The flow performance testing device of the ambient air sampler

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Abstract

In this paper, the flow measurement performance of the ambient air sampler is studied, which is widely used in environmental monitoring, health care and mining enterprises. The paper develops the flow rate performance test device of ambient air sampler, which consists of the high-low temperature test device, the load performance test device, the flow standard device and the pressure measurement device. For various types of ambient air samplers and its calibrators, the device can carry out flow performance tests with the flow range of 10mL/min~265L/min, with flow indication error no more than ±2%, the high-low temperature tests with the range of (-20~40)℃, and the load performance tests in the range (-50~0)kPa. The uneven capability of temperature adaption of different types of samplers or from various manufacture is found through experiments research, but the flow metering performance of samplers is significantly improved compensated by temperature in this paper. In the load test, the sampler load condition of different ranges or manufacturers are different, which meets the requirement of more than 50% the air extraction capacity.

1 Introduction

Currently, the monitoring of ambient air pollutants adopts the combination method of physical and chemical at home and abroad[1-3], and the sampler to capture pollutants in the ambient air[4-5]. Therefore, strengthening the measurement performance study of the ambient air sampler is beneficial to unifying the on-site traceability method, perfecting the traceability system realizing the accuracy measurement of instrument and equipment. It provides uniform measurement performance standard for production enterprises, technical support for environmental monitoring and management, and has good social and economic benefits.

Based on the isothermal measurement method used by Guo Gang[6-9] and the design concept of Yue Jin[10-15] on the new gas flow standard device, this paper designs and develops the ambient air sampler flow performance test device, including the high-low temperature experimental device, the load performance experimental device, the flow standard test device and the pressure measurement test device. The device can perform the following performance tests on different types of samplers and its calibrators: the flow performance tests with the flow range of 10mL/min~265L/min , the flow indication error not exceeding ±2%, the high-low temperature tests with temperature range of (-20~40)℃ and the load performance tests with load range of (-50~0) kPa .

2 The high-low temperature experimental device

The high-low temperature experimental device shown in Figure 1 is mainly composed of cooling tower, with refrigeration device, dehumidifier, heater, constant temperature and constant flow box, ambient air sampler, heat exchanger, flow standard device, etc. Based on the un-isothermal measurement principle, the ambient air

sampler is put in the thermostat filled with high temperature (low temperature) gas to simulate fully the metering performance of the ambient air sampler under the actual working condition and ambient temperature. The test device is conduct the high-low temperature tests in the temperature range (-20~40)℃. The negative pressure method of sampling in its working process is that the sampling pump of the sampler draws the gas in the constant temperature test chamber to the inlet, the heat exchanger and the standard device, and extracts it from the outlet of the sampling pump. The test gas is sent to the incubator after being dehumidified by the dehumidifier. The high temperature environment is heated by the heater in incubator, the low temperature environment is cooled by the refrigerator outside the box. After the heated or cooled gas in the incubator reaches the preset temperature, it flows out of the sampler to the heat exchanger outside the incubator for heat exchange to keep the temperature of the gas flowing through the standard at (20±5)℃. After flowing through the standard, the test gas is discharged from the outlet of the sampling pump.

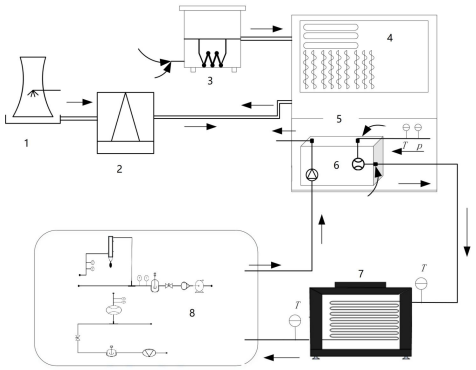

Figure 1: The high-low temperature experimental device

Note: 1-The cooling tower, 2-The refrigeration device, 3-The dehumidifier, 4-The heater, 5-The constant temperature constant current box, 6-The ambient air sampler, 7-The heat exchanger, 8-The flow standard device

