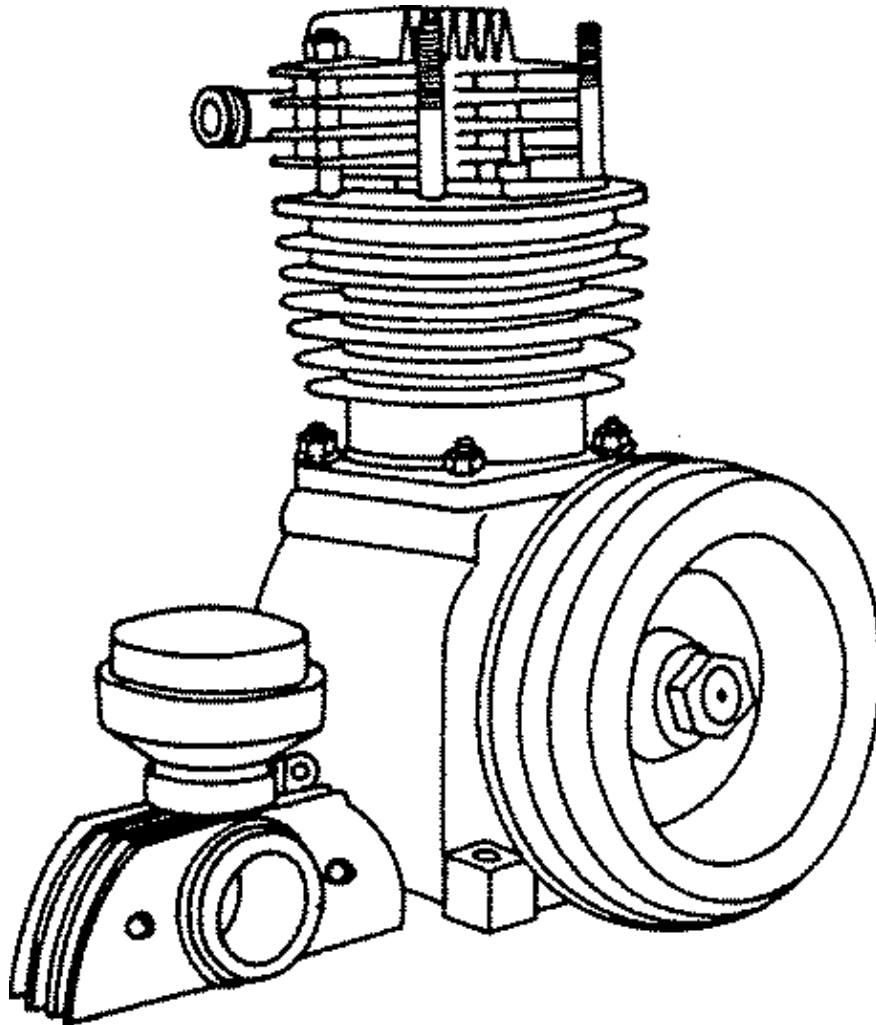


Fig. 1/2 Compressor – opened with one half of the compressor head laid before

Fig. 1/2 shows the same compressor again. Here, one half of the compressor top has been taken away. This will demonstrate that machines always consist of a number of machine parts or components.

• Components or parts of machines are functional parts carrying out a certain partial function of the overall work of the machine. Parts of machines or components alone are unable to do any work.

In Fig. 1/2, the individual parts are to be seen which may be detached further on without their functionality being neutralized or destroyed (hexagonal nuts, for instance). They are called machine elements.

• Machine elements are the simplest basic units of the machine. They cannot be furthermore detached without making them useless for their working purpose.

All parts our commodities, machines and appliances consist of are produced according to special technological documents and in a quality that guarantees their unobjectionable functioning.

Quality is the totality of all the qualities of an article determining the degree of its suitability for its appropriate application.

The presupposition of quality production is that the usability of the product and of each of its elements are known. "Testing" is the method of stating these service qualities. After these qualities have been found out by the various tests, they are fixed in technical documentations for future repetition of all test procedures.

Documents in which product qualities (such as kind of material used, form, dimensions of all parts and elements, surface condition etc.) have been laid down are called "Standards".

By standardization the exchange of units or elements between products of similar function in any place and at any time is enabled.

It is the task of "Testing" to check the product qualities fixed in standards or other technical documents and this way to guarantee a constant quality of the products.

## 1.1. The system of units

### 1.1.1. Linear measures

All differences of length, external and internal diameters of round or oval bodies, differences of diameters and generally also distances between two points (A, B) represented by straight line segments and measured by a linear measure are lengths.

Figures 1/3; 1/4 and 1/5 show linear measures at differently shaped workpieces.

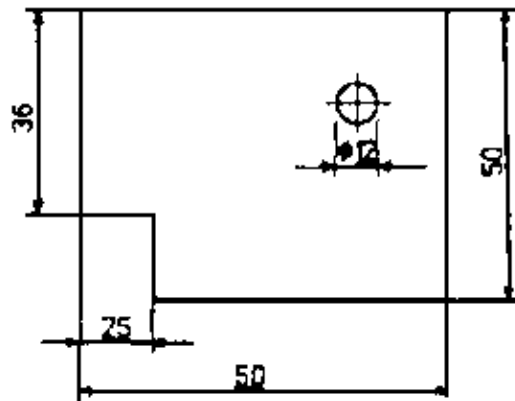


Fig. 1/3 Not-to-scale dimensioning of a straight-lined workpiece with bore hole

Fig. 1/3 shows the simple non-scale indication of dimensions of a straight-lined workpiece containing one bore hole. The diameter of the bore hole is indicated as a simple length too. At the shaft shown in Fig. 1/4

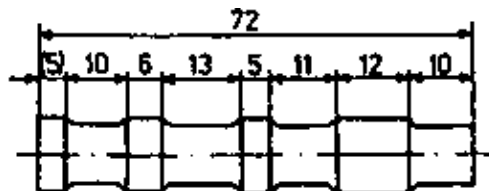


Fig. 1/4 Measures combined in a dimension chain at a shaft

– cylindrical workpiece – all differences of length are embraced in a dimension chain.

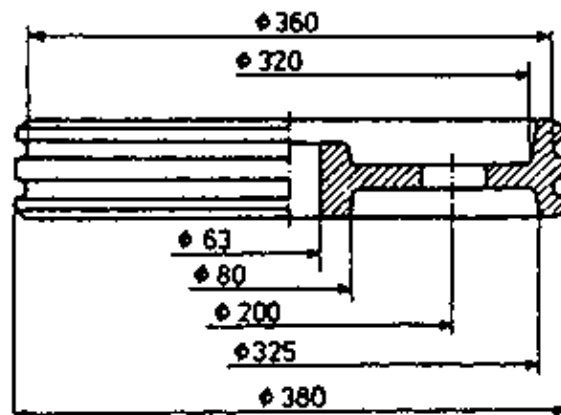


Fig. 1/5 Diameter indications at a round workpiece shown in a half section

Finally, in Fig. 1/5 showing a half section of a round workpiece, all the different diameters measurable at the workpiece are indicated as straight lines.



Lengths are measured by linear measures. The unit of the length is called metre.

The survey below shows the most common linear measures. Only those linear measures are compiled which are generally used in metal working.

Table 1/1 The most common linear measures in metal working

Designation	Abbreviation	Comparative value to the unit	Power to the unit
Metre	m	unit of length	
Decimetre	dm	0.1 m	$10^{-1}$ m
Centimetre	cm	0.01 m	$10^{-2}$ m
Millimetre	mm	0.001 m	$10^{-3}$ m
Micrometre	μm	0.000 001 m	$10^{-6}$ m

1) Put in the vales left out in the vertical columns of the below table!

Unit	Metre	Centimetre	Millimetre	Micrometre
Metre	0.35			
Centimetre		12.3		
Millimetre			42.4	
Micrometre				120

### 1.1.2. Angle measures

Every difference of the direction between two straight lines or two plane surfaces forms an angle. The size of the angle is determined by the size of the difference of the direction between the lines or the surfaces.

For a better understanding of this angle definition have another look at Fig. 1/3. All boundary lines of the workpiece shown take a certain direction which determines the shape of the workpiece. In the present case, all angles formed by the edges of the workpiece are right-angles. Such differences of direction are normally not indicated by special measure indications. In such cases, the angle size may be determined from an imaginary reference line in the form of a horizontal. The shaft shown in Fig. 1/4 is crossed by a horizontal line in longitudinal direction. These cutting lines are, in general, the reference lines for angle measuring.

Angles are measured by angle measures. For measuring by degrees, the unit of the angle measure is the degree (abbreviation  $n^\circ$ ). One full circle is the equivalent of  $360^\circ$  (degrees), one degree being ( $1^\circ$ ) the 360th part of a full angle (circle).

In technical drawings, angles can be indicated in different ways.

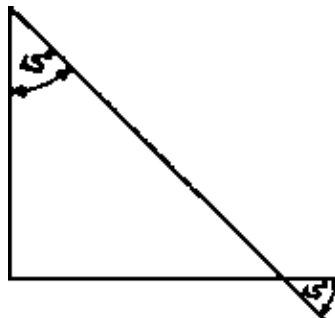


Fig. 1/6 Angle indication at a workpiece

Fig. 1/6 shows an angle indication at a workpiece as it is mostly used.

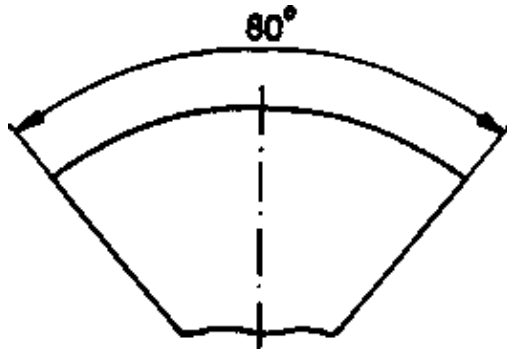


Fig. 1/7 Angle indication over a curved line

The pure indication by figures as shown in picture 1/7 over an arched line indicates the size of the angle by circular measure. If such an indication appears over a straight measuring line (not over an arched line), it is a chordal dimension.

Like the linear measures, the angle measures, too, are divided in smaller units of measurement, in order to enable more exact measuring. The following survey shows the most common angle measures.

Table 1/2 The most common angle measures in metal working

Basic measure	Abbreviation	Units derived from the basic measure
1 degree	1°	1 degree = 60 minutes (60') 1 minute = 60 seconds (60")

The angles are divided according to their opening:

- perigon = circle = 360°
- straight angle = straight line = 180°
- obtuse angle = smaller than 180° but wider than 90°
- right angle = 90°
- acute angle = smaller than 90°

In practical work, the necessity of converting an angle measure into another measure may occur.

## 1.2. The elementary testing methods

By elementary tests all those tests are understood which are carried out in the direct production process by the skilled worker at his own responsibility. The elementary tests are technologically fixed and are part of the immediate production process. They must be reasonable in respect of measurement technology and practicable with the help of the testing equipment and methods in use.

Table 1/3 Testing

Dimensional testing		Non-dimensional testing
Measuring	Gauges	Comparing with samples
Measuring of the length	Testing by limit gauges	Testing by sight
Angle measuring	Testing by profile gauges	Acoustic test
	Testing by limit gauges	Sensing

### 1.2.1. Non-dimensional testing

Non-dimensional testing is the comparison of the qualitative properties of the object to be tested (workpiece) with quality informations according to memory or documentation.

The qualitative properties of the object to be tested include all those properties that cannot be represented by mathematically defined quantities (length, pressure, temperature, power etc.). In the simplest case, the qualitative properties are inspected by sensorial comparison with samples or fixed information. Where the sensorial inspection is not sufficient for a safe statement of the qualitative condition of workpieces or materials, scientifically based laboratory inspections such as tests of material, X-ray examination of welds etc, are carried out. In direct production, mainly three kinds of non-dimensional testing are used.

### Visual inspection

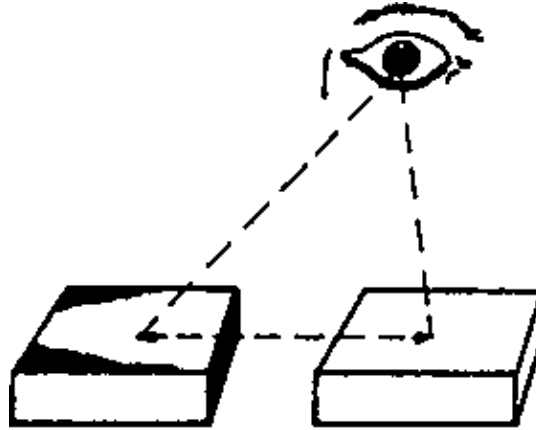


Fig. 1/8 visual inspection

By visual inspection, an object to be tested is compared by visual examination with a sample or with information according to memory. This way, external shortcomings as well as intentionally and systematically caused changes (e.g. during hardening of tools – temper colours) can be recognized.

### Acoustic inspection

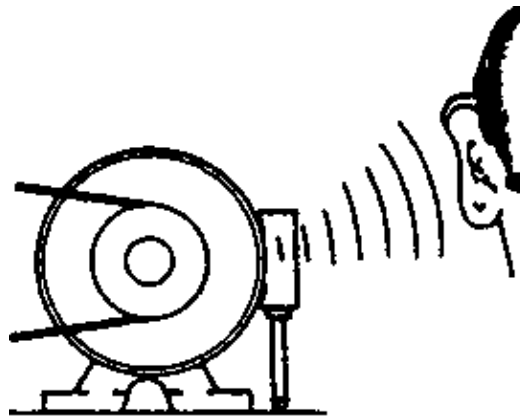


Fig. 1/9 Acoustic inspection

During the acoustic test, a noise caused by the object to be examined is compared with memory information. Certain sounds can give an information about the condition of machine parts not to be seen on the surface (running noises of parts moving against each other, bearings, noises caused by materials of a certain degree of wear etc.

### Sensing inspection

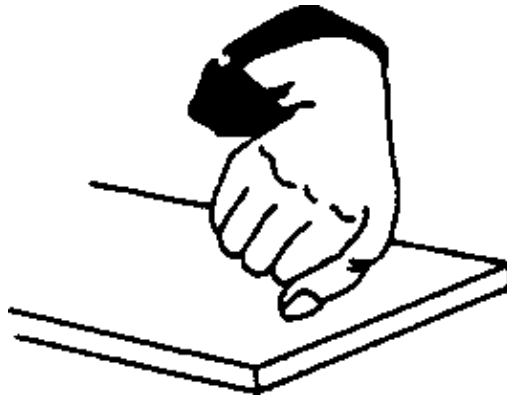


Fig. 1/10 Tracing

By sensing of the surface of an object to be inspected by finger-tips or with the help of the nail test – Fig. 1/10 – unevennesses of the surface are found out.

Taste and smell test

Under certain conditions (provedly harmless), also the senses of smell and taste can be used for examining the qualitative properties of materials. In metal working such cases are seldom and such ways of testing are strongly warned against.

The risk of most serious damages to health due to inhaling toxical vapours such as dissolvents, (benzol) or taking toxical heavy metals salts (verdigris) is incalculably great. Therefor, be most careful with these sorts of tests!

**1.2.2. Dimensional testing and measuring**

In contrast to non-dimensional testing, for dimensional testing or measuring testing and measuring instruments are used equipped with a measuring indication (unit lengths, angle units etc.) and enabling a direct comparison of size between the object to be tested and the measuring instrument.

Dimensional testing or measuring is always a comparison of an object to be tested with a measuring instrument equipped with units of measurement.

The measured values can never be absolutely correct since the measuring instruments, in spite of greatest possible carefulness, cannot be manufactured with absolute accuracy. All measuring instruments show errors within the limits of admitted tolerances.

The measuring process

In practical work, three measuring methods are distinguished:

Table 1/4 Measuring

Direct measuring	Indirect measuring	Comparative measuring
rules	sine bar	dial gauge
vernier caliper	level	indicating micrometer
micrometer protractor dial gauge	angle level	

During direct or immediate measuring, the measure to be verified is tested by direct comparison of the object to be tested with the measuring device. For this, the measuring instrument must have a sufficiently large indicating range.

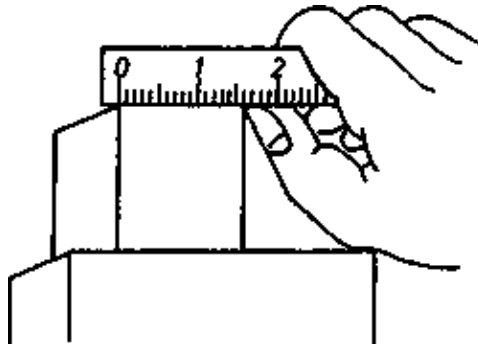


Fig. 1/11 Direct measuring by steel rule

The indicating range of a measuring instrument or device is the representation of the measuring units on the scale of the instrument. It must be possible to read it without errors.

Indirect measuring is applied if the measure to be verified is difficult of access or not accessible. The actual measuring result has to be calculated from the indication of the measuring instrument.

Thus, with the help of length measurement followed by a calculation, the size of an angle can be found out which is impossible to determine by direct measuring. Practical work often requires measurements that cannot be carried out by direct means of measurement, i.e. directly indicating measuring instruments or devices. The values to be measured are so small that an indication on a normal graduation is impossible. For the measurement of that small measures, special precision measuring instruments have been developed. These instruments transfer the smallest values into readable values by a mechanism of transfer such as gear wheel transmission or screw transmission. The indicating range of such measuring instruments is generally very small. With the help of extremely accurate comparison bodies. e.g. parallel gauge blocks, they are adjusted to the desired measure required (nominal size) and then used for the measurement of the difference between the measure of the workpiece (actual size) and the comparison body (represented required measure or nominal size).

By difference measurements, not the actual size of a workpiece is measured but the difference between the size of the object to be tested and the comparison piece accurate in size.

#### Technical basic notions of testing

In the preceding paragraphs, a number of technical terms of testing were mentioned that shall be explained in the following.

Measure. Embodiment of a unit such as line standard, end measure, litre and also the size of a property expressed in figures, for instance length and volume.

Unit of measurement. Fixed unit for the determination of physical and technical quantities such as length, weight, time. Measuring a physical or technical quantity means to find out how many times a quantity of the same kind fixed as unit – the unit of measurement – is contained in the quantity to be measured.

Measured quantity. Physical or technical quantity which is to be measured.

Measured value. Product of numerical value (indication of the size) and chosen unit of measurement, for instance 1.25 m/15.3 kg/35 s.

Measuring result. Result of a comparisons between a measured quantity and a unit of measurement of the same kind (result of the measurement).

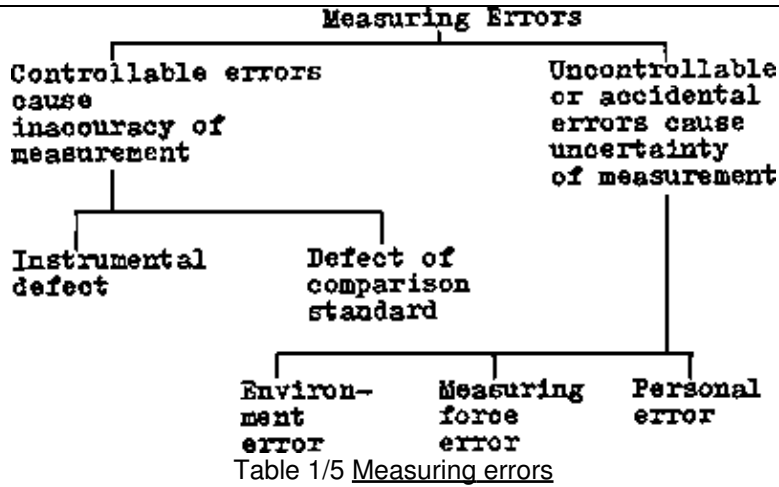
Desired or nominal value. Indication of measured value in technical documentation, drawing or sketch.

Actual size. Actual size of a workpiece stated by measurement.

Dimensional variation. Variation in size between required measure (nominal measure) and actual size. (See Paragraph 2.7.1.).

### 1.3. The measuring errors

The difference between measuring result achieved and the real size of the object to be measured is called measuring error. A distinction is made between controllable and non-controllable measuring errors. Measuring errors that cannot be controlled are normally those which occur accidentally. Defects of devices can be controlled and corrected.



Errors caused by environmental factors such as temperature variation, insufficient or wrong lighting of the workshop place and percussion due to running machines can be kept under control by considering the reasons. Errors due to too strong or to weak measuring force lead to different deformations of the workpiece to be tested. They can be limited by series of measurements followed by average determination. Personal errors, i.e. mistakes made by the person who carries out the measurement can be kept low by experience

Every measurement requires the greatest possible carefulness and sense of responsibility.

The decision about the measuring instruments to be used is determined by the required degree of accuracy. As a principle applies:

Not as accurate as possible but as accurate as necessary!

If simple measuring devices are sufficient, no high-grade testing instruments should be used in order to avoid unnecessary expenditures.

- 2) What is the difference of direct and indirect measuring?
- 3) What are the pre-conditions of farrest possibly correct measurements free of errors?

### 2. The linear measurement

Table 2/1 Length measuring instruments

Length measuring instruments	Accuracy of reading	Use
Steel rule	1 mm	coarse measurement (e.g. sheet blank)
Vernier caliper	0.1 mm	machine building fitter's shop
Micrometer	0.01 mm	fine measuring (e.g. fits)
Dial gauge	0.01 mm	differential measurement (e.g. in mass production)

Read the definitions and principles given in Paragraph 1.1.1. once again. Answer the following questions:

- What is a length?
- How are lengths represented in technical documentation
- How are lengths measured?
- Which linear measures are generally used in metal working?

## 2.1. Measuring by steel rule

In most cases, the steel rule with millimetre pitch is used. To improve the measuring accuracy, also rules 1/2 mm pitch are applied. The use of them requires great concentration.



Fig. 2/1 Steel rule

Fig. 2/1 shows a steel rule of a measuring range of 300 mm the prescribed measuring accuracy of which is  $\pm 0.5$  mm and which is normally used in machine building.

Rules of the same pitch and measuring accuracy with a measuring range of 500 mm are also available.

Measurements by steel rules are carried out either directly, by putting the rule on the workpiece and reading the measured value, or by measure transfer to a caliper (see Paragraph 2.6.) or compass, respectively. The adjusted caliper or compass openings are used as testing means for measures or for the transfer of measures to a workpiece.

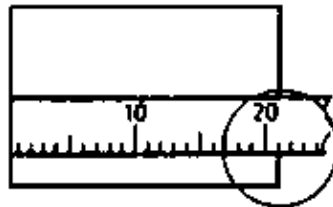


Fig. 2/2 Correct application of the steel rule

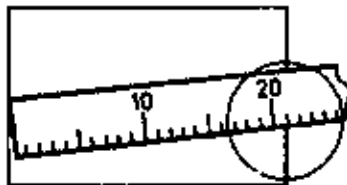


Fig. 2/3 Measuring errors due to an inclined position of the rule

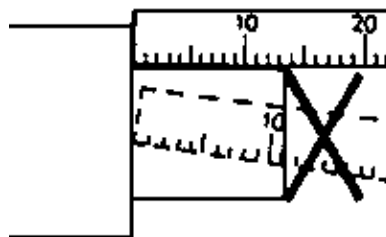


Fig. 2/4 Measuring errors due to an inclined position of the steel rule at a shaft

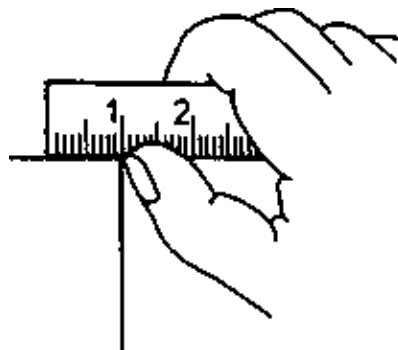


Fig. 2/5 Correct measuring of the length by steel rule with finger support

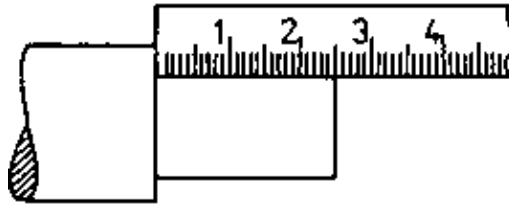


Fig. 2/6 Correct application of the steel rule to a shaft

In order to avoid measuring errors, as shown in Figures 2/4 and 2/3 attention has to be paid to the correct positioning of the steel rule at the objects to be measured. Support by fingers, as is to be seen in Fig. 2/5 prevents gliding off or getting out of place of the rule. Where there are supporting edges (Fig. 2/6), they should be used in any case.

