A Test Method for Testing the Flow of Air Oxygen Supply Equipment

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With the development of aviation military and civilian aircraft, the aviation oxygen supply equipment also has higher technical improvements and system innovations. In order to simulate the work of aviation oxygen supply equipment and accurately test the volume flow under high altitude condition, the flow detection method of damping equipment is adopted to detect the flow of oxygen equipment. The gas density correction is not needed during the testing process. The range setting, damper tube structure and other aspects are described, the test principle, identification/calibration methods were studied and verified and the flow test method has been applied for the new test equipment.

I. Nomenclature

Q =Flow through the damper tube
q =Flow through the capillary tubes
ΔP =Pressure difference formed when flow Q flows through the pressure tapping section
M =Dynamic viscosity coefficient of the flow medium
L =Length of pressure tapping section
r =Filling density
R =Density of glass fiber
D =Diameter of the inner cylindrical cavity in the damper tube
F =Oxygen content percentage (%) of gas output by the oxygen regulator
Q_{mix} =Environment volume flow ratio L/min of the gas output by the oxygen regulator
Q_{oxygen} =Environment volume flow L/min of oxygen input into the system terminal
Q_{air} =Environment volume flow L/min of the air sucked in by the oxygen regulator
Q_{use} =Regulating flow L/min consumed by the regulator to establish the small residual pressure

II. Introduction

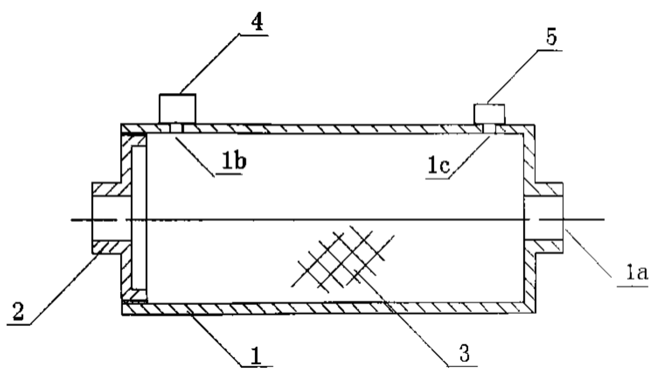
Establishing and measuring the volume flow under the negative pressure at a given or any cockpit height (generally 0~10km) is a major function of the flow measurement device for aviation oxygen supply equipment [1-3]. As the altitude of the cockpit increases, the ambient air pressure declines exponentially, when a rotameter or orifice flowmeter is used to measure the volume flow at different altitude, due to different pressure of the gas flowing through the flowmeter, it is needed to correct the calibration value of the flowmeter against the pressure value corresponding to the cockpit altitude one by one. This brings a lot of trouble to the measurement and calibration work. Take the orifice flowmeters with 4 ranges (0.006-0.06 L/min,0.06-0.6 L/min,0.5-5,4-40L/min) and 2 ranges (40-160 L/min,160-600 L/min) provided for the French SBU-5 measurement device for oxygen supply equipment as an example, these two groups of flowmeters are calibrated against the air medium under the condition of 101.325kPa pressure and 15℃temperature, when the rotameter and orifice flowmeter are used to measure air volume flow at high altitude, because the density of the medium varies with cockpit altitude, when the volume flow at each given or any altitude is measured, calculation for pressure correction must be performed. For the measurement with orifice flowmeter, it is also needed to obtain the pressure difference between the two ends of the orifice plate according to the magnitude of the flow when the operating pressure is calculated, which makes the measurement work tedious [5,6]. Therefore, this paper thinks that it is not a reasonable scheme to use rotameter or orifice flowmeter to measure the volume flow at high altitude in the measurement device for oxygen supply equipment. In recent years, European and American countries began to use electronic mass flowmeter to measure volume flow[7-9]. Because measurement involves the density of the medium, it is also needed to make corresponding correction calculations when it is used for measurement of volume flow at high altitude[10].