3 The load performance test device

The load performance test of ambient air sampler is completed by connecting the sampler with the standard in the laboratory environment. It is mainly composed of the flow standard device, the triplet, the pressure regulating valve, the pressure gauge, the temperature and pressure measuring unit, as shown as Figure 2. The test device can carry out the load performance test in the range (-50~0)kPa and adopts the principle of negative pressure method. The sampling pump of the ambient air sampler operates to generate the pressure difference value at both ends of the connecting pipeline. The air is sucked into the flow standard device, then pumped to the sampler through the pressure regulating valve and the three-way connecting pipe, and finally discharged from the outlet of the sampler. The tee is connected with the pressure regulating valve to adjust the pipeline load, the pressure gauge to measure the pipeline load between the pressure regulating valve and the sampler; and the tested sampler. Adjusted the aperture of the pressure regulator valve according to the difference value between the pressure gauge and the preset to stabilize the pipeline load to the preset pressure.

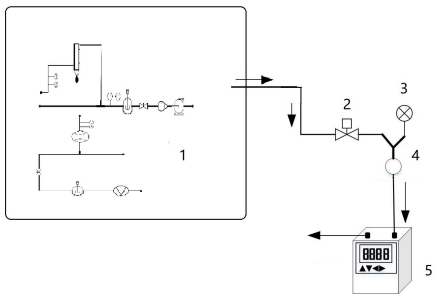

Figure 2: The load performance test device

Note: 1-The flow standard device, 2-The pressure regulating valve, 3-The electronic pressure gauge, 4-The tee, 5-The ambient air sampler

4 The flow standard device

4.1 The electronic soap film flowmeter

The ambient air sampler with the sampling flow range of 10mL/min~6000mL/min with motive power, the electronic soap film flowmeter measurement pipeline shown in Figure 3 is used for parameter traceability and transmission. First, connect the air inlet and outlet A of the test sampler with the hose, close the pipeline pressure sensor pipeline, and open the outlet A pipeline; then turn

on the test sampler and the electronic soap film flowmeter (the flow range is (1~6) L/min) to calibration. At the process, the gas flow direction is ambient air→1→2→3→4→5→6. This is the measurement mode of the electronic soap film flowmeter.

For the ambient air sampler with the sampling flow range of 10mL/min~6000mL/min without motive power, the electronic soap film flowmeter measurement pipeline shown in Fig.3 is used for parameter traceability and transmission. The process is as followed: first, connect the air outlet and the air inlet of the calibrator with the hose (see Fig.3), and close the air outlet A; then, turn on the calibrator and the electronic soap film flowmeter (the flow range is (1~6)L/min), and turn on the gas sampling pump (the speed of the gas sampling pump is adjusted through the data fed back by the pressure sensor and temperature sensor); finally, adjust the flow to the working flow point through the manual regulating valve, and start calibration after the flow is stable. So, the gas flow direction is ambient air→1→2→3→4→5→7→8→9→10→11→12→13. This is the control mode of the electronic soap film flowmeter.

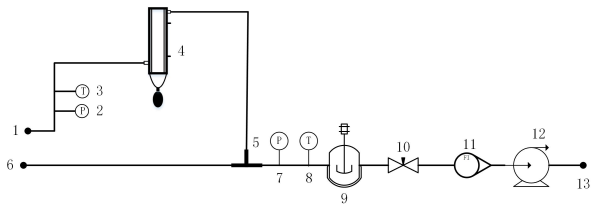

Figure 3: The electronic soap film flowmeter measurement part of flow standard device

Note: 1-The air inlet, 2-The front pressure sensor of flow-meter, 3-The front temperature sensor of flow-meter, 4-The electronic soap film flowmeter, 5-The three way solenoid valve, 6-The air outlet A, 7-The pressure sensor, 8-The temperature sensor, 9-The buffer tank, 10-The manual regulating valve, 11-The rotameter, 12-The gas sampling pump, 13-The air outlet B

