Systematic study on the reappearance of the horizontal position of Standard Metal Gauge and related problems

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Abstract

Standard metal gauge, especially the first class metal gauge, it is mainly responsible for the second class, third class standard metal gauge value transfer function; In the actual verification work of standard metal gauge, if the level deviates from the source position or is not adjusted for human reasons, the accuracy of the measurement results will be directly affected, resulting in the deviation of the measurement value transmission. By studying the influence of the level deviation from the tracing position of the leveler on the level, the deviation function of the measuring neck and the level tube is obtained. In addition, based on the analysis of common metal level compensation gauges, the formulas for calculating the level compensation of various kinds of compensation gauges are obtained. Based on this, some suggestions are put forward for the compensation gauge with the level tube arranged vertically. By analyzing the incline between measuring neck, liquid level pipe, scale and main part produced in the production process, it is concluded that the installation incline has no influence on the measurement results.

1. Introduction

Standard metal gauge (hereinafter referred to as gauge) are standard measuring instruments widely used in capacity measurement work. According to the accuracy grade, they are divided into three grades: first, second and third [1].

The accuracy of the gauge is very important to the measurement results, and there are many factors affecting the accuracy of the measuring results [2] [3]. Among which, the measurement of the relative height of the liquid level of the gauge is very important, and the commonly used resolution is 0.02mm vernier caliper or the height caliper is modified. At present, there are also applications of magnetostrictive liquid level gauges or machine vision liquid level measurement mechanisms on the gauge [4].

The gauge is generally composed of overflow cover, measuring neck, liquid level pipe, measuring neck scale, measuring body, valve, bracket and leveling bolt.The two mutually vertical horizontal directions of the gauge body are respectively installed with 0.05mm/m tubular level.

When in use, close the drain valve and fill the measured volume of liquid into the gauge until it appears in the level tube. After the foam is

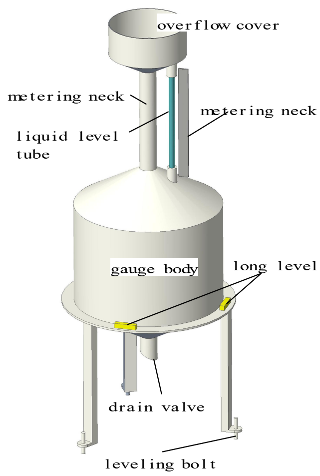

Figure1: Structure diagram of standard metal gauge

eliminated, align the apex of the liquid meniscus with the metering neck ruler and read the ruler reading.

The basic formula of the volume to be measured is: $V = V_0 + \Delta h \cdot V_j$, ignoring the influence of temperature change. Where: V_0 is the nominal volume of the gauge, V_j is the corresponding volume of the metering neck per millimeter, Δh is the difference between the ruler reading and the height of the liquid level corresponding to the nominal volume.

In use, the leveling device often appears fixed failure or damage phenomenon, and the operator also carries out the work without leveling adjustment. The above reasons make the measuring device not in the horizontal position, which will directly affect the correctness of the measurement results. In order to quantitatively analyze the influence of the above level state on the measurement results, the paper carries out research on the recurrence of the level position of the gauge and related issues[6] [7].

2. The influence of the recurrence difference of the horizontal position of the gauge on measurement results

2.1 The influence of the inclination of the gauge on the height measurement of the liquid level due to the failure of the level gauge

For the convenience of expression, the change in the traceability state of the gauge caused by the fixed failure of the gauge [8] was referred to as the failure tilt of the gauge.

When tilting, the liquid level rises or falls in the liquid level tube, and correspondingly, the liquid level changes inversely in the metering neck. Since the cross-sectional area of the metering neck and the liquid level tube is quite large, and the volume of liquid rising in the liquid level tube is equal to that falling in the metering neck, the change of liquid level in the metering neck is smaller than that in the liquid level tube.

For the convenience of analysis, four preconditions are set: 1. The liquid level does not rise or fall in the metering neck during tilting. 2. The gauge is a single liquid level tube structure. 3. The metering neck is in a vertical state when the gauge is traceable. 4. The shape of the meniscus does not change when it is inclined.