Because the essence of correction calculation of the damper tube type flow detection device under the operating condition is the correction of dynamic viscosity of the gas medium rather than correction of density of the gas medium, when it is used for measuring the volume flow at different cockpit altitude, unlike the rotameter and orifice flowmeter, which are corrected one by one according to different pressure related to medium density, flow characteristic curve of the flowmeter calibrated at a given altitude (e.g. 2km) can be applied to flow measurement at all altitudes, and the flowmeter readings are the volume flows of the points where they are located[11-13].

For this reason, based on the analysis and comparison of various types of flow measurement elements, in this paper the flow measurement method with the damper tube as the damping element is selected for measuring the volume flow at high altitude, which is more reasonable than previous schemes. And researches are carried out on its range setting, structure of the damping element, measurement principle, certification and calibration, etc., which provides a guarantee for extensive application of the measurement method.

III. RANGE SETTING OF THE FLOW SECTION

For the flow measurement method with the damper tube as the damping element, the magnitude of its flow depends on the structure of the damper tube and compactness of the filler material in the damper tube, and the structural diagram of the damper tube is shown in **Fig. 1**.



1. **Case; 2.end cover; 3. damping unit; 4.the incoming terminal of the first pressure sensor; 5. incoming terminal of the second pressure sensor; 1a. outlet nozzle, 1b. pressure tap at high pressure; and 1c pressure tap at low pressure side**

Fig. 1 the structural diagram of the damper tube

After experimental exploration on actual filling, the diameter of the inner cylindrical cavity of the large-flow damper tube is big, but its length is relatively short, whereas the diameter of the inner cylindrical cavity of the small-flow damper tube is small and its length is relatively big, the material filled and structural style are different, large-flow damping unit ($Q<1L/min$) is composed by rolling several layers of glass fabric into a cylindrical shape and putting it into the cylinder, the structural diagram for rolling of the glass fabric into a cylindrical shape is as shown in **Fig. 2**; the small-flow damping unit ($Q\geqslant 1L/min$) is composed by pressing the multiple layer of circular glass wool in the cylinder, the structural diagram of the multilayer circular glass wool is as shown in **Fig. 3**.

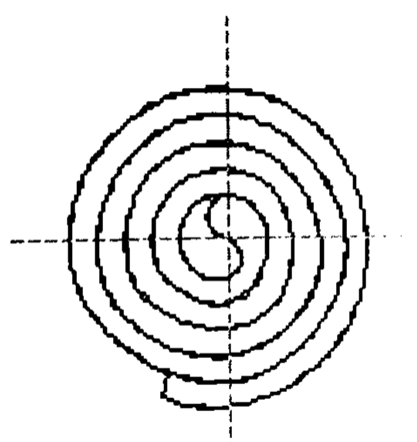


Fig. 2 The structural diagram for rolling of the glass fabric into a cylindrical shape

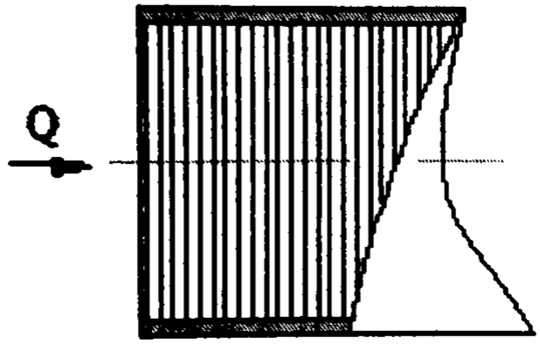


Fig. 3 The structural diagram of the multilayer circular glass wool

The glass fibers filled in the damper tube can be regarded as a parallel combination of many capillary tubes, and the flow through the damper tube is the superposition of flow in the capillary tubes.

The damper tube is composed by rolling glass fabric into a cylindrical structure or superimposing and assembling the round pieces of glass wool, its flow characteristic is obtained by experiment: Q=C△P, where △P is the pressure difference of the pressure tapping section formed when flow Q passes through it, C is a coefficient related to dimensions of damper tube, filling compactness of glass fibers and the flow medium. In practical applications, too tight filling will crush the glass fibers, and too loose filling will cause unstable performance. Generally, the specification of glass fiber and specification value of filling compactness are determined through experiments, and when the filling rate of the flow cylinder is given, the standard damper tube can be established.

