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ARTICLE

Study on Calibration period of Gas Sensor in Exercise Pulmonary Function Instrument

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ABSTRACT

Objective: to study the calibration period of the main motor pulmonary function instrument sensor. Methods: A matched control group was used, one was calibrated periodically and the other was not calibrated. The calibration values of oxygen sensor and carbon dioxide sensor were compared. Results: the oxygen sensor of electrochemical type was most sensitive to the change of time and environment, and the carbon dioxide sensor of infrared type was more sensitive to the change of time and environment. Conclusion: oxygen sensors of electrochemical type and carbon dioxide sensors of infrared type should be calibrated before each use.

1. Introduction

Pulmonary function examination plays a very important role in the diagnosis of respiratory system diseases and is an important part of chest and lung diseases and respiratory physiology. The International Space Station has already carried out regular pulmonary function tests in orbit. With the further development of the space station mission in China, it is necessary to check the astronauts' lung function regularly in order to stay in orbit for a long time and ensure the health of the astronauts in orbit.[1]

The exercise pulmonary function instrument is a portable device to detect the volume and rate of inhaled and exhaled gases in order to understand whether the respiratory physiology and respiratory function are normal.[2] Because the pulmonary function test is a medical examination item

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which is easy to be influenced by many factors, and the performance difference of the exercise pulmonary function instrument itself,[3] it is very necessary to carry on the quality control to the exercise lung function instrument. In developed countries, the American Thoracic Association (ATS), the European Society of Respiratory (ERS), successively formulated the quality Test Standard for Pulmonary Functionometers.[4] In 2008, China promulgated the JJF1213-2008 Standard for the Calibration of Pulmonary Functionometers.[5]

Exercise pulmonary function instrument is a kind of instrument with high precision, high sensitivity and multi-sensor. In order to ensure the validity of the test data, it is necessary to calibrate the sensor coefficient of the instrument regularly to compensate for the influence of the surrounding environment on the instrument.[6]

2. Calibration Principle

The movement lung function instrument mainly consists of the lung meter, the gas analyzer and the pressure gauge, through their combination, may measure the lung function the majority index.

The main stream of pneumometers is velocity measurement, which has the advantages of small volume and easy operation. The principle is to measure the rotational velocity of rotating parts (impellers or turbines) in direct proportion to the velocity of the fluid. According to the law of physics, let the volume flow rate of a given moment be Q, the volume of fluid flowing in a certain time t is V, then V = dV/ Qdt or Q = dV/ DT,[7] that is, the velocity of the fluid flowing through a pipe with a certain cross-sectional area is first measured. Then work out the flow rate. The impeller or turbine rotates when the airflow passes. The impeller adopts the principle of optoelectronic modulation, and the turbine adopts magnetoelectric modulator by optoelectric effect. By magnetoelectric effect, the mechanical rotation signal of impeller or turbine is converted into electrical signal output.

The principle of gas analyzer is electrochemical analyzer, which converts the chemical quantity of measured medium (such as O_2) into electric quantity by electrochemical reaction on the interface of electrode medium. The basic measuring system includes electrolyte solution, electrode and measuring circuit. Once activated, continuous chemical reactions consume electrolyte solutions and electrodes, leading to a shorter service life (usually half a year to one year).[7] CO_2 monitoring is based on the infrared absorption principle.[8]

The pressure gauge is the diaphragm offset type. The displacement signal is converted into electrical signal output[9] by the displacement of the diaphragm relative to the measured pressure sensing element, and the displacement signal is marked and recorded.

3. Test Design

The calibration experiment was carried out by the matched control group method. The test objects were two same type instruments defined as C01-01 and C01-02, respectively. The performance indexes of the two machines were the same as those of C01-01 and C01-02. Before the start of the test, the same set of calibration equipment was used for calibration. The test period was 210 days. During the period, the C01-01 machine was not calibrated and the C01-02 machine was calibrated regularly (about 15 days). After the calibration was completed, the two products were calibrated and checked with standard gas cylinders. The change of sensor index was recorded in real time. Throughout the calibration test, the same set of gas sampling tubes and turbine sensors are used to ensure gas sampling tubes and turbine transmissions. The effect of the inductor on the two products is the same.

The test environment is as follows: temperature is 22℃ to 27℃ , humidity is 10% to 60 mm, atmospheric pressure is 1002 mmHg to 1028 mm Hg. In the analysis of test data, the influence of ambient temperature, humidity and atmospheric pressure on product calibration is not considered.

