Lecture 4: Determining Main Structural Parameters and Technical Specifications

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Determining Parameters & Specifications: Outline

- ❒ **Basic concepts**
- ❒ **Different methods**

Basic Concepts

- 仪器结构参数及技术指标的数值是根据仪器的功能、精度要求、测量范围、使用要求和条件，以及有关标准规定等许多因素确定

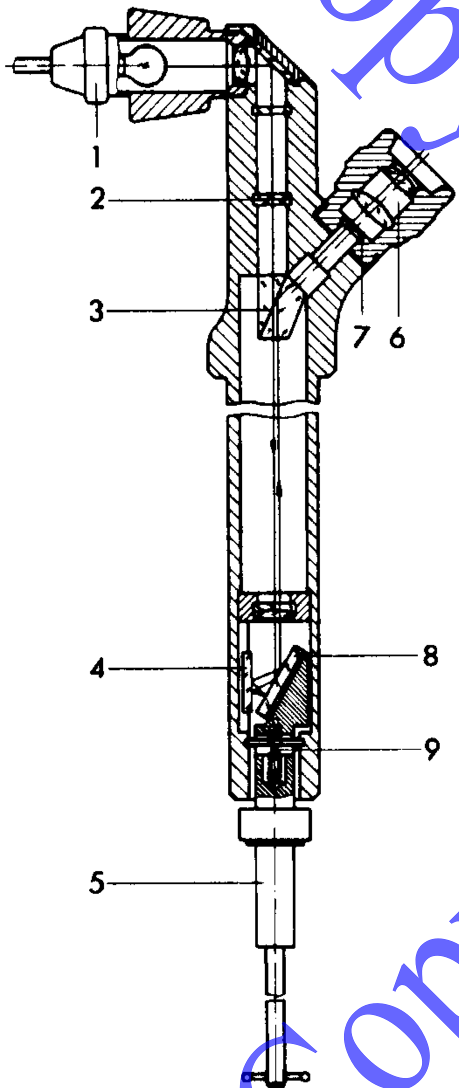
Different Methods

- According to the precision
  - Ex: Determine the lever ratio of Optically-Indicating Contact Sensor
- According to the measuring range
  - Ex: Determine the parameters of involute profilemeter
- Based on the error compensation
  - Ex: Determine the parameters of the Capacitive Pressure Transmitter/transducer