Most of the measuring errors with steel rules are caused by carelessness. Mostly, lack of parallelism (see Fig. 2/3) of the rule and the length to be measured or an inclined position of the rule are the reasons for measuring errors (Fig. 2/4).

Measuring errors are also due to a wrong line of sight during the measuring process.

Measured values always have to be read vertically to the pitch of the measuring instrument!

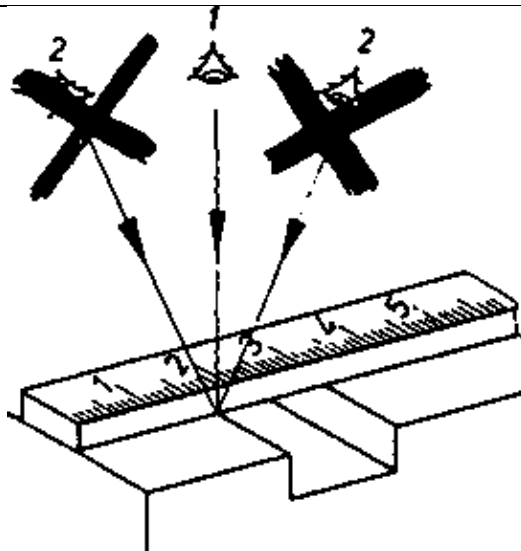


Fig. 2/7 Avoiding of reading mistakes by correct direction of sight

- 1 Correct direction of sight
- 2 Wrong direction of sight

By lateral shifting of the line of sight, it comes to reading errors finally leading to a measuring error.

Every measurement requires attention and concentration. Every measurement should be repeated (control measurement) to spot possible measuring errors. Measuring instruments are no tools! They must be treated carefully and cleaned thoroughly after use (at least after a work is completed). The measuring instrument has to be rubbed with a little non-acid grease as rust preventive. (vaseline). Measuring instruments have to be kept in a safe place on a soft support!

## 2.2. The vernier caliper

### 2.2.1. The structure of the vernier caliper

The vernier caliper shown in Fig. 2/8 enables a safe reading of 1/10 mm (0.1 mm). The movable side (3) with the vernier (2) is slidable on the measuring beam (1). For measuring internal and external measures, the movable and the fixed side (4) are equipped with measuring edges (5), For fixing a measure taken from the



object to be measured, there is the binder or, with some types the binding screw (6).

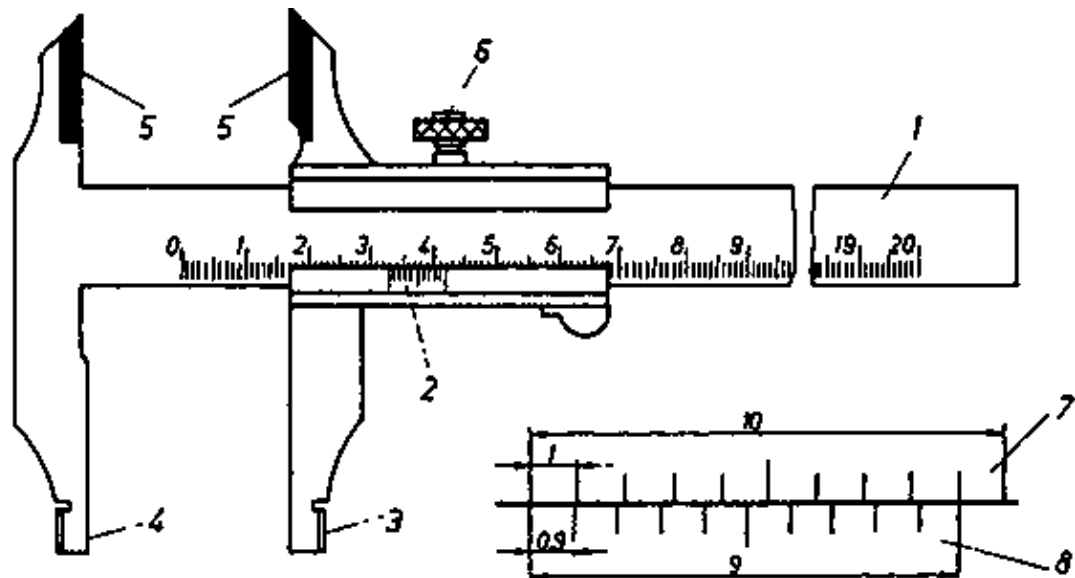


Fig. 2/8 Vernier caliper

- 1 Measuring beam,
- 2 Vernier,
- 3 Moveable side,
- 4 Fixed side,
- 5 Measuring edges,
- 6 Binder screw
- 7 Main graduation on the measuring beam,
- 8 Auxiliary graduation on the vernier

On the back of the rule there is a slot in which a depth gauge connected with the vernier caliper is sliding. The measuring beam is provided with a millimetre pitch. On the vernier, parallel to this main rule (7), there is another pitch (8) the graduation marks of which are closer-spaced by  $1/10$  mm than the millimetre pitch auf the measuring beam. 10 vernier marks are the equivalent of 9 mm measuring beam. Hence each vernier fraction is  $1/10$  mm smaller than a mm. If the first graduation mark of the vernier coincides with any graduation mark of the measuring beam, the measured workpiece is  $1/10$  mm bigger than indicated by the full millimetres of the measuring beam. If the third graduation mark is congruent with any graduation mark of the measuring beam, the measured workpiece is  $3/10$  mm bigger than indicated by the full millimetres of the measuring beam and so on.

The mark of the measuring beam that stands before the zero mark of the vernier indicates the full millimetres of a measurement. The vernier mark coinciding with a mark of the measuring beam indicates the tenth millimetres of a measurement.

### 2.2.2. Measuring by vernier calipers

Three different measurements of the length can be carried out by a vernier caliper:

- Measurement of external dimensions
- Measurement of internal dimensions (distances, recess diameter)
- Measurement of the depth (recess depth, bore holes).

In Fig. 2/9, the correct measuring of the diameter of a circular workpiece is shown. The workpiece has always to be measured with the help of the full gauging surface of the measuring jaw halves.

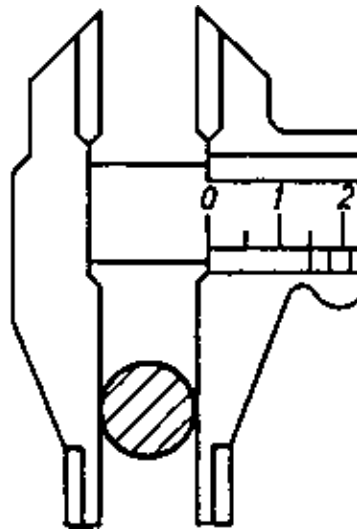


Fig. 2/9 External measurements with the help of the measuring sides

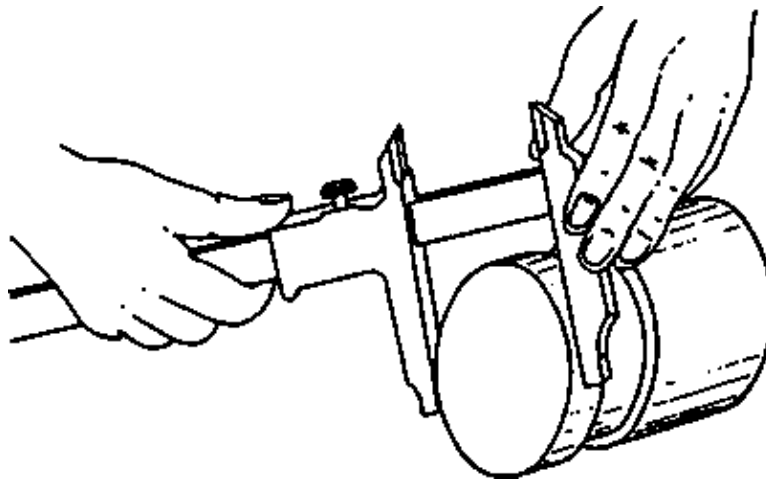


Fig. 2/10 Measuring of clamped workpieces

Fig. 2/10 shows an external measurement at a rotary part. Here, the following principle applies:

Never carry out any measurements at a moving (rotating) workpiece! The vernier caliper becomes unserviceable because of the grinding effect of the moving workpiece damaging the edges of the measuring jaw halves.

Moreover, there is the risk of accident if the vernier caliper becomes jammed at a rotating workpiece!

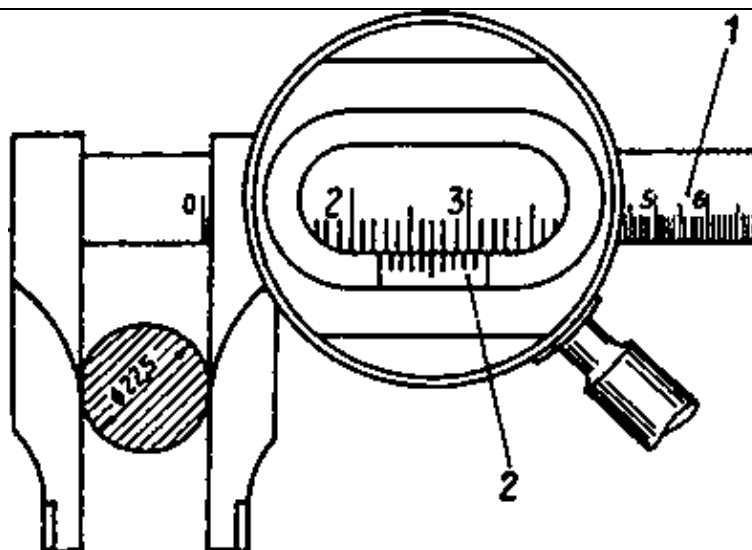


Fig. 2/11 Example of the reading of measuring results from the vernier caliper

Fig. 2/11 once again shows an external measurement. The measuring result is to be seen on the scales (measuring beam and vernier) as 22.5 mm.

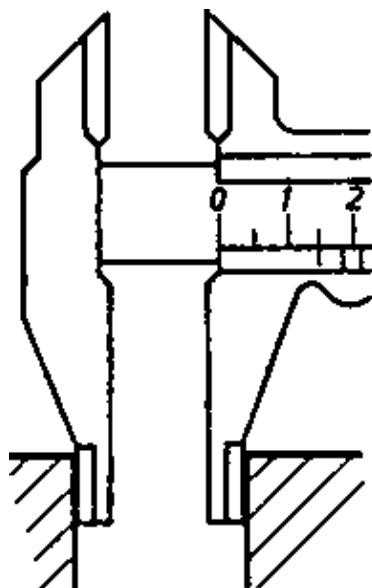


Fig. 2/12 Internal measurements with the help of the measuring jaws

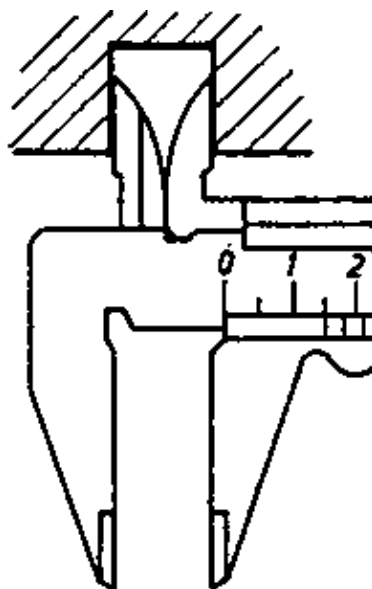


Fig. 2/13 Internal measurements with the help of the cross jaws

Figures 2/12 and 2/13 show the measuring of internal measures. Internal measures occur in the forms of distances between two parts of a workpiece, internal measures of pipes, internal measures of bore holes, so-called recess measures.

If the radiused measuring pins for internal measurements are at the long parts of the measuring jaw (cf. Fig. 2/12), 10 mm have to be added to the measured values read. The thickness of the pins is always 5 mm each. With such vernier calipers, the indication of the measured value always refers to external measures.

If an internal measure or recess measure or the measure of a distance is taken with the help of the measuring pins at the measuring jaw halves, 10 mm pin thickness have to be added to the measured value indication.

If the internal measurement is carried out with the help of the measuring edges (Fig. 2/13), the measuring result is used without any addition to the measured value indication.

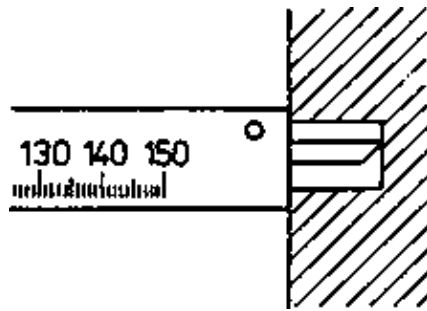


Fig. 2/14 Measuring of a depth by the vernier caliper

Fig. 2/14 shows a depth measurement with the help of a vernier caliper. For this purpose, the caliper, which is connected with the depth tracer is slipped into the recess to be measured the end of the rule resting on the edge of the workpiece. The measuring result is read from the measured value indication.

With measuring by vernier caliper, three major errors occur due to mistakes in handling the measuring instrument:

- Measuring with the tips of the measuring jaw halves;
- Measuring with too strong pressure on the halves of the measuring jaw;
- Tilting of the vernier caliper, lacking parallelism to the workpiece and the attempt to force the vernier caliper between the crank pins with the sliding member arrested.

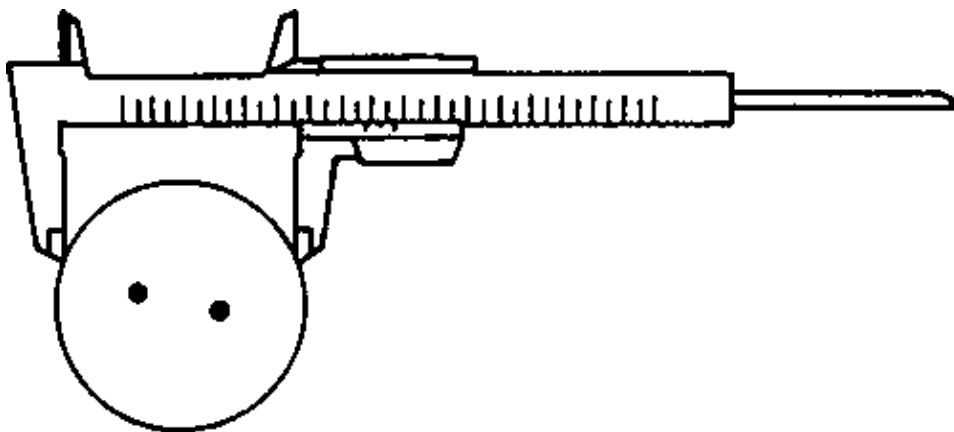


Fig. 2/15 Measuring errors due to wrong application of the vernier caliper

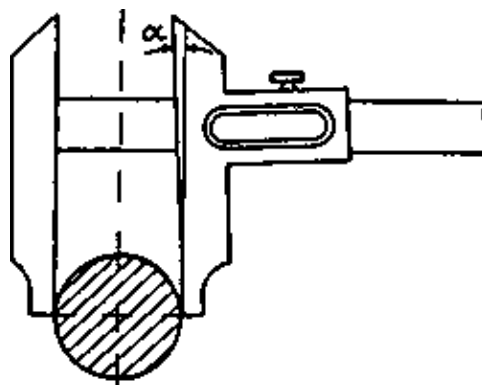


Fig. 2/16 Measuring errors due to wrong application of the measuring force on the vernier caliper

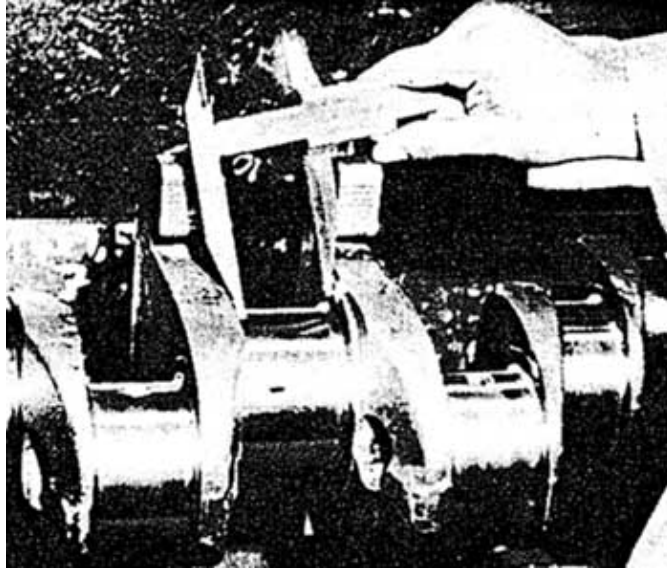


Fig. 2/17 Measuring errors due to tilting of the vernier caliper

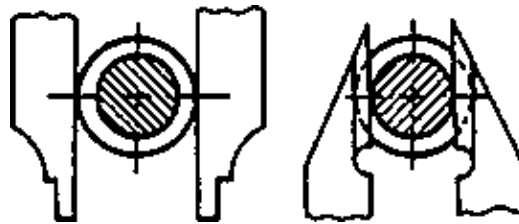


Fig. 2/18 Measuring of a thread by a vernier caliper

With the help of the keen edges (measuring edges) of the long or short halves of the measuring jaw, measurements of threads can be carried out (Fig. 2/18).

For working with the vernier caliper, the following general principles have to be observed:

Put the vernier caliper with loosened clamping device slightly on the workpiece or into the recess of the workpiece, respectively. Press the halves of the measuring jaw firmly against the measuring surface. Do not use force. Arrest the sliding member with the help of the clamping device (binding screw) and take it off the workpiece. Read the measured value and carry out a control measurement. Do never force the vernier caliper on a workpiece or into the recess of a workpiece with the sliding member arrested! Never take any measure only with the help of the tips of the measuring jaw! The vernier caliper is no drawing set! Therefore draw no parallel lines by the keen measuring edges!

### 2.2.3. Measuring by depth gauges

The depth gauge is a special form of vernier caliper derived from the normal version. The depth gauge, too, consists of a measuring beam (1) as the basic element. The measuring beam ends in the depth stop (4). The sliding member (2) with two measuring jaw halves is designed that way that these two halves form one self-contained gauging surface (3). The vernier (5) and the binding screw (6) are similar to those of the normal vernier caliper.

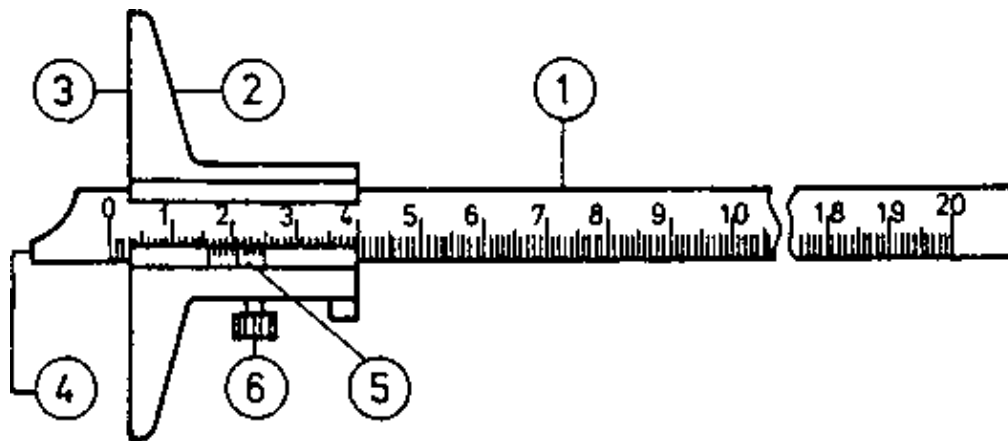


Fig. 2/19 Depth gauge

- 1 Measuring beam,
- 2 Sliding member,
- 3 Measuring jaw halves with gauging surface,
- 4 Depth stop,
- 5 Vernier,
- 6 Binder screw

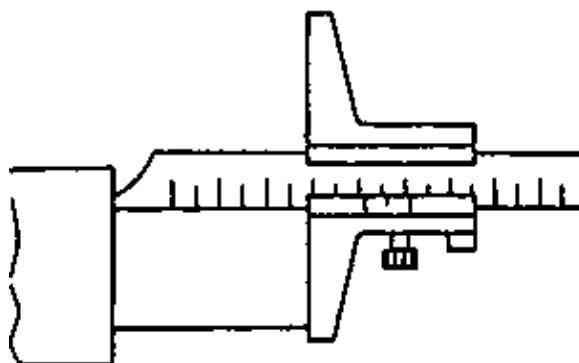


Fig. 2/20 Longitudinal measurement by a depth gauge shaft journal

By the depth gauge, especially recess depths, the length of internal and external ledges, depths of slots and bore holes are measured. In the Figures 2/20; 2/21 and 2/22 examples of the use of a depth gauge are to be seen.

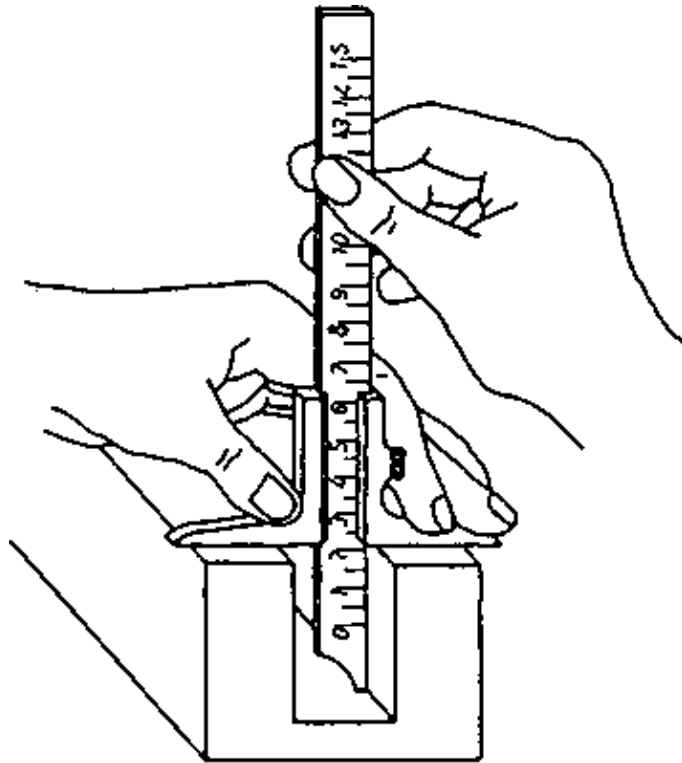


Fig. 2/21 Measuring of smooth recesses by the depth gauge

Fig. 2/22 shows the measurement of thicknesses, which cannot be measured by a normal vernier caliper. In fact, this special form of a depth gauge represents a much simplified normal vernier caliper.

