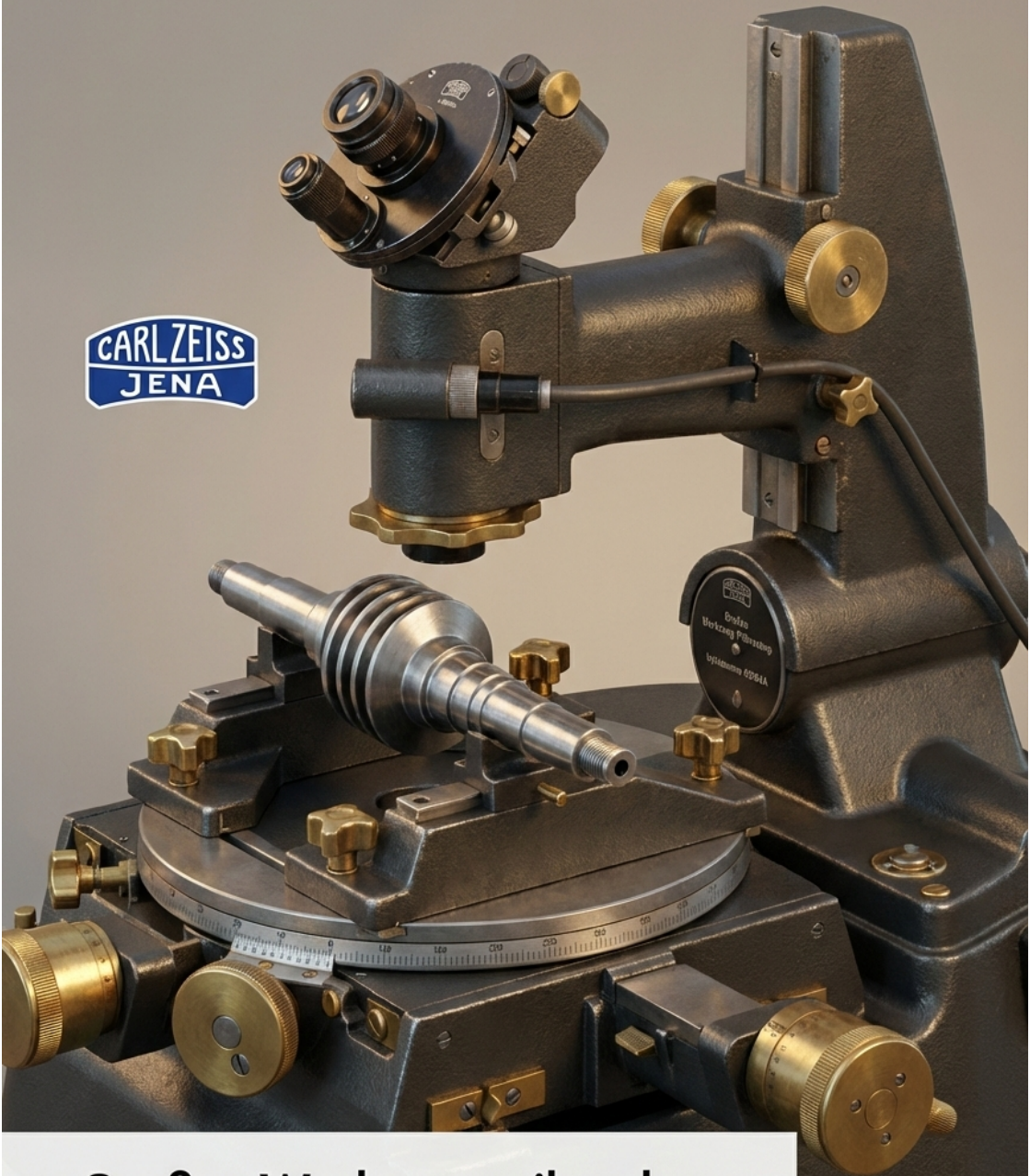


ZEISS Large Toolmaker's Microscope

User Instructions



Großes Werkzeugmikroskop



ZEISS Large Toolmaker's Microscope User Instructions

Newer Version (circa 1974)

Translated from a German original document

Translated and Typeset by
sBs (<http://fif.viri.cat>)

March 4, 2026

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1 Applications

Due to its robust construction, the Large Toolmaker’s Microscope can be used both in the inspection room and in the workshop for a wide range of measuring and inspection tasks. It is suitable for the following applications:

- Length measurements in rectangular and polar coordinates.
- Angle measurements on tools, thread gauges, milling cutters, cutting punches, form gauges, templates, etc.
- Thread measurements, including pitch diameter, major and minor diameters, lead, flank angle, profile alignment relative to the thread axis, and thread form (rounding, truncation, flank straightness).
- Profile comparison against pre-drawn reference profiles, and tracing of projected profiles.

2 Principle of operation

The workpiece to be inspected is placed in the beam path of an illumination system, producing a shadow image that is viewed through the microscope. This image is formed in the image plane of the objective and is observed through an eyepiece. The eyepiece may contain a suitable mark for aiming at measurement points on the workpiece or—more commonly—reticle patterns, for example for thread forms or radii, and standard reticles for comparison with the shadow image of the workpiece. When checking frequently changing, non-dimensioned profiles, the shadow image of the workpiece can be

projected onto a focusing screen; the corresponding enlarged drawing must then be prepared on tracing paper.

To enable not only profile comparison but also measurement, the workpiece is moved and/or rotated on a measuring table using micrometer heads.

In addition to this method, the so-called shadow-image method, measurements can also be carried out using the axial-section method, which is recommended especially for thread measurements. In this method, cutting edges are brought into contact and measurements are made on the defined axial section of the thread. This method allows certain measurements to be performed more accurately than with the shadow-image method.

3 Specifications

3.1 Instrument dimensions

Quantity	Value
Width	510 mm
Length	900 mm
Height (without projection unit)	550 mm
Mass of complete instrument	80 kg

3.2 Scale divisions

Quantity	Value
Micrometer head division	0.01 mm
Angle division (angle-measuring eyepiece)	1'
Angle division (revolving eyepiece)	10'
Angle division (rotary table)	3'

3.3 Measuring ranges and limits

Measuring ranges

Characteristic	Value
x-slide travel, micrometer head only	25 mm
x-slide travel, micrometer head + setting gauges	150 mm
y-slide travel, micrometer head only	25 mm
y-slide travel, micrometer head + setting gauges	50 mm

Measuring limits

Quantity	Value
Angle-measuring eyepiece range	0° to 360°
Rotary table angle range	0° to 360°
Swing range of microscope carrier	-12° to 12°
Rotary table diameter	280 mm
Reach of microscope arm	167 mm
Maximum clamping length in tail-stock housing, specimens up to 39 mm diameter	315 mm
Maximum clamping length in tail-stock housing, specimens 40 mm to 85 mm diameter	235 mm
Maximum specimen diameter when using the V-block	130 mm

3.4 Revolving eyepiece heads

Quantity	Value
Apparent scale-division size	1.1 mm
Angle measuring range ¹	±7°
Angle-scale division	10'
Eyepiece magnification	10×
Total magnification (depending on objective)	10×, 15×, 30× and 50×
Field of view (depending on objective)	21, 14, 7 and 4 mm

¹For eyepieces C 2, H 2, JS 2, N 2, O, P 2, Q, R, W 3, and Z.

3.5 Angle-measuring eyepiece

Quantity	Value
Coarse scale division	1°
Fine scale division	1'
Apparent fine-scale division size ²	0.5 mm
Measuring range	0° to 360°
Eyepiece magnification	10×
Microscope magnification for circle-scale reading	40×
Maximum inaccuracy of the angle-measuring eyepiece	1'

3.6 Double-image eyepiece

Total magnification and field of view:

With objective	1×	1.5×	3×	5×
Total magnification	14×	21×	42×	70×
Field of view (mm)	14	9.5	5	3.2

Additional specifications:

Quantity	Value
Apparent field of view	210°
Uncertainty of coincidence/symmetry setting ³	0.5 μm

3.7 Measuring-lever attachment

Quantity	Value
Swing range of the feeler	3°
Maximum insertion depth	15 mm
Measuring force	0.098 N
Reversal span (maximum)	1.3 μm

4 Accuracy of the instrument

We guarantee that, for none of our Large Toolmaker's Microscopes, the instrument error exceeds the values stated below. The measurement uncertainties were calculated taking unfavorable conditions into

²Referenced to a conventional viewing distance of 250 mm.

³Simple geometric shapes with good line/edge quality are assumed.

account and represent the maximum values to be expected. The reference temperature is 20 °C.

4.1 Meaning of the symbols used in the formulas

L measuring length, in mm.

D diameter, in mm.

H height of the measurement plane (setting edge or cutting-line height above the table plate), in mm.

P lead, in mm.

F flank length (or length of the angle arm), in mm.

d_2 pitch diameter, in mm.

$\alpha/2$ half flank angle.

γ mean lead angle of the thread, in °.

K edge-quality factor.

Recommended values for K :

- $K = 1$: ground workpieces with sharp, well-defined edges (new cutting wheels and form tools, foils).
- $K = 2$: flat workpieces up to 1 mm thick (surface gauges; very clean stamped parts).
- $K = 3$: flat workpieces up to 3 mm thick (clean stamped parts).
- $K \geq 4$: workpieces thicker than 3 mm with poor edge quality.

4.2 Shadow-image method

Length measurements

In x -direction:

$$\pm \left(3.5 + 0.7K + \frac{L}{46} + \frac{H \cdot L}{1500} \right) [\mu\text{m}]$$

In y -direction:

$$\pm \left(3.5 + 0.7K + \frac{L}{50} + \frac{H \cdot L}{2000} \right) [\mu\text{m}]$$

Angle measurements on flat parts (angle-measuring eyepiece)

$$\pm \left(1.0 + \frac{1.5}{P} \right) [']$$

Diameter measurements on smooth cylinders

$$\pm \left(4 + \frac{D}{25} \right) [\mu\text{m}]$$

4.3 Thread measurements

Pitch diameter

$$\pm \left(2.5 + \frac{3}{\sin(\alpha/2)} + \frac{d_2}{25} \right) [\mu\text{m}]$$

Flank angle

With angle-measuring eyepiece:

$$\pm \left(1 + \frac{1.5}{P} \right) [']$$

With revolving eyepiece head:

$$\pm \left(6 + \frac{2}{P} \right) [']$$

Lead

$$\pm \left(2.5 + \frac{3}{\cos(\alpha/2)} + \frac{P}{20} \right) [\mu\text{m}]$$

4.4 Axial-section method (cutting-edge measurement)

In this section, the stated uncertainties apply when using new cutting edges, when using the new bright-field reflected-light illumination, and when setting to the line mark of the cutting edges. For all measurements, the crosshair of the angle-measuring eyepiece should be set approximately to the center of the thread flank.