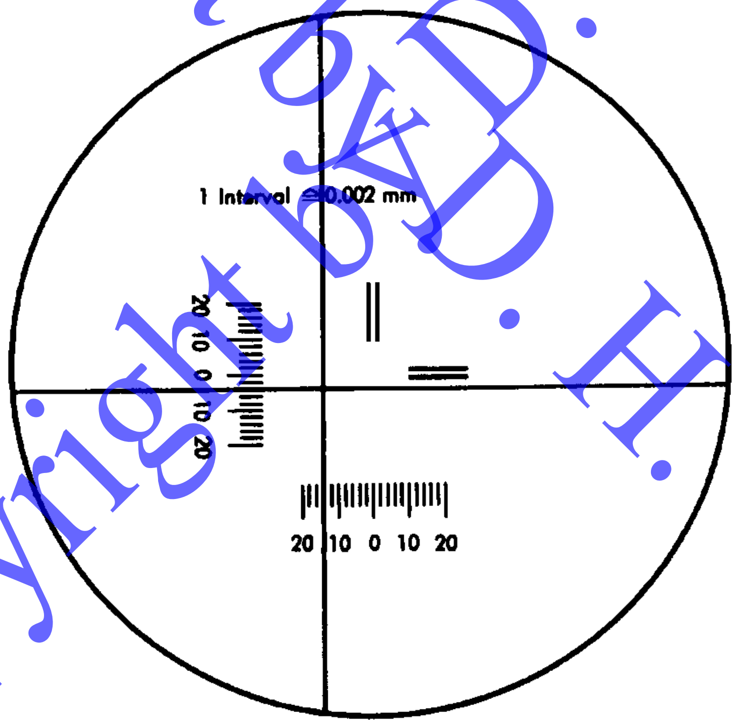
According to the Precision

- Ex: Determining the lever ratio of Optically-Indicating Contact Sensor

Determining Lever Ratio of Optical-Position Indicator



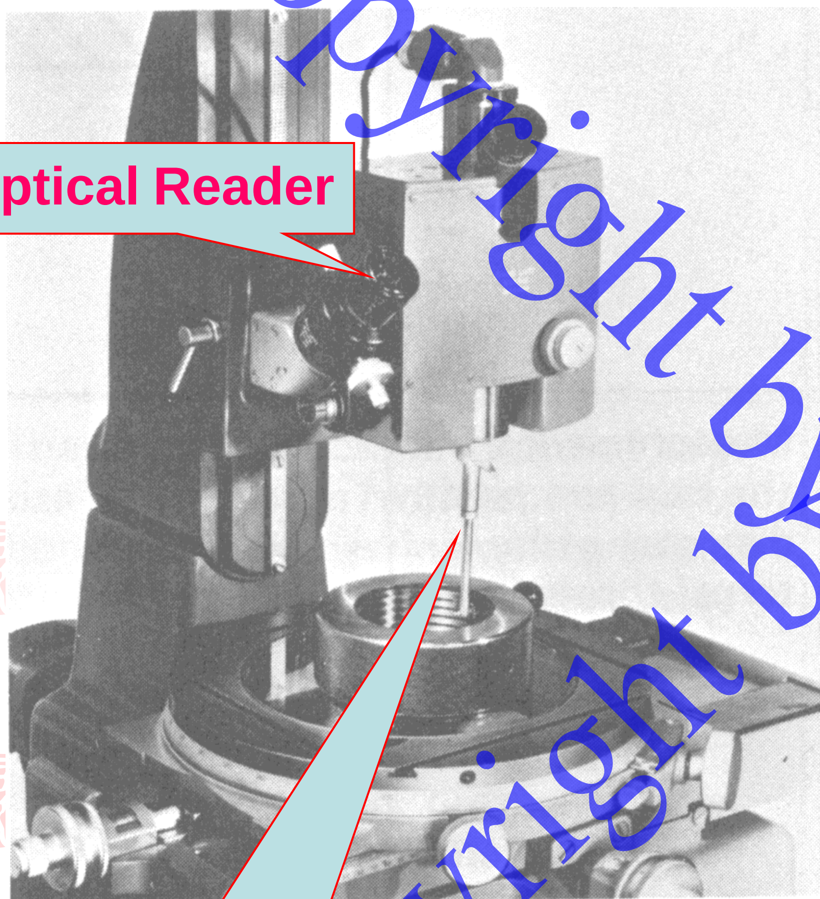
- ← Elements of a mechanically contacting optical-position indicator
- ↘ Field of view of an optically-indicating mechanical contact sensor



Francis T. Farago, *Handbook of Dimensional Measurement*, Industrial Press Inc. 1982

Determining Lever Ratio of Optical-Position Indicator

Optical Reader



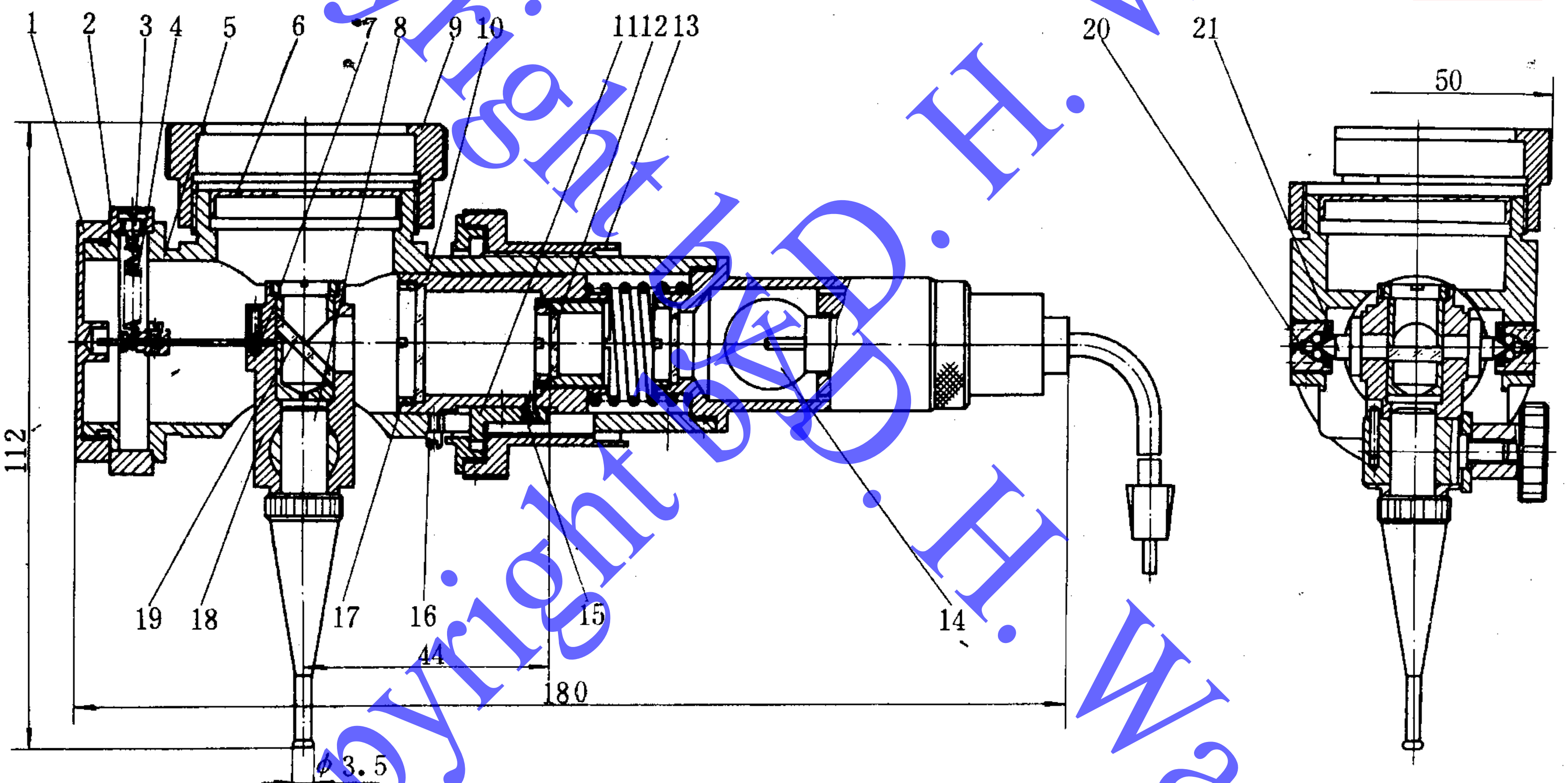
Optical-Position Indicator

- The mechanically contacting optical-position indicator mounted on a microscope stand in combination with a vertical displacement measuring head which is equipped with a master scale and optical reader.