For working with depth gauges, the following principles should be observed:

The gauging surface of the depth gauge has to be pressed firmly – but without effort – against the surface of the workpiece.

The depth stop must be led vertically against the bottom of the recess and put on firmly – do not use force! (see Fig. 2/21).

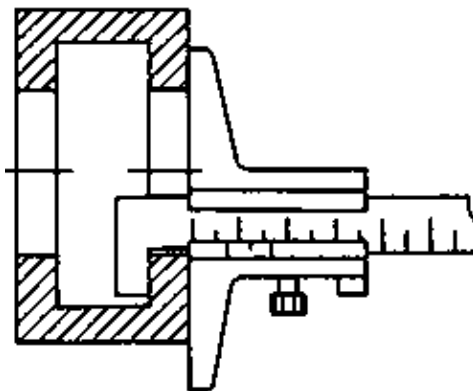


Fig. 2/22 Depth gauge with angular neck for thickness measurements into depth

For measuring the length of the shaft journal or other external ledges, only the lower half of the gauging surface has to be held against the workpiece.

In doing so, attention has to be paid to a safe application of the measuring instrument, without tilting!

The depth stop (measuring beam) resting on the shaft journal (Fig. 2/20) has to be pushed to the stop.

The measured value, as with a normal vernier caliper, is read on the vernier.

At the end of the work, the vernier caliper is thoroughly cleaned by a soft cloth and then rubbed with an acid-free grease (vaseline) for rust prevention. Vernier calipers are sensitive instruments. Consequently, they

have always to be kept on a soft support. The measuring edges must be protected by the protective caps provided for this purpose in order to avoid damages.

The accuracy of vernier calipers must be checked in appropriate intervals. For this purpose, the vernier has to be adjusted to zero and, against a source of light, it has to be found out whether there is any gap between the gauging areas.

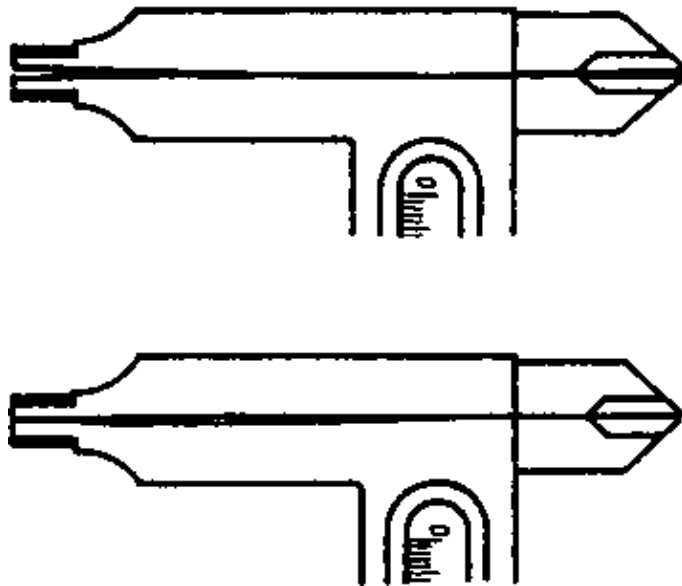


Fig. 2/23 Vernier caliper with blocking measuring edges

- 4) Describe the principle structure of a vernier caliper!
- 5) Describe the structure and the measuring function of a vernier!



Fig. 2/24 Reading examples a)



Fig. 2/24 Reading examples b)



Fig. 2/24 Reading examples c)

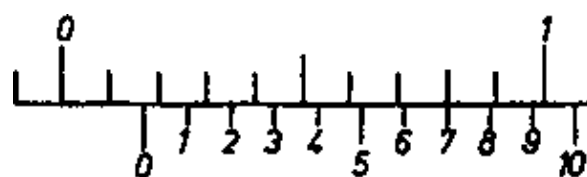


Fig. 2/24 Reading examples d)



- 6) Give the vernier measured values indicated in Fig. 2/24!  
 7) What handling mistakes are the main reasons of measuring errors with vernier calipers?

### 2.3. Micrometers

Micrometers are precision measuring instruments with which – compared with the vernier caliper –

- the measure carrier is a screw;
- by turning the screw, the gauging surfaces are moved against each other;
- the measuring range (25 mm with all micrometers) is limited by the length of the screw.

All micrometers enable the reading of hundredth millimetres (measuring accuracy 0.01 mm).

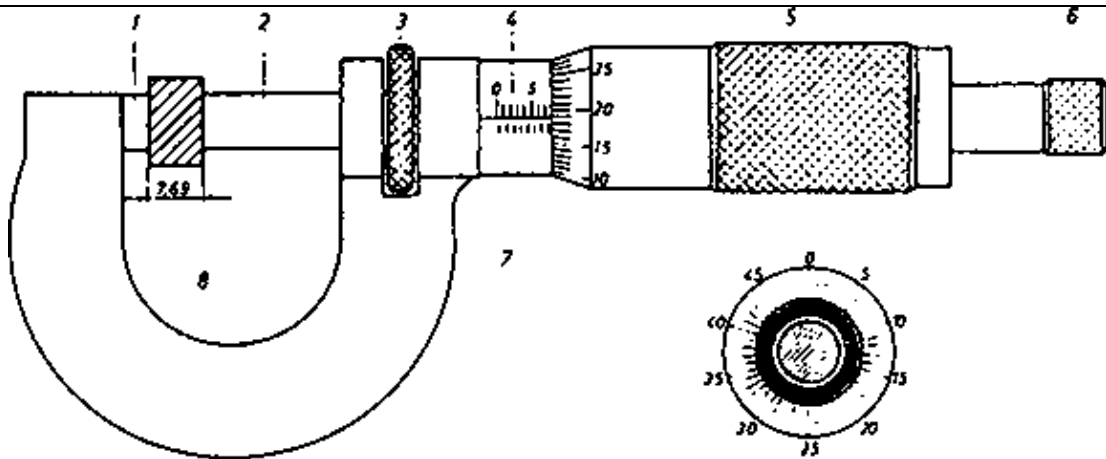


Fig. 2/25 Micrometer screw

- 1 Anvil,
- 2 Measuring spindle.
- 3 Lock nut as clamping device,
- 4 1 mm reading,
- 5 Graduated drum
- 6 Knurled knob,
- 7 Scale case,
- 8 Bow

The bow of the micrometer (8) is normally fixed to the scale case (7). The measuring screw (2) and the drum (5) are bolted. This enables an accurate adjustment of the micrometer screw. The micrometer screw has a thread pitch of 0.5 mm. The micrometer screw can be arrested by the lock nut (3). The facing gauging surfaces at anvil (1) and micrometer screw are parallel-ground and made wear-resistant by covering with carbide tips. The ratchet stop prevents an exceeding of the measuring force. If the measuring force becomes too strong, the micrometer screw comes to a stop. The knurled knob (6) often serves as the so-called rapid drive.

Since the measuring range of micrometer screws is only 25 mm, micrometers with different bows and standard measuring ranges are available for measuring various distances, diameters and so on.

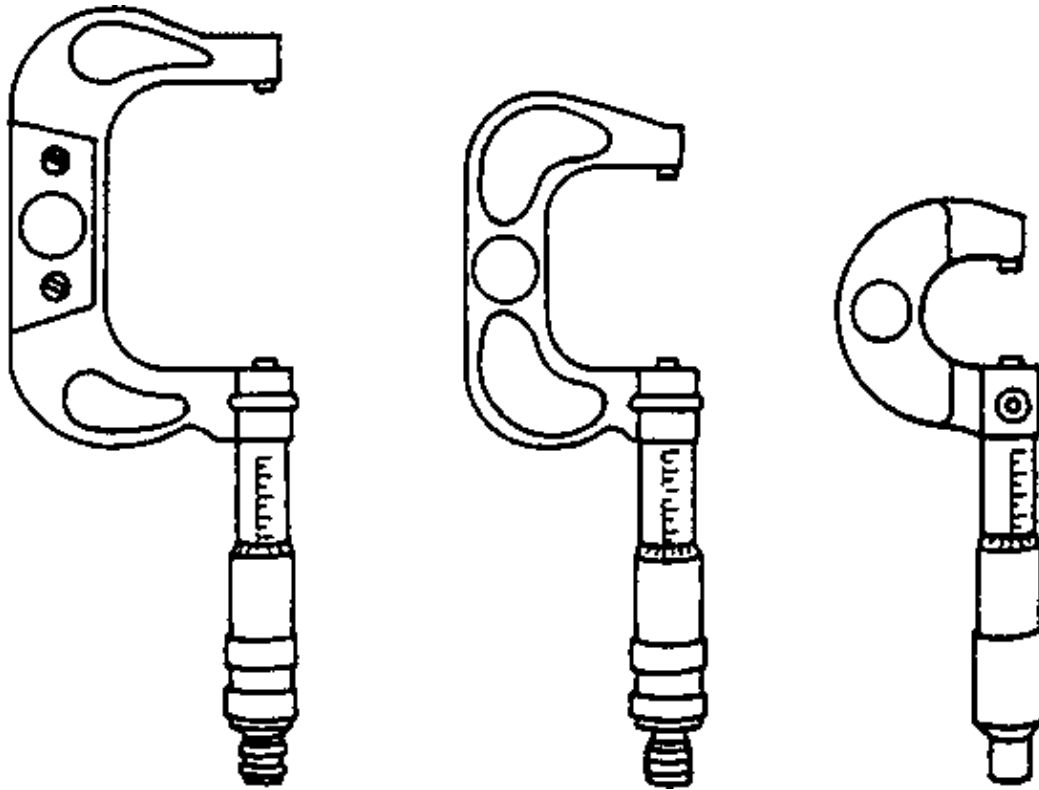


Fig. 2/26 External micrometer with different measuring ranges

There are:

- micrometers for measuring external dimensions;
- micrometers for measuring internal dimensions;
- micrometers for carrying out depth measurements.

### 2.3.1. Operating mode and handling of micrometers

During measuring by micrometers, always the bow is held fast and the micrometer screw is turned!

The micrometer screw turns simultaneously with the micrometer drum. Since the thread pitch is 0.5 mm, the micrometer screw moves 0.5 mm with every full revolution. On the perimeter of the micrometer drum there is a graduation of 50 equal parts. If the measuring screw is turned by only one of these parts, it is moved by  $0.5 : 50 = 0.01$  mm.

The graduations on the inner case of the micrometer screw as well as on the micrometer drum represent – in their entirety – the vernier of the micrometers.

On the vernier of a micrometer, the full and half millimetres are successively read on the inner case and then the hundredth millimetres on the micrometer drum. Both are added, which gives the final total value.

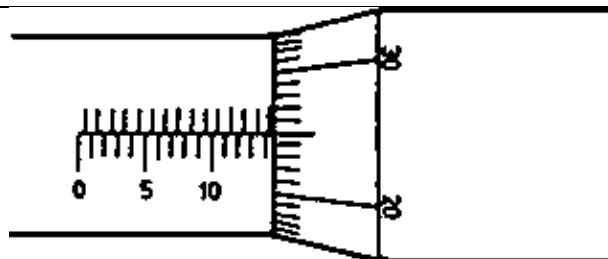


Fig. 2/27 Vernier at the external micrometer

Hence the vernier indication in Fig. 2/27 reads:

- 14,00 mm (full millimetres on the inner case);
- 0.50 mm (half millimetres on the inner case);
- 0.25 mm (hundredth millimetres on the micrometer drum);
- 14.75 mm = measured value result.

Measuring by external micrometers should be carried out according to the following principles:

- tighten the measuring screw with the help of the ratchet so that the workpiece is slightly touched;
- block the lock nut in order to fix the measuring result. Then pull the external micrometer off the workpiece without effort;
- read the value measured;
- carry put a control measurement.

### 2.3.2. Measuring by external micrometers

In Fig. 2/28, the measurement of the thickness of a piece of flat material is shown. Here the handling of the external micrometer by only one hand is demonstrated. The other hand holds the workpiece, because there is no holding device. It is better to carry out measurements at workpieces which need not be held by hand but rest on a support or holding device (Fig. 2/29). In this case, the external micrometer can be operated by both hands which helps to prevent measuring errors to a large extent. In the Figures 2/29; 2/30 and 2/31, correct and wrong placing of an external micrometer is shown.

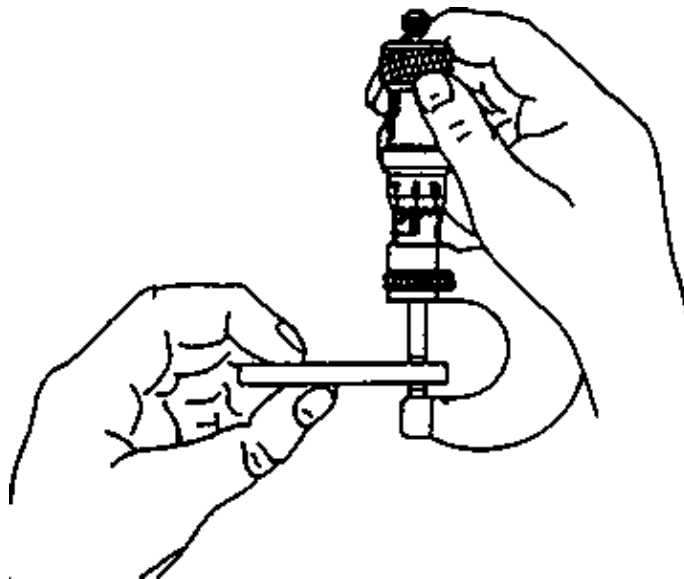


Fig. 2/28 Measuring by external micrometer operated by one hand

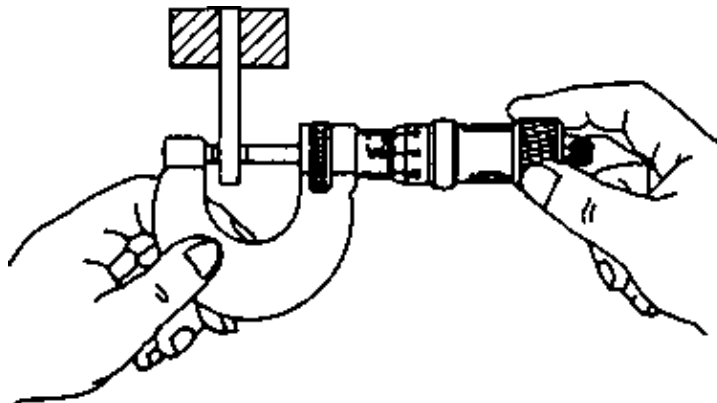


Fig. 2/29 Measuring of clamped workpieces by external micrometer

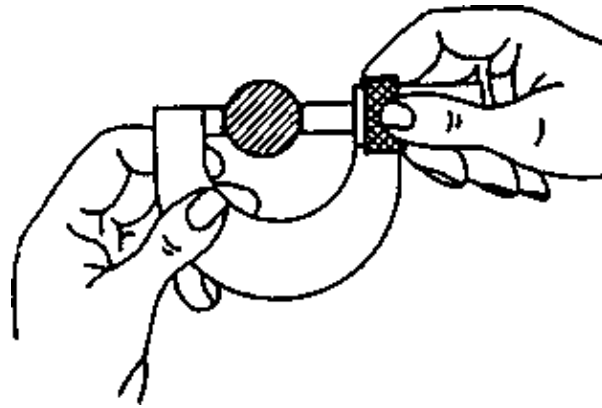


Fig. 2/30 Measuring of round material by external micrometer

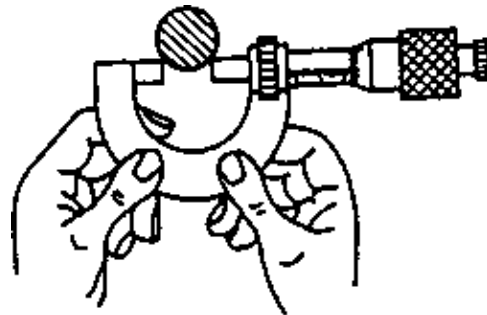


Fig. 2/31 Measuring errors with measuring of round material by external micrometer

External micrometers have to be placed at workpieces only that way that the total length to be measured is taken between the gauging surfaces of the external micrometer (the example shows the diameter of a shaft). If a workpiece only rests on the gauging surfaces, a value smaller than the actual one is measured.

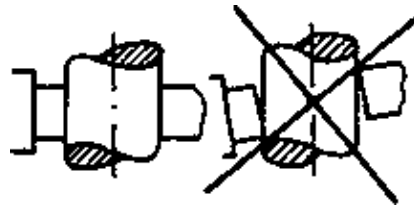


Fig. 2/32 Correct and wrong application of the external micrometer

Fig. 2/32 too shows the correct and wrong application of an external micrometer. The wrong examples shows the gauging surfaces of an external micrometer in a tilted position. Such tilting leads to reading a value bigger than the real size. With all measurements by external micrometers and micrometers in general it has to be taken into consideration that these measuring instruments belong to the group of precision measuring devices and that the smallest unit is a hundredth millimetre.



Fig. 2/33 Correct handling of the external micrometer

In the Figures 2/33 and 2/34, the correct and the wrong use of an external micrometer is once again shown on the basis of a concrete example.

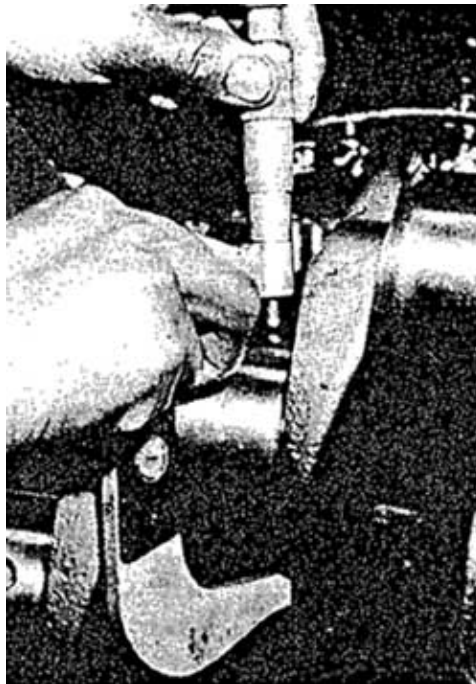


Fig. 2/34 Gross mistake in handling the external micrometer

Fig. 2/34 shows the following mistakes in handling an external micrometer:

- the micrometer is tilted;
- the ratchet and the knurled knob are impaired by a wrong finger position (finger pressure on the knurled knob);
- the external micrometer is not held by the hand protection as is prescribed by directly by the metal bow. By transmission of the temperature of the hand to the micrometer (expansion of the bow), the measuring result is falsified.

### 2.3.3. Measuring by depth micrometers

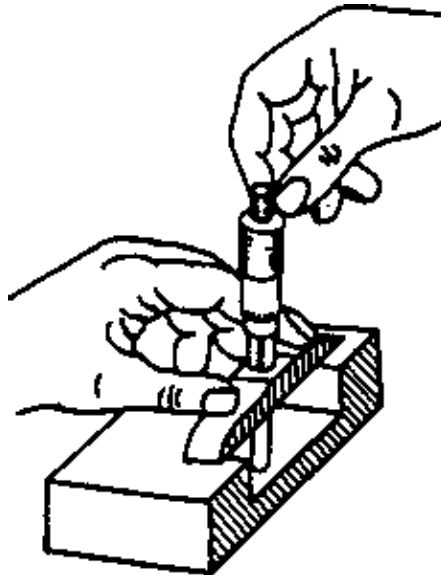


Fig. 2/35 Measuring by depth micrometer

Like the depth gauge, the depth micrometer too, is used for depth measurements exclusively. With handling a depth micrometer, strict attention has to be paid to the bridge – like the gauging surfaces with the depth gauge – firmly and safely resting against the workpiece and being not tilted. Measurements of the depth are made by turning down the measuring screw to the bottom of the recess to be measured. This procedure is similar to that carried out by a normal external micrometer. Normally, several differently long and interchangeable measuring screws belong to one depth micrometer in order to extend the measuring range.

### 2.3.4. Measuring by Internal micrometers

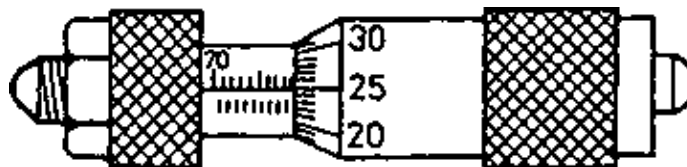


Fig. 2/36 Internal micrometer

The internal micrometer is also called inside micrometer. It is used for measuring cavities such as bore hole diameters etc.

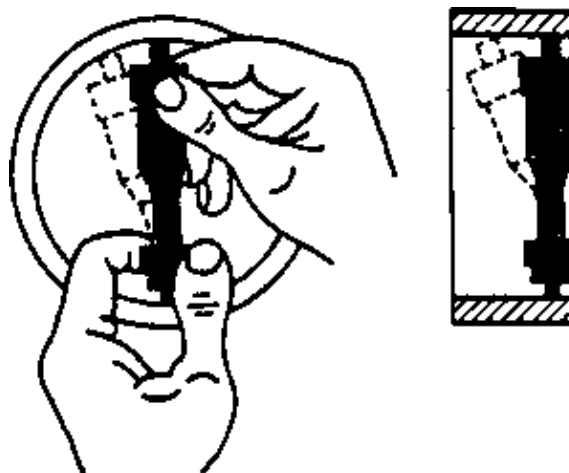


Fig. 2/37 Correct and wrong measuring by internal micrometer

For carrying out a measurement by an internal micrometer, the micrometer is put vertically on the wall of a bore hole or other cavity. In doing so it is held by the lower locking screw. During slow lengthening by revolving the ratchet, it is moved inside the bore hole till no further movement is possible. The measuring

result is read on the vernier as it is the case with the normal micrometer.

For handling micrometers the following principles have to be observed:

- Attention has to be paid that during the measuring process the micrometer and the workpiece to be measured have approximately the same temperature. Big difference of temperature falsify the measuring results.
- Micrometers are always to be held by the handles provided for this purpose (wood or plastic parts), so that the measuring result cannot be falsified by heat transmission from the hands.
- Micrometers have to be checked with respect to accuracy every day before use.
- After use, the micrometers must be cleaned with a soft cloth that does not unravel and rubbed with a thin (•) film of vaseline.
- Micrometers must always be kept in the cases provided for this purpose.

8) Describe the structure of an external micrometer!

9) Describe the structure and measuring function of the micrometer vernier!

10) Tell the vernier measures indicated in the Figures 2/38 a–d!

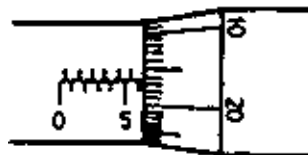


Fig. 2/38 Reading exercises at the vernier of the micrometer a)

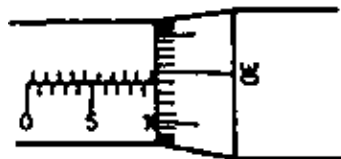


Fig. 2/38 Reading exercises at the vernier of the micrometer b)

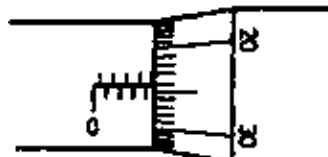


Fig. 2/38 Reading exercises at the vernier of the micrometer c)

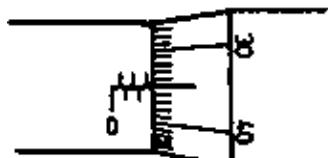


Fig. 2/38 Reading exercises at the vernier of the micrometer d)

11) What handling mistakes lead to measuring errors?