This experiment is to study the sensitivity of gas sensors (including carbon dioxide sensors, oxygen sensors) to time-varying changes. The instrument is the product of Cortex's MetMax3B Sports Lung Function Instrument. Specific types of sensors are shown in Table 1.

Table 1. Types and Indicators of Sensors

Name	Type measurement	Range	Error
Carbon dioxide sensor	NDinfrared	0 ～ 12.4 Vol %	0.1Vol%
Oxygen Sensor	Electrochemical sensor	5.05 ～ 21.8Vol%	0.1Vol%

4. Experimental Results Analysis

4.1 C01-02 Gas Calibration and Analysis

C01-02 was calibrated first. Figure 1 shows the offset curves of the O_2 and CO_2 sensor coefficients. It can be seen from the diagram that the maximum value of sensor coefficient offset is 0.367, the minimum value is -0.285, the maximum value of sensor coefficient deviation is -0.021, the minimum value is -0.006, and the fluctuation amplitude is 0.15. It shows that the amplitude of the shift of the sensor coefficient of O_2 is larger than that of the CO_2.

Calibration checks are performed using ambient air and standard gas sources provided by Cortex. The gas composition of the surrounding air is by default a standard value, that is, the content of O_2 is 20.93 Vol. and the content of

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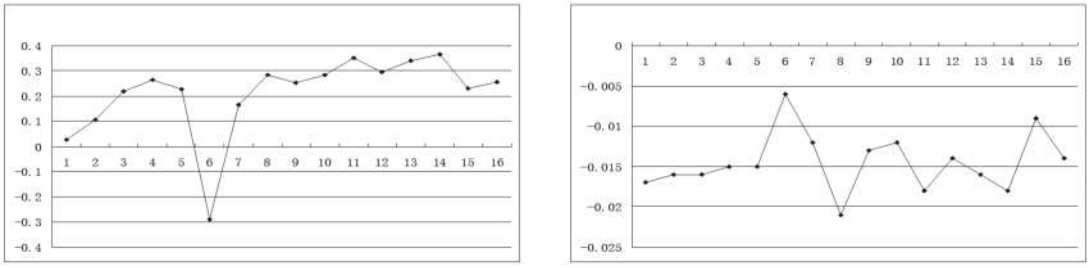