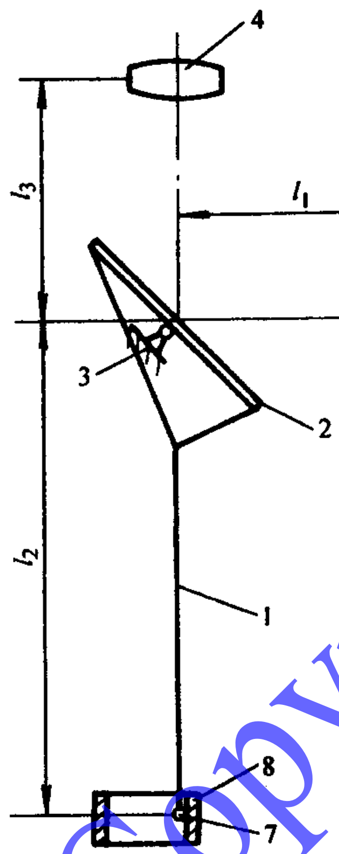
Francis T. Farago, *Handbook of Dimensional Measurement*, Industrial Press Inc. 1982

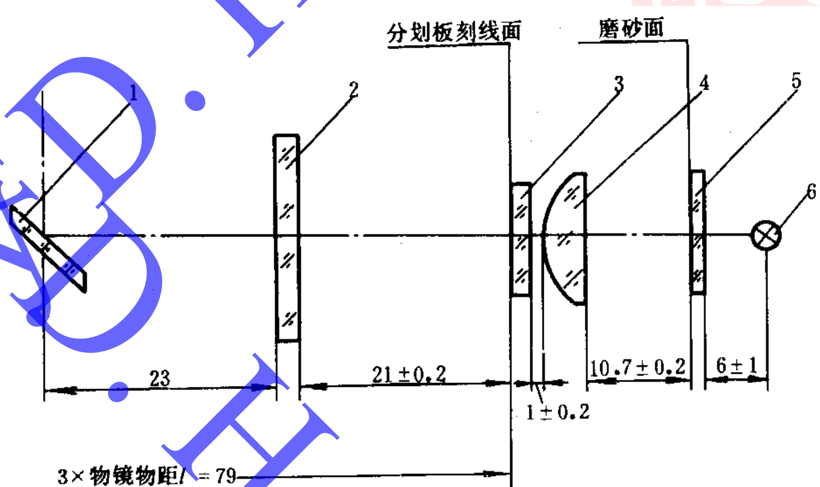
Determining Lever Ratio of Optical-Position Indicator

❒ Configuration

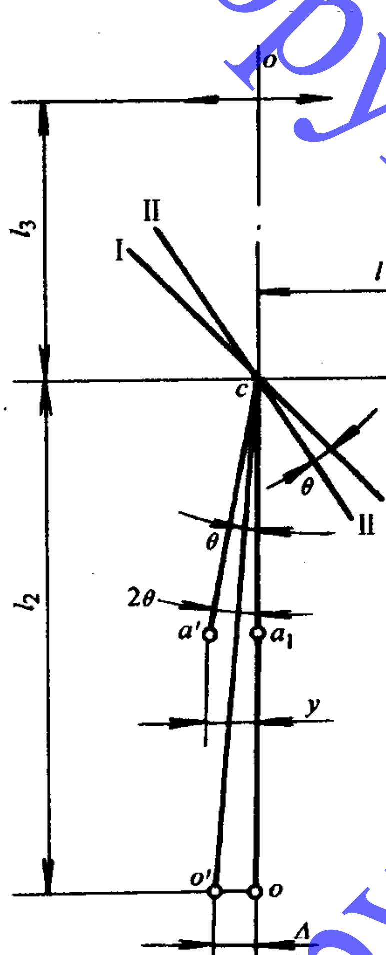


- 问题?
  - 如何通过设计达到1 um的瞄准精度?