## 2.4. The dial gauge

Dial gauges are precision measuring instruments changing a linear fine movement of a micrometer screw into a readable pointer deflection by suitable transmission elements. They are mainly used for differential measurements. The measuring range is maximally 10 mm. The measuring accuracy of measuring gauges is a hundredth millimetre.

### 2.4.1. Structure of the dial gauge

On a dial, there is one big pointer for the indication of the hundredth millimetres (2) and one small pointer for the indication of the full millimetres (1). The rim of the case is equipped with adjustable tolerance marks (3). The dial gauge case is fixed to a clamping shaft, in which the micrometer screw and the tracer pin are sliding (5).

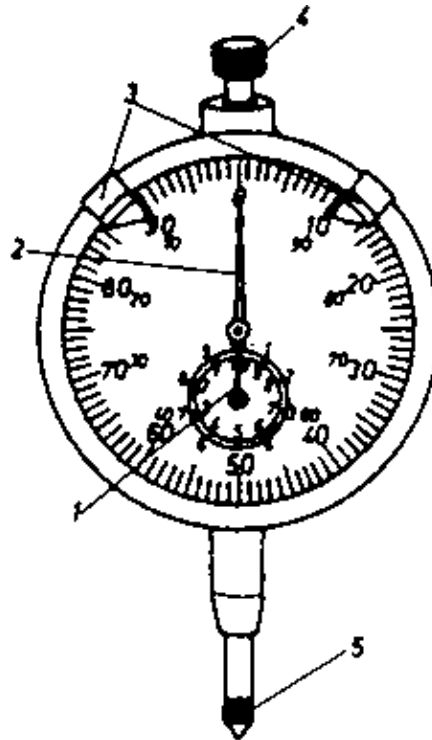


Fig. 2/39 The dial gauge

- 1 Small indicator for 1 mm indication,
- 2 Big indicator for 0.01 mm indication,
- 3 adjustable tolerance marks,
- 4 Knob for the zero adjustment of the indicator,
- 5 Tracer pin.

By the tolerance marks, a certain test range can be set. This way, without reading concrete measured values, it can be found out whether the measures to be tested lie within a given tolerance.

### 2.4.2. Measuring by dial gauge

The field of application of dial gauges is relatively large. In general, they are used for measuring deviations from a certain nominal size or average. The actual size of a workpiece can only be measured if it lies within the range of the dial gauge (10 mm). In general, dial gauges are used with the help of a holding device. An impairment of the measurement by the operator is thus almost excluded.



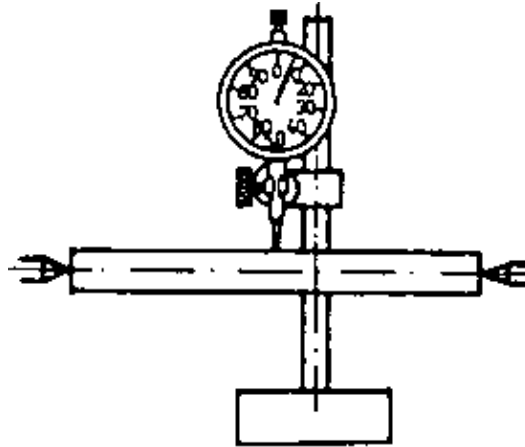


Fig. 2/40 Concentricity test at a shaft by dial gauge

In Fig. 2/40, the true running test of a shaft with the help of a dial gauge is shown. For this purpose, the shaft is pivoted in the picture between two centres), placed centrally under the dial gauge and turned slowly around its longitudinal axis. The extent of the pointer deflection caused is a measure of the deviation from the true running.

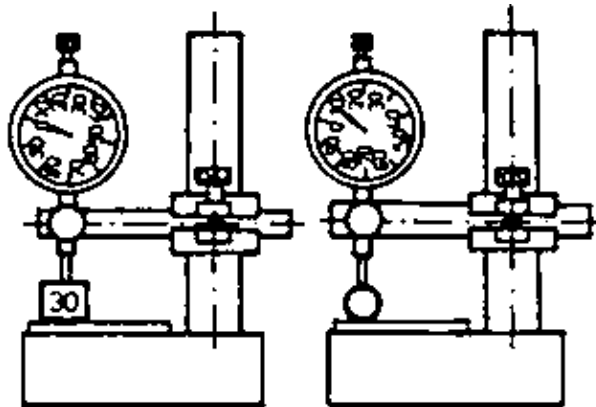


Fig. 2/41 Indirect thickness measurement by a dial gauge by comparison with a block gauge

By dial gauges also the thickness of a workpiece can be measured indirectly (see Fig. 2/41). For this, the dial gauge is fixed in a holding device, adjusted to zero by a block gauge and then – after removal of the block gauge – the thickness of the workpiece is measured by shifting it under the tracer pin of the dial gauge. In fact, the dial gauge only indicates the deviation of the workpiece size from the endmeasure. The deviation indicated by the dial gauge has to be subtracted from the endmeasure or added to it, respectively.

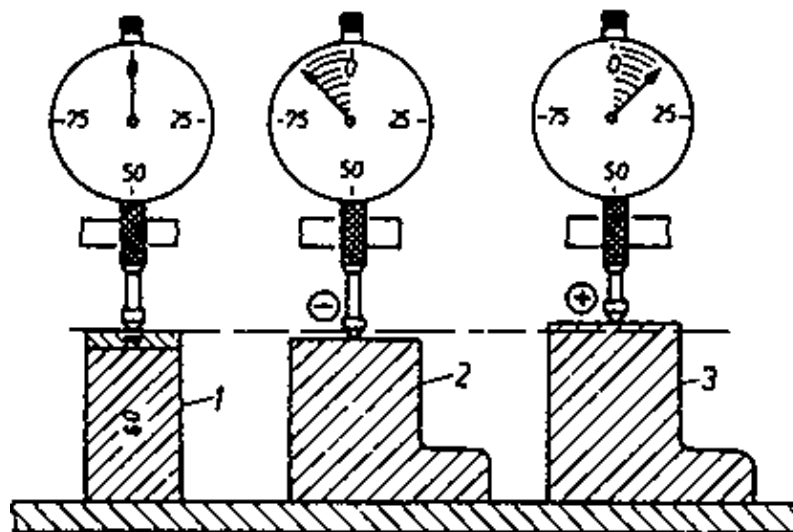


Fig. 2/42 Determination of the deviations from the required measure

- 1 The required measure of 68 mm is adjusted with the help of the block gauges
- 2 – tolerance of the workpiece from the required measure

3 + tolerance of the workpiece from the required measure

Indirect length measurements by dial gauges are always made as comparison measurements to an end measure by which the dial gauge is adjusted to zero. The measure indicated by the dial gauge

- is subtracted from the end measure, if the workpiece length (thickness) is smaller than the end measure;
- is added to the end measure, if the length to be measured (thickness of the workpiece) is bigger than the end measure.

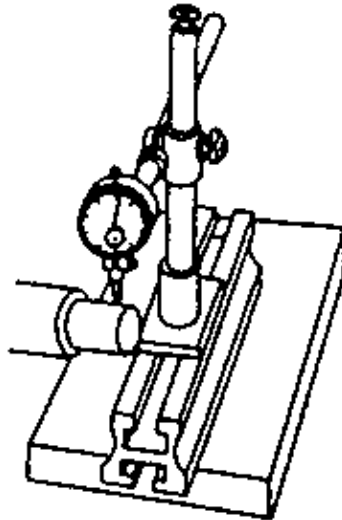


Fig. 2/43 True running measuring at external circumferential surfaces

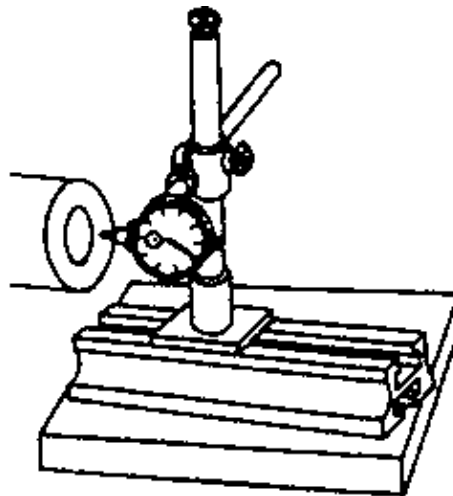


Fig. 2/44 True running measuring at front surfaces



Fig. 2/45 Distance testing at a crankshaft by an indicating dial gauge



Fig. 2/46 Gross mistake with testing by an indicating dial gauge at a crankshaft

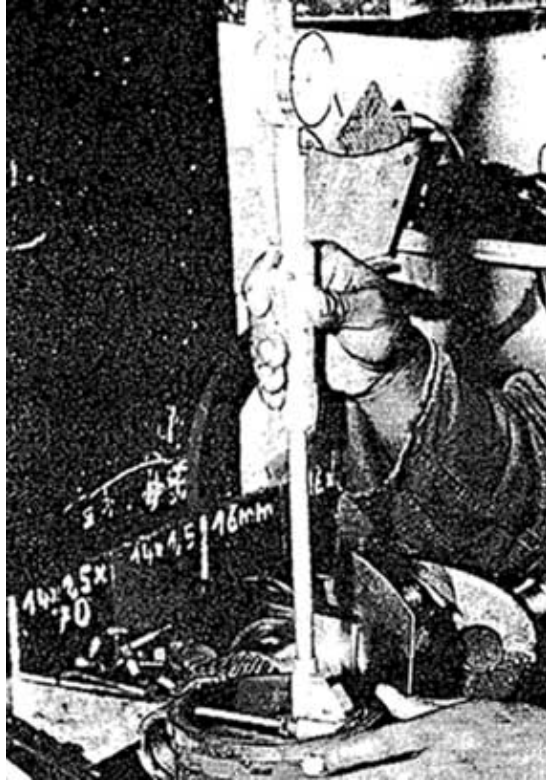


Fig. 2/47 Correct handling of an indicating dial gauge with diameter testing

By complementary instruments, the field of application of the dial gauges can be enlarged remarkably. Such attachments include:

- tracing lever (straight and angle tracing lever);
- lever-type indicator (straight and angle leverage);
- attachment for depth measuring bolt.

In the Figures 2/45 to 2/48 the application of such angle tracing leverages is shown.



Fig. 2/48 Gross mistake with testing a diameter by an indicating dial gauge

12) Look at the Figures 2/46 and 2/48. Describe the handling mistakes in the examples of application shown.

As by vernier calipers and micrometers, depth measurements such as recesses, bore holes, depth or length of edges can also be carried out by dial gauges. For this purpose, the dial gauges are equipped with

measuring bolts of different length which can be exchanged against each other.

With depth measurements by a dial gauge, the normal measuring direction is reversed. Consequently, the value indicated by the dial gauge has to be read in the opposite direction.

With depth measurements, the actual measured value is always the lower one of the two figures indicated on the measuring bolt, to which the indication of the dial gauge in reversed indicating direction has to be added.

The following general principles have to be observed when working with dial gauges:

- Dial gauges are sensitive precision measuring instruments. They are mainly used for indirect measurements and comparison measurements.
- Dial gauges are normally clamped in holding devices and used as fixed testing means, except very few exceptional cases – see Fig. 2/45 to 2/48.
- The field of application of dial gauges can be extended by suitable complementary devices including hand measuring instruments.
- During measuring by dial gauges attention has to be paid that the tracer pins of the dial gauges are not pushed on the workpieces. Therefor:
  - a) lift the tracer pin;
  - b) Put the workpiece to be tested under the tracer pin (with round workpiece such as shafts etc. pay attention that the centre of the workpiece is placed under the tracer point);
  - c) Set the tracer pin slightly on the surface of the workpiece.
- With thickness measurements adjust the zero position of the dial gauge in comparison to end measures.
- Dial gauges have to be protected against shock and impact, temperature variations and moisture by keeping them in the appropriate boxes, cleaned and with the screw slightly greased.

13) Describe the structure and mode of functioning of a dial gauge!

14) What are the most frequent mistakes in working with dial gauges?

## 2.5. Block gauges and their application

Block gauges are hardened measuring blocks of special steel. They are characterized by high measuring accuracy, evenness and parallelism of their gauging surfaces. With the help of them, measures can be determined precisely and used for various measuring and testing purposes. They are called master standards or control standards. Their measuring accuracy lies in the range of ten thousandth millimetres. All block gauges are highly polished.

Block gauges are standardized measuring means (see Paragraph 1.). They are manufactured in four degrees of accuracy (0, I, II and III) and classified in two groups according to their respective purposes:

- Block gauges of the degree of accuracy of 0 or I are used as master or control standards (testing of gauges).
- Block gauges of the degrees of accuracy of II and III are only used as control standards (testing of working gauges and measurements in practical work).

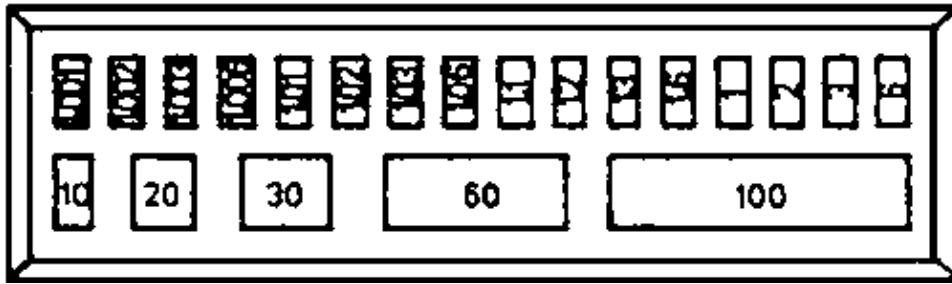


Fig. 2/49 Keeping of the block gauges

One set of block gauges (Fig. 2/49) consists of at least 10 but maximally 100 pieces of block gauges of different sizes. The composition of block gauge sets and their combination in set boxes is made in such a way that by the block gauges of one set a maximum number of different measuring lengths can be achieved within a given measuring range. Block gauges are put together by "wringing".:

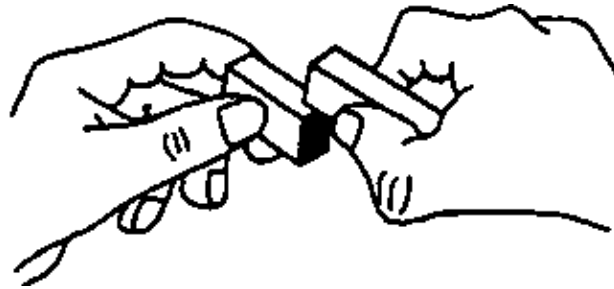


Fig. 2/50 Wringing of block gauges

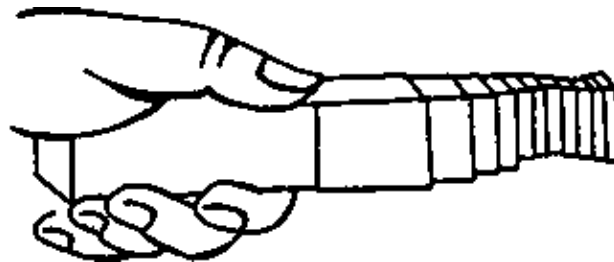


Fig. 2/51 Sticking block gauges

The adherence of clean, dry and grease free block gauges, without application of pressure, is called "wringing". Block gauges are shoved against each other by slight pressure and turning (Fig. 2/50). This way, they stick to each other (Fig. 2/51).

The following rules apply to the combination of block gauges:

- Block gauges have to be degreased before wringing. (All non-aggressive, deposit-free and not water-bonded agents may be used as dissolvents: ether, light petrol, chloroform. Cotton is the most suitable dissolvent carrier.).
- With wringing of different block gauges, it must be begun with the smallest block. Always, the block of the higher measure has to be wringed to the smaller one!
- The wringed block gauges have to be lined up to a straight measure line on an even and clean support.
- Block gauges must not remain, wringed for a longer time! Due to the effect of the external air-pressure, it comes to "cold welding". The block gauges can then be separated only by great effort, which mostly leads to damages.
- After use, block gauges have to be slightly rubbed with vaseline and put in their place in the box!

The following series of pictures gives a survey about the various application possibilities of block gauges.

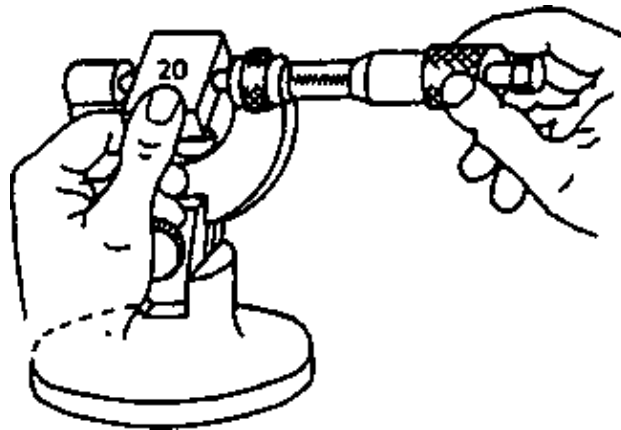


Fig. 2/52 Testing of an external micrometer screw by a block gauge

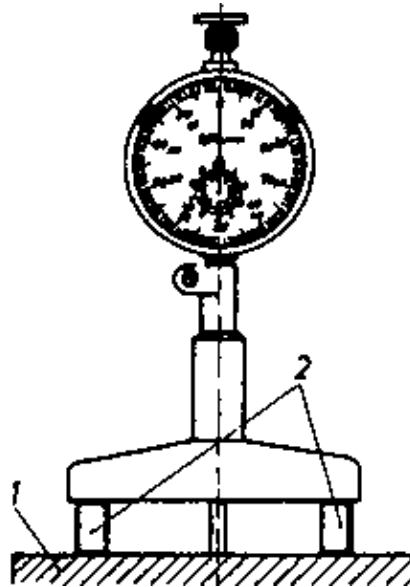


Fig. 2/53 Adjusting the depth micrometer of a dial gauge with the help of block gauges

- 1 Plane plate
- 2 Block gauges

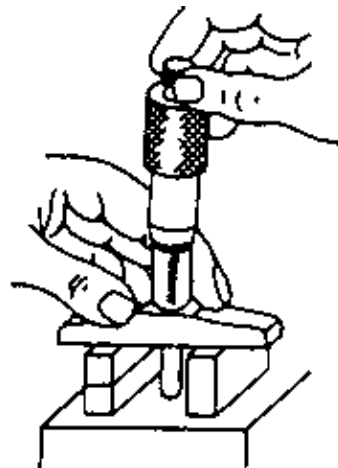


Fig. 2/54 Testing of a depth micrometer by block gauges

For testing precision measuring instruments, normally block gauges of the degrees of accuracy of 0 and I are used. For settings at machine tools (turning machines etc.) or for the use of block gauges in connection with complementary parts for measuring or testing purposes as well as for high precision drawing (Fig. 2/55), block gauges of the degrees of accuracy of II and III are sufficient.

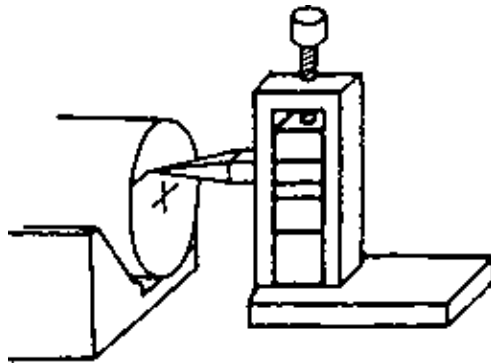


Fig. 2/55 Marking by block gauges and marking-out table

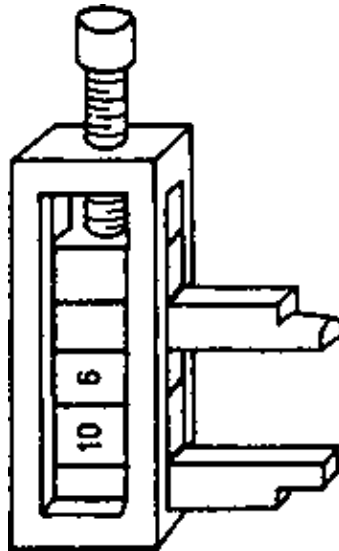


Fig. 2/56 Combination of block gauges and testing jaws

In the Figures 2/57 and 2/58, the use of block gauges as direct measures for measuring workpieces is shown. For such measurements, block gauges of the degrees of accuracy of II and III are sufficient.

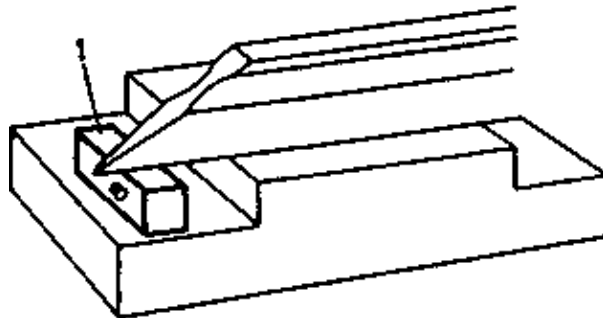


Fig. 2/57 Measuring of the height of a shoulder by a block gauge

1 Block gauge

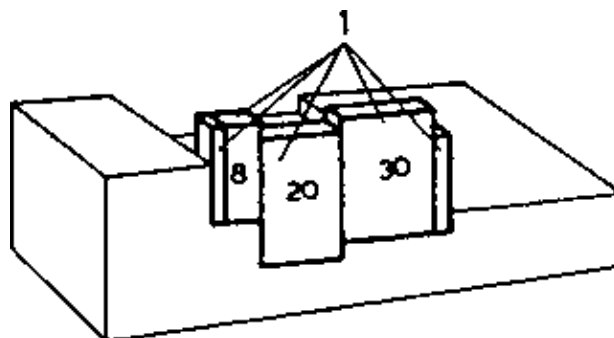


Fig. 2/58 Measuring of slots by block gauges



## 1 Block gauges

Block gauges are high-grade and expensive measuring means. They should always be treated with greatest caution and care. Block gauges are highly sensitive to shock and blow. The highly polished gauging surfaces must be protected against contamination, especially against dust. Block gauges of the degrees of accuracy of II and III (control standards directly in the working process) have to be tested with respect to their measuring accuracy.

15) Speak in a few sentences about the range of application of block gauges!

16) Describe the process of connecting block gauges and give the rules to be observed in this context!

17) What has to be observed in working with block gauges?

### 2.6. Testing equipment for the testing of the length

Read Paragraph "Technical basic notions of testing" again and keep in mind especially the terms

- measure
- measured value
- required measure or nominal size
- actual size

and the explanations given in this connection.

Equipment for length testing consists of most simple testing devices, by which just deviations from a given required measure are found out. By these means, no direct measurement is carried out, i.e. no actual size is determined.

In general, linear testing instruments are not suited for accurate testing. They are used for so-called quick tests at the workshop place directly in the production process.

In Paragraph 1., testing was explained only as a method of determining service qualities of articles manufactured. In order to achieve a better understanding of the term "linear testing equipment" the basic notions of "testing" and "measuring" once again shall be set against each other.

Testing is the verification carried out with the help of testing equipment as to whether the nominal sizes given for workpieces have been observed in production so far that the actual sizes measured at these workpieces lie within the limits specified for their usability.