Figure 1. C01-02 O_2 and CO_2 Sensor Coefficient Offset Curves

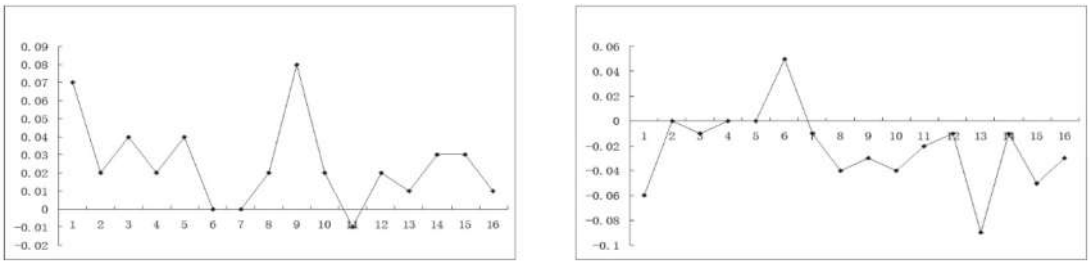

Figure 2. C01-02 Gas Calibration to Check O_2 Offset

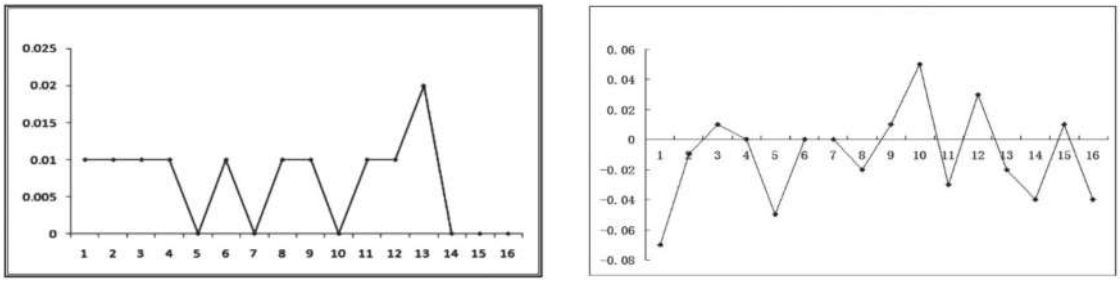

Figure 3. C01-02 Gas Calibration check for CO_2 Offset

Table 2. C01-02 Gas Calibration Results

Gas types	Use of ambient gases offset (Vol. %)	Use of standard gases offset (Vol. %)	Use of standard gases offset (Vol. %)	Results
O_2	0.08 ～ -0.01	-0.09 ～ 0.05	0.1	After the instrument is calibrated, O2 detection of ambient air and standard gas meets the requirements of the specifications.
CO_2	0.02 ～ 0	-0.07 ～ 0.05	0.1	After the instrument is calibrated, O2 detection of ambient air and standard gas meets the requirements of the specifications.

Table 3 Calibration Results of C01-01 Gases

Gas types	Use of ambient gases offset (Vol. %)	Use of standard gases offset (Vol. %)	Use of standard gases offset (Vol. %)	Results
O2	0.57 ～ -0.08	0.29 ～ -0.13	0.1	There are four points of excess displacement in the surrounding air; The standard gas has 8 points of excess offset.
CO2	0 ～ -0.02	-0.22 ～ 0.13	0.1	The ambient air meets the target requirements; The standard gas has 5 points of excess offset.

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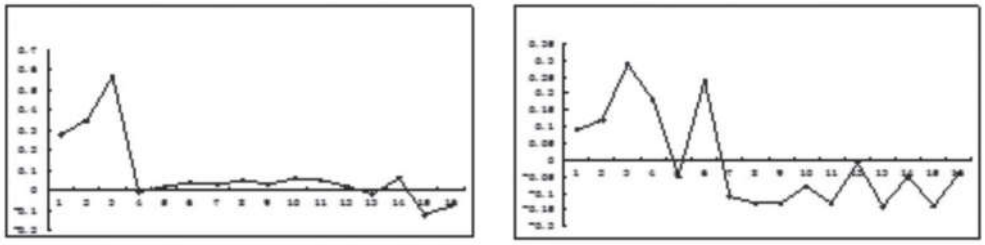

Figure 4. C01-01 Gas Calibration to Check O_2 Offset

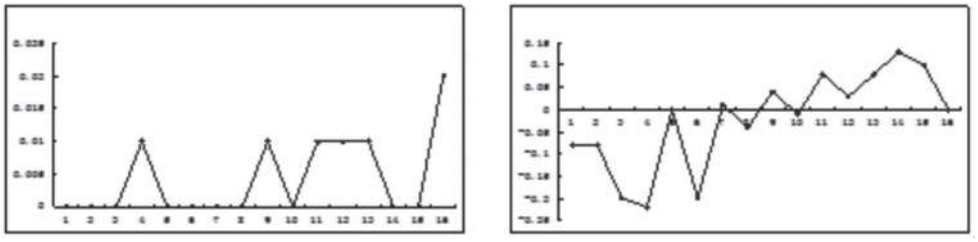

Figure 5. C01-01 Gas Calibration to Check CO_2 Offset

CO_2 is 0.03 Vol. the standard gas component provided by Cortex is the content of 15. 00 Vol. and the content of CO_2 is 5.00 Vol.

Figure 2 shows the O_2 offset for the C01-02 gas calibration check, and figure 3 for the C01-02 gas calibration check CO_2 offset, as shown in Table 2.

4.2 Analysis of Gas Calibration Inspection for C01-01

C01-01 product as control group, in the course of the test no calibration settings, only for calibration inspection. Gas calibration checks are performed on ambient air and standard cylinders, as with C 01-02 products. Figure 4 shows the O^2 offset for the C01-01 gas calibration check and figure 5 for the C01-01 gas calibration check CO_2 offset, as shown in Table 3.

Results: Compared with Table 2 and Table 3, the oxygen sensor drifts greatly with time, and is most sensitive to time and environmental changes. It needs to be calibrated regularly. The carbon dioxide sensor becomes unstable with time, sensitive to time and environmental changes, and needs to be calibrated regularly.

5. Conclusion

Based on the above results, the following conclusions are obtained, which can be applied to the same type of sensors.

The electrochemical oxygen sensor is the most sensitive to the change of time and environment. It is suggested that the sensor should be calibrated before each use; the infrared carbon dioxide sensor is sensitive to time and environment, so it is recommended to calibrate it before each use. If the error is beyond the range after calibration, the sensor coefficient can be calibrated several times.

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