Determining Lever Ratio of Optical-Position Indicator



$\boxed{\theta \approx \Delta / l_2}$

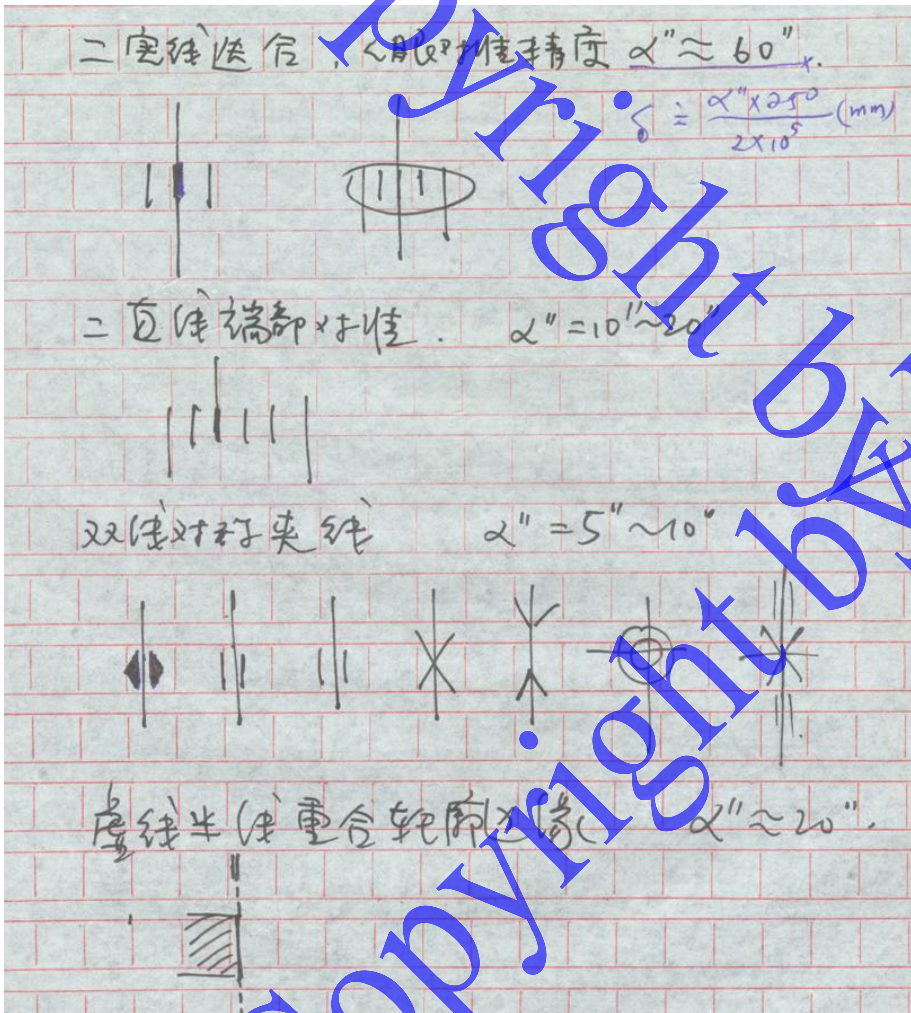
$\boxed{y \approx 2 l_1 \theta}$

❒ Principle

$$\left. \begin{array}{l} y \approx 2 l_1 \theta \\ \theta \approx \dfrac{\Delta}{l_2} \end{array} \right\} \Rightarrow y \approx \frac{2 l_1 \Delta}{l_2}$$

Δ--以线值表示的瞄准误差值

Determining Lever Ratio of Optical-Position Indicator



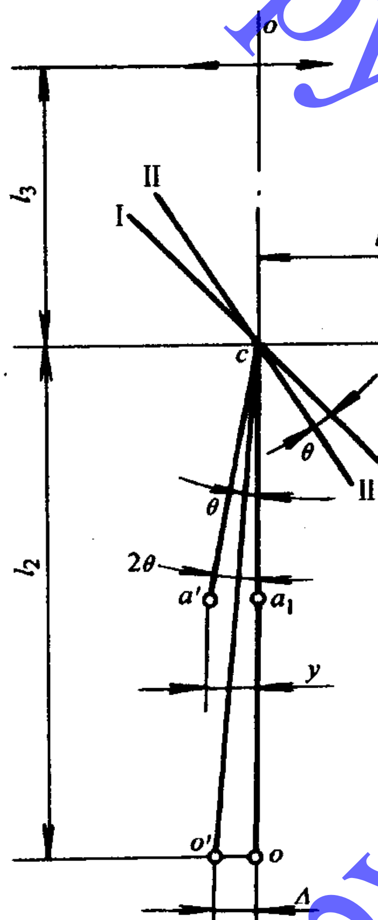
- Referencing methods and referencing accuracy
- Referencing accuracy

$$\delta = \frac{\alpha' \times 250}{2\times 10^5} mm$$

- Referencing accuracy (with microscope)

$$\delta' = \frac{\delta}{\beta}$$

Determining Lever Ratio of Optical-Position Indicator



$\theta \approx \Delta / l_2$

$y \approx 2 l_1 \theta$

$$y_{\min} = \frac{250 \times 10^3 \alpha'}{\beta}$$

$$\alpha' = 10'' = 5 \times 10^{-5}\ rad$$

$$\beta = 30$$

$$y_{\min} = \frac{5 \times 10^{-5} \times 250 \times 10^3}{30} \mu m \approx 0.4 \mu m$$

$$y \approx \frac{2 l_1 \Delta}{l_2} \Rightarrow \boxed{\Delta = \frac{l_2 y}{2 l_1}}$$