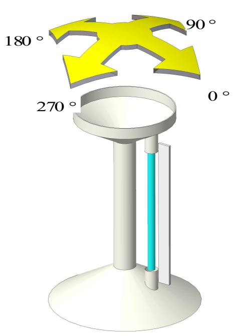

Figure 2: Four specific angles at which the gauge is tilted

There are four specific tilt states when the gauge is tilted, as shown in Figure 2. In the figure [9].

The gauge is tilted toward the ruler, and the tilt direction is 0°. The intersection point of the liquid level and the liquid level tube axis rises along the axis, and the rising height increases with the increase of the inclination angle. The liquid level and the liquid level tube axis oblique intersection; the gauge is tilted perpendicular to the ruler in the directions of 90° and 270°. The intersection point of the liquid level and the axis of the liquid level tube does not change, that is, the height of the center of the liquid level remains unchanged, and the liquid level and the axis of the liquid level tube oblique intersection; the gauge is tilted in the opposite direction of the ruler to 180°. The intersection of the liquid level and the axis of the liquid level tube decreases along the axis, and the descending height increases with the increase of the inclination angle. The liquid level intersects the axis of the liquid level pipe obliquely.

Starting from tilting to 0° in the direction of the ruler, the gauge is inclined at an angle of α in the direction of the angle β with the plane formed by the metering neck-ruler axis (simply expressed as: inclination α in the direction of β), as shown in Fig. 3. It is assumed there is a liquid level tube at the point O_2 and point A in the β direction, represented by dotted line, and the position conditions meet: $O_0O_1 = O_0O_2$、 $O_1A \perp O_0O_2$。

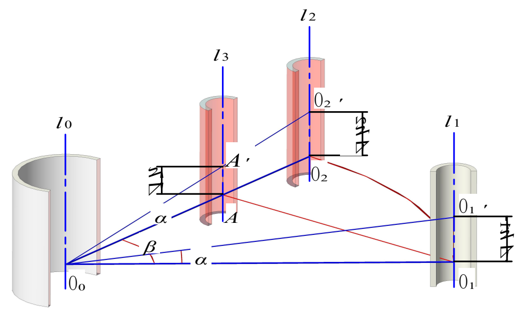

Figure 3: Space diagram of metering neck and liquid level pipe

In the figure:

l_0- the axis of metering neck
l_1- the axis of liquid level tube
l_2- the axis of the liquid level pipe assumed to be at point O_2
l_3- the axis of the liquid level pipe assumed to be at point A
O_0 -the intersection of the liquid level of the metering neck and the axis of the metering neck l_0
O_1- the intersection of the liquid level and l_1 before the gauge is tilted
O_1'- the intersection of the liquid level and l_1 when the gauge is tilted toward the ruler at α Angle

O_2- the intersection of the liquid level of liquid level tube and l_2 assumed before the gauge is tilted

O_2'- the intersection of the liquid level with l_2 after the level tube is assumed to be tilted α Angle in the direction of β

A - the intersection of the liquid level of liquid level tube and l_3 assumed before the gauge is tilted

A' - the intersection of the liquid level with l_3 after the level tube is assumed to be tilted α Angle in the direction of β

Set $O_0O_1 = a$, $O_1O_1^{'} = \Delta h_1$, and a is the wheelbase of metering neck and liquid level tube. Then, when the metering neck is tilted toward the ruler at α Angle, the rising height Δh_1 of the liquid level in the liquid level tube can be calculated as follows (1) [10]:

$$\Delta h_1 = O_0O_1 \cdot tan\,\alpha = a \cdot tan\,\alpha \qquad (1)$$

Obviously, when the gauge tilts α Angle to the direction of β, it is assumed that the change of the liquid level at point O_2 *i*s equivalent to that at point O_1 when the gauge tilts α Angle to *0*°, i.e., $\Delta h_1 = \Delta h_2$. Similarly, when the gauge tilts α Angle to the direction of β, the liquid level change (Δh_1) of the liquid level pipe at point O_1 is equivalent to that of assumed point A. Therefore: $O_0A = O_0O_1 \cdot cos\,\beta$, $AA^{'}/O_0A = O_2O_2^{'}/O_0O_2 = O_1O_1^{'}/O_0O_1 = \Delta h_1/a$

It can be obtained that the change of liquid level Δh_1 in the liquid level tube at point O_1 when the gauge tilts α Angle to the direction of β

$$\Delta h_1 = AA^{'} = O_0A \cdot \Delta h_1/a = a \cdot tan\,\alpha \cdot cos\,\beta \quad (2)$$

2.2 Correction of liquid level rise height Δh_1 in liquid level pipe

The above analysis process pre-sets the condition that the level of the metering neck remains unchanged, and in-depth analysis of the variation rule of the liquid level in the metering neck and the level pipe can further correct the influence of tilt on the measurement results [11].

