Application of the Indoor Large-length Standard Device

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Abstract—The indoor large-length standard device is a comprehensive standard for traceability of large-length measurement value. It provides that the standard ensures its accuracy and reliability in the effective detection range. In order to ensure the accuracy of the quantity traceability of the large-length measuring instrument, we independently developed the domestic first set of metal linear guide indoor large-length standard device in the southwest. The high-precision metal linear guide cooperating with precision gear rack transmission is used in this device. The main drive system with an independent position closed-loop control is employed to eliminate effectively the influence of a series of problems, including the unstable floating track deformation and loss of friction wheels, difficult maintenance. The device can also hold an accurate and reliable statue throughout the execution, which can also maintain stable acceleration and velocity and has the advantages of no vibration transmission system, automatic operation. The measuring range of the device is (0~56) m, and the uncertainty of measurement is $U=0.14um+10^{-7}L$ (k=2). Its function is mainly used to carry out the distance meter, laser interferometer, laser tracker, standard steel tape equipment, and terrestrial laser scanner; also the device can also be used for linear displacement sensors, liquid level measuring devices, standard baseline feet, and other non-standard class length equipment calibration.

1. Introduction

At present, there are about 100,000 hand-held laser distance meters, 40,000 high-precision total stations, and photoelectric rangefinders in China, which are widely used in control measurement, precision engineering measurement, seismic deformation measurement, hydropower dam safety monitoring, nuclear power plant and high-speed railway construction. Nearly 600 laser trackers and an increasing number of the terrestrial laser scanners and radar scanning measurement systems are widely used in the field of national defense industry, aerospace, shipping, and equipment manufacturing, and the number of such instruments is growing at a rate of 20%~30%. In addition, there are some precision instruments,
such as laser interferometer, laser scanner, standard steel tape measure, and other equipment, and the accuracy of large length measurement instruments is of great significance.

In the international community, including China, only seven countries, such as Germany, the United States, Finland, and Japan, have established large-length standard devices. In terms of length, Japan has 100 mi-line guides. China's first 80-meter-long standard device was set up in 2012 at the China Academy of Metrology. Identified metrological testing technology research institute of Beijing Great Wall (304) established 35 mickey line, metrology institute, Shanghai (east China national metrology test center), Guangzhou institute of 50 meters indoor baseline field have been established, measurement science research institute of Shanxi Province built in 2013, 26 meters indoor baseline field metrology institute of Liaoning province (northeast national metrology testing center) 24 meters indoor baseline field acceptance in October 2014, xi’an aerospace research institute set up 10 meters metering indoor baseline field. There is no civil baseline field in southwest China, which is mainly used for the calibration of the laser tracker of our factory.

Based on this, our unit independent research the first set of metal linear guide indoor large length standard device in the domestic. The device adopts precision metal linear guide cooperates with precision gear rack drive, has an independent position closed loop of main drive system. This design effectively avoids a series of problems such as unstable floating rail, easy deformation, and friction of the wheel, difficult maintenance, etc., so that the device has the advantages of accurate and reliable movement, stable acceleration and speed, no vibration of the transmission system, automatic operation and so on.

2. The Indoor Large-length Standard Device
The Indoor large-length standard device is composed of guide rail system, space triangle laser length measuring system, environmental parameter real-time correction system, control system, aiming and image acquisition system, data processing system hardware, and software. The measurement system diagram is shown in Figure 1, and the software interface is shown in Figure 2.

![Image](image1.png)

**Figure 1** Measurement system diagram

![Image](image2.png)

**Figure 2** Software measurement diagram
3. The calibration business that can be carried out
Indoor length standard device use is more, mainly to carry out the laser tracker 3-Dimensional measuring system, terrestrial laser scanner, laser interferometer, distance meters, equipment calibration services, such as scale, the device can also be used for linear displacement sensors, liquid level measuring devices, due to standard baseline feet as well as other non-standard class length equipment calibration.