IV. MEASUREMENT PRINCIPLE

The flow measurement method with damper tube as a damping element is based on the Bernoulli equation and the flow continuity equation. When the flow flows through the damping unit, there will a pressure difference produced between both sides, which is directly proportional to the flow theoretically[14-16].

Assume that the glass fiber flow damper tube is considered as a combination of numerous capillary flows connected in parallel, then the flow through the damper tube Q is the superimposition of flow q through the capillary tubes, given the equivalent diameter of round tube of the capillary tube is d, then:

$$Q=\Sigma q= (\pi \Delta P/128\mu L)d(1 - r/R) \quad (1)$$

ΔP - Pressure difference formed when flow Q flows through the pressure tapping section;

μ - Dynamic viscosity coefficient of the flow medium;

L - Length of pressure tapping section;

r - Filling density;

R - Density of glass fiber;

D - Diameter of the inner cylindrical cavity in the damper tube.

V. IDENTIFICATION / CALIBRATION METHOD

The flow measurement device with damper tube as the damping element is calibrated by the standard instrument. Here it is calibrated by taking the large-flow damper tube type flow measurement device as the example, its calibration steps are as follows.

a. Determine the gas medium;

b. Determines the metering device: the bell type gas flow metering device is used for calibration;

c. Install the calibrated damper tube type gas flow measurement device: connect the calibrated damper tube type gas flow device to the calibration system of the bell type gas flow device;

d. Charge gas into the bell type gas flow device: charge the bell of the bell type gas flow standard device full with gas medium and maintain it under a certain pressure value, then close the charging pipeline, record the pressure value; the said pressure value is the operating pressure value of the calibrated damper tube type flow measurement device;

e. Pressure difference versus flow value curve under the calibration pressure value: open the switch in the calibration pipeline, regulate the flow valve to make it under a flow state, let the gas in the bell flow through the calibrated damper tube type flow measurement device, record the amount of decrease of gas volume in the bell and elapsing time, calculate the flow value of the damper tube type flow measurement device under the condition of this flow, at the same time, record the difference between the first pressure sensor 4 and second pressure sensor 5, this difference corresponds to the above calculated flow value, mark it in the two-dimensional coordinate system by using this difference as the horizontal coordinate and the flow value as the vertical coordinate, as a point on the pressure difference versus flow curve; adjust the flow valve to make it under second flow state, mark second point on the pressure difference versus flow curve according to the above method, and so on, mark at least 10 points on the pressure difference versus flow curve, then smoothly connect each marking point to form the corresponding pressure difference versus flow curve..

VI. IDENTIFICATION / CALIBRATION ERROR

For the damper tube type flow measurement device with single-point graduation and scatter-point graduation, all the graduation points shall be 100% calibrated; the damper tube type flow measurement device with continuous graduation allows to be calibrated by randomly checking not less than 5 points in the upper, middle and lower part of the scale, and the indicated values of all the graduation points should meet the requirements for the permissible basic error, as shown in **Table 1**:

Table 1 The requirements for the permissible basic error

Accuracy class	Measuring range		Application	
	Q＜1L/min	Q≥1L/min		
2.5	±0.1L/min	±2.5%Q	Special-purpose	
4	±4%Q		currency	

VII. EXAMPLE VERIFICATION OF THE MEASUREMENT DEVICE

The example verification is carried out by using the large flow damper tube as a damping element, at the center of damper tube end cover 2 there is an gas inlet, rolled glass fabric is filled fully in case 1, the glass fabric is made of JC170-73 material, the distance between the axis of the pressure tap 1b at high-pressure side and axis of pressure tap 1c at low pressure side L1=360mm, L2 is the axial length of the inner cavity of case 1, L2=400mm, and D is the radial diameter of the inner cavity of case 1, D=85mm. The first pressure sensor and the second pressure sensor are respectively connected to the corresponding pressure taps. At the center of end cover 2 there is a gas inlet and the outlet nozzle 1a is connected to the calibration system.