2.2.1 The amount of liquid level change when the gauge tilts α angle to the ruler

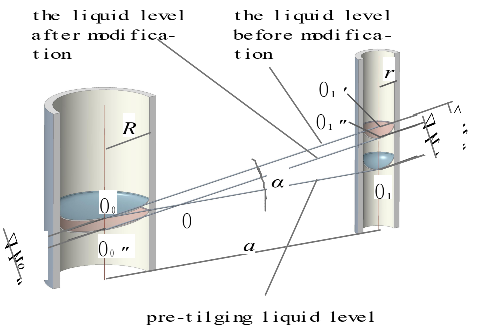

Figure 4: Space diagram of the gauge tilting α angles to *0*°

As shown in Fig. 4, the axes of the metering neck and the liquid level pipe are on the left and right sides of point O respectively. When tilt occurs, the liquid level in the metering neck drops from O_0 to $O_0^{"}$ along the axis, and the axial length is denoted as $\Delta h_0^{"}$. Correspondingly, the liquid level in the liquid level pipe rises along the axis from O_1 to $O_1^{"}$ instead of $O_1^{'}$, and the change of the liquid level along the axis is recorded as $\Delta h_1^{"}$ instead of Δh_1 as described above.

Points O_0 and O_1 are on either side of point O, so when the gauge is tilted in the direction of *0*°, point O_1 is equivalent to tilting in the direction of 0°, and point O_0 is equivalent to tilting 180°. According to the analysis of formula (2), it can be known that there is a coefficient of cos180° =-1 for the rise and fall of $\Delta h_0^{"}$ and $\Delta h_1^{"}$, which just explains the difference between $\Delta h_0^{"}$ and $\Delta h_1^{"}$ in the opposite lifting direction.

When tilted, the liquid level rises and falls in the metering neck or liquid level pipe, and the liquid level and the pipe axis gradually produce a dip angle. In a single pipe, the liquid level on both sides of the central point of the liquid level approximately presents a symmetrical compensation relationship, so it can be considered that the rise and fall of the liquid level in the metering neck or liquid level pipe is equivalent to the vertical rise and fall of the liquid level. Since the volume of liquid level falling in the metering neck is the same as that of liquid level rising in the liquid level pipe, and the liquid level change is opposite,

$$\pi R^2 \cdot \Delta h_0^{"} = -\pi r^2 \cdot \Delta h_1^{"}$$

In the formula:

r - hollow radius of the liquid level pipe

R- hollow radius of the metering neck

The amount of liquid level change in the liquid level pipe after correction

$\Delta h_1^{"} = \Delta h_1 + \Delta h_0^{"} = \Delta h_1 - \Delta h_1^{"}(r/R)^2$, Substituting equation (1) into the formula:

$$\Delta h_1^{"} = \Delta h_1/[1-(r/R)^2] = a \cdot tan\,\alpha/[1-(r/R)^2] \qquad (3)$$

The amount of liquid level change in the metering neck after correction

$$\Delta h_0^{"} = -\left(\frac{r}{R}\right)^2 \cdot \Delta h_1^{"} = a \cdot tan\,\alpha \cdot (r/R)^2[(r/R)^2 - 1] \qquad (4)$$

2.2.2 *The amount of liquid level change when the gauge tilts α angle in any β direction*

Obviously, the liquid level change in the liquid level pipe follows formula (2) and Formula (3).Therefore, the liquid level change in the liquid level pipe after modification

$$\Delta h_1^{"} = a \cdot \tan\alpha \cdot \cos\beta/[1-(r/R)^2] \qquad (5)$$

Similarly, the level change in the metering neck after modification

$$\Delta h_0^{"} = \Delta h_1^{"} \cdot (r/R)^2 \cdot \cos\beta = a \cdot \tan\alpha \cdot \cos\beta \cdot (r/R)^2/[(r/R)^2 - 1] \quad (6)$$

2.2.3 *Simplification of the formula*

For a certain gauge, the wheelbase a of the metering neck and the liquid level tube, the hollow radius of the liquid level pipe, and the hollow radius R of the metering neck are all fixed values, let $b = a/[1-(r/R)^2]$、$c = a \cdot (r/R)^2/[(r/R)^2-1]$

Then equations (5) and (6) can be simplified as

$$\Delta h_1^{"} = b \cdot tan\alpha \cdot cos\beta \quad (7)$$

$$\Delta h_0^{"} = c \cdot tan\alpha \cdot cos\beta \quad (8)$$

Equations (7) and (8) show that for certain gauges, the change of liquid level rise and fall caused by tilting is directly proportional to the tangent of tilting angle tanα, and changes periodically with the tilting direction *β*.

