Investigation on Sampling Flow Rate Calibration Method of Air Sampler

Jin Song, Chao Chen, Yiping Liu, Haiyang Li

Shanghai Institute of Measurement and Testing Technology, Shanghai Key Laboratory of On-line Testing and Control Technology，Shanghai 201203, China

E-mail: songj@simt.com.cn

Abstract

In order to obtain the most accurate and effective sampling flow rate calibration method of air sampler, several different equipments were used under two different installation conditions in this paper. According to the experimental results, the calibration results of ultrasonic flowmeter and special orifice flowmeter will be affected by the installation conditions. Consequently, while ultrasonic flowmeter and special orifice flowmeter are used to sampling flow rate calibration, it is necessary to first calibrate the two flowmeters with filter paper, and then use the corrected results to calibrate the sampling flow rate. Based on the results of further experiments, calibration datas of gas roots flowmeter and special orifice flowmeter are consistent with the results obtained from gas flow standard facilities by negative pressure method, at the same time, there is still an error of 3%~5% when corrected ultrasonic flowmeter is used. Therefore, gas flow standard facilities by negative pressure method and gas roots flowmeter can be directly used for sampling flow rate calibration of air sampler, if it is not convenient , special orifice flowmeter which calibrated with filter paper is also a good choice, ultrasonic flowmeter is not recommended.

***Keywords*:** air sampler; flow rate calibration; special orifice flowmeter; ultrasonic flowmeter

1. Introduction

Air sampler is one of the important equipment for environmental monitoring, which is mainly used to collect atmospheric particulate matter. The accuracy of sampling flow rate directly affects the reliability of monitoring data[1]. A typical air sampler, as shown in Figure 1, is composed of sampling pump, flow measurement device, filter holder and filter paper. Usually the flow measurement adopts the principle of differential pressure, and the sampling flow rate is calculated by measuring the differential pressure between the air inlet and outlet [2].

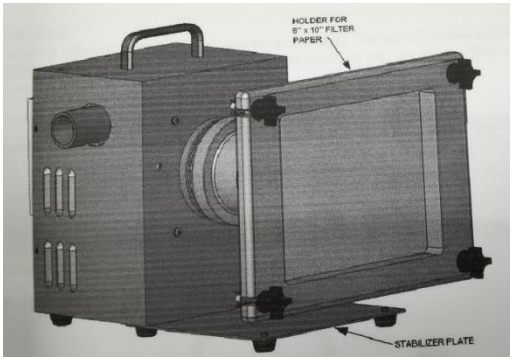

Figure 1: A typical air sampler.

There is no uniform calibration method at present for sampling flow rate of air sampler. According to previous experience, the most commonly used equipment in the laboratory for its flow calibration is gas flow standard facilities by master method, for ease of operation, gas roots flowmeter and low-pressure ultrasonic flowmeters are also used. In recent years, with the emergence of special orifice flowmeter, because it is easy to carry, simple to operate, it is widely used in field calibration for sampling flow rate of air sampler[3]. Figure 2 shows the device structure used by manufacturer to calibrate its flow rate, the flowmeter used is similar to a special orifice flowmeter [4].

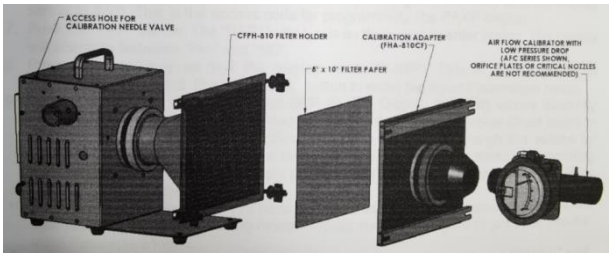

Figure 2: The device structure used by manufacturer for sampling flow rate calibration

In this paper, four different devices were used to calibrate the sampling flow rate, at the same time, we compared the calibration results under different installation conditions. According to the experimental results, the most accurate and effective sampling flow rate calibration method of air sample can be determined, the relevant results

and methods can also provide reference for the formulation of relevant technical basis.