Diameter measurements on smooth cylinders

$$\pm \left(2.6 + \frac{D}{25} \right) [\mu\text{m}]$$

Thread measurements

Pitch diameter:

$$\pm \left(2.5 + \frac{1}{\sin(\alpha/2)} + \frac{d_2}{25} \right) [\mu\text{m}]$$

Lead:

$$\pm \left(2.5 + \frac{0.7}{\cos(\alpha/2)} + \frac{P}{20} \right) [\mu\text{m}]$$

Flank angle:

$$\pm \left(0.8 + \frac{1.2}{P} \right) [^\circ]$$

4.5 Special methods

Length measurements with reflected-light illumination

In x-direction:

$$\pm \left(2.6 + 0.7K + \frac{L}{46} + \frac{H \cdot L}{1500} \right) [\mu\text{m}]$$

In y-direction:

$$\pm \left(2.6 + 0.7K + \frac{L}{50} + \frac{H \cdot L}{2000} \right) [\mu\text{m}]$$

Length measurements with the measuring-lever attachment

In x-direction:

$$\pm \left(4.1 + \frac{L}{46} + \frac{H \cdot L}{1500} \right) [\mu\text{m}]$$

In y-direction:

$$\pm \left(4.1 + \frac{L}{50} + \frac{H \cdot L}{2000} \right) [\mu\text{m}]$$

The uncertainties stated in this section:

- Apply when measurements require switching the measuring-force direction. If switching is not required, the reversal span of the measuring-lever attachment can be avoided; in that case, the smaller value 2.8 applies instead of 4.1.
- For double measurements, 3.8 replaces 4.1 (measurements with switching the measuring force), or 2.5 replaces 4.1 (measurements without switching the measuring force).

5 Unpacking and setting up the device

The Large Toolmaker Microscope is shipped packed in two crates. The larger of the two crates contains the main unit, while the smaller one houses the accessories (see Fig. 2). Before unpacking, it is advisable to prepare the table on which the device will be set up. The table height should be approximately 600 mm for seated observation and 950 mm for standing observation.

Open the lid of the shipping crate and remove the glass tabletop (located on one side wall). Unscrew the nuts (Fig. 1-2,3), pull out the threaded bolts, and remove the locking blocks.

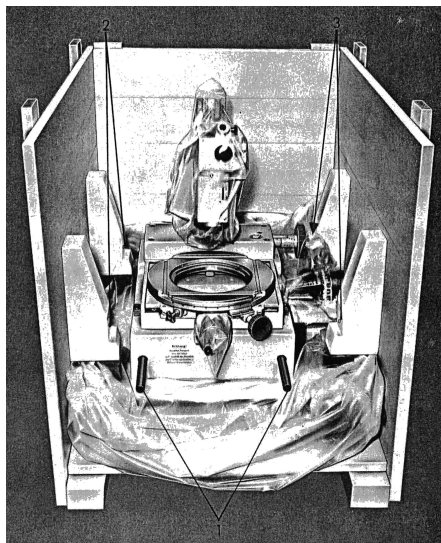


Figure 1: Instrument in shipping crate

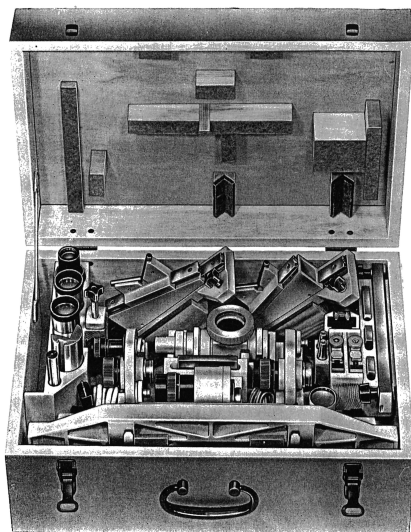


Figure 2: Accessory container

Carefully remove the padded wooden frame (Fig. 3-4) with the device attached to it from the shipping crate. Unscrew the three threaded bolts that are screwed through the wooden frame from below into the microscope base. To do this, place the wooden frame with the microscope on suitable blocks so that the threaded bolts are easily accessible.

Lift the microscope off the wooden frame using the support rods (Fig. 1-1) and place it on the prepared table. Screw the three leveling screws (Fig. 4-12) (located in the box) into the microscope base. Remove the support rods. Level the instrument using the bubble level (Fig. 4-25) built into the microscope base. Unscrew the locking screw (Fig. 5-40) for the tilting mechanism of the microscope stand.

Unscrew the lamp socket from the wooden frame, fit the lamp, and attach it to the instrument.

Four retaining blocks (Fig. 6-5, 6, 7,

8) are attached to block the longitudinal and transverse movement of the measuring stage. These must be unscrewed before commissioning. These blocks must be screwed back into the designated locations (threaded holes) each time the tool microscope is transported to prevent damage from sudden movement of the measuring stage. After removing the wrapping paper, all bare parts must be cleaned of corrosion protection grease with a clean cloth soaked in light naphtha or methanol. Then, a very thin film of acid-free petroleum jelly (Vaseline) should be applied to these parts.

6 Description of the individual instrument components

The Large Toolmaker's Microscope consists essentially of the cast base (Fig. 4-9),

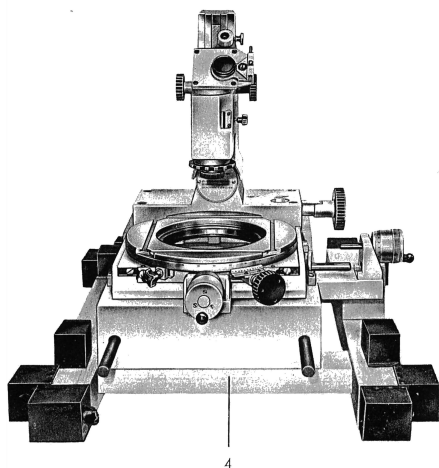


Figure 3: Instrument on transport locking frame

the main illumination unit (Fig. 5-37), the stand with support arm (Fig. 4-24), and the viewing microscope (Fig. 4-20).

The rigid cast base rests on three leveling screws (Fig. 4-12), which are used to align the instrument with the aid of the circular bubble level (Fig. 4-25). Mounted on the base is the coordinate measuring table (Fig. 4-10), which comprises two slides—one for the x -direction and one for the y -direction—and a rotary table (Fig. 4-16) that carries the table glass plate (Fig. 4-17). The slides run on precision ball bearings in hardened guides, providing smooth, play-free travel. Two micrometer heads (Fig. 4-14, 27), each with a measuring range of 0 mm to 25 mm, provide displacement of the measuring table in the x - and y -directions.

By using setting gauges (Fig. 7-31), inserted between the micrometer heads and the contact surfaces of the slides, the measuring range can be extended from 0 mm to 25 mm to 0 mm to 150 mm in the x -direction and to 0 mm to 50 mm in the

y -direction. If an end-dimension combination is required in the x -direction, the combined setting gauges are clamped in the gauge-block holder (Fig. 7-30) and inserted together with it. The rotary table (Fig. 4-16) is provided with a 360° scale and a vernier (Fig. 4-11). Rotation is locked by the knurled knob (Fig. 4-13) in conjunction with the cross-handle screw (Fig. 4-15). The grooves in the rotary table serve for fastening various accessories and auxiliary fixtures.

The viewing microscope (Fig. 24-20) is mounted on the support arm of the stand (Fig. 4-24). The support arm can be adjusted in height by the rack-and-pinion drive (Fig. 4-22) and clamped with the cross-handle screw (Fig. 4-23). For thread measurements using the shadow-image method, the stand can be tilted about an axis at the height of the tailstock housing, allowing it to pivot to either side. The tilt is set with the knurled knob (Fig. 4-26), which is connected to a scale from which whole and half degrees can be read. Fine focusing of the viewing microscope is carried out with the star-shaped nut (Fig. 4-19). The required objective (Fig. 4-18) is screwed into the tube. The prism box at the top of the microscope carries the eyepiece (Fig. 4-21). The microscope is transmitted-light; thus, when viewing through the eyepiece, a correctly oriented image of the workpiece is seen.

On the rear side of the cast base (Fig. 4-9) is the main illumination unit (Fig. 5-37). It is equipped with a 12 V, 50 W lamp; its light beam is directed via a permanently installed mirror through the table glass plate (Fig. 4-17) into the viewing microscope.

The tailstock housing (Fig. 7-35) is placed on the rotary table (Fig. 4-16) and fastened with four cross-handle screws. In addition to two solid and two hollow

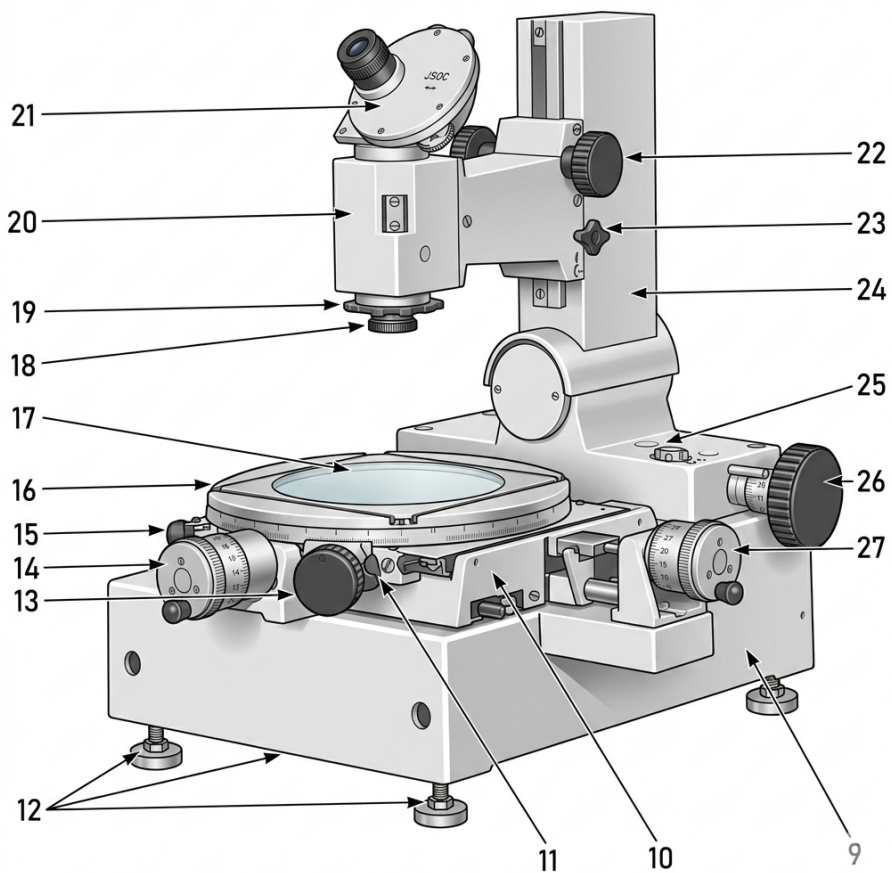


Figure 4: Front view of the instrument

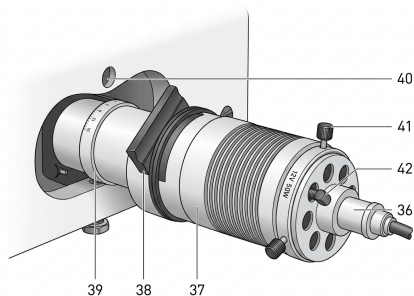


Figure 5: Main illumination

centers, the tailstock housing includes a special fixture with V-block (Fig. 7-32) for small parts that cannot be held between centers. The two ground contact faces (Fig. 7-34) have T-slots between the cross-handle screws for mounting the cutting-edge unit.

Accurate adjustment of the viewing microscope to the center plane is carried out using the mechanical setting gauge (Fig. 8-74), which contains a cutting edge that can be set precisely to the correct center height. In addition, the V-blocks (Fig. 7-29) that can be adjusted in the x - and y -directions can be attached to the rotary table, as can the clamping fixture (Fig. 7-28) suitable for holding flat parts.

Power for the electrical units is supplied via the adjustable transformer (Fig. 9). On its front panel are the main switch (Fig. 9-44), the switch for the potentiometer (Fig. 9-45), the changeover switch (Fig. 9-46), and two built-in sockets (Fig. 9-43). The potentiometer allows the voltage to be adjusted from 4 V to 7 V; for visual observation, the selector switch must be set to "4-7 V". For projection, the setting "12 V" must be selected.