4.2 The roots flow-meter

For the ambient air sampler with the flow range of 6L/min~265L/min with motive power, the roots flow-meter measurement pipeline is used for parameter traceability and transmission shown in Fig.4. The roots flowmeter has measurement mode and control mode. Connect the air inlet of the test sampler and outlet A with a hose, close the pipeline of the manual control valve, open the pipeline of the outlet A, and start the test sampler and the roots flow-meter to calibration. The gas flow direction is ambient air→1→2→ 3→4→5→6. This is the measurement mode of the roots flowmeter.

For the ambient air sampler with sampling flow range of 6L/min~265L/min without motive power, the roots flow-meter measurement pipeline is used for parameter traceability and transmission shown in Figure 4. The air outlet of the calibrator is connected with the air inlet through a hose, and close the air outlet a pipeline, and open the three-way manual control valve pipeline, and open the calibrator and the roots flowmeter; set the sampling flow of the gas sampling pump above the common working flow point of the calibrator, adjust the flow to the working flow point through the manual control valve, and start calibration after the flow is stable. The gas flow direction is ambient air→1→2→3→4→5→7→8→9→10. This is the control mode of the roots flow-meter.

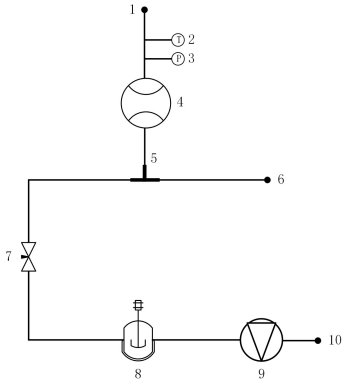

Figure 4: The roots flow-meter measurement part of the flow standard device

Note: 1-The air inlet, 2-The temperature sensor in front of flow-meter, 3-The pressure sensor in front of flow-meter, 4-The roots flow-meter, 5-The three way solenoid valve, 6-The air outlet A, 7-The manual regulating valve, 8-The buffer tank, 9-The gas sampling pump, 10-The air outlet B

5 The pressure measuring device

Trace to the source of the front pressure of the flow-meter, the static pressure and the load capacity of the ambient air sampler, and use the automatic addition and subtraction pressure measuring pipeline pressure shown in Figure 5. Connect the addition and subtraction pressure interface, the front pressure of the flow-meter/static pressure interface of the sampler and the gauge pressure measuring interface through the tee. The positive pressure and negative pressure are applied continuously and evenly through the automatic addition and subtraction pressure device.

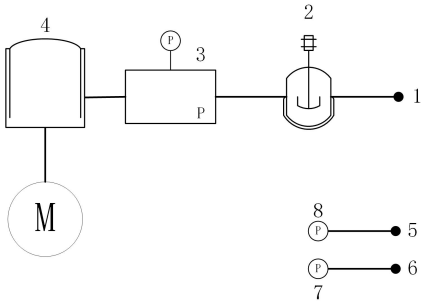

Figure 5: The addition and subtraction pressure measurement of the flow standard device

Note: 1-The addition and subtraction pressure interface, 2-The buffer tank, 3-The pipe pressure sensor, 4-The addition and subtraction pressure device, 5-The micro pressure measuring interface, 6-The gauge pressure measuring interface, 7-The gauge pressure sensor, 8-The micro pressure sensor

When the pressure is calibrated and traced, 1, 2, 3, 4, 6 and 7 are under the same pressure environment (shown in Fig.5). The addition and subtraction pressure device is composed of the screw nut drive system, the drive motor (frequency conversion), the manual gas collector and the nut collector connecting rod. When it is necessary to trace the source of the dynamic pressure of the ambient air sampler, the automatic addition and subtraction pressure measuring pipeline shown in Fig.5 is used for pressure tracing and transmission. The external three-way connecting valve connects the addition and subtraction pressure interface, the dynamic pressure interface of the sampler and the micro pressure measuring interface. The positive pressure is applied continuously and evenly through the automatic addition and subtraction pressure device. When the micro pressure sensor is used to test the pressure for calibration, 1, 2, 3, 4, 5 and 8 are under the same pressure environment.