3.1. Laser tracker 3-Dimensional measuring system
Laser tracker 3-Dimensional measuring system, takes laser as a means of ranging with reflecting target instruments, at the same time equipped with two-axis rotation Angle measuring mechanism, forming a complete spherical coordinate measuring system. It can be used to measure stationary targets, track and measure moving targets or combinations of them. It is the measuring equipment with high precision in the industrial measuring system. It has advanced technologies such as geometric laser interferometric ranging technology, photoelectric detection technology, precision machinery technology, computer and control technology, modern numerical calculation theory, etc., to track and measure the three-dimensional spatial coordinates of the moving target in real-time. It has the characteristics of high precision, high efficiency, real-time tracking measurement, quick installation, and easy operation, and is suitable for assembly and measurement of large size workpiece.

The regulation [1][2] requires that the length of the long scale used for calibration of the laser tracker's distance measurement indication should be no less than 20 meters. In the measurement of distance indication error, the length of the long scale should reach 72% of the maximum measuring range of the equipment under test as far as possible. It is also mentioned that the standard equipment of laser interferometer is needed in the error of length measurement indication in the military standard [3], the error of built-in laser interferometer, and the error of absolute distance measurement. FIG. 3 shows the calibration diagram of the laser tracker 3-Dimensional measurement system.

![Figure 3 Calibration diagram of 3d coordinate measuring system of the laser tracker](image)

3.2. Terrestrial laser scanner
The terrestrial laser scanner is mainly composed of a ranging laser system, laser scanning system, control system, power supply system, and accessories, etc. It can quickly and massively collect spatial point position information and build a three-dimensional point cloud model of scanning targets.

Radial distance calibration devices in the specification require a series of linear reference distances covering the calibration range [4], such as moving an object from one position to another. Figure 4 shows a legend for calibrating a terrestrial laser scanner.
3.3. Laser interferometer

The laser interferometer is a high-precision, multi-functional measuring instrument with laser wavelength as the measurement standard, and it is used to measure displacement, straightness, angle, and other geometric quantities. It uses two single-frequency laser beams or two double-frequency laser beams with a small fixed frequency difference for interferometry instruments. The laser interferometer includes a laser head, electric box (including data transmission card), optical module, computer, the multi-parameter sensor of environment, measurement software, etc. Mainly used for machine tools, machining centers, coordinate measuring machines, and other equipment detection.

In the verification regulation [5], the primary verification tool for linear displacement indication error is the laser interferometer or other laser length measuring device (U=0.14um/m, k=2), and the indoor length standard device can be used as the standard device through comparison.

3.4. Distance meters

The range finders are mainly hand-held laser distance meters [6] and ultrasonic ranger [7]. Among them, a hand held laser rangefinder is an instrument that USES laser to accurately measure the distance of the target. When the laser rangefinder is working, it shoots a very thin laser beam to the target. The reflected laser beam is received by the photoelectric element. The timer measures the time from emission to reception of the laser beam and calculates the distance from the observer to the target. It can measure distance, area, and volume, both indoors and outdoors.

In the calibration of indicating an error of the hand-held distance meters, within the measurement range of the 50 m or less, the standard steel tape measure is the main standard or other devices with standard length baseline equal to a standard degree, and the measurement range greater than 50m, other devices with standard length baseline or equal accuracy are required. In the process of ultrasonic rangefinder verification, range measurement, and range measurement also need a standard length verification field. The calibration of the hand-held laser rangefinder is shown in Figure 5.
3.5. Ruler equipment
At present, the scale equipment mainly consists of the standard steel tape \(^8\), steel measuring tapes \(^9\), special scale-bar’s length \(^{10}\), and scale bar \(^{11}\), etc.

