Research on Repeatability of Liquid Filling Mass Based on Weighing Method

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Abstract. The traditional dynamic flow controller has the problems of high conductivity, poor system stability and measurement accuracy. In this paper, the filling time of the liquid is controlled by the 0330 electromagnetic valve of Burkert company in Germany; the electronic balance is verified by the 100g weight of F2 grade of China Shuiling weight factory; the liquid mass after filling is measured by the bt4202s electronic balance of Sartorius company in Germany, and the repeatability of the experimental analysis of the liquid quality after filling is carried out. The experimental results show that the liquid filling mass of the device has high repeatability. It solves the problem of low repeatability of small flow liquid filling mass and has high application value.

1. Introduction

In recent years, with the rapid development of domestic pharmaceutical, food, beverage and other industries, the filling control accuracy of dynamic flow controller is required to be higher and higher for medical pharmaceutical, beverage and health care products. However, the accuracy of the electromagnetic flow controller produced so far in China cannot meet the requirements of the above industries. Therefore, to improve and improve the accuracy of dynamic flow controller has become the top priority of current research[1]. As we all know, high-precision dynamic flow controller is widely used in industry, agriculture, medicine, daily life and other fields[2]. With the continuous development of economy and technology, the relevant technology has also made some progress. At present, there are certain economic and technical strength in China to develop high-precision dynamic flow controller for filling with independent intellectual property rights.

The existing high-precision dynamic flow controllers in the market have the problems of relatively high conductivity, poor system stability and measurement accuracy[3], which cannot meet the requirements of GB17323-1998 "bottled drinking water" [4]. In this paper, the filling time of liquid is controlled by 0330 electromagnetic valve of Burkert company in Germany, and the mass of liquid after filling is measured by bt4202s electronic balance of Sartorius company in Germany, and the repeatability of liquid mass after filling is analyzed. The experimental results show that the device as shown in Figure 1 has high repeatability for the mass of filling liquid.
2. Electromagnetic Valve

2.1 Working Principle
In this paper, a two position two normally open electromagnetic valve and a two position two normally closed electromagnetic valve of Burkert company are selected. When filling liquid is needed, the upper computer gives a 5V high-level signal. However, since the electromagnetic valve needs to be driven by 24V, a drive circuit from 5V to 24V is added as shown in Figure 2(a). The drive circuit supplies 24V voltage to the normally closed electronic valve as shown in Figure 2(b), and the normally closed electromagnetic valve is opened. The liquid filling starts; similarly, when the time reaches the timer setting value, the trigger is interrupted, the drive circuit supplies 24V voltage to the normally open electronic valve, the normally open electromagnetic valve is closed, and the liquid filling ends.
3. Electronic balance

3.1 Verification of electronic balance
According to JJG 164-2000 verification regulation of liquid flow standard device [5], the bt4202s electronic balance has been verified. Since the measuring range of electronic balance is 0g-4200g, the 100g weight of F2 grade of Shuiling weight factory in Penglai City as shown in Figure 3 was used to verify the electronic balance.

3.1.1 Verification operation.
(1) Take 10 average distributed points (100g, 200g, 300g, 400g, 500g, 600g, 700g, 800g, 900g, 1000g) within the usage limit which is 4200g;
(2) Gradually load standard weight from 0g to 1000g to complete the first verification;
(3) Unload from 1000g to 0g and complete the second verification;
(4) Record the loading mass, unloading mass and electronic balance indication of each point respectively;
(5) Repeat 10 tests.

![100g standard weight of F2](image)

**Figure 3.** 100g standard weight of F2

3.1.2 Uncertainty calculation.
Refer to the calculation method of weighing instrument uncertainty specified in the verification regulation of JJJG164-2000 liquid flow standard device to calculate the uncertainty of electronic balance.

\[ \Delta m_i = R_{mi} - (m_j + R_0) \]  \hspace{1cm} (1)

In this formula: \( m_j \) - mass of the standard weight at point \( j \), kg;
\( R_{mi} \) - The indication of weighing instrument at the \( i \) times measurement of standard weight with mass \( m_j \), kg;
\( R_0 \) - Average the indication of \( n \) times measuring scale of empty container, kg.