When using reflected-light illumination and the illumination for the angle-measuring eyepiece at the same time, the

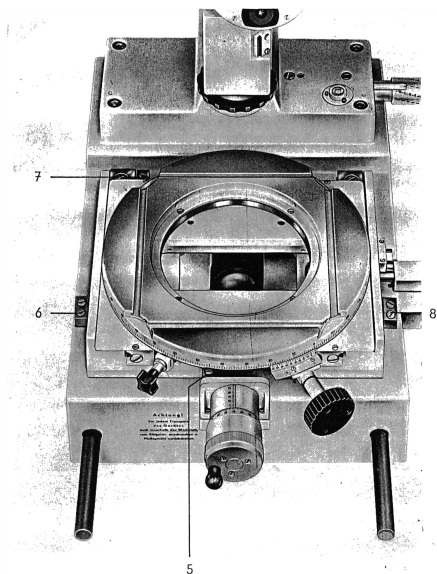


Figure 6: Securing the coordinate measuring table

use of a double socket is recommended.

6.1 Main illumination

The main illumination unit (Fig. 5-37), fitted with a 12 V/50 W incandescent lamp, is permanently mounted on the instrument. It must be connected to the 12 V output of the control transformer.

For visual observation, set the changeover switch (Fig. 9-46) to "4-7 V". The desired brightness is then adjusted using the potentiometer (Fig. 9-45). In this mode, the lamp is supplied with a voltage between 4 V and 7 V.

For projection, set switch (Fig. 9-46) to "12 V".

To replace the lamp, loosen the adjusting screws (Fig. 5-41) and remove the lamp holder. The lamp can then be replaced easily.

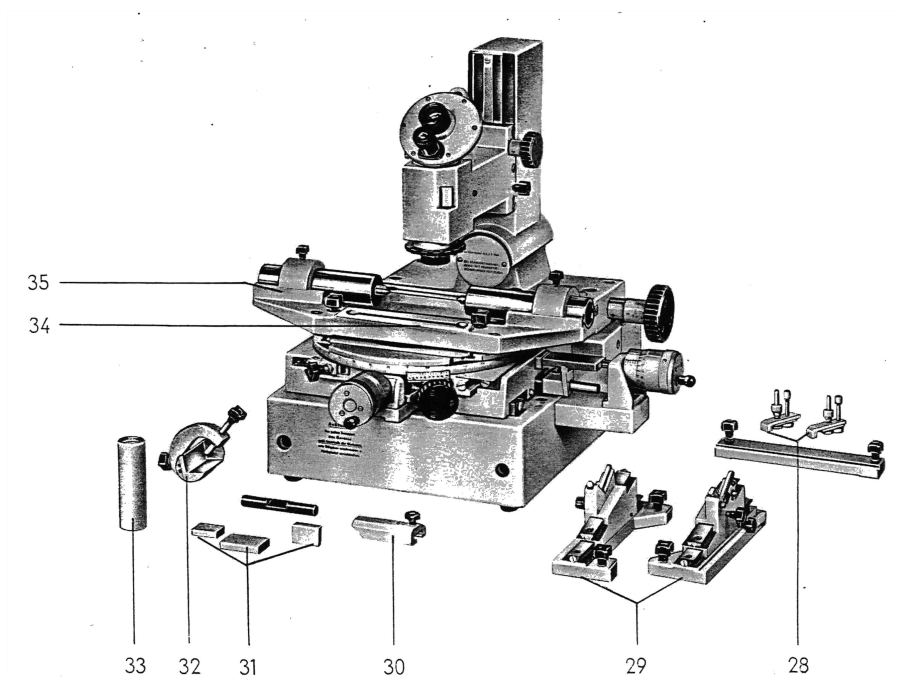


Figure 7: Instrument with accessories

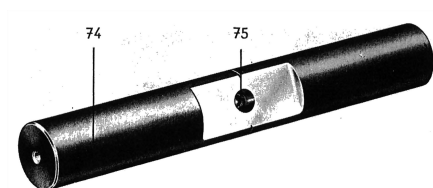


Figure 8: Mechanical setting gauge

that, when working with the projection and photographic equipment, the eye lens of the eyepiece in use is replaced with the eyepiece insert. The diopter ring is set to the index mark with the red mark.

6.2 Eyepieces

The basic equipment of the device includes the revolver eyepiece ISO 2 and the angle measuring eyepiece (Fig. 10).

Additional eyepieces are available for other measuring tasks and can be obtained from us. It is essential to ensure

6.2.1 Revolving eyepiece head C 2

Contains profiles for trapezoidal threads with pitches from 1 mm to 20 mm, one vertical and two horizontal divisions for quickly measuring flats, thread depths, and similar tasks, two double 30° angles for checking trapezoidal threads, cutting tools, and hob cutters, and a crosshair.

Required objectives: 1×; 1.5×; 3×.

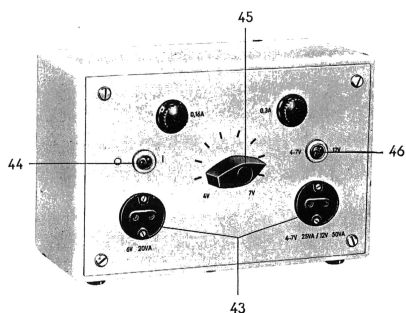


Figure 9: Control transformer

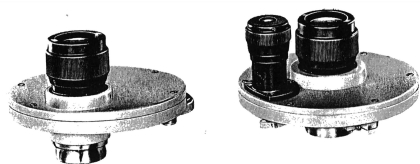


Figure 10: Revolving eyepiece head and angle-measuring eyepiece

6.2.2 Revolving eyepiece head E 2

Contains circular arcs for radii from 0.1 mm to 60 mm in various increments.

Required objectives: 1×; 3×.

6.2.3 Revolving eyepiece head H 2

Contains profiles for Whitworth threads (BSF, BSW), Unified threads (UNC, UNF, UNEF), BSC and BAS threads, one each of angles of 60°, 55° and 47°20', as well as a crosshair.

Required objectives: 3×; 5×.

6.2.4 Revolving eyepiece head ISO 2

The ISO 2 revolving eyepiece head contains standard profiles for ISO threads with pitches from 0.075 mm to 6 mm. For

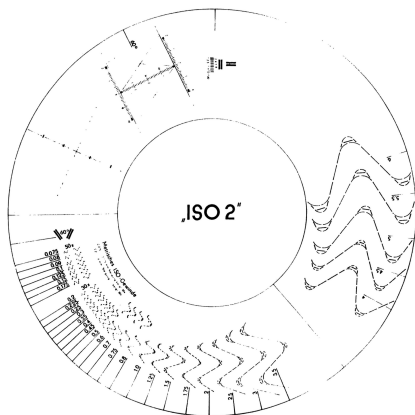


Figure 11: Reticle plate of the revolving eyepiece head, ISO 2

itches from 0.075 mm to 0.8 mm, the profile image is arranged side by side; for pitches from 1 mm to 6 mm, the profile image is arranged one above the other. This arrangement makes it possible to align the reticle with the shadow image of the thread profile. It is irrelevant whether the thread profile to be observed faces toward or away from the observer, i.e. whether it appears in the lower or upper part of the field of view. See Fig. 11.

The eyepiece head includes:

- two mutually perpendicular double-line reticles for setting the measuring edges (initial and final position of the measuring edge) at a light slit. In these reticles, the central slit is twice as wide as each of the two outer slits. With correct adjustment, the uncovered half of the central slit is the same width as the uncovered outer slit;
- a scale division for quick measurement of line widths from 0.01 mm to 0.1 mm;

- one vertical and two horizontal scales for quick measurement of flats, thread depths, and similar features (scale division 0.02 mm, measuring range 0 mm to 4 mm);
- a 60° double angle for checking the flank angle in thread measurements;
- a crosshair for setting the double-line mark when using the measuring-lever attachment, for measuring major and minor diameters on threads, for length measurements on suitable test pieces, and for angle measurements within the angle scale range ($\pm 7^\circ$);
- a reticle that forms an angle of 60° for pitch measurements on threads.

Required objectives: 3× and 5×.

6.2.5 Revolving eyepiece head N 2

Contains profiles for API Line Pipe Thread, API Casing and Tubing Round Thread, API Buttress Casing Thread, API V-0.040 Flat and V-0.050 Flat Forms, British Standard Taper Pipe Thread, British Standard Parallel Pipe Thread, one each of 60° and 55°, and a crosshair.

Required objective: 3×.

6.2.6 Revolving eyepiece head O

Contains arcs for radii from $\frac{1}{64}$ to $\frac{3}{4}$ inch (in $\frac{1}{64}$ inch increments) and a crosshair.

Required objectives: 1×; 3×

6.2.7 Revolving eyepiece head P 2

Contains full circles with radii from 0.1 mm to 8 mm in various increments and arcs for radii from 8.5 mm to 15 mm, as well as a crosshair.

All full circles are also provided with a crosshair and a setting line, enabling quick centering.

Required lenses: 1×; 3×.

6.2.8 Revolving eyepiece head Q

Contains arcs for radii from 0.5 mm to 60 mm in various increments and a crosshair.

Required lenses: 1×; 3×.

6.2.9 Revolving eyepiece head R

Contains arcs for radii from 25 mm to 80 mm in 1 mm increments and a crosshair.

Required lens: 1×

6.2.10 Revolving eyepiece head W 3

The W 3 revolving eyepiece head contains:

- standard profiles for metric threads for leads from 0.075 mm to 6 mm;
- standard profiles for Whitworth threads for *threads per inch* from 60 to 4 per inch;
- two double angles, 30° and 40°, for checking trapezoidal threads, thread gauges, and gear hobs;
- two double angles, 60° and 55°, for checking the flank angle of metric and Whitworth threads;
- one vertical and two horizontal scales for quick measurement of flats, thread depths, and similar features (scale division 0.02 mm, measuring range 0 mm to 4 mm);
- two reticles for setting measuring edges at a light slit (see ISO 2);

- two reticles in the same arrangement that form angles of 55° and 60°, for lead measurements on metric and Whitworth threads;
- a scale for quick measurement of line widths from 0.01 mm to 0.1 mm;
- a crosshair for setting the double-line mark when using the measuring-lever attachment, for measuring major and minor diameters, for length measurements on suitable workpieces, and for angle measurements within the angle-scale range ($\pm 7^\circ$).

Required objectives: 3× and 5×.

6.2.11 Revolving eyepiece head Z

The revolving eyepiece head Z contains reference profiles for involute gearing for the following modules:

Module <i>m</i>							
0.30	0.50	0.70	1.25	2.25	3.25	4.50	
0.35	0.55	0.80	1.50	2.50	3.50	5.00	
0.40	0.60	0.90	1.75	2.75	3.75		
0.45	0.65	1.00	2.00	3.00	4.00		

In addition to these involute reference profiles, the reticle plate provides—for each module listed—the nominal meshing position t_e for a pressure angle of 20°. This value is represented by two parallel lines arranged to the right and left of the reference profile.

It is possible to measure tooth-thickness dimensions and tooth-thickness variations (using the reference profiles), as well as the deviation of the meshing position for spur gears with sharp-edged end faces (using the parallel lines). Suitable test pieces are especially involute gears with $m < 1$. Use of the reference profiles assumes gears with unmodified tooth tips (the addendum circle is consistent with an involute profile).

For all measurements and inspections using revolving eyepiece head Z, it is recommended to mount the workpiece in an auxiliary fixture between vertical centers. The fixture should preferably include a drive for rotating the workpiece, and it should allow small angular adjustments. Place the fixture with the workpiece on the coordinate measuring table of the Large Toolmaker's Microscope.