6 Conclusion

The device designed in this paper can be used to test the flow performance of active and passive ambient air samplers and its calibrators of different manufacturers and models in the flow range of 10mL/min~265L/min at low temperature, normal temperature and high temperature. There are some differences in the temperature adaptability of samplers with different types and production enterprises, but the flow-meter stability performance of the sampler significant improvement with the temperature compensation of the ambient air sampler in the temperature range of (-20~40)℃ is established by linear fitting error distribution.The load condition is different with the flow rate range and the manufacture various under satisfying the requirement of the air extraction capacity of more than 50%,but suggested that the ambient air sampler should be applied under the condition of the pipe load pressure less than 20kPa to ensure the metering performance of flow-meter.

References

[1] Zhang Huiling, On site quality control countermeasures for air monitoring of environmental protection engineering[J], Leather making and environmental protection technology, 2022,3 (07): 52-54, DOI: 10.20025.

[2] Han Kangda, Quality control of air monitoring site in environmental engineering[J], Chemical engineering design communication, 2022,48 (03): 167-170.

[3] Zhou Zeyi, Zhou Yunchang, Guo Liang, Liu Bo, Development of on-line calibration device for ambient air monitoring gas analyzer[J], Chemical analysis and measurement, 2022,31 (03): 78-82.

[4] Yu Guannan, Quality assurance and control of automatic monitoring of ambient air quality[J], Chemical engineering and equipment, 2022 (02): 248-249 ,DOI:10.19566.

[5] Huang Hongxun, Research on the development and advantages of automatic monitoring of ambient air quality[J], New industrialization, 2021,11 (12): 45-46 +52 ,DOI:10.19335.

[6] Guo Gang, Jiang Hangcheng, Yang Lei, Discussion on testing method of limiting temperature error of membrane surface[J], Measurement technology, 2016 (3): 33-34

[7] Guo Gang, Yang Lei, Jiang Hangcheng, Design of membrane meter test device under extreme temperature[J], Industrial measurement, 2016, 26 (2): 47-50.

[8] Zhang Yue, Performance test of virtual cyclone biological aerosol sampler[D] , Wuhan: Huazhong Agricultural University, 2017

[9] Wang Gan, Evaluation of uncertainty of flow measurement under load condition of atmospheric sampler[J], Measurement and testing technology, 2015, 42 (3): 92-93.

[10] Yue Jin, Yang Yuanchao, Study on measurement performance test of 10 kPa gas piston pressure gauge[J], Journal of metrology, 2022,43 (04): 507-512.

[11] Xie Fei, Development of field gas flow standard device[D], Hebei University, 2021, DOI:10.27103.

[12] Lu Chun, Zhang Liang, Gu bin, Liu Xinxin, Application of small and micro gas flow standard device based on laminar flow technology[J], Instrument standardization and measurement, 2021 (05): 35-37+48.

[13] Chen Chao, Zhu Biyu, Shen Qiong, Calibration of piston type gas flow calibrator with positive pressure gas flow device[J], Measurement and testing technology, 2021,48 (06): 88-90, DOI:10.15988.

[14] Feng Jiaming, Wu Tingfeng, Li Sicong, Development of a new combined bell jar gas standard device[J], Metrology science and technology, 2021,65 (03): 71-74+62.

[15] Cui bao, Shang Zengqiang, Ma Bin, Development of electronic soap film flow standard device[J], Industrial measurement, 2021,31 (01): 50-52, DOI:10.13228.