Development of a Temperature Calibration Device for Refrigerated Centrifuge

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Abstract. This article presents a novel design of a temperature calibration device and calibration procedure for refrigerated centrifuge. The temperature calibration results of 8 typical types of refrigerated centrifuges and the uncertainty analysis shows that the calibration device and calibration procedure presented in this article can meet the requirements of the temperature calibration for refrigerated centrifuge and ensure the temperature reliability of refrigerated centrifuge in its daily use.

1. Introduction
Refrigerated centrifuge is widely used in biological and clinical laboratories which have high requirements on biological activity preservation of tested samples during the centrifugal extraction process. In order to maintain the biological activity of tested samples, the sample temperature needs to be strictly stabilized within a certain range during centrifugal extraction [1]. Temperature deviation from the standard requirement may seriously affect experimental results, therefore the temperature calibration of refrigerated centrifuge increases rapidly in recent years [2].

The temperature sensors of most types of refrigerated centrifuges are placed in the cavity of the device, and there are tubes, rotor, air and other media in between the sensors and the samples. When the centrifuge runs at high speed, there will inevitably be a temperature difference between the cavity or sample [3]. However, at present, there are few studies on the temperature calibration of refrigerated centrifuge. A research has conducted temperature calibration experiments on some refrigerated centrifuges with alloy rotors, and the test results show that the temperature inside the rotor will change with time during centrifugation but within the required temperature range [4]. Till now, there is no national temperature calibration specification for refrigerated centrifuge in China. This article studies the influential factors on the temperature measurement accuracy of refrigerated centrifuge, in order to design a novel temperature calibration device for it, and present an applicable calibration procedure, in order to ensure the temperature reliability of refrigerated centrifuge in its daily use.

2. Design of Temperature Calibration Device for Refrigerated Centrifuge
The experiment would be conducted in a closed space rotating at high-speed, therefore the wireless temperature transducer is adopted in the calibration device. The temperature calibration device for refrigerated centrifuge is mainly composed of wireless temperature transducer embedded with wireless signal generator and storage chip, as well as wireless signal receiver connecting a computer installed of the operating software of the calibration device.
According to the temperature controlling range of refrigerated centrifuge, 5°C, 10°C and 20°C are selected as temperature calibration points. Therefore, Pt100 thermometer is picked to be the transducer of the temperature calibration device for refrigerated centrifuge, due to high precision and stable performance of the thermometer. The temperature measuring circuit is demonstrated in Figure 1:

![Reference Circuit](image1)

![Voltage Step-up Circuit](image2)

![Signal Conditioning & Acquisition](image3)

Figure 1. Structure diagram of the temperature measuring circuit

The measuring range of the temperature calibration device is (0–56)°C, with the MPE of ±0.3°C. The picture of the wireless temperature transducer is demonstrated in Figure 2:

![Wireless Temperature Transducer](image4)

Figure 2. Picture of the wireless temperature transducer
Bluetooth is adopted as the means of communication between the wireless signal generator and receiver. The transmission radius of Bluetooth is 10 m, and bandwidth is 1Mbps. The communication medium of Bluetooth is electromagnetic wave with the frequency between 2.402 GHz and 2.480 GHz. Bluetooth can also meet the needs of the designed temperature calibration device, such as point to point transmission, low power consuming and low cost.

When the temperature transducer is measuring temperature inside the centrifuge, the measured temperature values will be stored temporarily in storage chip inside the transducer. After the measurement is completed, the generator will transmit the measured temperature values through Bluetooth to the signal receiver connecting a computer. The temperature measurement results will be recorded, analyzed and demonstrated by the operating software of the calibration device installed in the computer.