The definition of "measuring" given in Paragraph 1.2.2. is maintained and extended as follows:

Dimensional testing or measuring is always a comparison of an object to be tested with the units of measurement of a measuring device. Hence measuring is the determination of the numerical size of the actual dimensions – the actual size – of a workpiece.

Sometimes it is not easy to differentiate clearly between "measuring" and "testing" taking into consideration the measuring and testing devices employed for the two activities

#### 2.6.1. Testing by outside calipers

In Paragraph 1.1.1. it was precisely stated that all diameters – outside and inside diameters – are lengths. The outside caliper shown in Fig. 2/59 is used for testing outside diameters.

No measuring is carried out by this instrument!



Fig. 2/59 Outside calipers

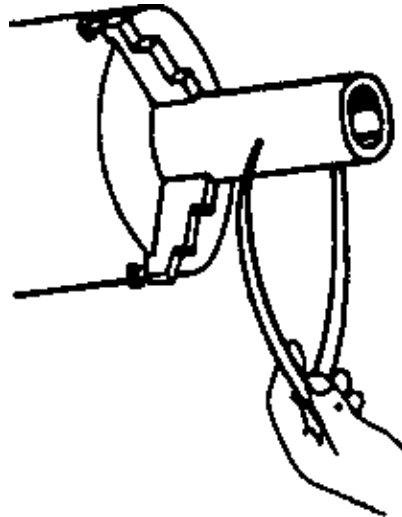


Fig. 2/60 Testing by outside calipers

It is only used for the purpose of finding out deviations from a given nominal size.

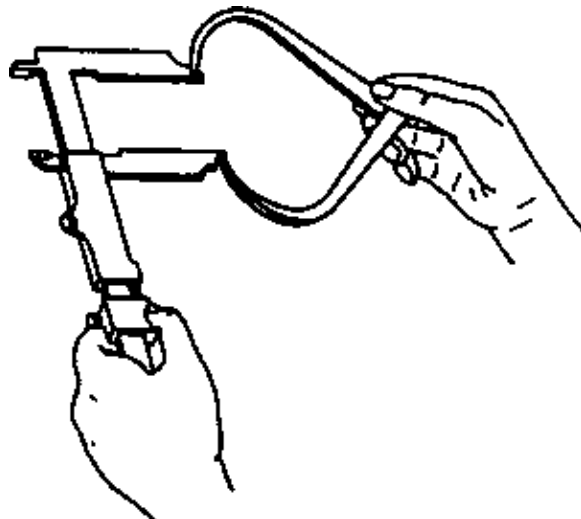


Fig. 2/61 Reading of the testing result from the outside calipers with the help of the vernier caliper

Outside calipers are adjusted with the help of a rule.

The distance of the caliper points test measure. For the purpose of testing, the caliper is held by the joint and shoved slightly over the workpiece – the shaft etc.

For instance, a lathe operator in a so-called quick test will – after he has stopped the machine – find out whether the desired measure is achieved with the help of an outside caliper adjusted at a rule or a comparison piece.

### 2.6.2. Testing by inside calipers

By inside calipers, the widths of recesses or bore holes are tested. They can be adjusted with the help of rules or between the measuring jaw halves of vernier calipers.

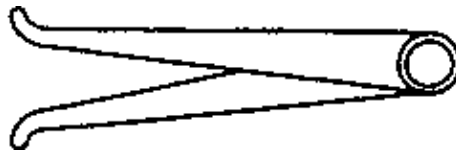


Fig. 2/62 Inside calipers

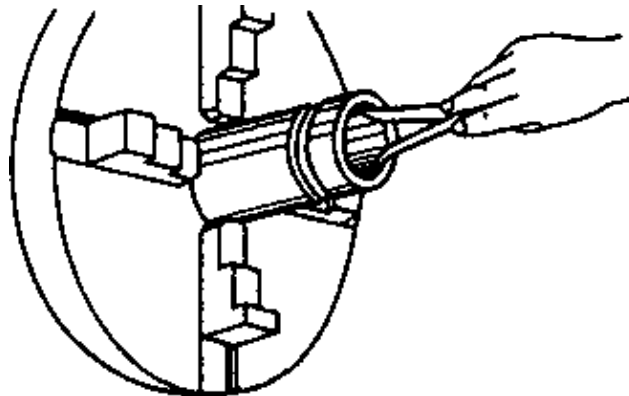


Fig. 2/63 Testing by inside calipers

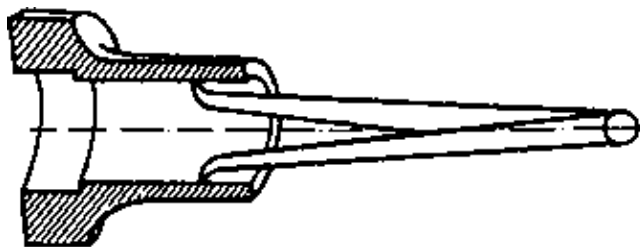


Fig. 2/64 Testing of internal diameters by inside calipers

Attention has to be paid to the correct handling of these instruments. Inside calipers are easily tilted which leads to useless testing results.

By spring calipers, simple and not very exact measurements can be made.

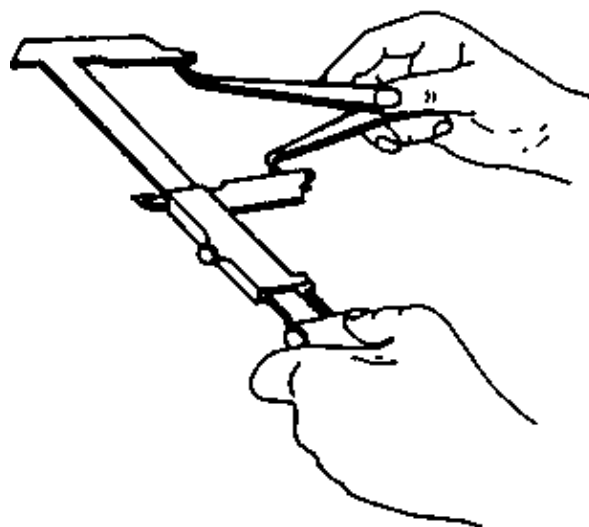


Fig. 2/65 Reading of the testing results with the help of the vernier caliper of the inside calipers

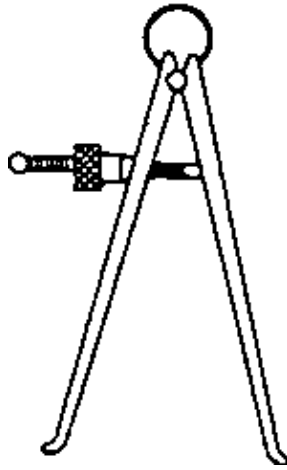


Fig. 2/66 Spring caliper

The spring calipers are put in the bore hole to be measured. The width measured is fixed by the binder screw and the spring caliper – by slight compression – pulled out of the bore hole. The re-appearing dimension can now be measured carefully by a vernier caliper. Such measurements are always control measurements and thus belong to testing.

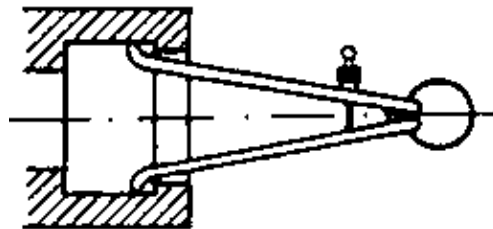


Fig. 2/67 Testing and measuring by calipers

18) In how far do "testing" and "measuring" differ from each other?

19) What are calipers used for and what has to be taken into consideration when handling these instruments?

## 2.7. The limit gauges

By limit gauges it is found out whether the actual size – the measurable inner and outer dimensions – lie within the allowed dimensional limits – maximum-limit and minimum-limit – i.e. within the tolerance band. Although gauges belong to certain measures, no measurements are made by them.

### 2.7.1. Tolerances and fits – basic knowledge

Tolerances are the admissible distances between the dimensional limits – the maximum-limit and the minimum-limit – which are decisive for the possible use of the workpiece as manufacturing or spare part.

The basis of an economically justifiable production of commodities is the manufacturing of them in large quantities. Such parts manufactured in volume production must be ready for use in any place at any time, without reworking.

This applies to the manufacturing of new parts – series production of commodities – as well as to necessary repairs in which often worn out parts of machines must be replaced by new serviceable ones.

The production of workpieces or elements of workpieces which enables the composition of these parts to a serviceable entirety at any time or an exchange of the parts in case of repair is called "exchange production".

If the interchangeability of workpieces is required these workpieces have to be manufactured with a sufficient

accuracy. A production of the parts with the greatest possible accuracy would be too expensive. The achievement of absolute accuracy is impossible.

If interchangeability of workpieces is required, it is sufficient, if their dimensions lie within certain allowed dimensional limits (tolerances). The range of tolerance is determined by the purpose of the workpiece.

For the connection of workpieces, the forms and dimensions of the workpieces to be connected have to be considered.

A valve stem must glide in its pilot hole, a shaft must rotate in its bearing, whereas a swivel pin must be fixed in its mortise (mount).

The connection true to form and size of two workpieces, i.e. between a workpiece and its counterpart is called "fit".

In order to achieve serviceable fits, workpiece forms and dimensions – the actual size – must be sufficiently accurate:

If the valve stem of a valve shall slide in its pilot hole, the diameter of the hole must not be smaller than the diameter of the valve stem. If, on the other hand, the diameter of the pilot hole is considerably bigger than the diameter of the valve stem, the latter does not glide within the pilot hole but knocks or vibrates. The valve stem can give way to pressure of motion exerted on it by considerable deformation (deflection). Due to such change of shape, the smooth functioning of the valve becomes uncertain.

By the minimum-limit of the valve stem and the maximum-limit of the diameter of the pilot hole, the possible allowance for clearance between the two parts is limited.

For the description to a fit, in addition to the nominal size two other dimensions have to be indicated limiting the allowance for fit between two mating workpieces. These limits are the maximum-limit and the minimum-limit. The distance between these two limits determined by the dimensional limits is the tolerance. The actual size of the workpiece must lie within this distance, i.e. within the range of tolerance, if the system shall function.

If a workpiece does not fit into its counterpart in the described way, it cannot be exchanged.

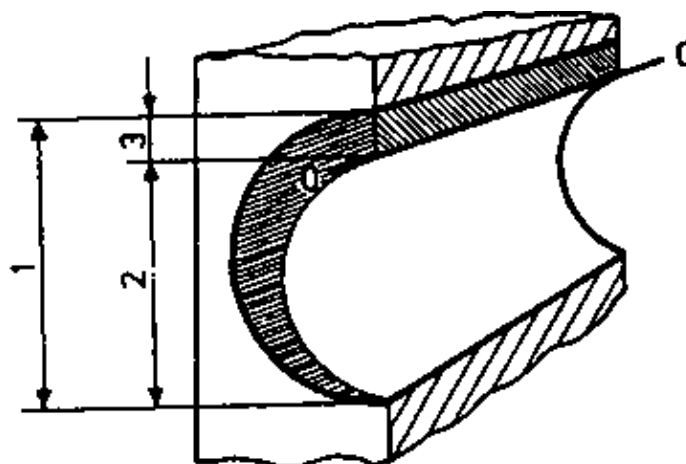


Fig. 2/68 Tolerance with bore holes

- 1 maximum diameter = maximum-limit
- 2 minimum diameter = minimum-limit
- 3 tolerance (tolerance zone)

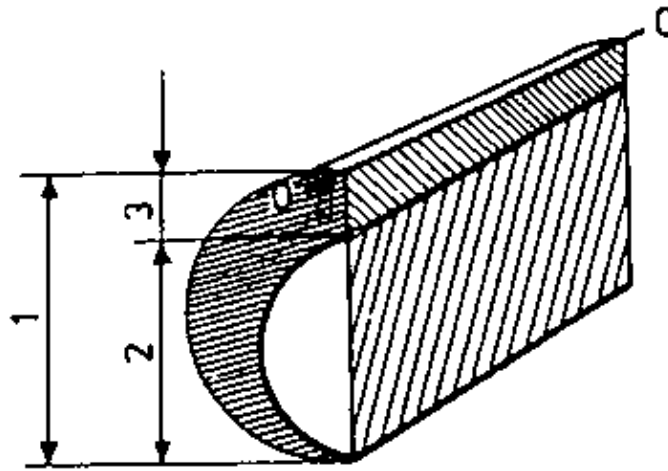


Fig. 2/69 Tolerance at shafts

- 1 maximum diameter = maximum-limit
- 2 minimum diameter = minimum-limit
- 3 tolerance (tolerance zone)

In the Figures 2/68 and 2/69, possible tolerance fields in bore holes and at shafts are shown.

The lettering in the pictures has the following meanings:

- zero line = reference line of dimensional variations and nominal size limits;
- 1 = maximum diameter = maximum-limit;
- 2 = minimum diameter = minimum-limit;
- 3 = tolerance (tolerance zone)

Hence a tolerance is calculated as follows:

tolerance (3) = maximum-limit (1) – minimum-limit (2). The field indicated by the maximum- and minimum-limits in the representation of a tolerance is called tolerance zone.

The zero line is the reference line for dimensional variations indicated by tolerances in pictorial representations. By them, the nominal size is limited. The zero line itself has the dimension 0.

A nominal size indicated by dimensional variations in technical documentations such as standards or drawings is called fitting size (see Figures 2/72 and 2/73).

Dimensional variations are the deviations of the dimensional limits of a workpiece from its nominal size. If the dimensional limit is bigger than the nominal size, it is called the upper deviation (1); if the dimensional limit is smaller than the nominal size, it is called the lower deviation (2).

In the Figures 2/70 and 2/71, the possibilities of the position of dimensional variations at bore holes and shafts are shown.

Looked at closely, the Figures 2/70 and 2/71 reveal the following:

If the actual size of a bore hole is bigger than the allowed maximum-limit or if the actual size of a shaft is smaller than the allowed minimum-limit, the respective workpieces are "scrap work". They cannot be improved by reworking.

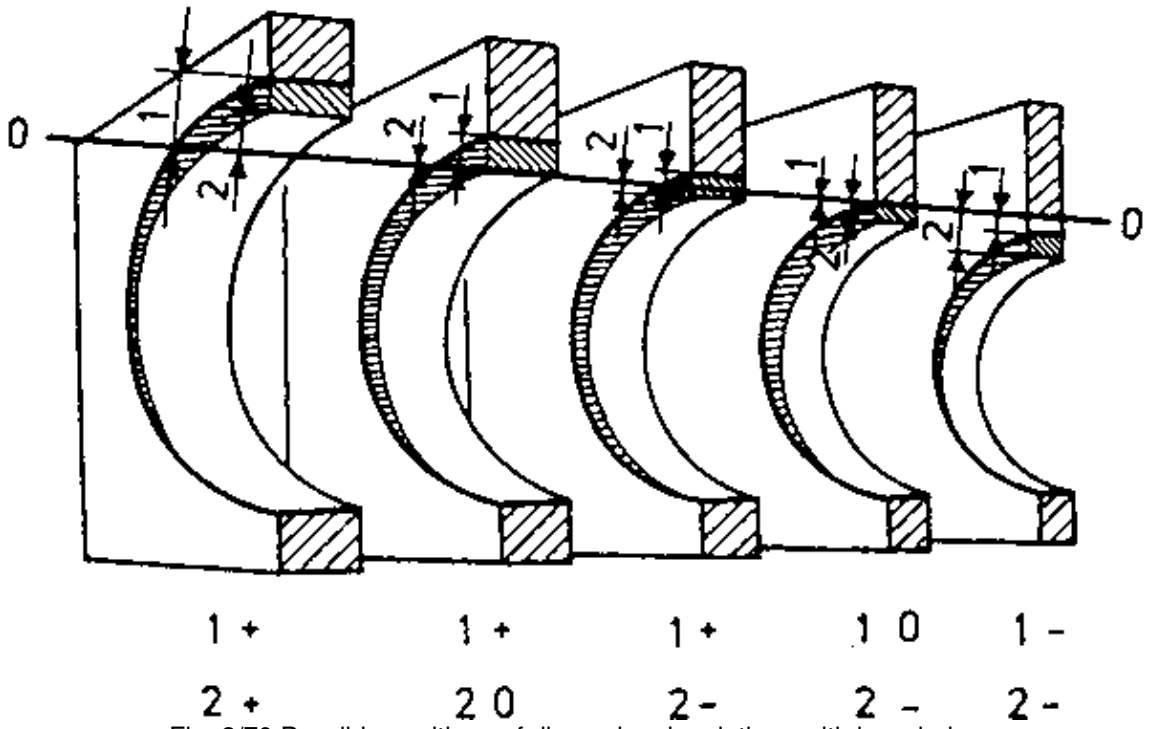


Fig. 2/70 Possible positions of dimensional variations with bore holes

1 upper dimensional variation  
2 lower dimensional variation

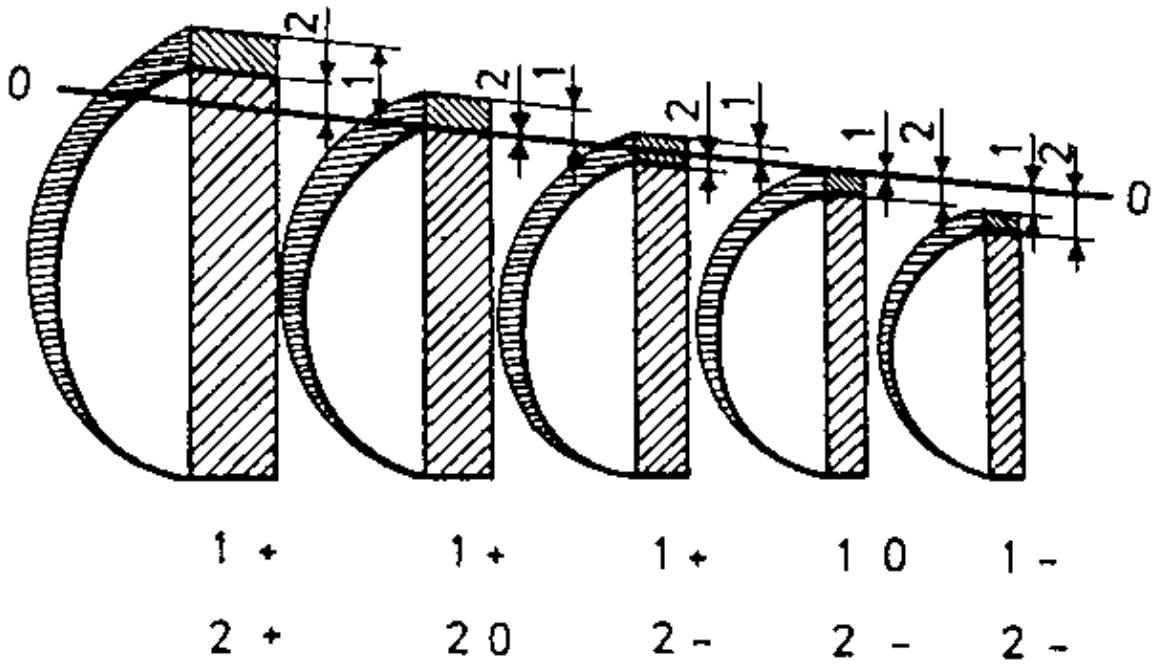


Fig. 2/71 possible positions of dimensional variations with shafts

1 upper dimensional variation  
2 lower dimensional variation

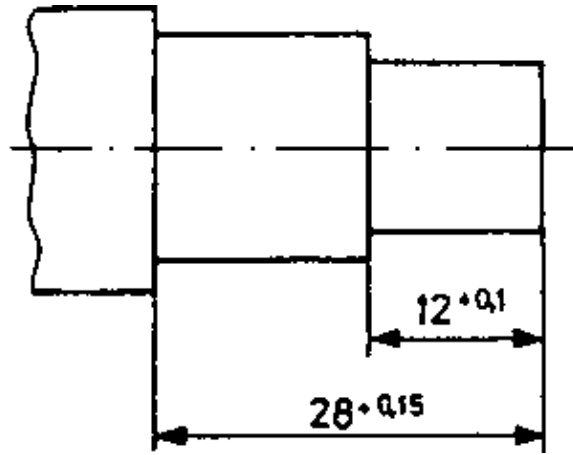


Fig. 2/72 Example of the indication of tolerances in technical drawings (positive variations)

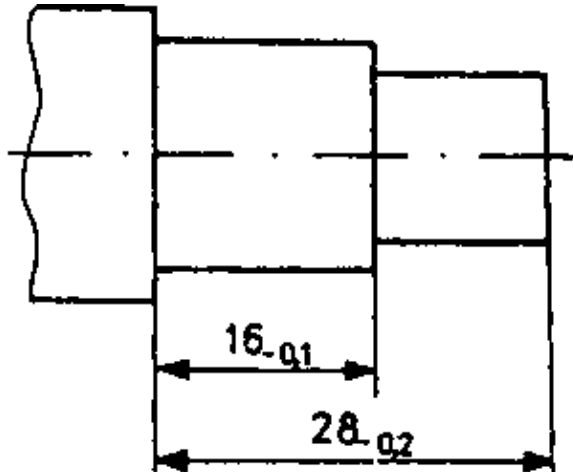


Fig. 2/73 Example of the indication of tolerances in technical drawings (negative variations)

A principle of manufacturing and testing (measuring) is:

Not as accurate as possible but as accurate as necessary for an unobjectionable functioning of a workpiece and so that it is economically justifiable.

- 20) What is the definition of tolerances and what is their task?
- 21) What is understood by interchangeability of workpieces and what does interchangeable manufacture mean?
- 22) What is a fit and by what measure is it indicated in technical documentations?
- 23) What is understood by dimensional variations? What is the importance of knowing the size of the dimensional variations?
- 24) By what dimensional limits is "scrap work" characterized?

### 2.7.2. The kinds of gauges

The gauges used for testing are divided in two major groups:

- fixed gauges;
- adjustable gauges which can be fixed.

Each group is further divided in normal gauges and limit gauges.

Fixed gauges are characterized by a certain unchangeable distance between their gauging surfaces.



They are preferably used for testing outer and inner dimensions.

The fixed gauges include:

Normal gauges, block gauges, external limit gauges, thread gauges, radius gauges and profile gauges.

### 2.7.2.1. Testing by external limit gauges

Once again read the definition of the term of "limit gauges" given in Paragraph 2.7.

It was stated:

- Limit gauges always belong to the certain dimensions;
- as a general principle, no measurements are carried out by limit gauges;
- by limit gauges it is only verified whether the dimensions of a workpiece lie within certain tolerances.

Read the definition of "tolerances" given under 2.7.1. over.

It was stated:

- Tolerance is the allowed distance between a maximum-limit and a minimum-limit.

From the contents of the two definitions, the following statements relevant to the use of limit gauges result:

- Every limit gauge must indicate the two limits of a tolerance zone unambiguously;
- for the unambiguous determination of the two limits of a tolerance zone, limit gauges have two sides – one "go end" and one "not-go end";
- limit gauges give no information about the position of the dimensions in the tolerance zone.

In a simplified and concise form, the statement of the two findings reads:

- By limit gauges it is only found out whether a workpiece is "good" or "useless" (scrap work).