In the liquid level pipe, $\beta = 0^{\circ}$, $cos\,\beta = 1$, *t*he gauge tilts to the ruler direction, and the liquid level rises to the highest point; $\beta = 180^{\circ}$， $cos\,\beta = -1$, the gauge tilts in the opposite direction to the ruler, and the liquid level drops to the lowest point; $\beta = 90^{\circ}$ or $\beta = 270^{\circ}$, $cos\,\beta = 0$, the gauge is tilted to the vertical direction of the ruler, and the central height of the liquid level is unchanged.

2.3 *Technical ways to eliminate the influence of tilt on the deviation of liquid level measurement*

If the distance between the axis of the metering neck and the liquid level pipe *a*=0, then b、c，$\Delta h_1^{"}$、$\Delta h_0^{"}$ are equal to *0*. It shows that if the metering neck and the liquid level pipe coincide, the intersection of the liquid level and the metering neck axis will not change. At present, there is a technology that can achieve the goal of *a=0* [12], that is, the tilt of the gauge has no effect on the liquid level height (the intersection of the liquid level and the axial position of metering neck), and the measurement of the relative height of the liquid level does not need to be corrected.

If the gauge can realize the horizontal position reoccurrence by itself, then the gauge does not incline to the traceable position. In this case, *α=0°, β=0°*, then *tan α*=0, *cos β=1*, and equations *(1)~(8)* above are all equal to *0*. At present, a variety of technical schemes can realize automatic reappearance of the horizontal position of the gauge. Even if the level fails, the tilt of the gauge cannot be caused, and the measurement of the relative height of the liquid level is not affected [7] [13]**.**

3 Influence of tilt on installation form of compensation gauge

The common installation method of the liquid level pipe of the gauge is to install one liquid level pipe in parallel on the side of the metering neck. In order to accurately measure the height of the liquid level and prevent the measurement error caused by the tilt of the gauge, the liquid level compensation gauge is often used. As shown in Fig. 5.

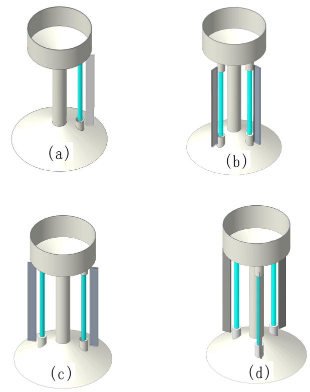

Figure 5: Distribution diagram of liquid level pipe of compensated standard metal gauge

The national verification regulations stipulate that the shape of the liquid level compensation gauge is as follows: three liquid level pipes and rulers are set in parallel along the metering neck symmetrically at 120°, and it is stated that he level is not required for the compensation gauge. In the work, it can also be seen that two liquid level pipes are arranged on the side of the metering neck axis at 90°, and two liquid level pipes are arranged on the axis of the symmetrical metering neck at 180°.

In the following, the influence of tilt on various compensation gauges is analyzed one by one under the condition that the gauge tilts by an angle α in the β direction. The liquid level deviation of the compensation liquid level pipe is represented by Δh_b , and subscripts 1, 2 and 3 respectively represent liquid level pipes at different positions.

3.1 *The amount of liquid level change when the gauge of one liquid level pipe is tilted*

When the gauge of one liquid level pipe installed is tilted, the measurement deviation of liquid level height caused by tilt follows the formula (7) of $\Delta h_1^{"} = b \cdot tan\alpha \cdot cos\beta$.

Since *b, tan α* and *cos β* are not equal to *0*, equation (7) shows that when the gauge is tilted, the reading of the liquid level measurment will have a deviation not equal to *0*. The deviation increases with the increase of the inclination angle and changes periodically with the different inclination direction.