The shadow image of the workpiece is then aligned with the reticle pattern. Displacements of the gear are measured in the *x*- and *y*-directions.

Required objectives: 1×, 1.5× and 3×.

6.2.12 Angle-measuring eyepiece

The angle-measuring eyepiece contains an open crosshair forming 60°, an interrupted crosshair at 90°, and four interrupted lines parallel to a reticle line of the 90° crosshair. These are used primarily for cutting-edge measurements and correspond, when using the 3× objective, to spacings of 0.3 mm or 0.9 mm in the object plane. The reticle plate can be rotated by the knurled knob (Fig. 12-80) located on the housing.

The respective angular value is indicated on a scale built into the angle-measuring eyepiece (see Fig. 13), which is read through a small reading microscope (Fig. 12-76) with 40× magnification.

The angle graduation is illuminated either by daylight or by the auxiliary illumination for the angle-measuring eyepiece (Fig. 14-47). This auxiliary illumination, equipped with an incandescent lamp rated at 6 V and 2.1 W, can be attached to the microscope tube by means of a dovetail guide (Fig. 15-81). It is used when daylight does not provide sufficient illumination of the graduation in the angle-measuring eyepiece. Connection is made

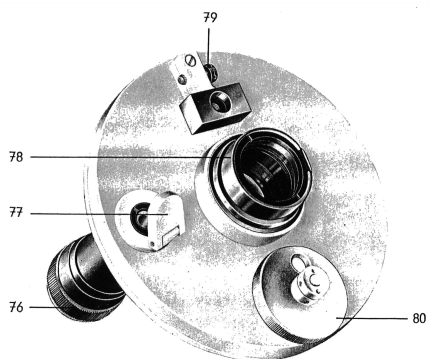


Figure 12: Angle-measuring eyepiece, rear view

to the 6 V output of the control transformer.

Required objective: 3× for cutting-edge measurements; when using the measuring-lever attachment, objectives may be selected as required.

6.2.13 Double-image eyepiece

The double-image eyepiece is used to measure center distances between bores, slots, reliefs, lines, and other symmetric features (see Fig. 16). It allows the optical axis of the viewing microscope to be set to the midpoint of these features and thus provides the reference setting for distance measurement.

When viewing through the double-image eyepiece, the feature brought into the field of view appears as a double image if its center is not on the optical axis of the viewing microscope. Two images rotated by 180° relative to each other are produced and used for measurement. This reduces the setting uncertainty by half. By shifting the workpiece, the two images can be brought into coincidence or into symmetric overlap. The midpoint of the superimposed image then lies on the

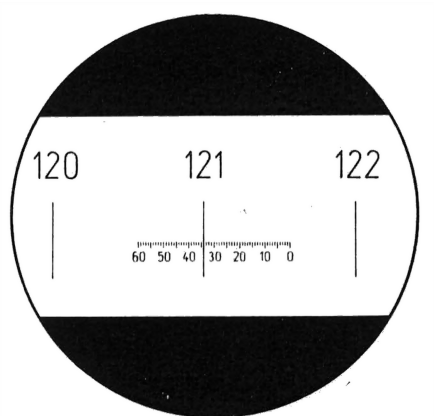


Figure 13: Angle reading in the angle-measuring eyepiece

optical axis of the viewing microscope.

6.3 Objectives

The test specimen must be imaged at a specific magnification against the reticle patterns of the individual turret eyepieces.

Objectives with magnifications of 1×, 1.5×, 3×, and 5× are available for this purpose (see Fig. 17). Which objective must be used is indicated on the reticle of the turret eyepiece, can be found in section 6.2, or can be selected based on the area of the test specimen to be viewed (viewing area):

Objective	Total mag.	Clear distance to object (mm)	Viewing area (mm)
1×	10×	85	21
1.5×	15×	85	14
3×	30×	81	7
5×	50×	45	4

The measuring lever attachment or the incident light illumination device can be attached to the screwed-in objectives.

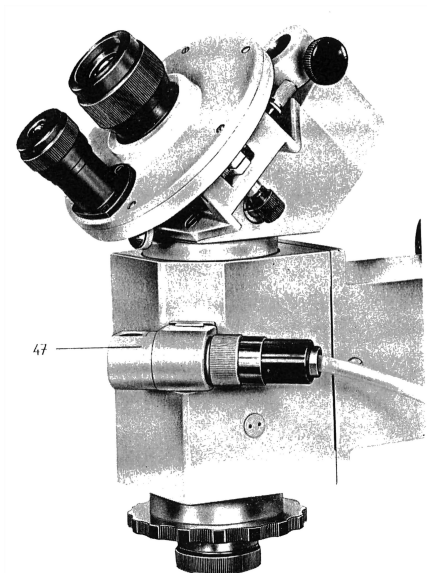


Figure 14: Viewing microscope with angle-measuring eyepiece and auxiliary illumination

6.4 Measuring lever attachment

The measuring lever attachment is an optical-mechanical unit used when optical probing of the test piece (shadow image method) is difficult or impossible. It is attached to the objective lens of the sighting microscope using the knurled ring (Fig. 18-51). It allows for distance and bore measurements, taper measurements, runout measurements, etc., in the x and y directions.

The feeler (Fig. 18-48), which is spring-loaded and mounted so that it can pivot, is connected to a mirror. Through this mirror, three double-line marks are imaged into the eyepiece field of view by the microscope objective. The double-line marks must be brought into sharp focus using the knurled ring (Fig. 18-52). Illumination of the double lines is provided

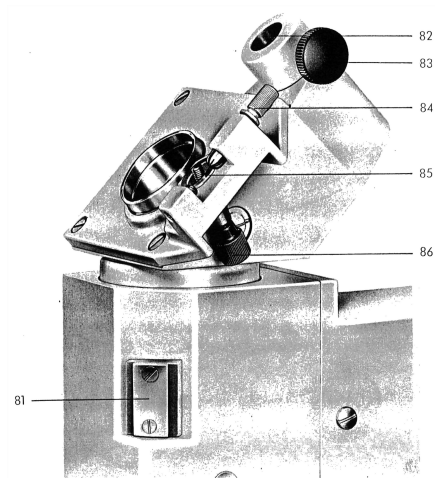


Figure 15: Viewing microscope without eyepiece

by the lighting unit (Fig. 18-53) with a 6 V 2.1 W miniature lamp. Since the mirror follows the movement of the feeler, this movement is indicated by the displacement of the double-line marks in the eyepiece field of view (see Fig. 31).

When the feeler contacts the test piece, a measuring force of 0.098 N is applied. Its direction is selected by operating the changeover switch (Fig. 18-50). The arrow whose color matches the marking dot

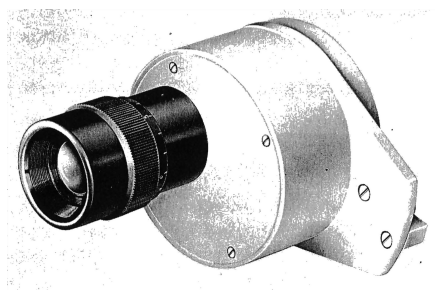


Figure 16: Double-image eyepiece

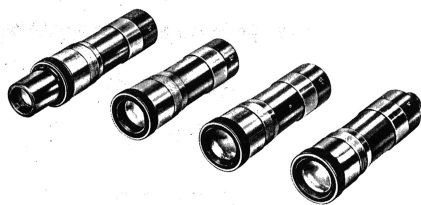


Figure 17: Objectives

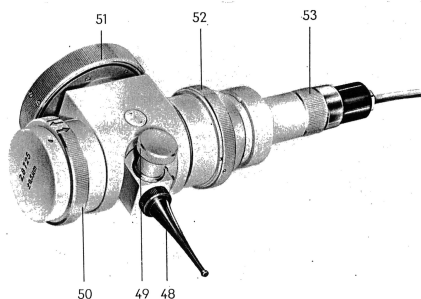


Figure 18: Measuring-lever attachment

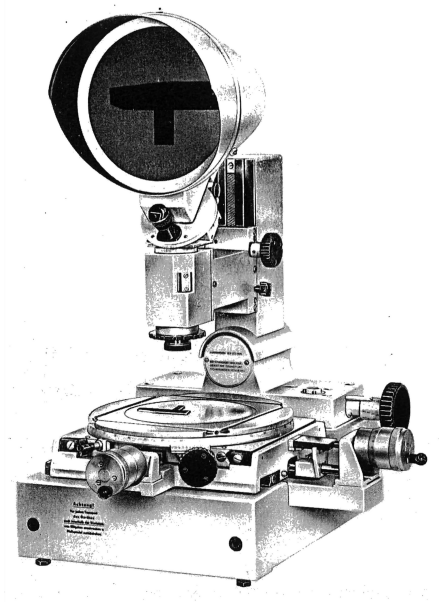


Figure 19: Instrument with projection unit

indicates the effective direction.

After loosening the clamping screw (Fig. 18-49), the feeler can be removed and replaced with one made by the user. In this case, it is essential to ensure that the replacement feeler is calibrated together with the measuring-lever attachment. The feeler supplied by us bears the number of the measuring-lever attachment on its shank and is intended for use with that attachment only.

Required objective: 3×

6.5 Projection device

Objective and eyepiece freely selectable according to requirements.

The projection device, used for comparisons or for tracing the test pieces, is an important addition to the large tool mi-

croscope. It can be used in conjunction with both the revolving eyepieces and the angle-measuring eyepiece. See Fig. 19.

For projection, the switch on the transformer must be set to "12 V".

The powerful illumination system allows working with projection even in relatively high ambient light. A built-in Fresnel lens ensures uniform illumination of the image field.

The device consists of the projection hood (Fig. 20-57) and the reading prism (Fig. 20-55).

The projection eyepiece included in the projection device projects a vertically and laterally inverted image onto the ground glass screen (Fig. 20-58).

A removable mounting ring (Fig. 20-54) allows drawing transparencies to be clamped. The glare shield (Fig. 20-59) is

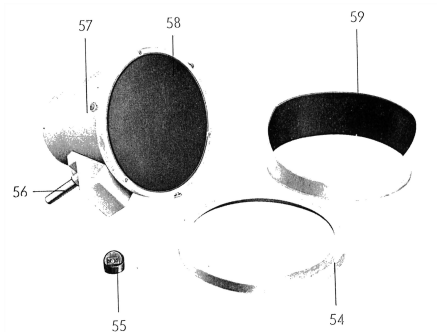


Figure 20: Projection unit

attached to a pin, which is located on the top of the projection hood. The reading prism (Fig. 20-55) is designed to be attached to the reading microscope of the angle-measuring eyepiece. The ground glass screen is cleaned with ether or liquid soap.

6.6 Photographic setup

Lens freely selectable.

Documentation and subsequent evaluation require photographic recordings; these are made possible by the 6.5 cm × 9 cm clip-on camera (Fig. 32-62).

The setup includes two 6.5 cm × 9 cm metal cassettes (Fig. 32-65), a ground glass screen (Fig. 32-64), an eyepiece insert (Fig. 32-63), and a cable release (Fig. 32-60).

The camera attachment is used in conjunction with a turret or angle-measuring eyepiece.

6.7 Cutting-edge unit

The cutting-edge (axial-section) method makes it possible to define a cutting plane through the workpiece without damaging it. Although this method is mainly used

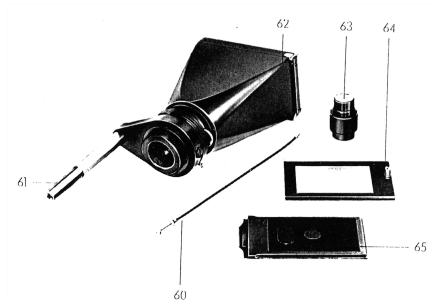


Figure 21: Photographic unit

for determining the individual parameters of threads, it is also used for measuring cylinders and cones. The cutting lines that are formed are indicated by fine hairlines on the cutting edge; their distance from the cutting edge is 0.3 mm or 0.9 mm.