$$l_1 = 40\,mm \qquad l_2 = 70\,mm$$

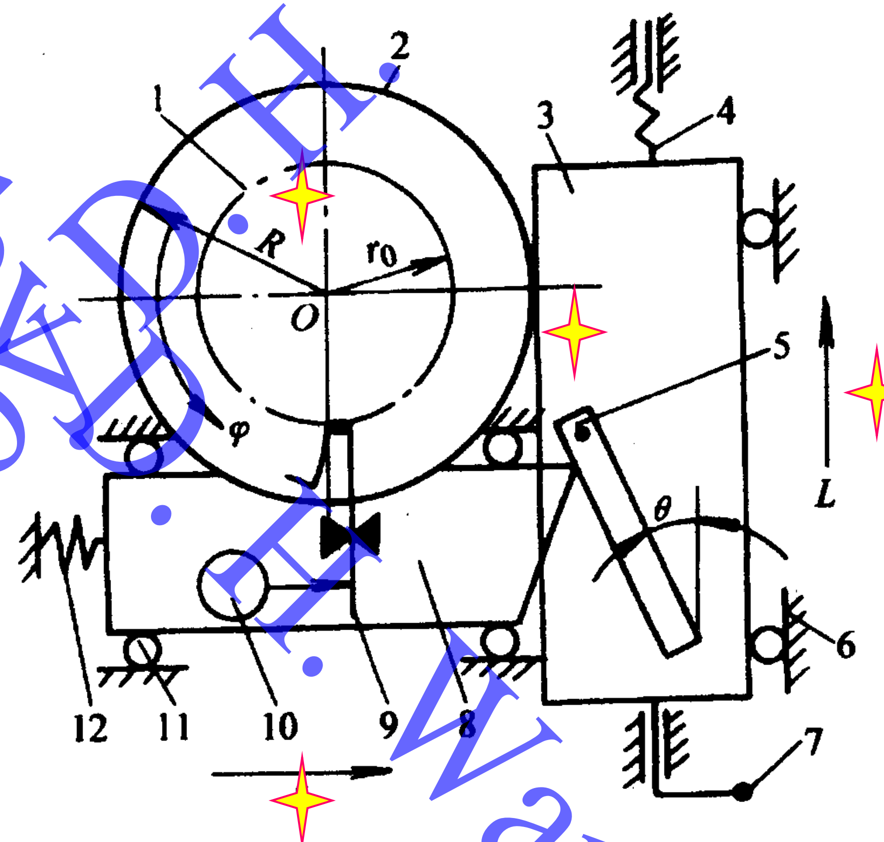
$$\Delta = \frac{0.4 \times 70}{2 \times 40} \mu m = 0.35 \mu m$$

According to Measuring Range

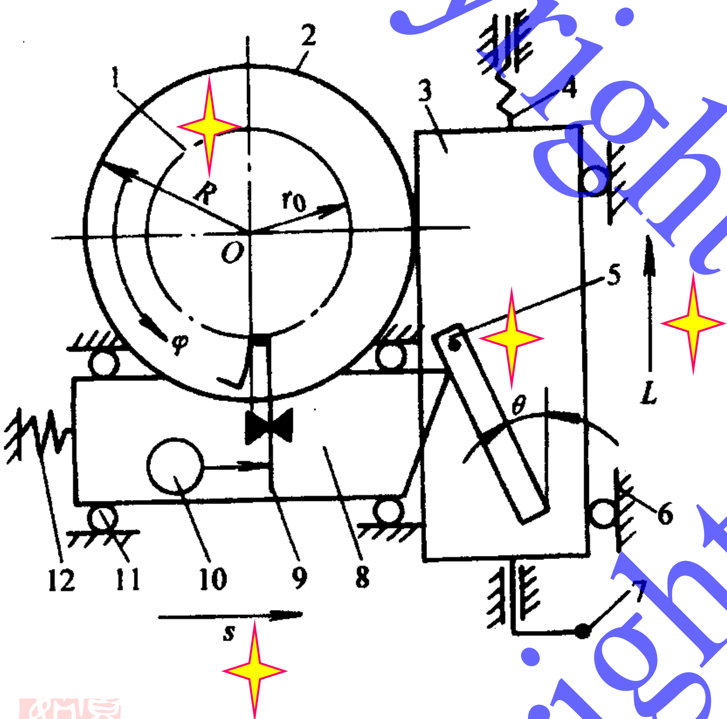
❒ **Ex: Determining the parameters of involute profilemeter**