3.2 *The amount of liquid level change after compensation when the gauge with two liquid level pipes vertically distributed with the axis of the metering neck is tilted*

The two liquid level pipes and the metering neck is distributed at 90°, as shown in Fig. 5(b). The Angle between the two liquid level pipes is 90°. The liquid level height after compensation is taken as the average readings of the two rulers, so the corrected and compensated liquid level height change in the liquid level pipe

$$\Delta h_1^{''} = (\Delta h_{b1} + \Delta h_{b2})/2 = b \cdot tan\,\alpha \cdot [cos\,\beta + cos\,(\beta + 90^{\circ})]/2 = b \cdot tan\,\alpha \cdot cos\,(\beta + 45^{\circ})/\sqrt{2} \quad (9)$$

Since b、$tan\alpha$、and $cos\,(\beta + 45^{\circ})$ are not equal to 0, equation (9) shows that when the gauge is tilted, the reading of the compensating level gauge will produce a deviation not equal to 0, and the deviation will increases with the increase of inclination Angle and changes periodically with the different inclination direction. and the deviation is slightly smaller than that of the first installation method.

3.3 *The amount of liquid level change after compensation when two liquid level pipes are symmetrically installed with the axis of the metering neck*

The angle between the two liquid level pipes installed symmetrically is taken as 180°, as shown in Fig. 5(c). The liquid level height after compensation is taken as the average of the readings of the two rulers, so the corrected and compensated liquid level height change in the liquid level pipe

$$\Delta h_b^{''} = (\Delta h_{b1} + \Delta h_{b2})/2 = b \cdot tan\,\alpha \cdot [cos\,\beta + cos\,(\beta + 180^{\circ})]/2 = 0 \quad (10)$$

Equation (10) shows that when the gauge is tilted, the change of liquid level introduced by the tilt can be completely compensated, and the compensation effect is very good.

3.4 *The amount of liquid level change after compensation when three liquid level pipes are symmetrically installed with the axis of the metering neck*

The angle between the three liquid level pipes installed symmetrically is 120°, as shown in Fig.5(d). The liquid level height after compensation is taken as the average of the readings of the three rulers, so the corrected and compensated liquid level height change in the liquid level pipe

$$\Delta h_{\mathrm{b}}^{''} = (\Delta h_{\mathrm{b1}} + \Delta h_{\mathrm{b2}} + \Delta h_{\mathrm{b3}})/3 = \mathrm{b} \cdot \tan\alpha \cdot [cos\,\beta + cos\,(\beta + 120^{\circ}) + cos\,(\beta + 240^{\circ})]/3 = 0 \quad (11)$$

Equation (11) shows that when the gauge is tilted, the change of liquid level introduced by the tilt can be completely compensated, and the compensation effect is very good.

Therefore, it can be seen that a gauge with one liquid level pipe will introduce measurement errors when there is a deviation in the horizontal position recurrence. When using this type of gauge, the state of the level should be carefully checked, and the liquid bubble should be adjusted and placed in an ideal position to reduce or eliminate the measurement error caused by the tilt.The effect of liquid level compensation measurement is poor when two liquid level pipes are arranged vertically. It is suggested to eliminate the production of this type of gauge. Symmetrical installation of liquid level pipe can play a good compensation role.

4 .The measurement data of the non-parallel phenomenon in the metering neck of the gauge

In the work, it is often found that the metering neck and the main axis of the qualified gauge are not aligned. For this reason, vernier calipers, dial gauges and magnetic seat are selected to measure the parallelism between the ruler and the liquid level pipe, and between the ruler and the metering neck of the four second gauge. The measurement data are shown in Table 1.

The above data show that there are parallel problems of different sizes between gauge ruler and liquid level tube, and between gauge ruler and metering neck, among which the maximum non-parallel degree can reach 14.54 mm/m [14].

5. The influence of the tilt of the gauge appearance due to the production process

The reasons and influences of the parallelism between the gauge ruler and liquid level pipe, as well as between the gauge ruler and the metering neck described in Table 1 are further analyzed below.