A cutting-edge unit consists of:

- two cutting edges 0.3 mm (Fig. 22-66) for cylinder and cone measurements,
- two right-hand cutting edges of 0.3 mm and 0.9 mm (Fig. 22-67),
- two left-hand cutting edges of 0.3 mm and 0.9 mm (Fig. 22-68).

The 0.3 mm cutting edges are especially intended for threads with leads < 3 mm; the 0.9 mm cutting edges are intended for threads with leads from 3 mm to 6 mm.

The cutting edges are very sensitive and must therefore be protected, in particular against impact.

The unit is completed by two intermediate plates (Fig. 22-69) with a cutting-edge holder (Fig. 22-70). With the aid of the reflected-light illuminator, the hairlines can be seen very clearly; the cutting edges can then be brought into contact and aligned accurately.

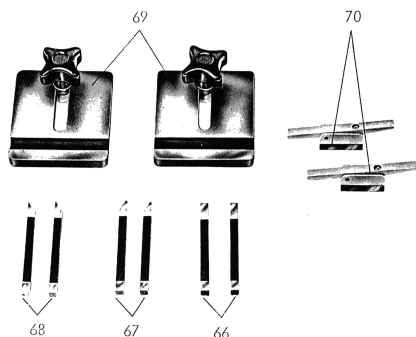


Figure 22: Cutting edges (measuring knives) unit

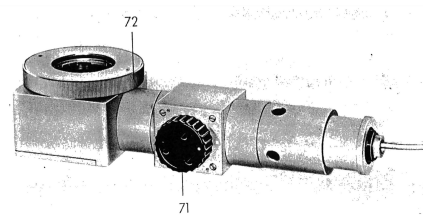


Figure 23: Reflected-light illuminator

6.8 Incident light illumination device

This device is used to illuminate blind holes, cutouts, line marks, etc., which cannot be measured using the transmitted light method. It is equipped with a 6 V 5 W projecting lamp and is connected to the 6 V output of the control transformer.

Brightfield and darkfield illumination can be switched on.

Using the switch (Fig. 23-71), a diaphragm (switch position black dot) can be switched into the beam path, creating a darkfield effect.

When changing the lamp, the socket must be pulled out.

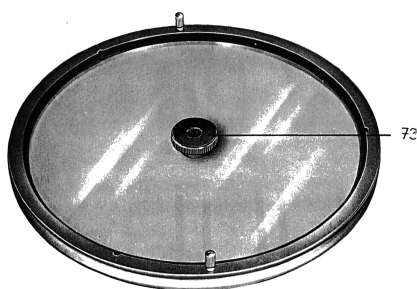


Figure 24: Table glass plate with centering insert

6.9 Table glass plate with centering insert

For measurements in polar coordinates, it is necessary to center the rotary table. A useful aid for this task is the table glass plate with centering insert (see Fig. 24). It is replaced with the standard glass plate of the basic equipment

In the center of the centering insert (Fig. 2473) is a crosshair that must be aligned with the crosshair of an eyepiece. After removing the centering insert, the specimen can then be easily positioned correctly.

6.10 Mechanical setting gauge

When using the shadow image method, the gauge (see Fig. 8) simplifies the adjustment of the sighting microscope to the tip height of the point stand. The sighting microscope is correctly adjusted when the cutting edge in the recess (Fig. 8-75) of the gauge appears sharp.

7 Setting up the instrument

7.1 Attaching the eyepieces

The turret, angle-measuring, or double-image eyepiece required for the measuring task is inserted into the prism housing on the sighting microscope with its spherical stem (Fig. 12-78). The spring bolt (Fig. 15-84) is retracted, the bridge with the anvil screw (Fig. 12-79) is pressed into the recess for the eyepiece anvil (Fig. 15-85), and the spring bolt is released. After the retaining screw (Fig. 15-86) is tightened, the reticle of the eyepiece is focused by turning the knurled ring, which is marked with diopter scales. The turret eyepieces are factory-adjusted, i.e., their zero line coincides with the x-direction of the coordinate measuring stage. The above also applies analogously to the angle measuring instrument when the angle scale in it shows 0° . If the daylight reflected by a mirror (Fig. 12-77) mounted on the underside is insufficient for reading the respective angle value in the reading microscope, the small illumination device (Fig. 14-47) is used.

7.2 Inserting the objectives

The selection of objectives is determined by the respective revolver eyepiece or is made according to the measuring task.

The objectives are provided with right-hand threads and are screwed into the sighting microscope from below. The annular groove located above the knurled section is used to attach the incident light illumination device or the measuring lever attachment

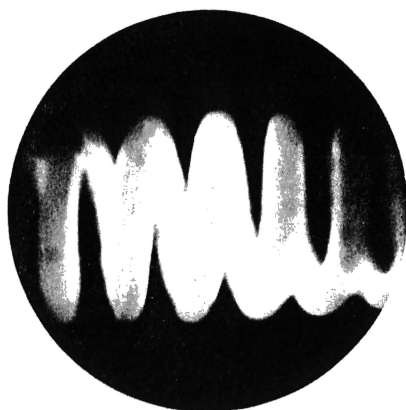


Figure 25: Lamp filament in the lamp-centering device

7.3 Centering the projecting lamp (main lighting)

The lamp centering device (Fig. 7-33) is placed on the coordinate measuring table in the beam path with the frosted glass plate facing upwards; the aperture (Fig. 5-39) on the main lighting is to be fully opened. After loosening the clamping screw (Fig. 5-42), the lamp socket (Fig. 5-36) is moved in its socket until the filament is sharply imaged on the frosted glass plate of the lamp centering device and the color fringes disappear.

Now, using the two adjusting screws (Fig. 5-41), as large a portion as possible of the entire filament is brought into focus (see Fig. 25). Then, the aperture is closed and one turn of the spiral is brought to the center of the aperture. The lamp adjustment is now complete.

7.4 Centering the coordinate measuring table

For measurements in polar coordinates and for measuring angular increments, it is necessary to center the rotary table. A useful aid for this task is the table glass plate with centering insert. It is exchanged for the standard table glass plate.

Centering the standard table glass plate is described in section 7.4.2.

Caution! Centering must always be performed with the eyepiece used for measurement. Changing the eyepiece between adjustment and measurement is not permitted.

7.4.1 Centering the glass table with centering insert

After loosening the four threaded pins (Fig. 26-87), the glass table is removed with the suction cup and replaced with the glass table with centering insert.

First, the centering insert (Fig. 24-73) is moved to the center under the sighting microscope by sliding the coordinate measuring table in the x and y directions using the micrometers or by adjusting the setting gauges by eye. By further sliding, the eyepiece crosshairs are aligned symmetrically with the double crosshairs of the centering insert. In this position, the coordinates x_1 , y_1 , and φ_1 are read on the micrometers and on the scale of the rotary table. Then, the rotary table is rotated 180° (pitch circle reading $\varphi_2 = \varphi_1 + 180^\circ$). In this position, alignment is again achieved using the micrometers until the double reticle is aligned with the reticle of the eyepiece; the new coordinates x_2 , y_2 , and φ_2 are read.

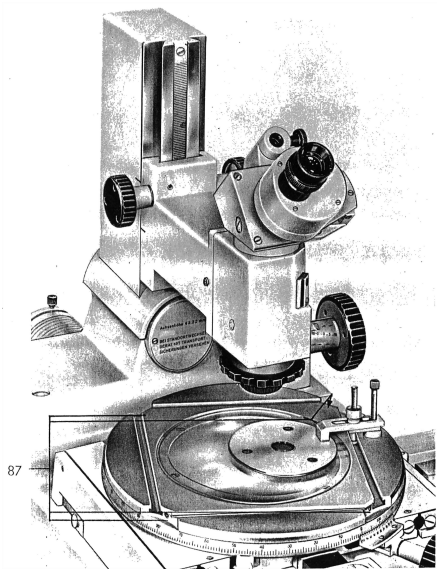


Figure 26: Instrument with double-image eyepiece

The coordinates

$$x_m = \frac{x_1 + x_2}{2} \text{ and } y_m = \frac{y_1 + y_2}{2}$$

indicate the exact centering position. The x - and y -slides must be brought into this position using the micrometer heads.

The double reticle is now moved with the four threaded pins (Fig. 26-87) until it again coincides with the eyepiece reticle. When the rotary table is rotated, the double reticle no longer moves.

Centering can also be performed very easily with the double-image eyepiece, whereby the coincidence of both partial images indicates the center position.

7.4.2 Centering the standard table glass

The table glass of the coordinate measuring table is centered under the lens by eye,

either by turning the measuring drums or, if necessary, by inserting setting gauges. As the rotary table is rotated, it is observed that all points move in a circular motion. The position of a prominent point (e.g., a speck of dust or a point on a placed part) is measured using the micrometers (readings x_1 , y_1 , and φ_1). After rotating the rotary table 180° ($\varphi_2 = \varphi_1 + 180^\circ$), the point is measured again (x_2 , y_2 , and φ_2). According to previous section, the coordinates x_m and y_m , which indicate the center position, are calculated. The x - and y -slides are set to these coordinates, and the adjustment is complete.

7.5 Focusing the specimen

Coarse focusing is carried out by adjusting the vertical movement of the microscope using the geared drive (Fig. 4-22), which is clamped with the knurled screw (Fig. 4-23). Fine focusing is performed by turning the star-shaped knob (Fig. 4-19).

A reference mark on the left side of the column and the support arm indicates the position of the arm. This position is used when employing a simple indexing device with the $3\times$ objective.

If cylindrical specimens or threads are to be repaired, then focusing must be carried out using the mechanical setting gauge (Fig. 8-74). It is held between centers for this purpose. The cutting edge in the recess (Fig. 8-75), which is located exactly on the axis of the center, is focused in the measuring microscope.

When measuring threads, it must also be considered that if the microscope is positioned perpendicular to the thread axis, both flanks of a thread groove will appear in focus at the same time. Therefore, the stand must be tilted using the knurled knob (Fig. 4-26) so that the centerline of the thread is inclined relative to the opti-

cal axis. The mean lead angle is calculated using the formula:

$$\tan \varphi_m = \frac{\text{pitch}}{\pi \cdot \text{pitch diameter}}$$

as a rule of thumb for helix angles up to 6° :

$$\varphi_m = \frac{\text{pitch} \cdot 18.25}{\text{pitch diameter}}$$

The helix angle above 6° is best set as follows: By turning the star-shaped nut (Fig. 4-19), the profile of the thread flanks can be alternately adjusted to be sharp and blurred. The stand is then tilted until both flanks become sharp or blurred simultaneously, or until the blurred edges on both flanks are of equal width. The tilt of the stand is the same on the front and rear generatrix (connecting line of the thread tips), but opposite in direction, which is why the stand tilt must always be changed when measuring thread diameters.

7.5.1 Setting the correct aperture value

A flawless image of the test specimen requires a specific aperture setting depending on its diameter (Fig. 5-39). Table 1 shows recommended apertures according to cylinder or thread characteristics.

For flat specimens, it is sufficient to adjust the aperture so that a sharp image without bright edges is obtained in sufficient light. The aperture should be fully opened for projection.

8 Measuring methods

With the Large Toolmaker's Microscope, the same measurements can often be carried out using different methods. In general, the choice of method depends on

Table 1: Recommended illumination apertures as a function of outside diameter for smooth cylinders, or pitch diameter for threaded parts.