Determining Parameters of Involute Profilemeter

❒ **Working Principle of Universal Involute Measuring Machine (UIMM)**



Determining Parameters of Involute Profilemeter

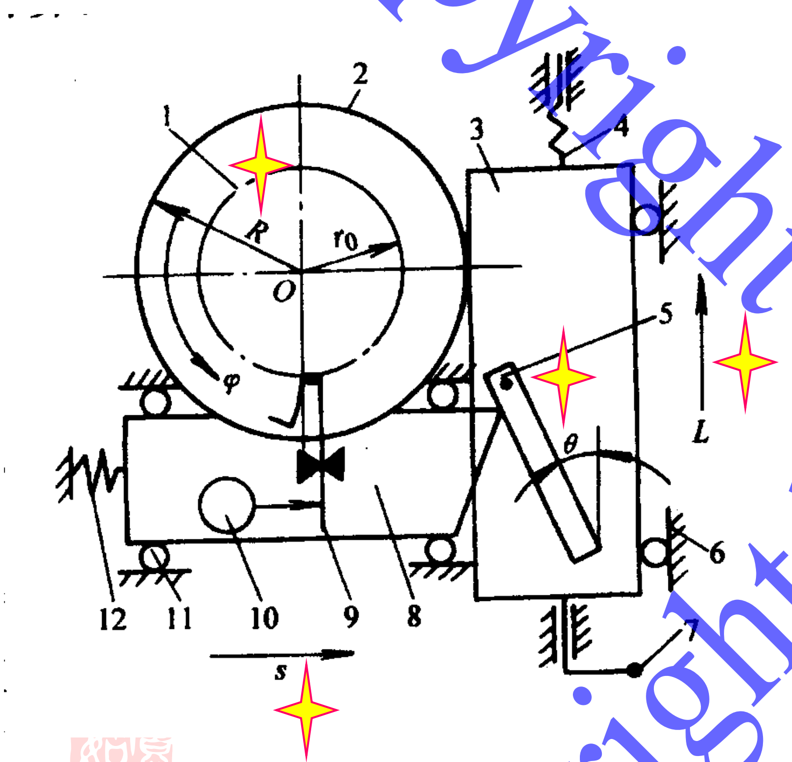


- **Measuring Ability**
  - **Maximum external diameter**

    $D_e = 120\text{mm}$

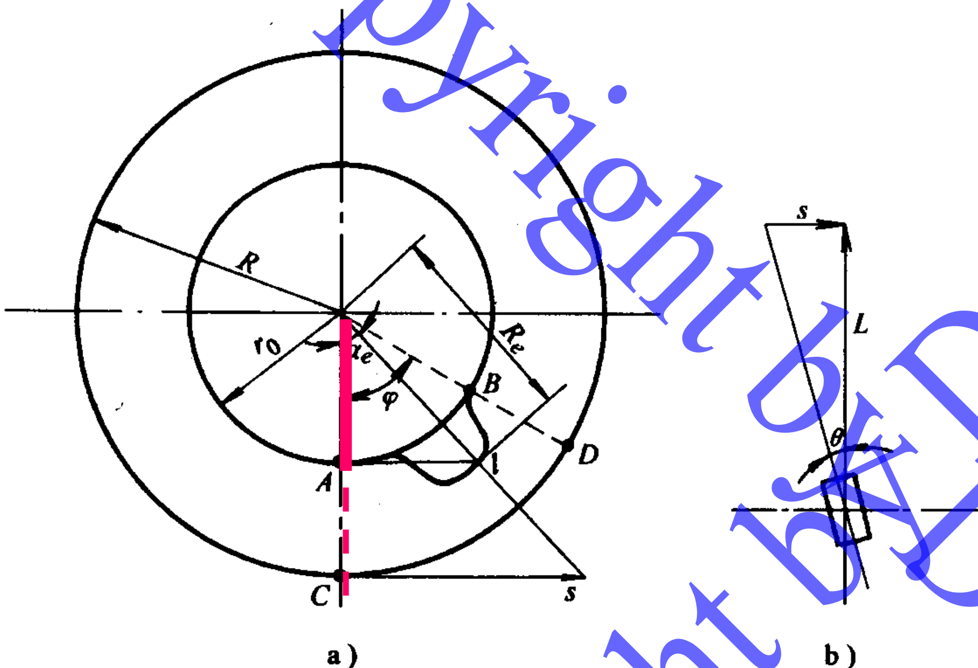
  - **Module** $m = 0.2 \sim 1.0\text{mm}$
- **Determining the main parameters of the involute profilemeter**
  - …

Determining Parameters of Involute Profilemeter



- Determining the main parameters of the involute profilemeter.
  - How to determine the adjustment angle of the sine bar (5) and the radius of the base disc (2)?
  - How to determine the maximum journey of the generating slide (3)?
  - How to determine the maximum journey of the indicator slide (8)?

Determining Parameters of Involute Profilemeter



- **Relationship of the parameters**

$$\frac{r_0}{R}=\frac{s}{L}$$

$$\tan\theta=\frac{r_0}{R}=\frac{s}{L}$$

$$D_e=m(Z+2f_0)=D_f+2mf_0$$

$$D_f=D_e-2mf_0$$

$$D_0=D_f\cos 20^\circ$$

Standard Involute Profile $\varphi=\dfrac{\overset{\frown}{CD}}{R}$

Measured Involute Profile $\varphi=\dfrac{\overset{\frown}{AB}}{r_0}$

Determining Parameters of Involute Profilemeter

- Determining the adjustment angle of the sine bar (5) and the radius of the base disc (2)

$\theta \leq 30^\circ$ --According to Experience

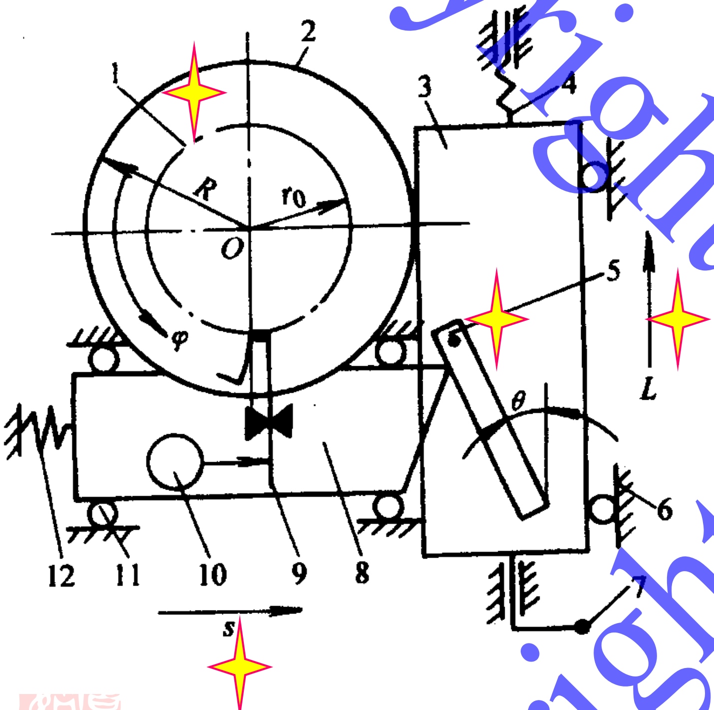
$$\tan\theta = \frac{r_0}{R} = \frac{s}{L} \Rightarrow \theta = \arctan(r_0/R)$$