It is generally considered that there are three main reasons for the non-parallel in the production process of the gauge: 1.There is a welding structure between the metering neck and the gauge body. Due to the welding process control or the thermal stress after welding, the axis of the metering neck and the level plane of the gauge appear nonperpendicular, and some gauge even have obvious metering neck skew; 2.The liquid level pipe and the metering neck are installed in the upper and lower mounting seats of the liquid level pipe in parallel, and are sealed by threaded extrusion rubber rings. The welded upper and lower mounting seats are separate parts. The coaxiality between the upper and lower mounting seats, as well as the parallelism between the two mounting seats and the metering neck, is difficult to control during welding, resulting in the non-parallelism between the liquid level pipe and the lower mounting seats of the liquid level pipe can be well guaranteed. At the same time, all the above problems can be solved by designing special fixture and optimizing process flow.

Tabel 1： Measuring data between ruler and liquid level tube and metering neck unit：mm

the basic information		Standard gauge number	0468		0470		0469	0471	note
		Measuring project	1000L(the double scale)		500L(the double scale)		200L	50L	
		Length of liquid level pipe (excluding mounting seat)	339.0	339.0	348.0	352.0	253.0	220.0	
Parallelism between scale and level pipe	Measuring data of ruler in mounting plane	①Deviation between upper and lower end of ruler and liquid level pipe	0.56	0.40	0.06	0.60	0.40	1.10	
		②Distance between upper and lower measuring points (length of liquid level tube)	339.0	339.0	348.0	352.0	253.0	220.0	
		③Parallelism deviation (unit: mm/m)	1.65	1.18	0.17	1.70	1.58	5.00	=1000*①/②
	The measuring data of the ruler perpendicular to the mounting plane	④ Deviation between upper and lower end of ruler and installation plane	0.432	2.775	2.129	1.141	1.239	1.274	
		⑤ Vertical distance between upper and lower measuring points	281	269	290	277	192	156	
		⑥Parallelism deviation (unit: mm/m)	1.54	10.32	7.34	4.12	6.45	8.17	=1000*④/⑤
Parallelism between ruler and measuring neck	Measuring data of ruler in mounting plane	(1) Distance deviation between upper and lower end of ruler and measuring neck	3.66	1.16	0.12	0.16	0.52	1.24	
		(2) Vertical distance between upper and lower measuring points	339	339.0	348.0	352.0	253.0	220.0	
		(3)Parallelism deviation (unit: mm/m)	10.79	3.42	0.34	0.45	2.06	5.64	=1000*(1)/(2)
	The measuring data of the ruler perpendicular to the mounting plane	(4) Deviation of parallelism between ruler and mounting plane	4.072	0.029	2.783	0.848	1.129	0.622	
		(5) Vertical distance between upper and lower measuring points	280	282	264	254	211	181	
		(6)Parallelism deviation (unit: mm/m)	14.54	0.10	10.54	3.34	5.35	3.44	=1000*(4)/(5)

metering neck; 3.There are sheet-like connecting plates welded on the upper and lower mounting bases of the liquid level pipe, and the ruler is fixed on the connecting plate by bolts. Generally, the diameter of the mounting holes on the ruler and the connecting plate is large, so the ruler has a certain adjustment space during installation. However, no adjusting mechanism perpendicular to the installation plane is designed on the existing gauge. At the same time, the looseness of the ruler often occurs in daily work [11], which leads to the non-parallelism between the ruler and the metering neck or the liquid level pipe. For ease of expression, these phenomena are called installation tilt.

There have been attempts in some technical improvement schemes. By improving the structure of the upper and lower mounting seats and making special fixtures, the coaxiality of the upper and

5.1 *Installation tilt of the metering neck*

Suppose that there is an independent vertical ruler H that is not associated with the tilt of the gauge. If the length of the metering neck is *h*, the circular cross-sectional area is s, and the height of the corresponding ruler *H* is *h*. If the metering neck is installed with an inclined Angle α, the height of the corresponding ruler *H* is $h' = h \cdot \cos \alpha$, and the cross-sectional area of the inclined ellipse is s'. The volume of the metering neck does not change after tilting, so $s' \cdot h' = s \cdot h$, cross-sectional area after tilting $s' = s/\cos\alpha$, the change of cross-sectional area after installation tilt $\Delta s = s' - s = s \cdot [(1/\cos\alpha) - 1]$.

In the case that the horizontal position of the gauge is reproduced, the liquid level measurement result of any number of times is *h'*, and the corresponding cross-sectional area of the metering neck is *s'*. This tilt has no effect on the correctness of the measurement results, and the visible tilt of the metering neck affects the appearance of the gauge.