Cylinder diameter or thread pitch diameter (mm)	Recommended illumination apertures			
	Smooth cylinders	Flank angle 30°	Flank angle 55°	Flank angle 60°
0.5	4.7	4.0	4.4	4.4
1.0	4.4	3.5	3.9	4.0
2.0	4.0	2.9	3.4	3.4
3.0	3.7	2.5	3.0	3.1
4.0	3.4	2.3	2.8	2.8
5.0	3.2	2.2	2.6	2.7
6.0	3.1	2.0	2.4	2.5
8.0	2.8	1.9	2.2	2.3
10.0	2.7	1.8	2.1	2.1
12.0	2.5	1.7	2.0	2.0
14.0	2.4	1.6	1.9	1.9
16.0	2.3	1.6	1.8	1.9
18.0	2.2	1.5	1.8	1.8
20.0	2.1	1.5	1.7	1.8
25.0	2.0	1.4	1.6	1.7
30.0	1.9	1.4	1.6	1.6
40.0	1.8	1.3	1.5	1.5
50.0	1.7	1.3	1.4	1.4
60.0	1.6	1.3	1.4	1.4
80.0	1.5	1.2	1.3	1.3
100.0	1.4	1.2	1.3	1.3
200.0	1.3	1.2	1.2	1.2

the required accuracy and the amount of work involved. The measuring methods available are described in more detail below.

8.1 Shadow-image method

The shadow outline of the test piece must be sharply focused in the eyepiece (see section 7.5). The line pattern used is then brought to the shadow boundary by shifting the test piece using the micrometer. This work must be carried out very carefully, since incorrect settings lead to measurement errors. At the shadow edge of the test piece, the adjustment is correct when the edge is covered halfway by the individual lines of the line pattern (Fig. 27-left).

When using the double-image eyepiece, the double images must coincide,

or touch one another without a gap of light. For each setting, the corresponding micrometer heads are read. Taking the difference yields the required measured value.

8.2 Axial-section method

The cutting method, or axial-section method, is an opto-mechanical measuring method. It is used primarily for measuring cylinders, cones, and threads, but it can also be applied to flat parts.

A prerequisite for using this method is that the test piece has clean, straight-line or planar boundaries in the measuring plane. When applying the axial-section method, “cutting lines” are used—these are brought into contact with the test piece in the axial-section plane. In addition, the 3× objective and the angle-measuring

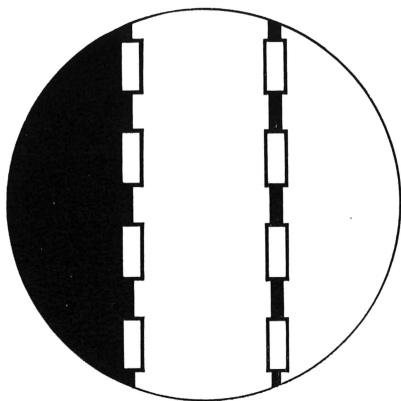


Figure 27: Sighting (aiming) the test piece

eyepiece are used. The choice of cutting lines depends on the shape and dimensions of the test piece. Figure Fig. 28 shows the instrument measuring using the axial-section method.

For cone and cylinder measurements, the cutting edges with a straight cutting line (Fig. 22-66) are to be used; these have a hairline of 0.3 mm. For thread measurements, the supplied cutting edges (Fig. 22-67, 68) are used; they have two hairlines, one for a pitch of 3 mm and the other for a pitch range from 3.5 mm to 6.0 mm. Before the cutting edges are mounted, the test piece and the cutting edges must be carefully cleaned with ether or petroleum ether (light benzine).

The intermediate plates (Fig. 22-69) for mounting the cutting edges are fastened to the ground surfaces of the tailstock housing using the cross-handle screws. Attach and lock the incident-light illuminator. During the measurement, the incident-light illuminator must not be removed or its position changed, otherwise operating errors may occur.

The cutting edges are then placed on the intermediate plates and brought to the test piece using the raised cutting-edge holder. The procedure is observed in transmitted light. The cutting edge is correctly positioned when a narrow slit of light is visible between the test piece and the cutting edge. When aiming at the test piece (or, when setting up the viewing microscope), the hairline of the cutting edge is adjusted (Fig. 29). For thread measurements it should lie on the flank centerline; for measurements on other objects the center of the contact line should be clearly imaged in the center of the field of view.

The hairline of the cutting edge is correctly set when it is symmetrically covered by the reticle lines of the eyepiece (Fig. 27-right).

The spacings of the hairlines from the cutting edge are compensated by using a suitable reticle line on the reticle plate of the angle-measuring eyepiece.

After adjustment, read the micrometer head and repeat the entire procedure at the other measuring point.

The cutting edges wear with time. Frequently used cutting edges must be replaced with new ones.

8.3 Reflected-light method

This method is used primarily for measuring blind holes, scored lines, grooves, engravings, and divisions on the surfaces of flat parts. The reflected-light illuminator is mounted on the objective and the viewing microscope using a knurled nut (Fig. 23-72) and connected to the control transformer. Measurement is carried out using the line patterns of the revolving eyepiece head or with the double-image eyepiece.

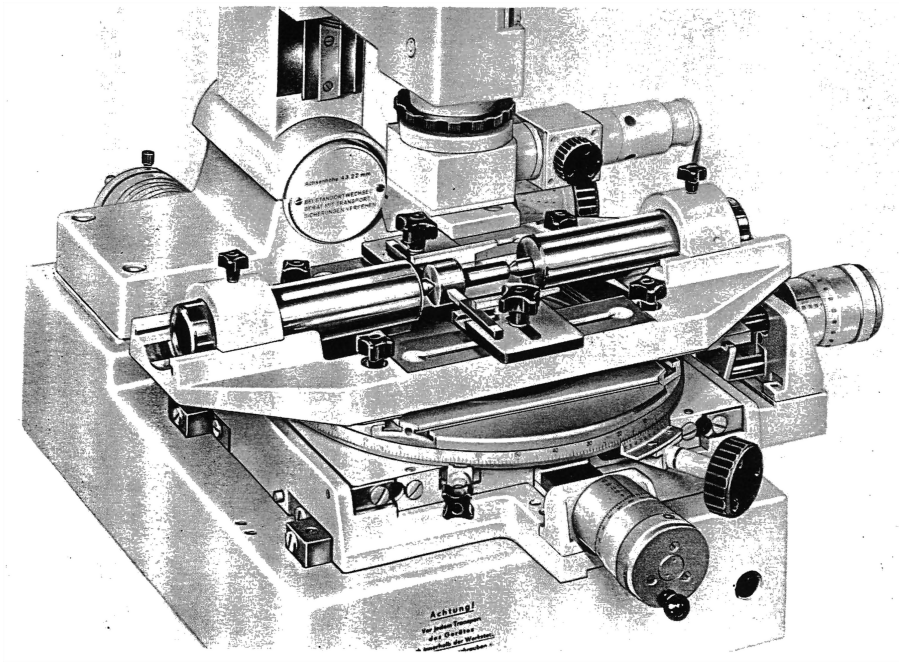


Figure 28: Measuring with cutting edges

During the measurement, the position of the reflected-light illuminator must not be changed, otherwise measurement errors may occur.

8.4 Measuring method using the measuring-lever attachment

(See also section 6.4)

The measuring-lever attachment is used mainly for measuring bores (see Fig. 30). The feeler (Fig. 18-48) of the measuring-lever attachment is fitted with a ball contact for probing. For internal measurements, the diameter of this ball must be subtracted from the measured value; for external measurements, it must be added. The ball diameter is precisely

calibrated; its value is engraved on the front face.

When measuring cylinders or bores, it is important first to find the position at which the true diameter is obtained. This position is indicated by the reversal point, i.e. the point at which the motion of the feeler reverses direction when the test piece is moved perpendicular to the measuring direction with the feeler in contact.

To probe a bore wall with the measuring-lever attachment (Fig. 31), the angle-measuring eyepiece shows the same coincidence setting for positions I and III. If the test piece is moved slowly from I to II (i.e. perpendicular to the measuring direction), the double lines initially move to the right. At a certain po-

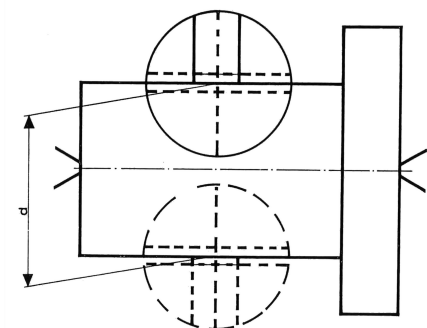


Figure 29: Diameter determination using the axial-section method

sition—corresponding to the bore diameter—they remain stationary (position II). If the movement continues in the same direction, the double lines reverse their direction of motion and move to the left.

After locating the reversal point, set coincidence again in the measuring direction in the angle-measuring eyepiece and check the position of the reversal point.

8.5 Use of the photographic unit

For subsequent evaluation of profiles or measurement settings, and for documentation, photographs can be taken using the photographic unit.

First remove the eyepiece and insert the eyepiece insert (Fig. 32-63) in its place. Then insert the photographic unit by guiding the guide pin (Fig. 32-61) into the locating bore (Fig. 15-82) of the viewing microscope and tighten it with the clamping screw (Fig. 15-83). To ensure the correct imaging scale, the knurled end of the guide pin must be fully seated.

Focusing is carried out using the coarse and fine drive (Fig. 4-19, 22). The correct setting is obtained when the shadow im-

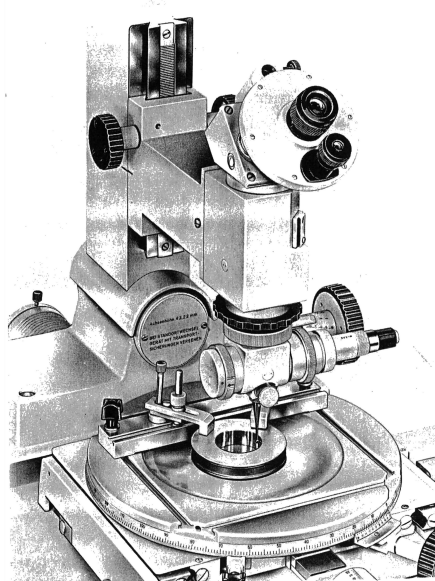


Figure 30: Measuring with the measuring-lever attachment

age and the line pattern appear sharply focused at the same time.

To assess the image section and to check image sharpness, the focusing screen (Fig. 32-64) can be inserted into the cassette holder.

When inserting the focusing screen, or later the cassettes (Fig. 32-65), make sure that the two locking levers are pressed in beforehand.

The 6.5 × 9 attachment camera is equipped with an automatic central shutter. This allows for the setting of shutter speeds (in s):

$$B \quad 1 \quad \frac{1}{2} \quad \frac{1}{5} \quad \frac{1}{10} \quad \frac{1}{25} \quad \frac{1}{50} \quad \frac{1}{125} \quad T$$

The time is set using the knurled wheel (Fig. 33-88) projecting from the side at the top of the shutter.