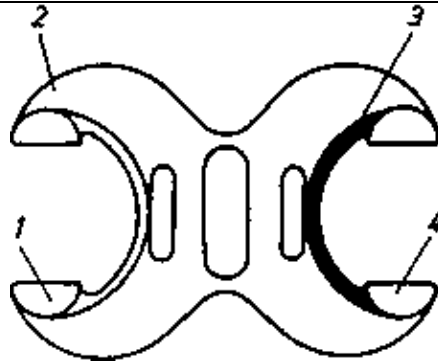


Fig. 2/74 External limit gauge

- 1 Testing points – go end
- 2 Gauge body
- 3 Read paint coating
- 4 Testing points – not-go end

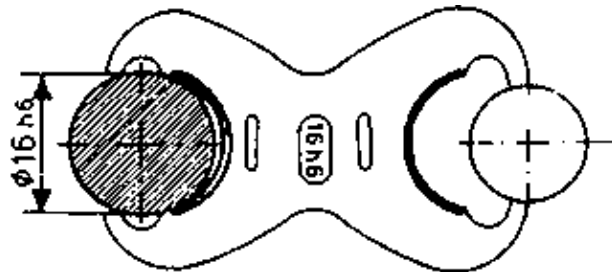


Fig. 2/75 External limit gauge with shaft

External limit gauges are normally provided with a black paint coat. On this coating, the nominal size which the gauge belongs to and the dimensional variations prescribed for this nominal size are indicated.

By this, the "go end" and the "not-go end" are indicated. Another sign of recognition of the "not-go end" is the slight inclination of the edges of the gauging jaw.

The following rules apply to the work with external limit gauges:

- By external limit gauges, only external dimensions such as external diameters are measured (tested).

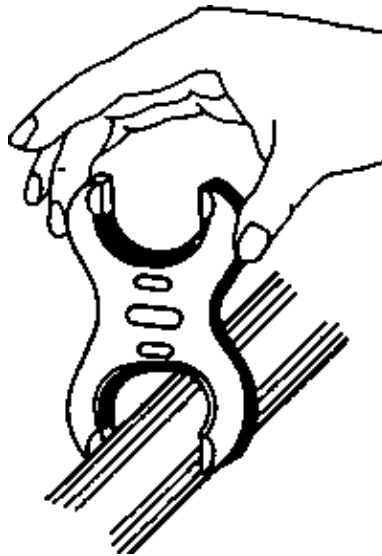
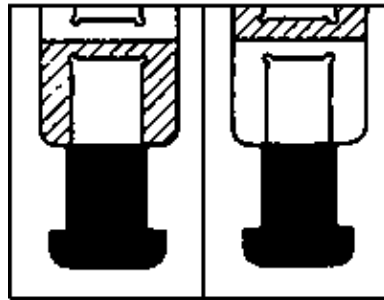


Fig. 2/76 Testing by external limit gauges

- The "go end" must always glide easily over the workpiece (Fig. 2/76).
- The "not-go end" is always narrower by the size of the tolerance – it is the minimum-limit). By its oblique gauging jaws, it must only touch the workpiece, not glide over it.
- External limit gauges must never be pressed over a workpiece with force (Fig. 2/77).
- If the "go end" cannot be shoved over a workpiece, the serviceability of the workpiece can be achieved by reworking.
- If the "not-go end" of the external limit gauges glides over the workpiece, the dimensions of the workpiece fall below the minimum-limit and the workpiece is scrap.



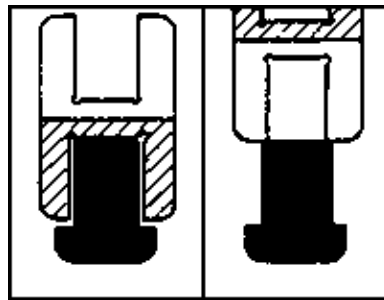
Fig. 2/77 Wrong application of the external limit gauge



a b

Fig. 2/78 Testing by external limit gauge (reworking of the workpiece is necessary)

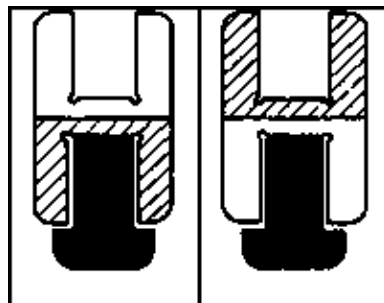
- a) go end,
- b) not-go end



a b

Fig. 2/79 Testing by external limit gauge (the workpiece is good)

- a) go end
- b) not-go end



a b

Fig. 2/80 Testing by external limit gauge (scrap)

- a) go end
- b) not-go end

External limit gauges have to be protected against shock and blow. They have to be kept in the cases provided for this purpose. The gauging surfaces of the external limit gauges must be degreased before use, thoroughly cleaned after use and rubbed with an acid-free grease (vaseline). External limit gauges must never be used at rotating or otherwise moving workpieces.  
 Accident hazard!

External limit gauges expand by the influence of heat. By this, the testing results are falsified. Therefore, attention has to be paid to the observance of the prescribed testing temperatures.

Testing by plug limit gauge

With the help of the plug limit gauge, bore hole diameters are tested.

Like the external limit gauge, the plug limit gauge, too has a "go end" and a "not-go end".

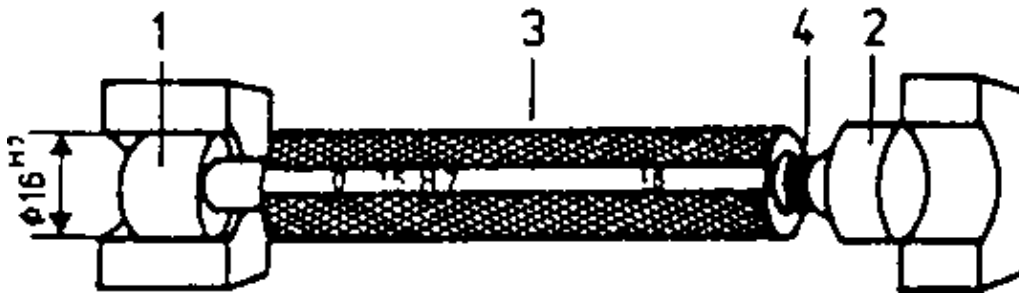


Fig. 2/81 Plug limit gauge

- 1 Measuring body – go end
- 2 Measuring body – not-go end
- 3 Gauge handle, A Red paint coating

The "not-go end" is bigger by the tolerance – it is the maximum-limit – and must not fit in the bore hole to be tested if the bore hole is in order. The "not-go end" is characterized by a shorter gauge cylinder and a red paint coat. In general, bore holes up to 100 mm diameter are tested by plug limit gauges. Diameters of 100 mm up to 260 mm are tested by flat limit gauges which are either! double-ended or consist of two pieces (Fig. 2/82). Diameters of more than 260 mm are tested by spherical-end measuring gauges (Fig. 2/83) which consist of two parts – "go-end" and "not-go end".

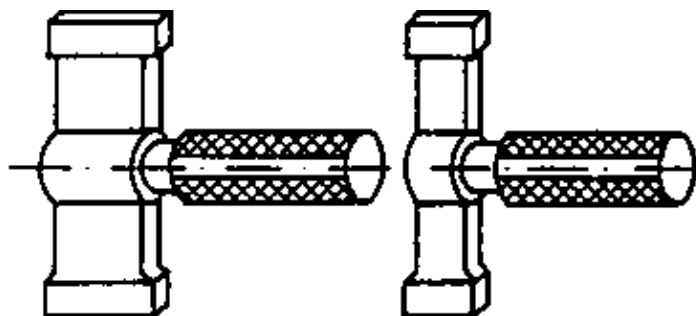


Fig. 2/82 Flat limit gauge

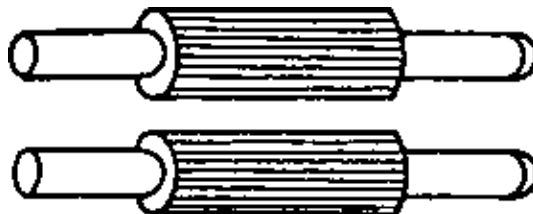


Fig. 2/83 Spherical-end measuring gauges

The following rules apply to the work with plug limit gauges, flat limit gauges and spherical-end measuring gauges:

- Plug limit gauges, flat limit gauges and spherical–end measuring gauges have to be put in the bore hole without effort.
- The "go–end" must glide in the bore hole with a slight suction; if this is not the case, the workpiece can be made serviceable by reworking (Fig. 2/84).
- The "not–go end" must not fit in the bore hole to be tested. It must only touch it. If it fits in the bore hole, the workpiece is scrap.
- The test cylinders of plug limit gauges, flat limit gauges and spherical–end measuring gauges have to be slightly greased before use.
- Never carry out tests at a moving (rotating) workpiece – accident hazard!
- The prescribed testing temperatures for both the parts – workpiece and gauge – have to be observed. Gauges can become jammed in workpieces.
- After use, the gauges have to be cleaned and slightly greased by an acid–free grease and put in the cases provided for this purpose.

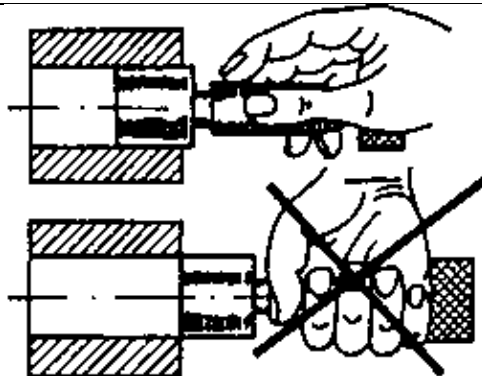


Fig. 2/84 Correct and wrong application of plug gauges

### Testing by thread gauges

The thread gauges are classified in:

- standards thread gauges (standard plug limit gauge and standard thread gauge ring).
- Thread limit gauges (plug thread gauge and thread gauge ring with flank snap gauge).

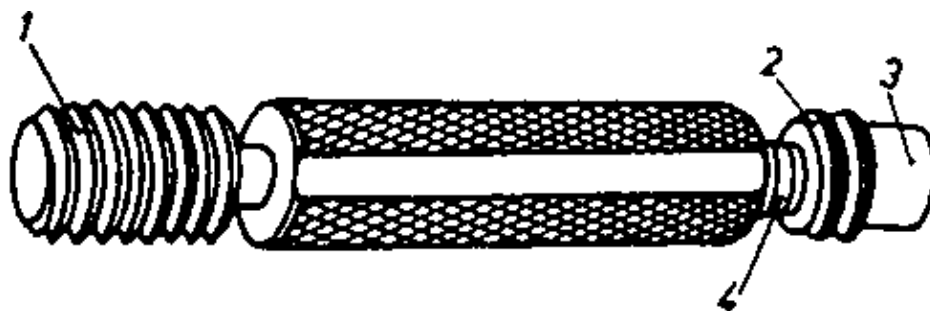


Fig. 2/85 Thread gauge for metric threads

- 1 Go end measuring body–thread
- 2 Not–go end measuring body–thread
- 3 Minor diameter,
- 4 Red paint coating



Fig. 2/86 Standard thread gauge

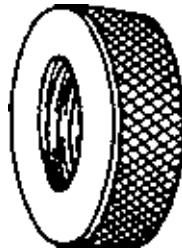
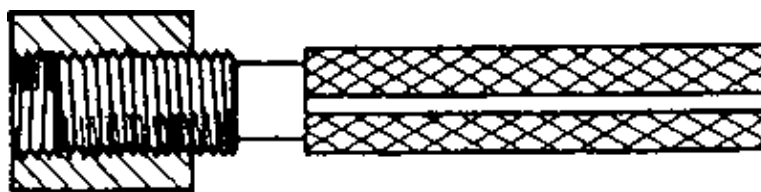


Fig. 2/87 Thread gauge ring

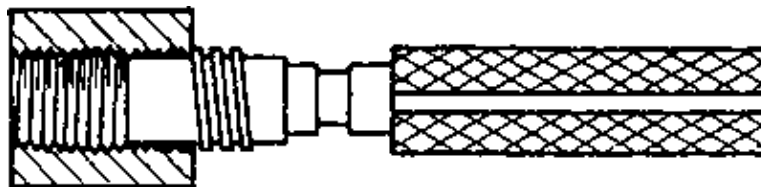
By standard thread gauges, only the thread pitch and the minor diameter of the thread as well as the nominal diameter of thread can be tested, whereas by thread limit gauges also the flank profile of the thread can be tested. By internal thread gauges internal threads are tested, external threads are tested by thread gauge rings.

The following rules apply to the work with thread gauges:

Fig. 2/88 Testing of a internal thread by thread gauge

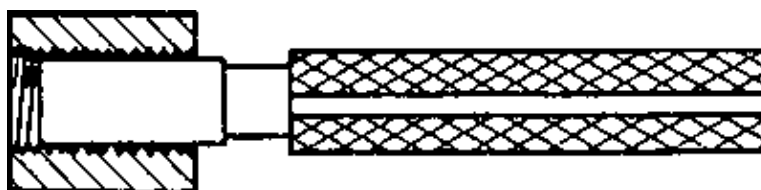


a) Testing by the go end of the thread

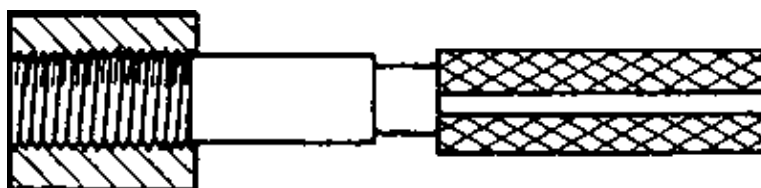


b) Testing by the not-go end of the thread

Fig. 2/89 Testing of the minor diameter by the thread gauge



a) Testing by the go end



b) Testing by the not-go end

• The "go-end" of the plug thread gauge must fit easily in the thread to be tested. Do never use force (Fig. 2/88)!

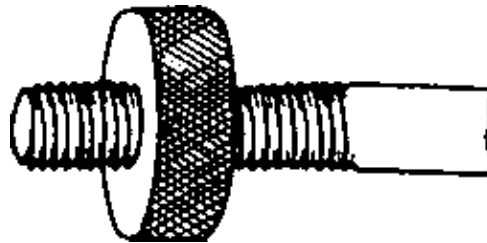


Fig. 2/90 Testing of a bolt thread by the thread gauge ring

- It must be possible to screw a thread gauge ring easily on a thread. Do never force a thread gauge ring on a thread (Fig. 2/90)!
- If also flank defects of a thread shall be spotted, always the thread gauge ring or the plug thread gauge has to be used.
- With the use of the plug thread gauge, the "not-go end" has several thread leads of shortened flanks but increased thickness of the flank profile. It must not be possible to turn this side in a thread to be tested. If it is possible, the thread is scrap!
- To maintenance and care of the thread gauges all the rules apply which are mentioned in connection with the rest of gauges.

25) What is the meaning of the term "gauges" and what testing devices belong to this group of testing means?

26) How are fixed gauges characterized and why are they preferably used for testing?

27) What general rules can be set up for the work with gauges?

### 3. Measurement of angles

Read Paragraph 1.1.2. over and answer the following questions for yourself:

- How is an angle formed and what determines its size?
- By what units of measurement are angles measured?
- What forms of angles do you know and what range of size do these angles belong to?
- What is the function of the cutting line or horizontal line with the measurement of angles?
- How are angles represented in technical documentations?

#### 3.1. Fundamental knowledge about angular measurement

Table 3/1 Units of measurement of angles

$$1 \text{ perigon} = 360^\circ = 21\,600' = 1\,296\,000''$$

$$1^\circ = 60' = 3\,600''$$

$$1' = 60''$$

° = degree, ' minute, '' = second

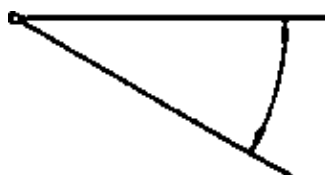


Fig. 3/1 Acute angle (smaller than 90°)

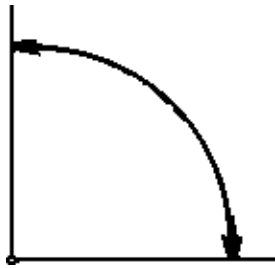


Fig. 3/2 Right angle ( $90^\circ$ )

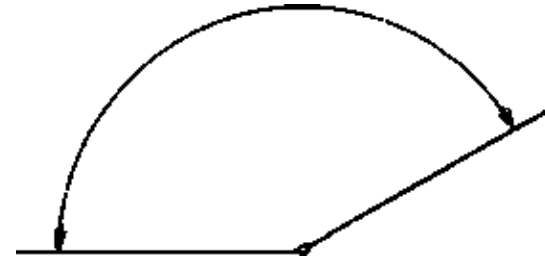


Fig. 3/3 Obtuse angle (between  $90^\circ$  and  $180^\circ$ )

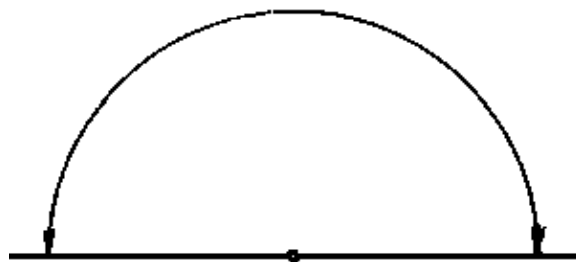


Fig. 3/4 Straight angle ( $180^\circ$ )

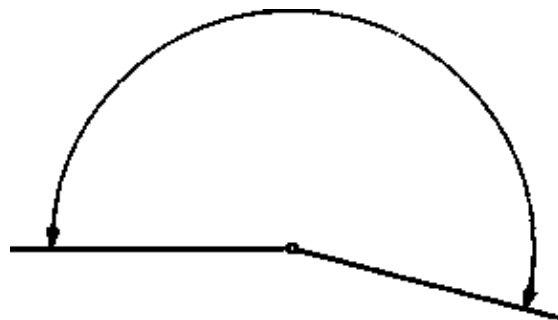


Fig. 3/5 Convex angle (more than  $180^\circ$ )

In the Figures 3/1 to 3/5, a number of important angles is shown. In order to determine the numerical size of an angle, we need instruments for angular measurement, such as simple protractor, universal protractor.

### 3.2. The measuring instruments for angular measurements

Angles are measured with the help of protractors. For simple measurements of a measuring accuracy of  $1^\circ$  (a degree) the simple protractor with the measuring beam arranged to swivel is used. If more accurate measurements shall be carried out a universal protractor of a reading accuracy up to 5 angular minutes is used.

#### 3.2.1. The measurement of angles by simple protractor

Simple protractor have a graduation in degrees of 0 degrees up to 180 degrees. Their reading accuracy is 1 degree.



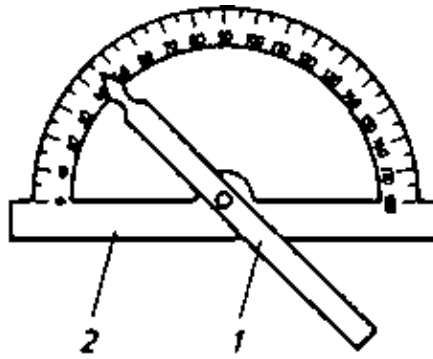


Fig. 3/6 Protractor with indicator

- 1 Rotatable measuring side with indicator
- 2 fixed side

For workshop use, protractors with swivelling measuring beam prevail (Fig. 3/6). There are two simple protractors which differ by their graduation in degrees on the reading semicircle:

- protractors with throughout graduation from 0 to 180 degrees;
- protractors with the graduation increasing from 0 to 90 degrees and falling to 0.

By simple protractors, angular size can be measured directly or indirectly:

- With direct measuring of angles, the workpiece angle is indicated in its real size (acute angle in Fig. 3/7; obtuse angle in Fig. 3/8).
- With indirect measuring of angles, the real size of the workpiece angle is calculated only by subtracting the actual indication of the measuring range of the measuring instrument (obtuse angle in Fig. 3/9; acute angle in Fig. 3/10).

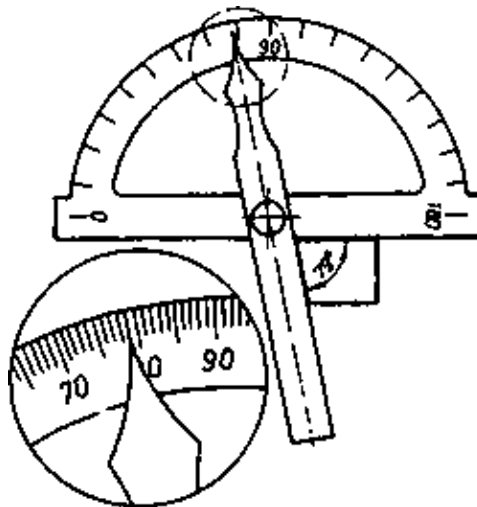


Fig. 3/7 Measuring of an acute angle by a simple protractor (the measuring value is the value indicated)

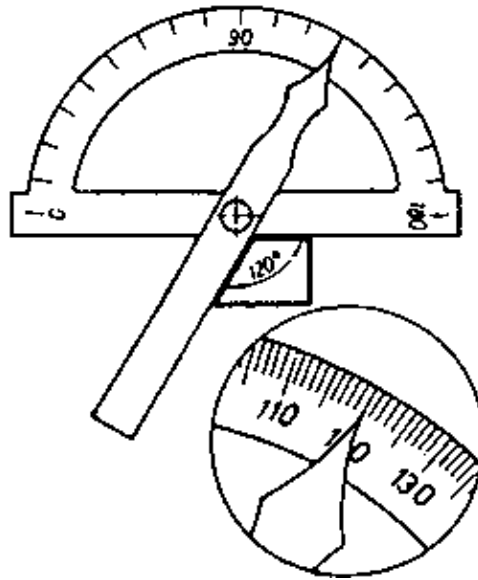


Fig. 3/8 Measuring of an obtuse angle by a simple protractor (the measuring value is the value indicated)

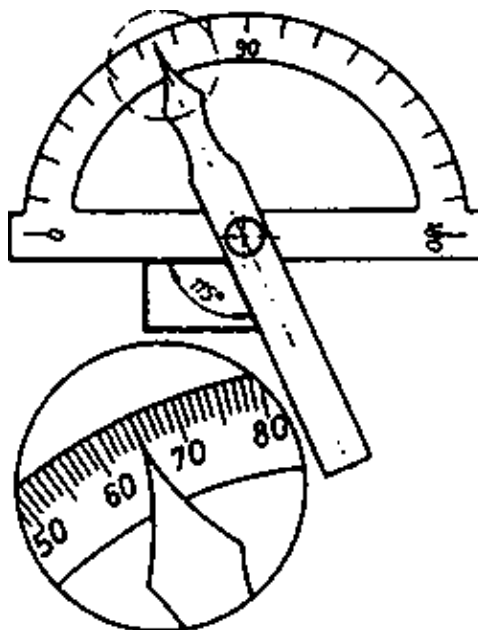


Fig. 3/9 Measuring of an obtuse angle ( $180^\circ - 65^\circ = 115^\circ$ )

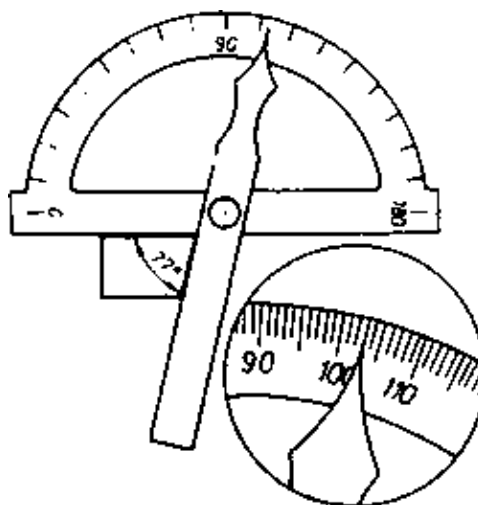


Fig. 3/10 Measuring of an acute angle ( $180^\circ - 103^\circ = 77^\circ$ )

To the angle measurement in Fig. 3/7 applies:

– The acute angle is measured by direct indication of the size of the workpiece angle of 79 degrees.