2. Experimental equipments and installation conditions

According to previous experience, gas flow standard facilities by master method, gas roots flowmeter, ultrasonic flowmeters and special orifice flowmeter are selected to calibrate the sampling flow rate. Two different installation conditions are referred to the filter paper installed and no filter paper installed at the air sampler inlet.

2.1 Gas flow standard facilities by master method

Gas flow standard facilities by master method is the most commonly used gas flow standard facilities, it is composed of gas roots flowmeter, gas turbine flowmeter, temperature transmitter, pressure transmitter and so on. Figure 3 shows the gas flow standard facilities used in this paper, with measurement range (0.5~7500)m^3/h, uncertainty of measurement is 0.30%(k=2). Other devices described below can also be traced to this standard facilities.

Figure 3: Gas flow standard facilities by master method.

When we test with this standard facilities, we can use the fan on the unit as the power source, since the sampler comes with a sampling pump, we can also use it to provide power. The pipeline connection during the test is shown in Figure 4. We conducted the test under two different installation conditions, namely the filter paper installed and no filter paper installed at the air sampler inlet.

Figure 4: The pipeline connection.

2.2 Gas roots flowmeter and ultrasonic flowmeter

The roots flowmeter and ultrasonic flowmeter all have the characteristics of high precision, good reliability, the difference is roots flowmeter is less affected by installation conditions, on the contrary, ultrasonic flowmeters are susceptible to flow field in pipes. Therefore, when we use roots flowmeter to test the air sampler, we can directly connect it to the air sampler, without the need for straight pipe section. The pipe connection is shown in Figure 5. Similarly, when using ultrasonic flow, we need to install a straight section of sufficient length in front and behind the flowmeter to meet its requirements, as shown in Figure 6.

Figure 5: The pipeline connection when roots flowmeter used.

Figure 6: The pipeline connection when ultrasonic flowmeter used.

2.3 Special orifice flowmeter

Special orifice flowmeter is based on differential pressure principle, because of its simple structure, easy to carry, so widely used in atmospheric environment flow measurement[5]. The specially machined orifice flowmeter can be directly connected to the sampler's filter holder, as shown in Figure 7, making it easy to measure the air sampler's flow rate.

Figure 7: The pipeline connection when special orifice flowmeter used.

3. Experimental results and analysis

In this article, we first test the same air sampler using gas flow standard facilities by master method, the test flow points are 1400L/min, 1050L/min, 720L/min, 360L/min and 280L/min. During the test, two different power supply methods were used, namely, powered by standard facilities(negative pressure) and air sampler (positive pressure) respectively. At the same time, the standard facilities and air sampler are installed under two different installation conditions, two different installation conditions are referred to the filter paper installed and no filter paper installed at the air sampler inlet. The relevant experimental results are shown in Table 1.

Table 1: The experimental results of different test conditions when gas flow standard facilities by master method used.

Test conditions	Errors(%)				
	1400 L/min	1050 L/min	720 L/min	360 L/min	280 L/min
negative pressure, no filter paper installed	-6.57	-6.15	-7.95	-16.75	-16.11
negative pressure, filter paper installed	-6.79	-6.16	-8.33	-16.14	-16.46
positive pressure, no filter paper installed	-5.12	-6.08	-8.99	-14.60	-13.76
positive pressure, filter paper installed	-5.26	-6.19	-8.52	-11.86	-11.97

The experimental results show that when the sampling flow rate is calibrated directly by standard facilities in the flow range(280~1400)L/min, filter paper has no effect on its calibration data, however, the calibration results of positive pressure and negative pressure are very different, especially at small flow rate, the error is 5% or more. This is because when using the positive pressure method, the connection of pipes between sampler and gas flow standard facilities is equivalent to increasing the load at the sampler outlet, so the pressure difference between the air inlet and outlet becomes larger, thus the the sampling flow rate also increases.