To determine the correct exposure time, the step-exposure method has proven ef-

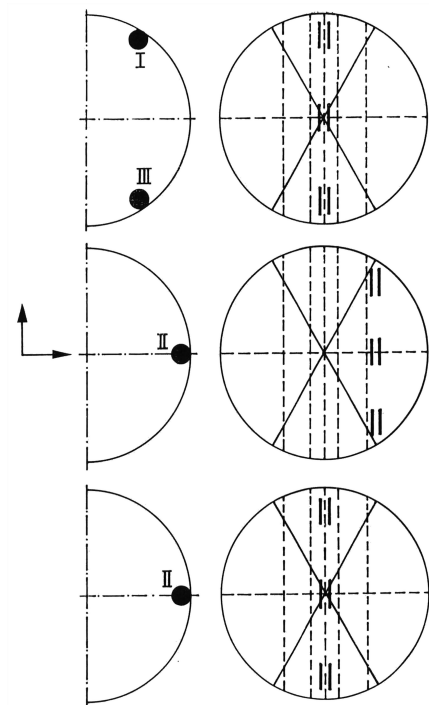


Figure 31: Determining the reversal point

fective. A test strip is exposed in successive steps using different exposure times, so that the exposure time to be selected can be estimated from the differing degrees of blackening.

For this purpose, the cassette slider is equipped with a ruled field. Its columns indicate:

- *Column B*: exposure times for the test strip, in minutes or seconds.
- *Column A*: exposure times for the photograph to be taken, read from the strip whose blackening corresponds to the desired density.

The exposure series begins at gradua-

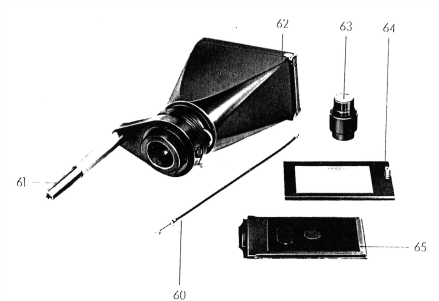


Figure 32: Photographic unit

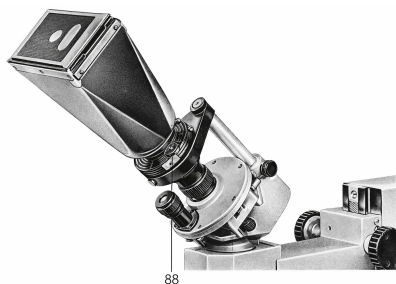


Figure 33: Instrument with photographic unit

tion field 0-0:

$1+1+2+4+8+\dots$ in minutes or seconds.

An example of an exposure series is shown in Fig. 34.

It should be noted that whenever the brightness changes (change in the reflectance of the test piece, change of the aperture stop, change in lamp voltage on the control transformer), new exposure times must be determined.

Depending on requirements (high contrast or low contrast), the upper part of the cassette holder can be rotated about the cassette axis and the optical axis. The preferred settings (90° , 180° , 270° , 360°) are detented.

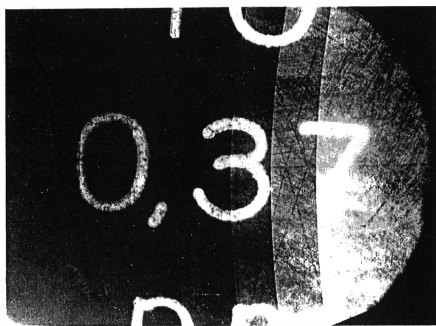


Figure 34: Example of an exposure series

9 Performing the measurements

9.1 Measuring flat test pieces

Using the clamping rail (Fig. 7-28), which is fastened in the corresponding grooves on the rotary table or on the rotary table itself, flat test pieces can be clamped securely. Alignment and focusing of the image are carried out as described in Section 7.

The microscope stand must be set vertical (upright).

9.1.1 Measuring in rectangular coordinates

Measurements in rectangular coordinates are performed by shifting the slides in the x - and y -directions. As a rule, the test piece must be aligned according to the measurement task with respect to the x - or y -direction of travel of the measuring slides. To do this, rotate the test piece together with the rotary table using the knurled knob (Fig. 4-13) and check the result.

Bring the edges, lines, or points to be measured successively into coincidence with the eyepiece crosshair, and read the

corresponding positions of the slides on the micrometer heads. If additional setting dimensions are used, their values must be added to the slide readings. Taking the difference yields the required measured values.

9.1.2 Measuring in polar coordinates

To measure in polar coordinates, first center the rotary table (see section 7.4). Then clamp the test piece and bring its coordinate zero point into coincidence with the center of the rotary table. For thread measurements, the test piece can be clamped in a custom-made intermediate sleeve that is inserted into a bore of the clamping plate. This avoids the otherwise time-consuming additional alignment.

The points to be measured are contacted with the corresponding line pattern, or—when using the double-image eyepiece—optically, or mechanically with the measuring-lever attachment.

Angular values are read from the angle scale of the rotary table. The x - or y -slide is used to determine the radial coordinate. The radius is obtained as the difference between the corresponding micrometer reading and the selected coordinate of the table center.

During centering and measurement, the viewing microscope must not be adjusted with the rack-and-pinion drive (Fig. 4-22); fine focusing with the star-shaped nut (Fig. 4-19) is permitted.

9.1.3 Measuring on surfaces

Measurements of scribe marks, punch marks, engravings, divisions, etc. require the use of the reflected-light method. The reflected-light illuminator (see also Section 6.8) is mounted on the objective of

the viewing microscope. Objectives and eyepieces may be selected as required.

The relevant points, bores, and edges are sighted using the eyepiece line patterns or the double-image eyepiece. Measurements are then carried out using the micrometer heads and the setting dimensions.

Combined reflected-light and transmitted-light illumination is possible by switching on the main illumination.

9.1.4 Measuring center distances of holes, slots and lines, and measuring line widths and hole diameters with the double-image eyepiece

Distance measurements with the double-image eyepiece can be carried out using two methods explained below.

Determining the distance using the x -slide Before starting the measurement, the measuring line must be aligned parallel to the x -direction of the coordinate measuring table. To do this, rotate the test piece together with the rotary table until, when traversing the measuring length, the images in the double-image eyepiece coincide (coincidence) or overlap symmetrically (Fig. 35-c, e, h).

Then bring the two images of one feature into coincidence by moving the x -slide and read the x micrometer. Proceed in the same way for the other features; do not move the y -slide while doing so. The differences between the corresponding readings give the required distances.

The measurement can also be performed in the y -direction in the same way.

Determination using the x - and y -slides If the measuring line is not par-

allel to the measuring direction, or if it is not possible to align it parallel due to the shape or size of the test piece, the required distances must be determined from the coordinate readings.

As an example, the distances a and b between three different features (Fig. 35-f) are to be measured. First, superimpose the double image of feature A (Fig. 35-g) using the x - and y -slides (Fig. 35-h). This places the left end point of the measuring line on the optical axis of the viewing microscope. Read and record the coordinates x_1 and y_1 from the micrometer heads. Then superimpose feature B (Fig. 35-b and c) and read x_2 and y_2 . Proceed analogously with feature C .

In the case shown in Fig. 35-a and i, the measuring line ends at the centroid of the triangle. If the relevant end point is the half-height of the triangle, the images must be superimposed as shown in Fig. 35-j. Any tilt of the triangle or of the superimposed double image has no influence on the measurement result.

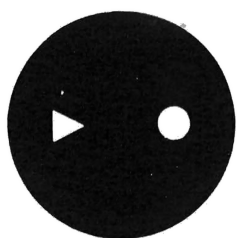
The calculation of the distances a and b is shown in the following numerical example (see Table 2).

With $x_a = 19.74$ mm, $y_a = 11.14$ mm, $x_b = 18.61$ mm, and $y_b = 22.28$ mm, the distances are:

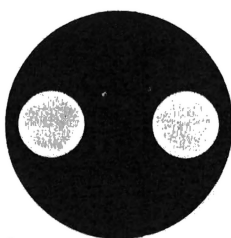
$$a = \sqrt{x_a^2 + y_a^2} = \sqrt{19.74^2 + 11.14^2} \\ = 22.67 \text{ mm}$$

$$b = \sqrt{x_b^2 + y_b^2} = \sqrt{18.61^2 + 22.28^2} \\ = 29.03 \text{ mm}$$

Measuring line widths and bore diameters Consider figure Fig. 36. The double images are arranged parallel to one another in one measuring direction (x - or



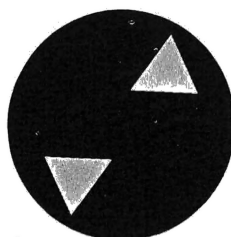
a



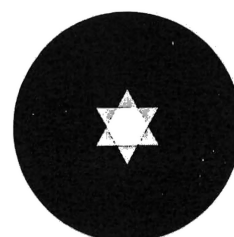
b



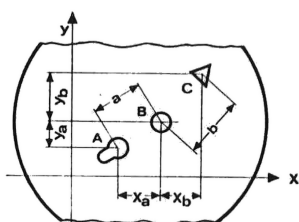
c



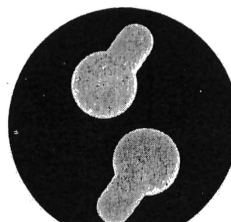
d



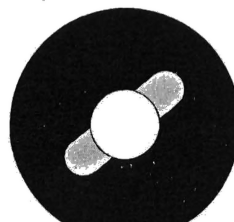
e



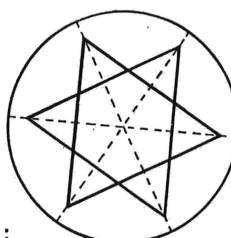
f



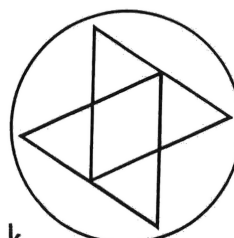
g



h



i



k

Figure 35: Distance measurement with the double-image eyepiece

Table 2: Coordinate readings and coordinate differences for determining distances a and b .

Point	x reading (mm)	Δx (mm)	y reading (mm)	Δy (mm)
A	21.37	—	14.39	—
B	41.11	19.74	25.53	11.14
C	59.72	18.61	47.81	22.28

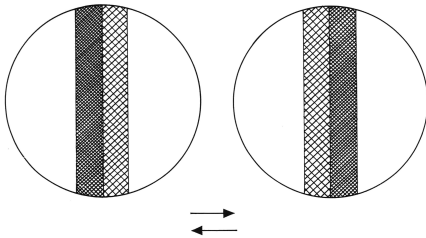


Figure 36: Measuring line widths with the double-image eyepiece

y -direction) and are offset slightly relative to each other.

After the initial value has been read from the corresponding measuring screw, the two images are moved over one another using the measuring slide. The image that was previously on the left is now shifted to the right. It is aligned with the disappearing light gap, and the final value is read.

The difference between the two readings gives the line width. Bore diameters are measured in the same manner as line widths.

9.2 Measuring cylinders

To measure cylinders, first align the tailstock housing so that it is parallel to the y -direction or to the x -direction. To do this, bring the generatrix of the test cylinder into the field of view—or use a setting cylinder (e.g. a mechanical setting gauge)—and align it with the horizontal line of the eyepiece crosshair by rotating

the rotary table and shifting the y -slide.

Then traverse the x -slide while observing the shadow boundary. If the shadow edge drifts away from the crosshair line during this traverse, readjust. In each case, correct by rotating the table and shifting the y -slide by *half* of the observed drift.

If different settings are required for the front and rear generatrix, this indicates that the cylinder being measured is conical.

Cylinder measurements using the shadow-image method (see section 8.1) are performed either with the angle-measuring eyepiece (settings 0° , 90° , 180° , or 270°) or with the crosshair of a revolving eyepiece head.

Cylinder measurements using the axial-section method (Fig. 28) are carried out with the straight cutting edges and the angle-measuring eyepiece (see section 8.2).

9.3 Measuring bores

Bores are inspected using the revolving eyepieces O, P, Q, or R. Measurements on bores are carried out either with the double-image eyepiece (see section 9.1.4) or with the measuring-lever attachment (see section 8.4).