There are four types of the standard cue, namely the code standard bar, the cross target standard pole, the angle cone prism standard bar, and the ball standard bar, among which the coded standard cue is also a special rod. In the standard cue verification regulation, it is mentioned that the measuring uncertainty of the cue length verification device is \(U = 0.2\mu m + 0.2 \times 10^{-6}L (k=2)\), and the measuring range is 2000mm. The standard indoor device can meet this measuring condition.

The standard steel tape is made of high-quality carbon steel, tile, and other materials. It is a standard instrument of length measurement made by precision engraving. It is mainly used to trace the measuring value of ordinary steel tape and sounding steel tape and is also directly used in precision engineering measurement. It has mostly various specifications such as 5m, 10m, 20m, 30m, and 50m, etc., and other specifications can also be made according to the special needs of users. In the verification regulations, the calibration table, laser interferometer, degree microscope with 0.001mm, temperature, air pressure, and humidity measuring system are needed for the indicating error and the stability of indicating an error. The specific verification table is shown in FIG. 6.

![Figure 6 Calibration table for the standard steel tape measure](image)

3.6. Linear displacement sensors
A linear displacement sensor is a device capable of sensing changes in length and size and making output signals available to the converter. Also known as the linear sensor, which is a kind of metal induction of linear devices, the role of the sensor is to convert various measured physical quantities into electric quantity. In the process of production, the measurement of displacement is generally divided into two kinds: measurement of physical size and mechanical displacement. The displacement sensor can be divided into the analog type and digital type according to the different transformation forms of measured variables. The analog type can be divided into the physical types and structural types. The most commonly used displacement sensors are analog type, including potentiometer type displacement sensor, inductive type displacement sensor, self-integrating machine, capacitive type displacement sensor, eddy current type displacement sensor, Hall type displacement sensor, etc. An important advantage of the digital displacement sensor is that it is convenient to send the signal directly to the computer system. This kind of sensor develops rapidly and is used more and more widely.

In the specification \(^{12}\), at least, inductive displacement sensor, the direct differential transformer displacement sensor, and differential transformer displacement sensor, magneto telescopic displacement sensor, resistance type displacement sensor, the thread (rope), displacement sensor, laser displacement sensor mentioned standard laser interferometer, the equipment can be realized in the length of the standard device.
3.7. Liquid level measuring devices
Liquid level measuring devices indicate and control the fluid level and interface in industrial process measurement and control systems [13]. The ultrasonic level meter occupies a certain proportion in the liquid level meter. It is an instrument to measure the water level by using the characteristics of reflection generated by the ultrasonic wave at different media interface. It can be used in monitoring the water level of rivers, coastal areas, lakes, locks, docks, large ships, and underground water tanks. Ultrasonic water level gauge is mainly composed of the probe, multi-core cable, main chassis, and printer. The probe is installed in the air (1 meter above the highest water level) to make the transmitting face downward, and the sound wave is emitted downward after reaching the water surface and reflected upward as the gas medium; the probe is installed in the water and the sound wave is emitted upward to form the liquid medium. Gas medium installation and use should be convenient, in the water level detection are more widely used.

In the regulations [14], a standard device for water level is required. The measurement range is (0~10.2) m, and the accuracy requirement is that the maximum allowable error is no more than 20% of the accuracy error of the measured water level meter. The indoor large-length standard device can meet this requirement.

3.8. Other non-standard systems
In addition to the above equipment can be measured with standard indoor equipment, there are some other measuring equipment can be used to measure the length of the device. For example, microwave equipment and geometric parameter detection equipment (lidar) are shown in FIG. 7 and FIG. 8.

Figure 7 Microwave measuring device

Figure 8 Geometric parameter detection equipment
4. Conclusion

The indoor unit for the length standard as the length of the source and large length measurement devices, it for precision manufacturing and other fields to provide the powerful guarantee, at present on the device has been in some measurement equipment calibration test work, believe in the future along with the advance of the development of the society and industry, there will be more measuring instruments need to be traced, it will continue to play its value.

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