a. Determine the gas medium to be air;

b. Determine to use the bell type gas flow metering device as a standard device;

c. Install the calibrated damper tube type flow measurement device;

d. Charge gas into the bell type gas flow device: charge gas into the bell of the bell type gas flow standard device until it is full and maintain the pressure at 0.1MPa.

e. Pressure difference versus flow value curve under the calibration pressure value: open the switch in the calibration pipeline, regulate the flow valve to make it under a flow state, let the gas in the bell flow through the calibrated damper tube type flow measurement device, record the amount of decrease of gas volume in the bell and elapsing time, calculate the flow value of the damper tube type flow measurement device under the condition of this flow, at the same time, record the difference between the first pressure sensor 4 and second pressure sensor 5, this difference corresponds to the above calculated flow value, mark it in the two-dimensional coordinate system by using this difference as the horizontal coordinate and the flow value as the vertical coordinate, as a point on the pressure difference versus flow curve; adjust the flow valve to make it under second flow state, mark second point on the pressure difference versus flow curve according to the above method, and so on, mark at least 10 points on the pressure difference versus flow curve, then smoothly connect each marking point to form the corresponding pressure difference versus flow curve, it is as shown in **Fig. 4**.

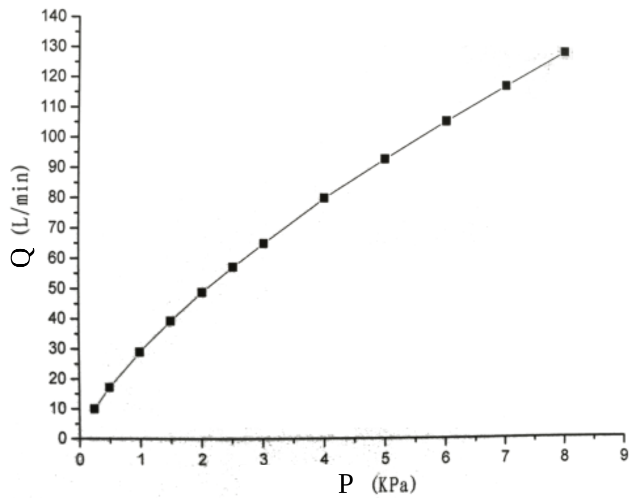


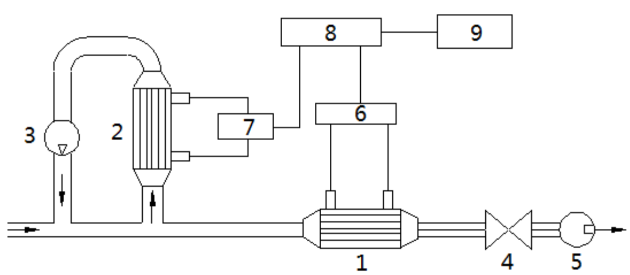
Fig. 4 Volume flow rate changes with pressure

VIII. THE APPLICATION OF MEASUREMENT DEVICE

One of the basic functions of a damped cartridge type flow detection device is to measure the volume flow rate at a given or any cabin altitude (typically 0-10 km) under negative pressure, i.e., a high-altitude volume flow rate test. It can be extended into many applications, such as mixed gas medium flow test, dynamic instantaneous flow test and mixed gas oxygen percentage test.

(1) Mixed gas medium flow test

Aeronautical oxygen-supply equipment outputs mixed gas flows with different components containing 21 to 98% oxygen in the cabin altitude range of 0 to 10 km. The volumetric flow rate of the output mixed gas medium needs to be tested. The schematic diagram of the mixed gas medium flow test device is shown in **Fig. 5**. The mixed gas medium flow test device provides a flow test method that automatically compensates for changes in the dynamic viscosity of the medium when the components of the gas mixture change.