9.4 Measuring cones

The tailstock housing must be aligned in the same way as for cylinder measurements (see section 9.2).

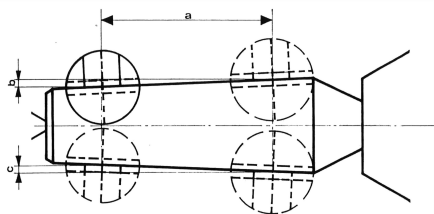


Figure 37: Cone measurement using the axial-section method

For cone measurements with lower accuracy requirements, the shadow-image method (see section 8.1) together with the angle scale of the angle-measuring eyepiece can be used. To eliminate errors due to tilt, measurements must be made on the front and rear sides of the test piece and an average value taken.

For cone measurements using the axial-section method (see section 8.2), two straight cutting edges are used. As shown in Fig. 37, they are applied to the cone. The corresponding lines of the angle-measuring eyepiece must be brought into coincidence with the fine hairlines of the cutting edges. The reticle plate of the angle-measuring eyepiece must be rotated accordingly.

The cone slope m is calculated from:

$$m = \frac{b + c}{2a}.$$

where

a length defined in Fig. 37 (mm)

b length defined in Fig. 37 (mm)

c length defined in Fig. 37 (mm)

m cone slope (taper)

9.5 Thread measurements

The most important parameters of a thread are the pitch diameter, the lead, and the flank angle, as well as the major and minor diameters. All of these parameters can be measured in a single setup, without reclamping the test piece.

Depending on the required accuracy, either the shadow-image method (see section 8.1) or the axial-section method (see section 8.2) is used. In both cases, the tailstock housing must be aligned as described for cylinder measurements (see section 9.2).

When using the axial-section method, the 3× objective, the reflected-light illuminator, and the angle-measuring eyepiece are used. The cutting edges must not be inserted into the thread root.

When using the shadow-image method, any objective can be combined with the angle-measuring eyepiece. For profile comparison, the objective to be used is specified on the reticle plate of the revolving eyepiece head. The aperture setting must be selected as for diameter measurements (see section 7.5.1). The microscope must be tilted by the mean lead angle φ_m (see section 7.5).

The major and minor diameters of threads are measured in the same way as for ordinary cylinders (see section 9.2). For minor-diameter measurements, however, the microscope must be tilted by the lead angle at the minor diameter, φ_{d_1} :

$$\tan \varphi_{d_1} = \frac{\text{lead}}{\pi d_1}$$

where d_1 is the minor diameter.

The remaining thread parameters and their measurement are described in the following sections.

Table 3: Thread parameters referenced in Section 9.5.

German term	English term	Notation used here
Flankendurchmesser	pitch diameter	(not specified)
Steigungshöhe	lead	$lead$
Flankenwinkel	flank angle	(measured with angle eyepiece)
Außendurchmesser	major diameter	(as for cylinders)
Kerndurchmesser	minor diameter	d_1
mittlerer Steigungswinkel	mean lead angle	φ_m
Steigungswinkel im Kerndurchmesser	lead angle at minor diameter	φ_{d_1}

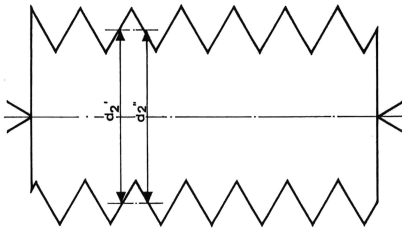


Figure 38: Measuring the pitch diameter: compensation method

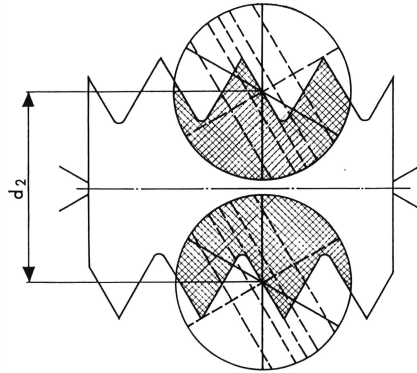


Figure 39: Measuring the pitch diameter using the shadow-image method

9.5.1 Pitch diameter

For symmetrical threads, the pitch diameter is the axial distance between two opposite, equally inclined flanks.

To eliminate flank-angle deviations (lack of parallelism) in the axial direction of the thread and in the measuring direction, determine the pitch diameter as the mean value of measurements taken on the left- and right-hand flanks of the same groove (Fig. 38):

$$d_2 = \frac{d_2' + d_2''}{2}$$

Measurement of the pitch diameter by the shadow-image method is carried out as shown in Fig. 39. Fig. 40 illustrates measurement by the axial-section method. To bring the measuring edges into contact, the microscope carriage is tilted by the mean lead angle; during mea-

surement it must be in the upright position.

9.5.2 Lead (thread lead)

The lead is the axial (axis-parallel) distance between two adjacent flanks that have the same orientation. According to this definition, adjacent flanks from different starts must also be measured. Measuring across several starts and then dividing by the number of starts in order to determine the "start error" is not metrologically meaningful.

If right-hand and left-hand lead are to be measured separately, measurements must be taken on the front and rear

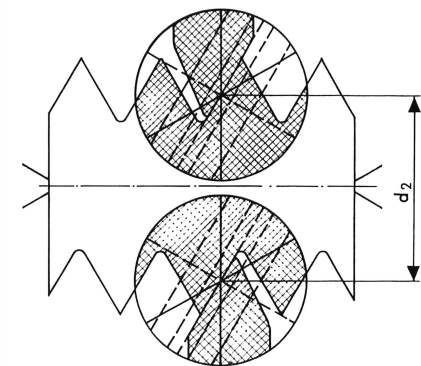


Figure 40: Measuring the pitch diameter using the axial-section method

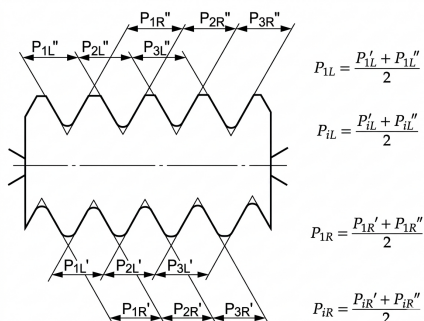


Figure 41: Lead measurement on a thread

sides of the thread profile to eliminate errors due to misalignment (tilt). The mean value is free of first-order tilt errors (see Fig. 41).

Lead measurements by the shadow-image method can be carried out either with the angle-measuring eyepiece or with the thread line patterns of the corresponding revolving eyepiece heads.

When the angle-measuring eyepiece is used, right-hand and left-hand lead are determined separately. Mean values are to be determined as shown in Fig. 41.

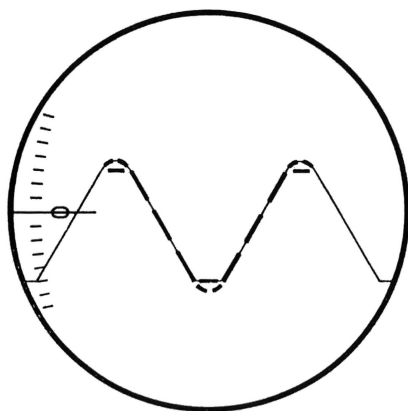


Figure 42: Lead measurement using a thread reticle pattern

If a thread line pattern is used, first bring the line pattern corresponding to the lead (for right-hand or left-hand threads and the number of starts) into the field of view by turning the knurled knob on the underside of the eyepiece. Set the reference line to zero (or to the adjacent angular divisions). Then, by shifting the x - and y -slides, adjust one thread groove so that the shadow profile of the thread coincides with the reticle profile (Fig. 42). Read the value in this position and repeat the procedure at the next thread groove.

Lead measurements by the axial-section method are performed using a cutting edge. With the microscope carrier tilted, bring the cutting edge into contact; then measure with the microscope upright. Carry out the measurement in the next thread groove in the same way. Mean values from measurements on the front and rear sides of the thread are calculated as shown in Fig. 41.

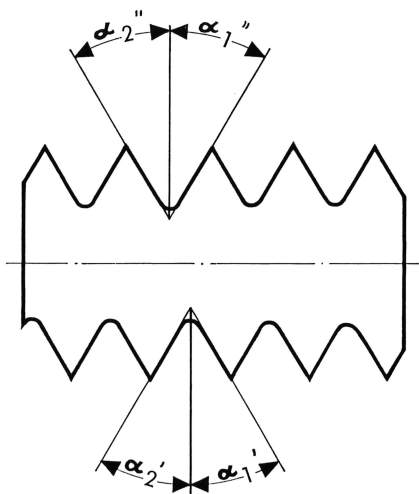


Figure 43: Measuring partial flank angles using the shadow-image method

9.5.3 Partial flank angles

The partial flank angles α_1 and α_2 are the two angles that the right-hand flank and the left-hand flank form with the axis normal in an axial section. The flank angle α is the sum $\alpha_1 + \alpha_2$. The measured values α_1 and α_2 also indicate how the profile is oriented relative to the axis normal.

The partial flank angles are determined in the shadow image (Fig. 43), with the viewing microscope tilted by the mean lead angle. By rotating the reticle plate of the angle-measuring eyepiece, one line of the crosshair is brought into coincidence successively with the right-hand and left-hand flanks, and the corresponding angular positions on the circle scale are read using the reading microscope.

When the partial flank angles are measured with the angle-measuring eyepiece, an average is taken from measurements on the corresponding flanks on the front

and rear sides:

$$\alpha_1 = \frac{\alpha'_1 + \alpha''_1}{2} \quad \alpha_2 = \frac{\alpha'_2 + \alpha''_2}{2}$$

The profile tilt is then

$$\delta = \frac{\alpha_1 - \alpha_2}{2}$$

The partial flank angles can also be determined using the line patterns of the revolving eyepiece heads. Deviations of the flank angle from the nominal value appear in that the two flanks of a thread groove (or a gap) are not both parallel to the line pattern; instead, a symmetric deviation is observed (Fig. 44). By rotating the reticle plate to bring one or the other flank into coincidence with the shadow boundary, the error can be read from the angle scale visible at the side. If the two readings are not equal, then—in addition to a partial-flank-angle error—there is also a profile-tilt error.

10 Maintenance of the instrument

The bare metal surfaces of the instrument and its accessories should always be protected with a thin film of Vaseline. This binds dust and makes cleaning easier. All bearings in the instrument and its accessories are permanently lubricated and require no maintenance.

Optical components should not be wiped frequently. Remove dust only with a soft, grease-free camel-hair brush. Grease deposits on optical surfaces should be removed only with a soft, lint-free cloth, lightly moistened with solvent. In all cases, blow off any dust first; otherwise dust particles may cause scratches.

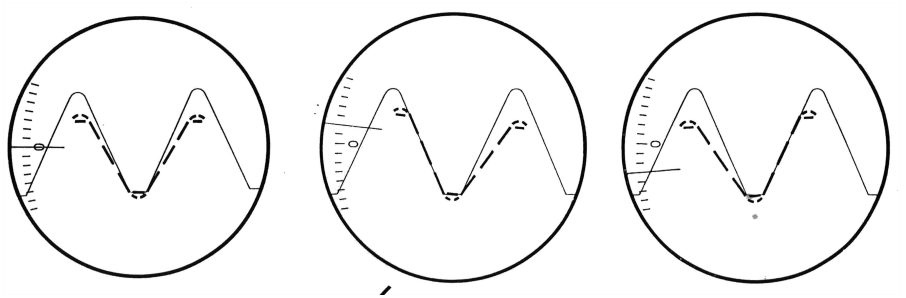


Figure 44: Measuring partial flank angles using a reticle pattern