$$r_0 = \frac{1}{2} D_0 = 56.1936 \text{ mm}$$

$$R = r_0/\tan 30^\circ = 97.3\text{mm}$$

$$R = 100\text{mm}$$

Determining Parameters of Involute Profilemeter



❒ **Determining the max. journey of the generating slide (3)**

$$L = R\tan\alpha_e = R\tan\left[\arccos\left(\frac{r_0}{R_e}\right)\right]$$

$$= R\tan\left[\arccos\left(\frac{mz\cos\alpha_0}{mz+2mf_0}\right)\right] = R\tan\left[\arccos\left(\frac{z\cos\alpha_0}{z+2f_0}\right)\right]$$

$$f_0 = 1, \alpha_0 = 20°$$

$R = 100\text{mm}$ $z = 8$（最少齿数）

$L = 100\text{mm} \times 0.877 = 87.7\text{mm}$ **89 mm**

α_e --齿顶园上的压力角

Determining Parameters of Involute Profilemeter

❒ **Determining the max. journey of the indicator slide (8)**

$$l = r_0 \tan \alpha_e \qquad l = \frac{1}{2} mz\cos\alpha_0 \tan\left[\arccos\left(\frac{z\cos\alpha_0}{z+2f_0}\right)\right]$$

When $m = 1\text{mm}, D_e = m(z+2f_0) = 120\text{mm}$, $z = 118$

$$r_0 = \frac{1}{2} mz\cos\alpha_0 = \frac{1}{2} \times 118 \times 0.93969 = 55.44\text{mm}$$

$$\tan\alpha_e = \tan\left[\arccos\frac{118\times 0.93969}{118+2}\right] = 0.41375$$

$$l = r_0 \tan\alpha_e = 22.939\text{mm}$$

When $m = 0.2\text{mm}, D_e = m(z+2f_0) = 120\text{mm}$, $z = 598$

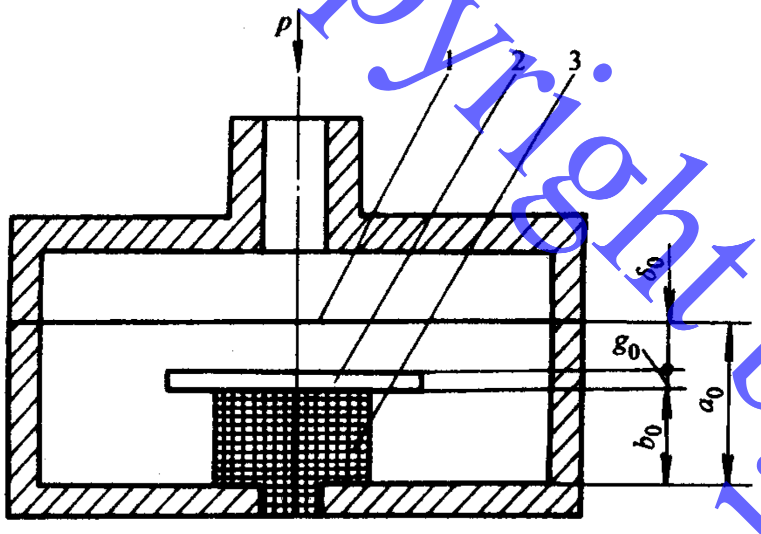
$$l = r_0 \tan\alpha_e = 56.19 \times 0.374\text{mm} = 21.030\text{mm}$$

29 mm

Based on Error Compensation

- ❒ **Ex: Determining the Parameters of the Capacitive Pressure Transmitter/transducer**

Parameters of Capacitive Pressure Transmitter



- **Working Principle of Capacitive Pressure Transmitter**

$$C = \frac{\varepsilon_0 \varepsilon_r S}{\delta_0} \qquad p \approx\propto \delta_0$$

- **Determining the parameters**

$$t = t_0 \ : \ \delta_0 = a_0 - b_0 - g_0$$

$$t = t_0 + \Delta t \ : \ \delta_t = a_0(1 + \alpha_a \Delta t) - b_0(1 + \alpha_b \Delta t) - g_0(1 + \alpha_g \Delta t)$$

$$\Delta\delta_t = \delta_t - \delta_0 = (a_0 \alpha_a - b_0 \alpha_b - g_0 \alpha_g)\Delta t$$

Parameters of Capacitive Pressure Transmitter

❒ **Determine the parameters**

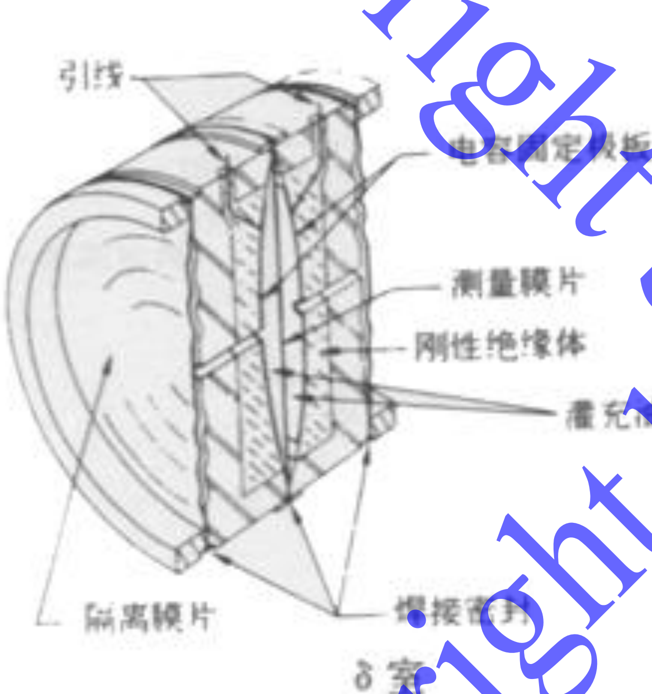
$$\Delta_t = \frac{C_t - C_0}{C_0} = \frac{\delta_0 - \delta_t}{\delta_t} = \frac{-\boxed{(a_0\alpha_a - b_0\alpha_b - g_0\alpha_g)}\Delta t}{\delta_0 + (a_0\alpha_a - b_0\alpha_b - g_0\alpha_g)\Delta t}$$