In addition, it can also be seen from the experimental results(Table 2) that when the three flowmeters are calibrated by the gas flow standard facilities, the gas roots flowmeter is not affected by installation conditions, but the calibration results of ultrasonic flowmeter and special orifice flowmeter will be affected by the installation of filter paper. For ultrasonic flowmeter, because of the installation of filter paper has an impact on the flow field at the back end of the flowmeter, calibration data with or without filter paper at the outlet varies by more than 12%. For special orifice flowmeter, this effect is relatively small, mainly on large flow rate, but also not more than 3%.

Table 2: The experimental results of different flowmeters calibrated by the gas flow standard facilities under different test conditions.

Flowmeters and test conditions	Errors(%)				
	1400 L/min	1050 L/min	720 L/min	360 L/min	280 L/min
gas roots flowmeter, no filter paper installed	-0.76	-0.87	-0.81	-0.96	-0.94
gas roots flowmeter, filter paper installed	-0.78	-0.83	-0.86	-0.89	-0.92
ultrasonic flowmeter, no filter paper installed	-1.14	-0.96	-1.75	-2.02	-1.42
ultrasonic flowmeter, filter paper installed	-20.18	-22.91	-26.94	-32.69	-35.87
special orifice flowmeter , no filter paper installed	-1.65	2.67	1.34	9.90	11.66
special orifice flowmeter , filter paper installed	1.00	2.30	1.56	9.02	11.60

Consequently, while ultrasonic flowmeter and special orifice flowmeter are used to sampling flow rate calibration, it is necessary to first calibrate the two flowmeters with filter paper, and then use the corrected results to calibrate the sampling flow rate. Table 3 shows the corrected errors of the flow rate of air sampler with filter paper calibrated by gas roots flowmeter, ultrasonic flowmeter and special orifice flowmeter. According to the experimental results, calibration datas of gas roots flowmeter and special orifice flowmeter are consistent with the results obtained from gas flow standard facilities by negative pressure method, at the same time, there is still an error of 3%~5% when corrected ultrasonic flowmeter is used.

Table 3: The corrected errors of the flow rate of air sampler with filter paper calibrated by gas roots flowmeter, ultrasonic flowmeter and special orifice flowmeter.

Flowmeter used in calibration	Corrected errors (%)				
	1400 L/min	1050 L/min	720 L/min	360 L/min	280 L/min
gas roots flowmeter	-6.89	-6.34	-7.76	-15.96	-15.45
ultrasonic flowmeter	-9.73	-11.47	-13.83	-19.00	-20.26
special orifice flowmeter	-6.81	-6.14	-8.76	-16.49	-15.95

4. Conclusion

The accuracy of air sampler sampling flow rate directly affects the accuracy and reliability of environmental monitoring data. In order to obtain the most accurate and effective sampling flow rate calibration method of air sampler, several different equipments were used under two different installation conditions in this paper. According to the experimental results, gas flow standard facilities by negative pressure method and gas roots flowmeter can be directly used for sampling flow rate calibration of air sampler in the laboratory. If it is not convenient, such as the calibration of air sampler used in the fields, special orifice flowmeter which calibrated with filter paper is also a good choice. At any time, ultrasonic flowmeter is not recommended.

References

[1] Kenneth M. Hart, Lorne M. Isabelle, and James F. Pankow, “High-volume air sampler for particle and gas sampling. 1. Design and gas sampling performance”, *Environmental Science and Technology,* **26(5)**, 1048-1052, 1992.

[2] J Klanova, J Kohoutek, L Hamplova, “Passive air sampler as a tool for long-term air pollution monitoring: Part 1. Performance assessment for seasonal and spatial variations”, *Environmental Pollution,* **144**, 393-405, 2006.

[3] Caizhe Hao, Xiaoming Song, Zhining Jia, “Influence of the Hole Chamfer on the Characteristics of a Multi-hole Orifice Flowmeter”, *Fluid Dynamics & Materials Processing,* **4**, 391-401, 2019.

[4] HI-Q Environmental products company,inc., Portable high volume air samplers, https://www.hi-q.net/product-category/portable-high-volume-air-samplers/.

[5] Bukhari Manshoor, Amir Khalid, “Numerical investigation of the circle grids fractal flow conditioner for orifice plate flowmeters”, *Applied Mechanics & Materials,* **229-231**, 700-704, 2012.