3. Calibration method

Place the wireless temperature transducers in the refrigerated centrifuge in an axisymmetric way as shown in Figure 3:

![Figure 3. Axisymmetric placement of wireless temperature transducers](image)

Set the temperature of the refrigerated centrifuge at 5℃, 10℃, and 15℃ respectively. When the temperature indication of the centrifuge stabilized at the set point, keep the centrifuge running for another 30 minutes, then change the set temperature of the centrifuge to another calibration point and repeat the procedure.

Transmit the measured temperature values to the computer. In order to evaluate the temperature controlling performance of the refrigerated centrifuge effectively, find out the minimum value $t_{min}$ and maximum value $t_{max}$ of the measured temperature at each set point $t_S$ after the indication temperature is stable. The upper temperature deviation $\Delta t_{max}$ and lower temperature deviation $\Delta t_{min}$ of the calibrated refrigerated centrifuge are calculated as follows:

\[
\Delta t_{max} = t_{max} - t_S \\
\Delta t_{min} = t_{min} - t_S
\]

4. Calibration results

Using the temperature calibration device to calibrate the temperature deviation of 8 typical types of refrigerated centrifuges. The calibration results are shown in Table 1:

| Type         | TD-6M | GTR16-2 | 3-18R | H2100R | HC-30 | EPPENDO RF 5418R | FRESKO 17R | KURABO 3740 |
|--------------|-------|---------|-------|--------|-------|------------------|------------|-------------|
| $\Delta t_{max}$ | 1.8℃  | 1.8℃    | 1.7℃  | 1.9℃   | 1.6℃  | 1.6℃            | 1.3℃      | 1.2℃        |
| $\Delta t_{min}$ | -1.9℃ | -1.6℃   | -1.3℃ | -1.5℃  | -1.1℃ | -1.0℃           | -1.0℃     | -0.8℃       |

None of the temperature deviation calibration results of 8 typical types are more than 2℃, which meets the requirement of YY/T 0657-2017 Medical Centrifuge.
5. Uncertainty analysis of measurement results [6]

5.1. Standard uncertainty introduced by measurement repeatability
Utilize the calibration device to measure the temperature of a selected refrigerated centrifuge at 5°C, repeat the procedure 10 times, and the obtained values are 4.7°C, 4.5°C, 4.6°C, 4.9°C, 5.2°C, 5.1°C, 5.3°C, 5.2°C, 5.3°C, 5.2°C. Calculate the standard deviation with Bessel formula:

\[ u_1 = s = \frac{\sum x_i^2}{n-1} = 0.3°C \] (3)

5.2. Standard uncertainty introduced by the traceability of the temperature calibration device
The MPE of the temperature calibration device is ±0.3°C. Hence the uncertainty component introduced by the traceability of the calibration device is:

\[ u_2 = 0.3/2\sqrt{3} = 0.1°C \] (4)

5.3. Standard uncertainty introduced by the indication definition of the temperature calibration device
The indication definition of the temperature calibration device is 0.1°C. Considering uniform distribution, the uncertainty component introduced by the indication definition of the temperature calibration device is:

\[ u_3 = 0.1/2\sqrt{3} = 0.03°C \] (5)

5.4. Synthetic standard uncertainty
Since \( u_1 \) is positively correlated to \( u_3 \), and \( u_1 \) is more than \( u_3 \), so only take \( u_1 \) into the calculation of the synthetic standard uncertainty:

\[ u_c = \sqrt{u_1^2 + u_2^2} = 0.33°C \] (6)

5.5. Extended uncertainty
Take the inclusion factor \( k=2 \) (confidence probability is 95%), the extended uncertainty is:

\[ U = u_c \times 2 \approx 0.7°C \] (7)

6. Conclusion
This article presents a novel design of a temperature calibration device and calibration procedure for refrigerated centrifuge. The temperature calibration results of 8 typical types of refrigerated centrifuges and the uncertainty analysis shows that the calibration device and calibration procedure presented in this article can meet the requirements of the temperature calibration for refrigerated centrifuge and ensure the temperature reliability of refrigerated centrifuge in its daily use.

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