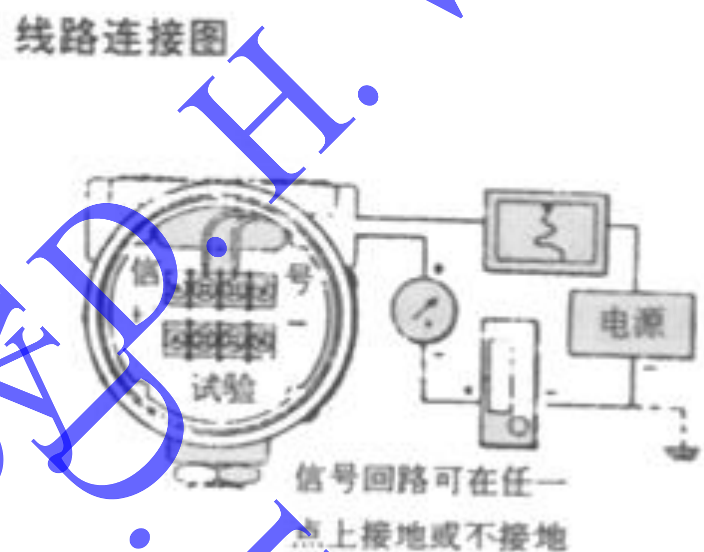
❒ **Let** $\Delta_t = 0$ **, then** $a_0\alpha_a - b_0\alpha_b - g_0\alpha_g = 0$

$$\Rightarrow \quad a_0 = b_0 + \delta_0 + g_0$$

$$\Rightarrow \quad b_0(\alpha_a - \alpha_b) + g_0(\alpha_a - \alpha_g) + \delta_0\alpha_a = 0$$

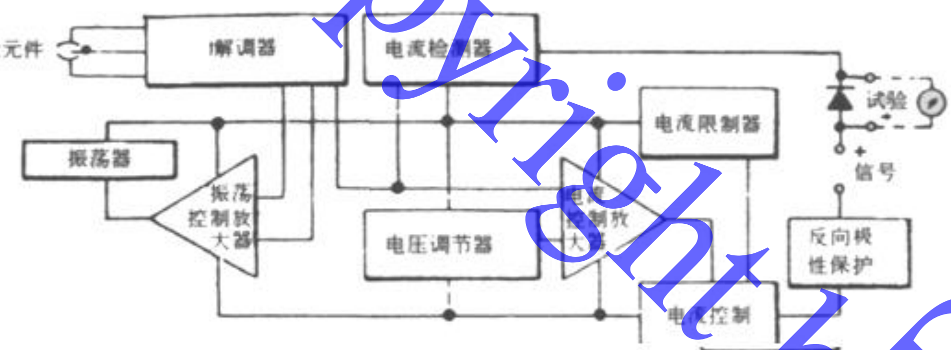
Differential Capacitive Pressure Transmitter/Transducer



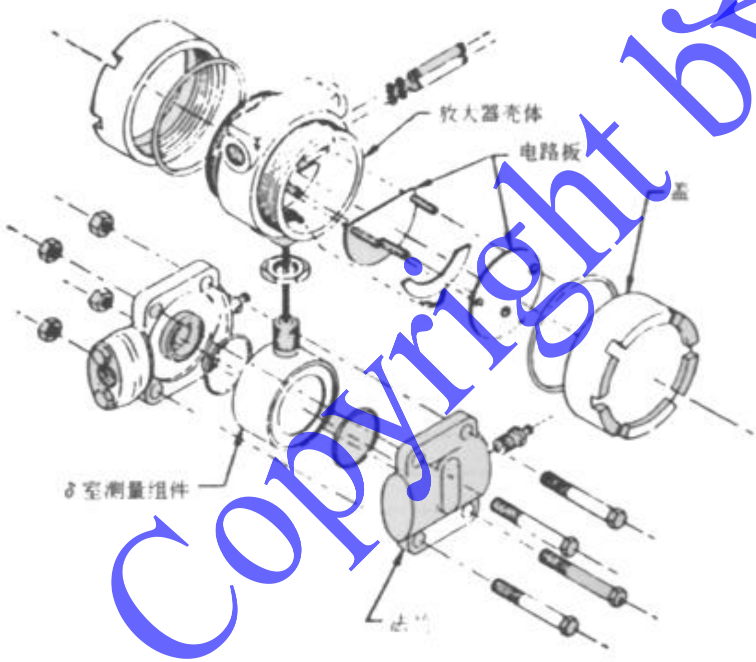


Differential Capacitive Pressure Transmitter/Transducer

电路方块图



1151 变送器装配图



The End

Thank you very much for your attention !

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