– The obtuse angle is measured indirectly – Fig. 3/9.

The size of the angle is calculated as follows:

measuring range – indication = size of angle

or  $180^\circ$  –  $65^\circ$  =  $115^\circ$

### 3.2.2. The measurement of angles by universal protractor

#### Structure and function of the universal protractor

In the workshops, two versions of universal protractors are in use:

- The older version which enables the reading of angle sizes up to 5 angular minutes;
- the younger version enables an angular size reading of 10 angular minutes, with an essentially simplified and improved vernier graduation.

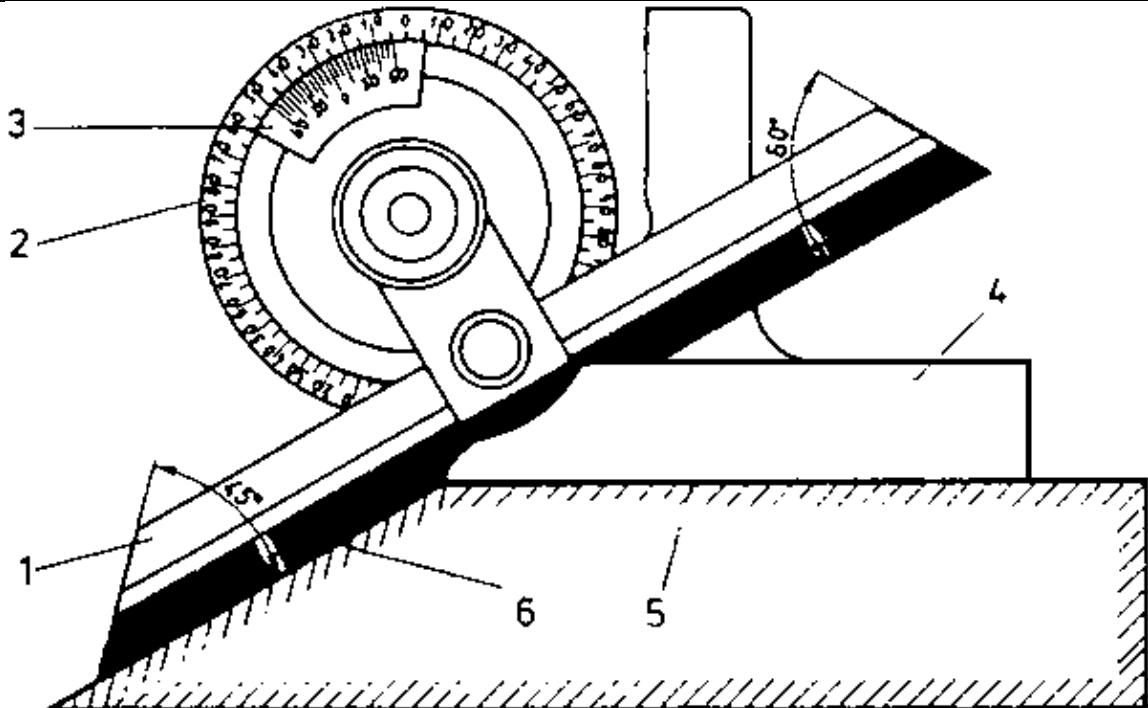


Fig. 3/11 Universal protractor

- 1 Moveable measuring beam connected with the vernier disk,
- 2 Main graduation for reading the angular degrees,
- 3 Vernier graduation for reading the angular minutes,
- 4 fixed measuring beam,
- 5 Application edge,
- 6 Application edge

The full circle connected with the fixed measuring beam (4), with the older version, carries a main graduation of four times 90 degrees (2). The movable measuring beam or the rule (1) is connected with the vernier carrier and moves the vernier (3) against the main graduation. The movable measuring beam can be laterally shifted in its guide it is limited by one  $45^\circ$  edge and one  $60^\circ$  edge. The movable measuring beam can be adjusted to every angle.

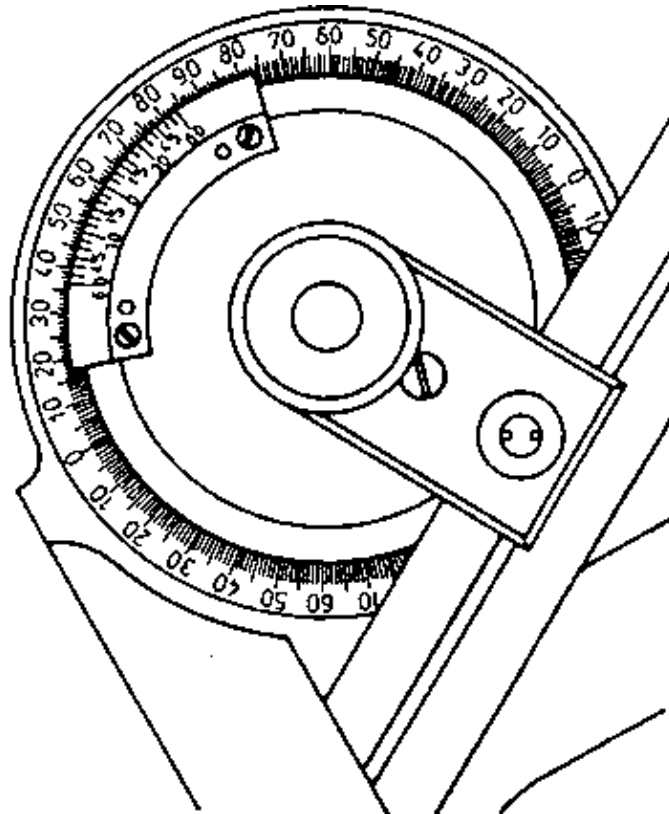


Fig. 3/12. Main graduation and vernier of a universal protractor

Handling of the universal protractor

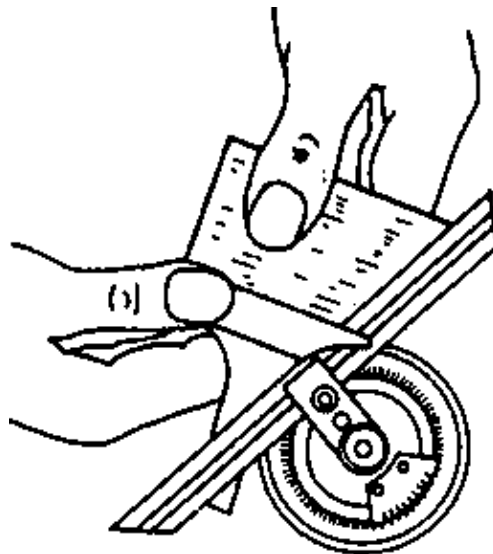


Fig. 3/13 Handling of the universal protractor

Fig. 3/13 shows the basic handling of the universal protractor.

The fixed measuring beam is placed on the surface of the workpiece, and by the movable measuring beam, the angle to be measured is set. For this purpose, the movable measuring beam is put closely on the surface of the angled part of the workpiece. The angle set is fixed by the binder screws and then read without the risk of displacing.

The series of pictures from Fig. 3/14 to Fig. 3/18 shows the various possibilities of use of the universal protractor

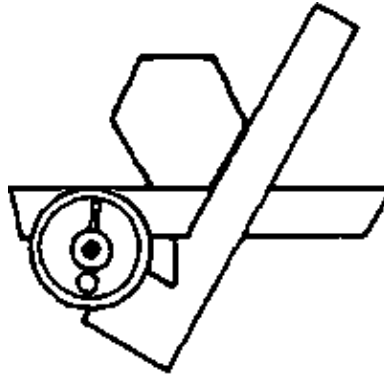


Fig. 3/14 Angular measurement at a hexagon

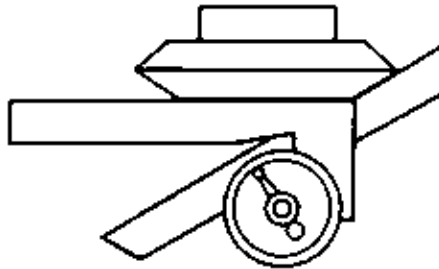


Fig. 3/15 Measuring of an obtuse angle

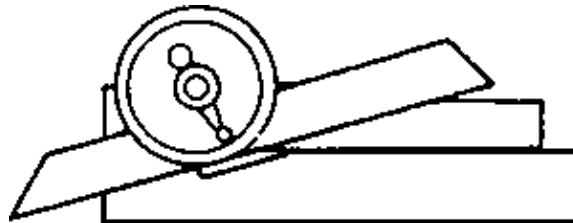


Fig. 3/16 Measuring of an acute angle

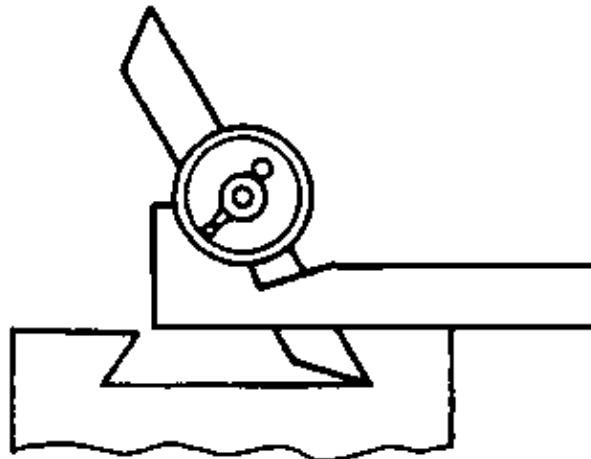


Fig. 3/17 Measuring of an internal angle

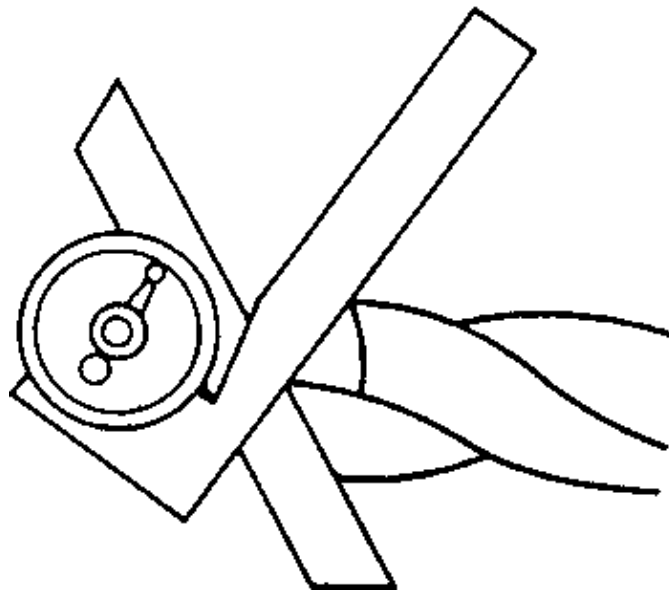


Fig. 3/18 Measuring of a cutting angle at a drill

The following general rule applies to the measurement of angles:

With every angular measurement, the angular degrees have to be read from the starting point of the angular measurement.

The following principles of handling apply to the measurement of angles by universal protractors:

- On principle, the full degrees are read from the main graduation at the zero mark of the vernier.

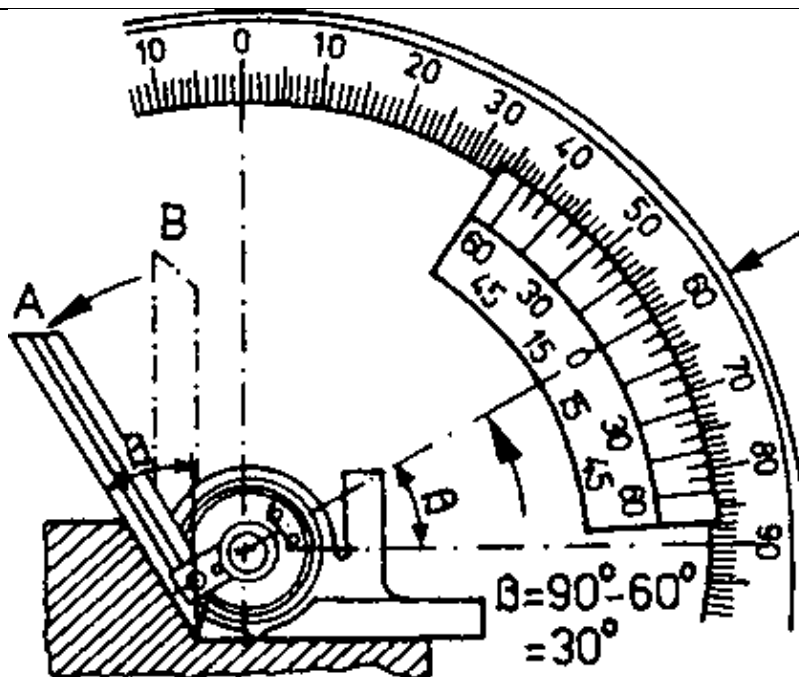


Fig. 3/19 Measuring of the full degrees

In the example given in Fig. 3/19, the fixed measuring beam is set on the horizontal edge of the workpiece. The movable measuring beam – the rule – is in vertical position (B). The full vernier mark and the 90° graduation mark of the main graduation are facing. For measuring, the movable measuring beam is lead to the angular edge of the workpiece – Position A. The result is read in front of the zero position of the vernier, at 60°.

If the deviation of the angle from the vertical shall be measured, the degrees read have to be subtracted from 90 degrees. Then, the indicated angle – beta – is 30 degrees.

– With the older version of the universal protractor (minimum measuring range = 5 angular minutes) the minute vernier consists of one uniformly shaped bow starting from zero with 23 degrees on either side. The two halves of the bow are divided in 12 equal parts each.

This means: 1 degree = 60 angular minutes. 60 angular minutes: 12 = 5 angular minutes. Each graduation mark on the minute vernier indicates an angle opening of 5 angular minutes.

Since compared with the main graduation 23 degrees are divided into 12, the actual graduation of the minute vernier with respect to the main graduation is  $1 \frac{11}{12}$  degrees. If the first graduation mark of the vernier graduation is congruent with an graduation mark of the main graduation, the angle is bigger by 5 angular minutes than the number of degrees indicated.

In the example shown in Fig. 3/20, the fixed measuring beam is put on the horizontal surface of the workpiece, and the movable measuring beam, by the longitudinal edge of the rule is put against the angle of the workpiece.

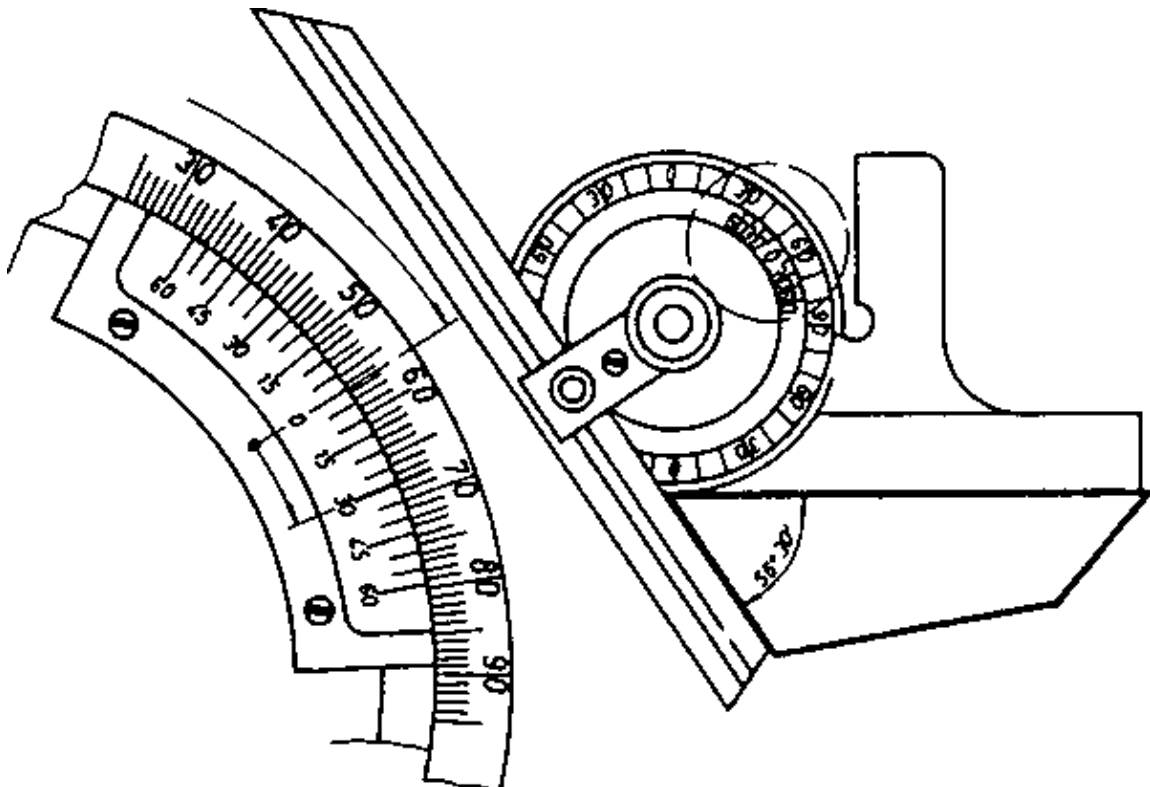


Fig. 3/20 Measuring of the full degrees and the angular minutes

The zero mark of the vernier indicates 56 degrees, and the 30–minutes mark of the vernier coincides with the graduation mark of the main graduation indicating 68 degrees. The angle measured has an opening of  $56^{\circ}30'$ .

– The  $45^{\circ}$  cant and the  $60^{\circ}$  cant of the measuring beam are preferably used for the internal measurement of angles – Fig. 3/17 – because the cants of the measuring beam can easily be put into angular recesses.

In the example shown in Fig. 3/21 too, a measurement is made by the  $45^{\circ}$  cant of the measuring beam.

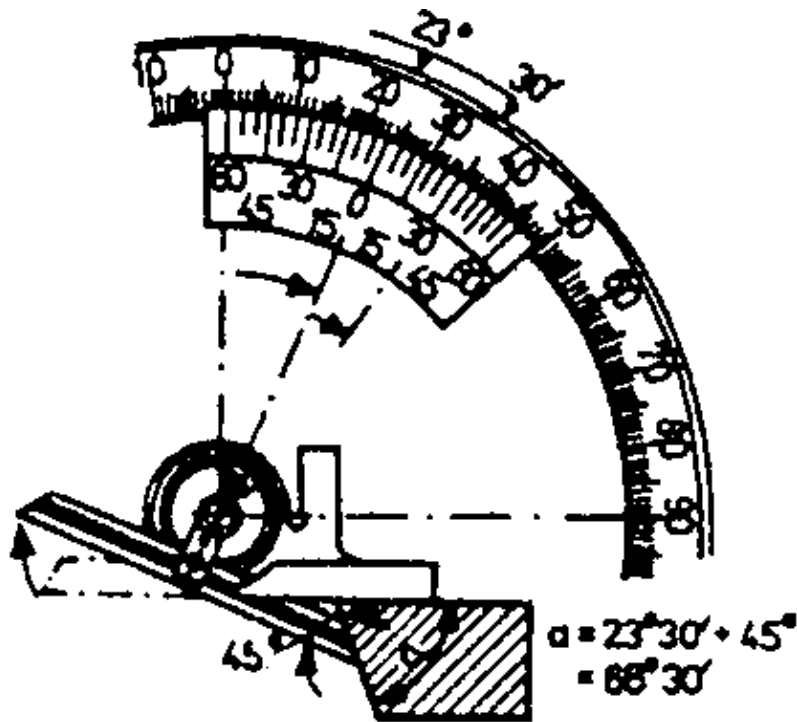


Fig. 3/21 Measuring by the 45°-side of the measuring beam

Here, the fixed measuring beam is put on the horizontal workpiece surface, and the movable measuring beam, by the 45° cant is turned against the surface of the angle to be measured the angle being read from the graduation. It is 23°30'. To this measuring result, the degrees indicated on the 45° cant have to be added. The total size of the angle is 68°30'.

• If the cants of the movable measuring beam are used as lay edges for the angle measurement, the degrees indicated by the cant used have to be added to the measuring result.

– With the younger version of the universal protractor, the main graduation is divided in two semicircles of 180 degrees each. Only the even degree numbers are indicated by graduation marks.



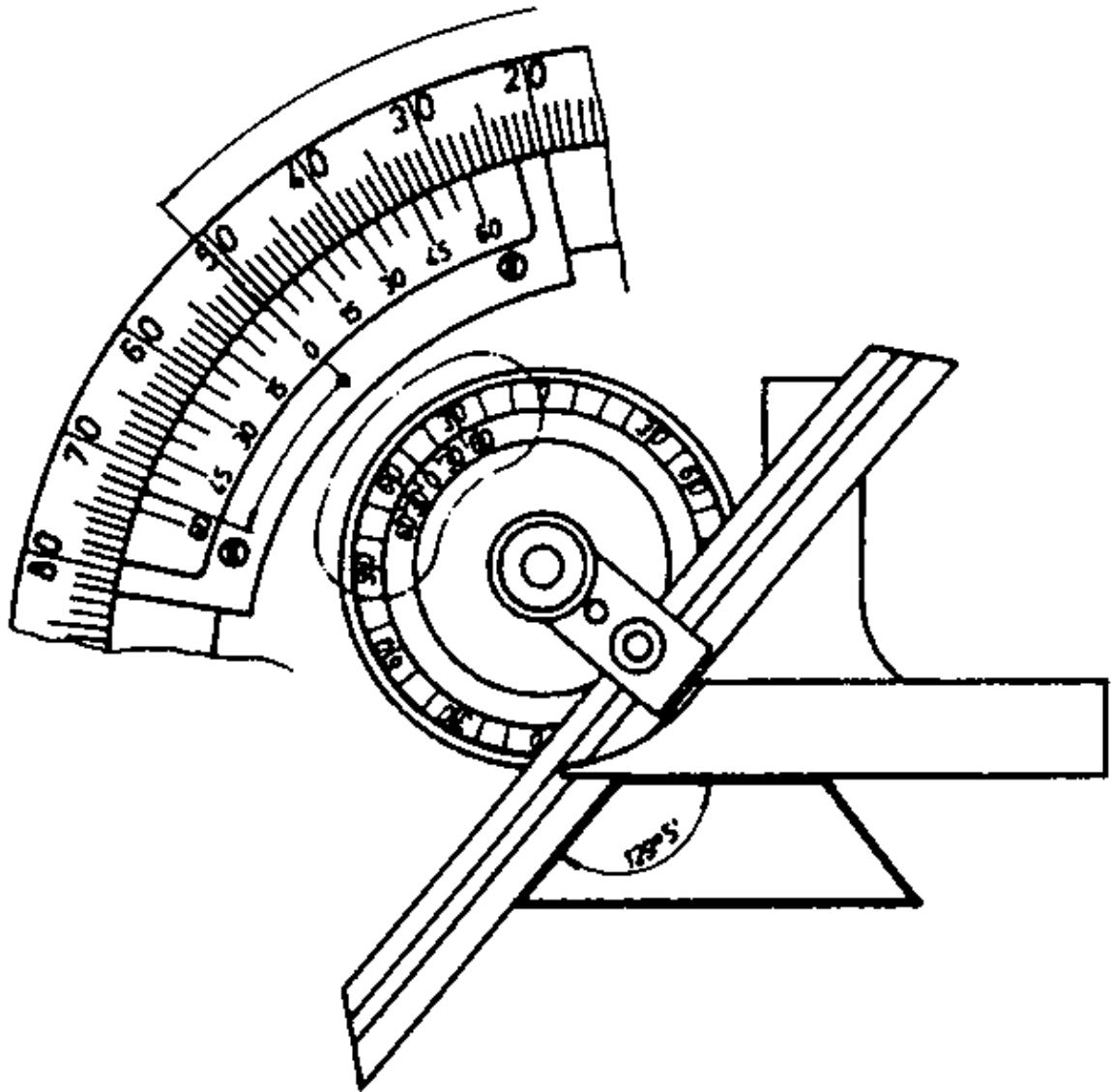


Fig. 3/22 Measuring of an obtuse angle by the universal protractor ( $180^\circ - 50^\circ 55' = 129^\circ 5'$ )

The minute vernier is on one direction from 0 to 2 degrees. Each degree of the vernier graduation stands against 23 degrees of the main graduation. Consequently, the two vernier degrees comprise a total of 46 degrees of the main graduation. If 46 main graduation degrees are divided by 12, each vernier graduation mark comprises  $3 \frac{5}{6}$  degrees. If a 10-minutes graduation mark of the vernier graduation coincides with a graduation mark of the main graduation, the minutes indicated by the vernier graduation – to be read over or in front of the vernier graduation mark – have to be added to the full degrees of the main graduation.