Average of point \( j \):
\[ \Delta m = \frac{1}{n} \sum_{i=1}^{n} \Delta m_i \]  \hspace{1cm} (2)

Class A relative standard uncertainty of point \( j \) single measurement:
\[
s_{2j} = \frac{1}{m_j + R_0} \left[ \sum_{i=1}^{n} (\Delta m_i - \Delta m)^2 \right]^{1/2} \times 100\%.
\]

Class B relative standard uncertainty of point \( j \) single measurement:

\[
u_{2j} = \frac{\Delta m}{2(m_j + R_0)} \times 100\%.
\]

Class A relative standard uncertainty:

\[
s_2 = (s_{2j})_{\text{max}}
\]

Class B relative standard uncertainty:

\[
u_2 = (u_{2j})_{\text{max}}
\]

**Table 1. Uncertainty of electronic balance**

| Class A relative standard uncertainty \( S \) | Class B relative standard uncertainty \( U \) |
|--------------------------------------------|--------------------------------------------|
| 0.00005%                                   | 0.001%                                     |

For multiple measurements, the relative standard uncertainty \( s_2 \) of class A is selected as shown in Table 1, and the maximum value \( S \) is taken in \( s_2 \), so the final uncertainty \( S \) of the electronic balance as shown in Figure 4 is 0.00005%.

**Figure 4.** Sartorius bt4202s electronic balance
3.2 Using weighing method to measure liquid filling mass and calculate its repeatability

The mass of liquid filling is measured by weighing method and the repeatability is calculated by range method.

3.2.1 Measurement of liquid filling mass by weighing method.

1. Open the repeatability test procedure of the equipment, and adjust the indication of the electronic balance to zero;
2. Turn on the equipment and set the PID control of the frequency converter to 50%. Start the frequency converter and wait for the device to reach a stable state;
3. Adjust the indication of the electronic balance to zero, then click the start test button to open the electromagnetic valve;
4. Record the data of electronic balance once every 20 seconds;
5. When the data recording is completed, the liquid in the container should be poured out, and the indication of the electronic balance should be adjusted to zero at the same time;
6. Repeat steps (4) and (5).

3.2.2 Uncertainty calculation.

1. Arithmetic mean \( \bar{x} \) of \( n \) times measurements of electronic balance:
\[
\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]  
(7)

2. Calculate the experimental standard deviation \( s(x_k) \) of single measurement \( x_k \):
\[
s(x_k) = \frac{R}{C}
\]  
(8)

In the formula, \( R \) is range, i.e. \( R = x_{\text{max}} - x_{\text{min}} \), \( C \) is the coefficient of range, from table 2:

| \( n \) | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| \( C \) | 1.13 | 1.69 | 2.06 | 2.33 | 2.53 | 2.70 | 2.85 | 2.97 |

(3) When a single measurement is taken as the measured result, the standard uncertainty is:
\[
u(x) = s(x_k)
\]  
(9)

(4) When the arithmetic mean \( \bar{x} \) is taken as the measured result, the standard uncertainty is:
\[
u(x) = s(\bar{x}) = \frac{s(x_k)}{\sqrt{n}}
\]  
(10)

(5) Repeatability:
\[
S = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2}
\]  
(11)

| Average value of scale indication | Repeatability |
|---|---|
| 47.447g | 0.07767% |
| 112.029g | 0.08731% |
### 4. Conclusion

Through the verification of electronic balance, and the use of weighing method and normally open and normally closed electromagnetic valve, the experimental results show that the repeatability of filling liquid mass is within 0.15% after multiple measurements as shown in Table 3, which has a high repeatability. This method solves the problem of low repeatability of small flow liquid filling mass in enterprises, and has a high application value.

### References

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