5.2 *Installation tilt of liquid level pipe*

Both the liquid level pipe and the metering neck are circular tubular structures, so the installation tilt of the metering neck is the same as the installation of the metering neck, which has no effect on the correctness of the measurement results. The visible liquid level pipe tilt affects the appearance of the gauge.

5.3 *The installation tilt of the metrology ruler*

Suppose that there is an independent vertical ruler H that is not associated with the tilt of the gauge. If the length of the metering neck ruler is l and the ruler is installed at α Angle, then the height on the corresponding ruler H is $l' = l \cdot \cos\alpha$. The tilt of the ruler results in the change of the ruler in the vertical direction $\Delta l = l' - l = l \cdot (\cos\alpha - 1)$.

In the case that the horizontal position of the gauge is reproduced, the liquid level measurement result of any number of times is *l'*. This tilt has no effect on the correctness of the measurement results, and the visible ruler tilt affects the appearance of the gauge.

5.4 *Influence of level resolution on measurement results*

JJG 259-2005 "Standard Metal Measuring Instrument Verification Regulations" stipulates that the resolution of the tubular level installed on the gauge is 0.05mm/m, which is converted into an angle of 10.314". Affected by the resolution of the level, the inclination angle α of the gauge in any direction is acceptable within ±10.314". It can be seen from formula (5) that the height deviation of the liquid level caused by the recurrence of the horizontal position of the gauge is $\Delta h_1^{''} = a \cdot \tan\alpha \cdot \cos\beta / [1-(r/R)^2]$。 Let $\beta=0$ (that is, the gauge is inclined to the direction of the liquid level tube), $(r/R)^2$ is ignored, then $\Delta h_1''$ is the maximum value, $\tan\alpha = 5\times10^{-5}$. Generally a < 200 mm, then $\Delta h_1'' \approx 0.01mm$, which is about 1⁄2 ruler index of 0.02 mm.

However, from the appearance of the level installed on the existing domestic gauge, the resolution parameter is basically not marked on the level. From the appearance of the level, the resolution will not be better than 0.5mm/m, and the corresponding angle value is about 1.72'. Let $\beta=0$, $(r/R)^2$ is ignored, and calculated by α=1.72', a< 200 mm, tan α $=5\times10^{-4}$, then $\Delta h_1'' \approx 0.1mm$, which is about 5 times of the ruler index of 0.02 mm.

It can be seen that the choice of the resolution of the level directly affects the recurrence of the horizontal position of the gauge, and has a significant impact on the liquid level measurement. Therefore, in the verification of the gauge, the requirements for the resolution of the level should be increased.

It can be seen that the selection of the resolution of the level has a direct impact on the recurrence of the horizontal position of the gauge, and has a significant impact on the level measurement. Therefore, the requirements of the resolution item of the level should be increased in the calibrating work of the gauge.

6 Conclusions and recommendations

To sum up, the level height in the metering neck and liquid level pipe will change according to certain rules due to the recurrence of different level position of the gauge, and the error introduced by this should be eliminated in the work. Reducing or even eliminating the distance between the metering neck and the liquid level pipe, or the gauge can realize the automatic recurrence of the traceable position, can partially or completely eliminate the influence of tilt on the liquid level height measurement; The appearance of the gauge is inclined due to the production process, and the accuracy of the measurement results will not be affected under the condition of horizontal reappearance.

On this basis, it is suggested that: 1. Eliminate the production of liquid level compensation gauge with vertical distribution of two liquid level pipes and metering necks; 2. Strengthen the control of the distance, parallelism and symmetry angle between the liquid level pipe of the symmetrical compensator gauge and the axis of the metering neck to ensure the compensation effect; 3. Strengthen the control requirements for the level in the traceability of the standard metal gauge, and increase the level of resolution verification items. 4. Strengthen the process management and supervision of the use of the gauge to eliminate the measurement error caused by the repetition of the horizontal position of the gauge to the maximum extent. If vacuoles are loose or damaged, the work should be stopped immediately and returned to the factory for repair, and sent to the higher-level metrological verification agency for verification. It can be put into use again. 5. The metering neck, liquid level pipe and scale produced in the production process are not perpendicular to the horizontal plane, which has no influence on the measurement result. However, from the perspective of the appearance of the gauge, it is suggested to add the corresponding technical index requirements in the verification regulation.

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