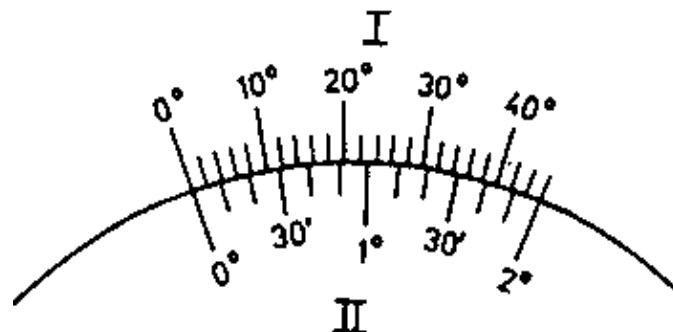


Fig. 3/23 Vernier in zero position

- I Main graduation
- II Vernier

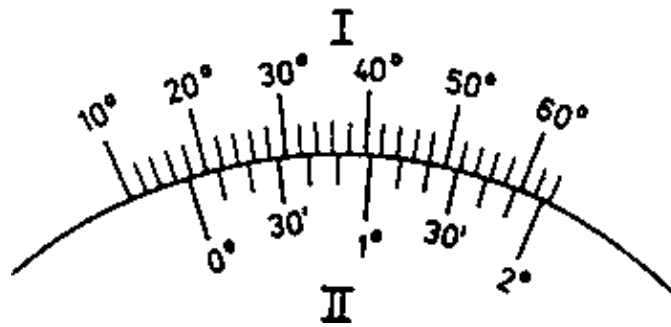


Fig. 3/24 Vernier at 17° 20'

- I Main graduation
- II Vernier

The Figures 3/23 and 3/24 show the vernier positions of a new universal protractor at 0 degree – zero position of the vernier – and at 17° 20'.

The universal protractor is a highly sensitive precision measuring instrument. Blow, shock and moisture lead to premature wear.

Although the movable measuring beam is made as a hair rule, it should never be used apart from the protractor, because this would lead to unilateral wear. The keen edges of the rule must not be used as marking-out means.

Measuring instruments are not tools! After use, the universal protractor has to be carefully cleaned and slightly greased by vaseline. It has to be kept in the appropriate case.

### 3.3. Testing instruments for angles and their application

Testing means for angles are angle representations true to size, in which certain angles – required measures – are fixed in templates for comparison purposes.

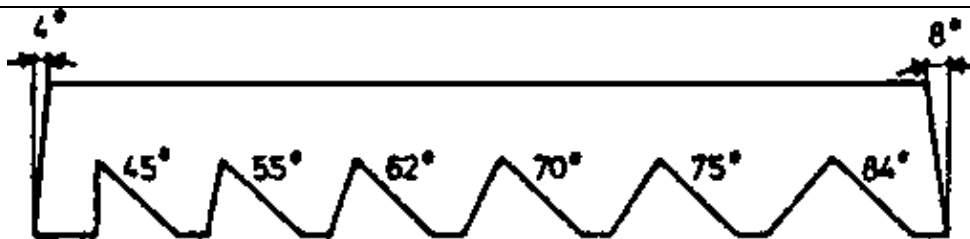


Fig. 3/25 Angle template

By angle templates, tool angles, their size and accuracy are tested in cutting workshops.

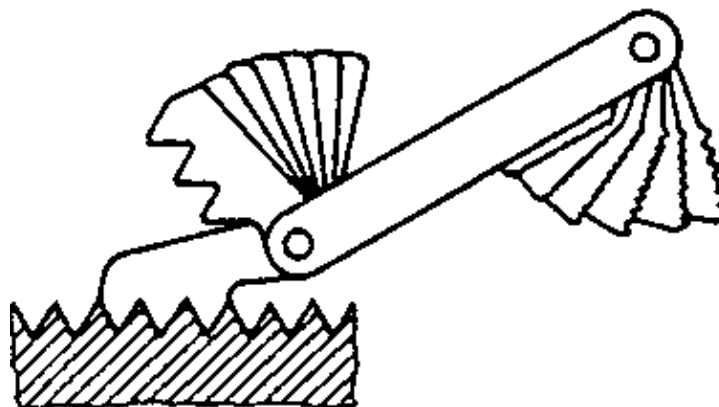


Fig. 3/26 Thread pitch gauge

With the help of thread form templates which may be combined in sets as shown in Fig. 3/26, the length and flank profile of threads of sufficient pitch are tested.

Such screw-pitch gauges are combined in sets for metric and inchmeasure screw threads.

For testing, the individual gauges are put in the threads to be tested. With good threads, no light must be to be seen between gauge and thread.

28) Explain the structure of a universal protractor!

29) How is the universal protractor used and how are the values indicated read from the graduation of the protractor?

30) What is understood by testing means for angles? What are these testing means used for?

## 4. Testing by limit gauges and profile gauges

### 4.1. Testing by limit gauges

Limit gauges are accurate templates by which it can be tested whether one or more measures of a workpiece have been observed. These instruments are testing means only, although they could be used as measuring instruments due to their accuracy.

#### 4.1.1. Testing by feeler gauge

Feeler gauges – so-called spies – are mainly used in auto mechanics.

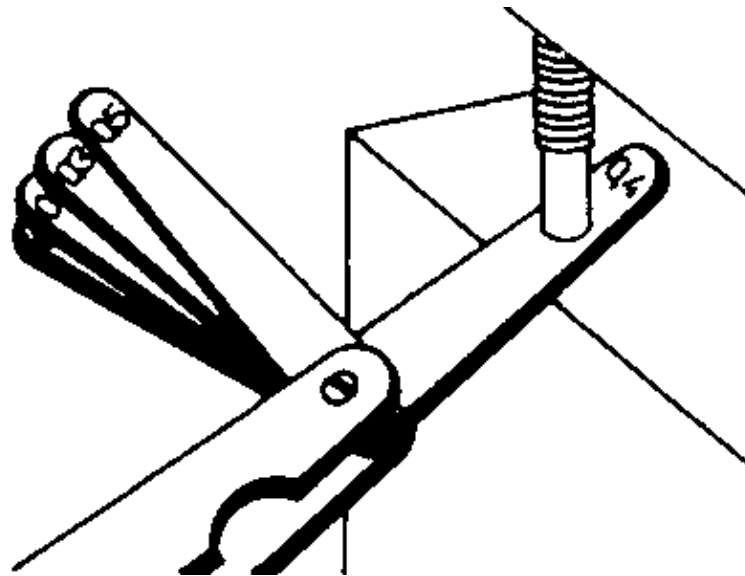


Fig. 4/1 Peeler gauge

They serve for fine adjusting certain variable distances between parts of workpieces such as interelectrode gaps at sparking plugs.

Their measuring accuracy is normally 0.1 mm.

#### 4.1.2. Limit gauges for material stores

Plate gauges and wire gauges are limit gauges for material stores. By them, deviations are found out at semi-finished products.

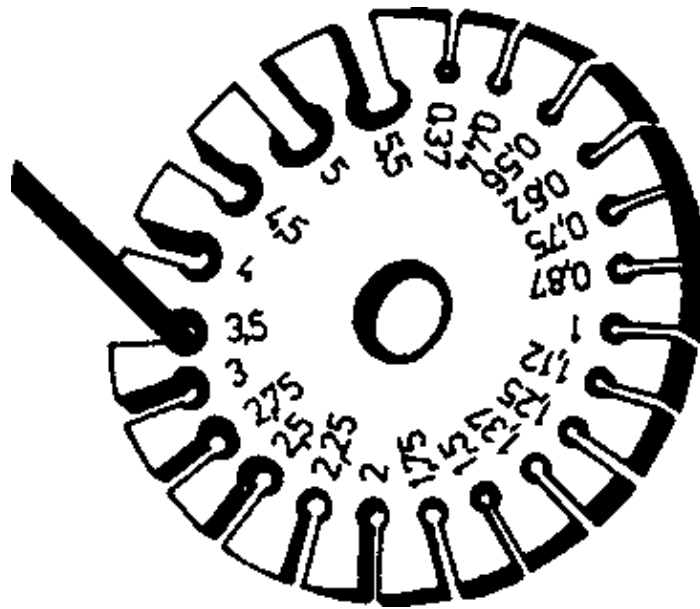


Fig. 4/2 Plate gauge

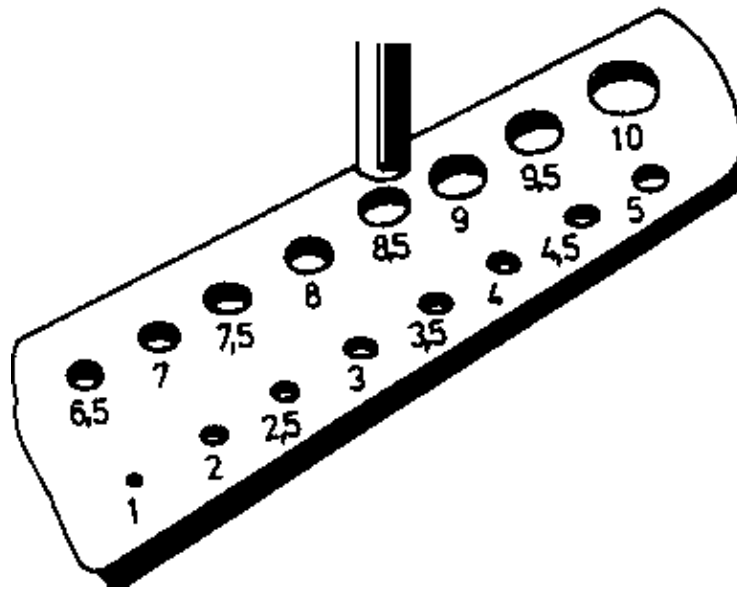


Fig. 4/3 Wire gauge

By plate gauges, plate thicknesses of sheet metal and drawing plates between 0.1 and 5.0 mm are tested. By wire gauges, similar tests are made at round material such as wires and others of a diameter of up to 10 mm.

Plate gauges and wire gauges are no drawing tools. No changes to thickness or diameters must be made by them. Do not use force in carrying out tests by limit gauges. Limit gauges have to be attached to the workpiece in such way that they slide with slight suction.

Limit gauges and especially feeler gauges are sensitive to buckling and fraction. They must be treated carefully and protected against damages.

#### 4.2. General testing instruments for forms

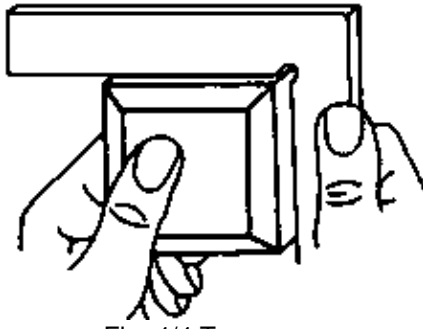


Fig. 4/4 Try square

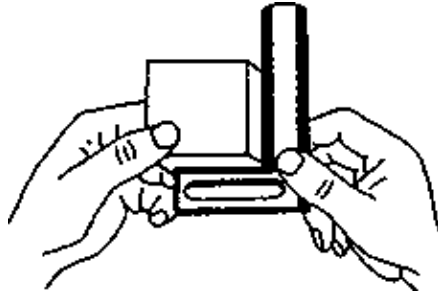


Fig. 4/5 Hair angle

By form gauges, tests are carried out as to whether a workpiece deviates from one or more given forms. These gauges are not used in a measuring way. By them it is only found out whether a workpiece is "good".

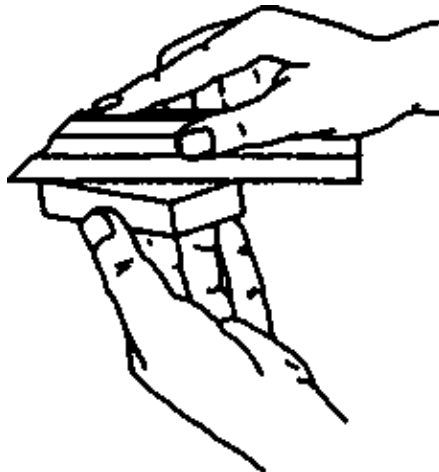
The general testing instruments for forms include:

- try square (workshop square)
- hair angle (angle standard)
- hair rule
- radius gauge
- profile gauge



Fig. 4/6 Hair rule

Fig. 4/7 Holding of hair rule and workpiece



a – The workpiece is held in the left hand, the right hand hold the hair rule and puts it vertically on the workpiece.



b – Testing is made according to light slit method at eye-level.

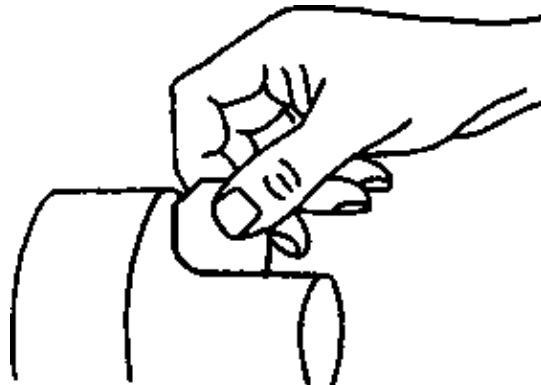


Fig. 4/8 Radius gauge (inside)

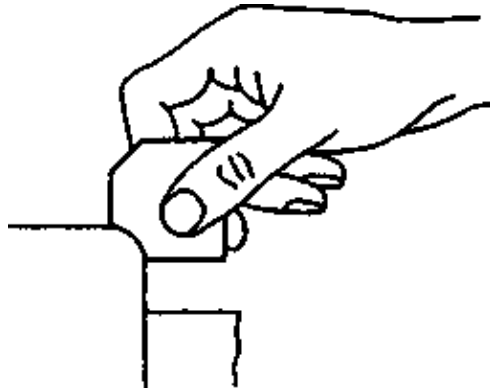


Fig. 4/9 Radius gauge (outside)

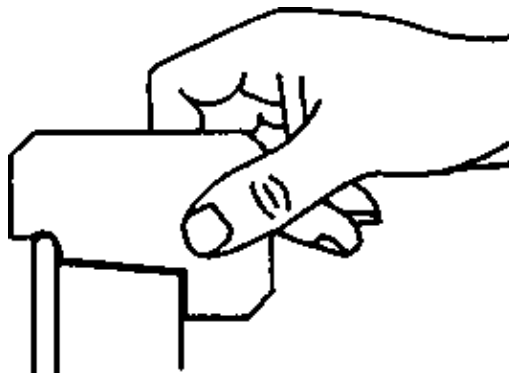


Fig. 4/10 Profile gauge

By indicating shortcomings of the form of a workpiece it is shown – as it is by other kinds of gauges too – that the respective workpiece does not meet the requirements. Profile gauges do not indicate the extent of possible deviations.

31) What is the difference between limit gauges and profile gauges?

32) What has to be especially observed in keeping and transporting measuring and testing instruments?

## 5. Answers to and solutions of exercises and tasks

1)

Unit	Metre	Centimetre	Millimetre	Micron
Metre	(0.35)	0.123	0.0425	0.000 120
Centimetre	35	(12.3)	4.25	0.012
Millimetre	350	123	(42.5)	0.120
Micron	350 000	123 000	42 500	(120)

2) With immediate or direct measuring, the measuring result is achieved by direct comparison of the object to be measured with the measuring instrument. With indirect measuring, values are achieved by substitute measurements with the help of which the actual dimension can be calculated.

3) The necessary pre-suppositions are:

- unobjectionable measuring instruments;
- observance of the reference temperature;
- observance of the optimum measuring force;
- creation of uniform measuring conditions.

4) The basic element of the vernier caliper is the rule. On the rule moves the sliding member. The rule is provided with a millimetre pitch. The sliding member carries the vernier. The rule and the sliding member carry the halves of the measuring jaw.

5) 10 vernier graduation marks are the equivalent of 9 mm rule length. Consequently, each vernier mark is by 1/10 mm shorter than 1 mm. The full millimetres of the measurement are indicated by the rule mark standing before the zero mark of the vernier. The vernier mark coinciding with a mark of the rule graduation indicates the tenth millimetres of the measurement.

6) 53 mm/0.4 mm/30.6 mm/1,7 mm

7)

- Measuring by the tips of the measuring jaw with too strong measuring force.
- Tilted measuring jaw halves.
- Missing parallelism to the object to be tested.
- Not vertically applied depth micrometer during depth measurements.
- Measuring edges not sufficiently reaching into the thread grooves during thread measurements.

8) The carrier element is the bow fixed to the scale case. The measuring spindle and the measuring drum are screwed, so that the micrometer screw can be adjusted. The measuring spindle can be fixed by the lock nut. The gauging surfaces at anvil and measuring spindle are covered by carbide tips. The ratchet prevents the tightening of the micrometer screw. Normally, the knurled knob is designed as fast drive.

9) The vernier consists of the graduations on the inner case and the measuring drum. On the inner case, the full and half millimetres are to be read. The hundredth millimetres are read from the measuring drum.

10) 6.165 mm/10.31 mm/4.74 mm/2.85 mm

11)

– Tilting of the micrometer screw;

– the micrometer screw does not comprise the full measure;

– the micrometer screw has been extended by the temperature of the band and will have to be cooled down to the reference temperature;

– the difference between the temperature of the micrometer screw and the temperature of the workpiece is too big;

– micrometer screws must not be operated by swivelling the bow, because this leads to damages to the fine screw thread and thus to the loss of the measuring accuracy of the micrometer.

12) Fig. 2/46: The lever-type indicator is tilted and not applied parallel to the workpiece.

Fig. 2/48: The angle lever-type indicator is much tilted at both the levels (there are deviations from the total horizontal line as well as from the left side).

13) The dial gauge has two indicators with the help of which full millimetres – small indicator – and hundredth millimetres – big indicator – can be read from the dial. For the adjustment of tolerance ranges, two movable tolerance marks are to be found on the rim of the dial gauge case. The case is fixed to the clamping shaft in which the measuring spindle with the tracer pin slides.

The zero position of the dial gauges is achieved either by adjusting the button or by turning the dial.

14)

a) Pushing-upon of the tracer pins;

b) incorrect settling of the tracer pins on the workpiece with respect to the measuring direction, i.e. out of the centre with round workpieces, not vertically with straight test objects.

c) Deviations from the measuring level – from the horizontal – when using auxiliary equipment for bent levers or lever-type indicators.

15) Block gauges are mainly used for the manufacturing, maintenance and testing of the measuring accuracy of other measuring instruments. They are called master standards – degrees of accuracy of 0 and I – or control standards – degrees of accuracy on II and III.

16) Block gauges are shoved against each other with slight pressure and turning at a time.

They have to be thoroughly cleaned and degreased before use. After every use, the wringed block gauges have to be separated in order to prevent cold welding. They have to be cleaned and greased with vaseline. They have to be deposited orderly in the set. box.



17) Block gauges have to be treated with greatest care. They are sensitive measuring. means that have to be protected against shock and blow as well as contamination – especially dust.

18) With testing, no actual measurement is carried out. It is only tested, whether the actual dimensions of a workpiece lie within given dimensional limits. With measuring the value of a dimension of a workpiece is determined.

19) Calipers are used for testing diameters. They must not be used for measuring. Calipers are not suited for exact testing. When testing by calipers, attention has to be paid that they are not tilted or pushed with effort on or in a workpiece.

20) Because manufacturing and testing absolutely true to size is impossible but a certain accuracy of dimensions is required for series production and for the interchangeability of workpieces, deviations from the dimensions within given dimensional limits are allowed. (Tolerances).

21) Similar workpieces the dimensions of which deviate within the allowed limits (tolerances) from the nominal size can be exchanged against each other. The series production of such workpieces which can be interchanged due to the conformity of their dimensions is called exchange or replacement production.

22) If a workpiece can be fitted to another one – a counterpart – due to the conformity of dimensions and form, this is called a fit. A fit is described by the mating measure.

23) Deviations of the limiting dimensions of a workpiece from its nominal size are called dimensional variation. The knowledge of the extension of the dimensional variation enables the decision whether the workpiece can be used. – necessity of reworking – or is not usable – scrap.

24) If the external dimensions of a workpiece are smaller than the allowed minimum–limits or if the internal dimensions of a workpiece are bigger than the allowed maximum – limits, the workpiece cannot be used. It is scrap.

Calipers are not used for measuring purposes but only to state that a workpiece is "good" or "scrap". The group of calipers includes: normal calipers, block gauges, external limit gauges, thread gauges, plug gauges, radius gauges and profile gauges.

26) Fixed gauges have an unchangeable measure between their gauging surfaces. They do not need to be adjusted by measuring instruments.

27) Do never use force when working with gauges! Always lead gauges lightly. If gauges have a "go end" and a "not–go end", both tests have to be carried out. Do never work with gauges on moving or rotating workpieces! Accident hazard. With gauges, pay attention to the testing temperature indicated. Treat the gauges carefully and protect them against shock and blow.

28) On the fixed measuring beam there is a circular disk with the main graduation. The main graduation may consist of four times 90 degrees (old) or two times 180 degrees (new), A moveable measuring beam – the rule – is fixed to the vernier carrier. The two parts are turned against the main graduation during the measurement of angles. The angular workpiece is measured between the fixed and the moveable measuring beams. The moveable measuring beam in the form of a rule is laterally limited by edges of 45 degrees and 60 degrees of canting. It can be laterally shifted over its full length.

29) For the measurement of angles, the universal protractor by its fixed measuring beam is set on the workpiece. The moveable measuring beam is turned towards the angular surface and put on it closely. The full degrees measured are read before, above or at the zero mark of the vernier – with new protractors – in front of or above the vernier zero mark, with old protractors at the zero mark of the vernier. The minute degrees are read at the graduation mark of the vernier coinciding with a graduation mark of the main graduation and added to the full degrees.

30) Testing instruments and angles are represented by templates and gauges, which are accurate representations of angles used for the testing of tool angles or profile angles of threads at screws.

31) By limit gauges, the dimensions of workpieces or materials are tested with respect to their usability – good or scrap. By form gauges, forms of workpieces are tested as to their conformity with a counterpart true to size and their usability – good or scrap. The counterpart is represented by the form gauge.

32) Measuring and testing instruments, especially gauges, have to be protected against shock and blow. They always have to be kept separately from other tools in protecting cases.