1. Main damping tube; 2. Additional damping tube; 3. Constant flow pump; 4. Flow valve; 5. Vacuum pump; 6. Differential pressure gauge 1; 7. Differential pressure gauge 2; 8. MCU; 9. Monitor

Fig. 5 the structural diagram of mixed gas medium flow test device

(2) Dynamic instantaneous flow test

The research on the flow characteristics of aviation oxygen supply equipment involves the testing of dynamic instantaneous flow[17-20]. For example, for the special situation where the oxygen supply equipment in lateral pipe suit system is connected to pressurized oxygen supply — when the pilot does not wear the pressure compensating suit, and the suit pressure nozzle of pressure ratio regulator is equipped with a nozzle cap instead of safety valve, if the pressured oxygen supply is turned on in the case of reduced pressure in the cockpit (suppose when the aircraft flies at a high speed at an altitude of 9~10 km and the cockpit canopy is thrown), the ground oxygen flow charged to the pressure compensating suit at more than 200 L/min will be expanded to 800~1200L/min high-altitude flow within 5~7 seconds and is charged into the mask (the uncompensated pulse peak pressure of more than 4kPa is formed in the mask). In the test, the dynamic flow measuring device is used to record the 828 L/min oxygen flow formed instantaneously at the moment when the pressurized oxygen supply is turned and charged into the mask when the low-pressure compartment rises up at a speed of 70m/s. The dynamic flow measuring device used is a flow measuring device with a cylindrical damping tube made of a stainless-steel toothed foil and flat platinum rolled together as a throttling element. Its characteristics are:

(a) Only slight differential pressures (e.g., 0.1 kPa or less) are formed at both ends of the damping tube in the range of the working flow rate;

(b) The differential pressure sensor has a test range corresponding to a small differential pressure and an accuracy of not less than 0.5;

(c) Sensor and recorder systems with a frequency response of not less than 60 Hz and a sensitivity of 249 Pa;

(d) The non-linearity error of the flow characteristics of the foil damping tube is less than 1.5%.

(3) Mixed gas oxygen percentage test

The percentage oxygen content refers to the percentage concentration of oxygen in the oxygen regulator output gas. When the cockpit height is in the range of 0 km to 10 km, the aviation oxygen supply system generally satisfies the anti-hypoxia requirement by increasing the oxygen content percentage of the inhaled gas. Where, the high-pressure oxygen storage type oxygen supply system usually achieves the relation between the cockpit height and the oxygen content percentage of the output gas by three methods: altitude oxygen supply mechanism+oxygen content percentage mechanism, or altitude oxygen supply mechanism+air suction valve mechanism, or oxygen content percentage mechanism. The percentage of oxygen content in the mixed gas supplied by the aviation oxygen supply equipment is measured by using a flow measurement algorithm.

The flow measurement method is applicable to the oxygen supply system of the high-pressure oxygen storage type oxygen source, and the oxygen concentration of the output gas is determined by the oxygen supply flow and the suction air flow, and the output mixed gas flow of the system terminal is equal to the sum of the oxygen supply flow and the suction air flow, that is,

$$Q_{oxygen} + Q_{air} = Q_{mix} \quad (2)$$

Assuming that the oxygen concentration of oxygen source is 100% and the oxygen concentration of suction air is 21%, then the oxygen concentration of output gas can be calculated by Formula (3) or (4):

$$F\% = \left(21 + 79 \times \frac{Q_{oxygen}}{Q_{mix}}\right)\% \quad (3)$$

$$F\% = \left(100 - 79 \times \frac{Q_{air}}{Q_{mix}}\right)\% \quad (4)$$

It needs to be pointed out that the Russian oxygen regulator has no flow regulation consumption in the height range of 2km to 10km. The oxygen flow supplied to the oxygen regulator is equivalent to the oxygen flow at the input system terminal, and Q_{oxygen} in formula (3) is equal to the flow of oxygen input into the oxygen regulator. Whereas on the domestic oxygen regulator, the oxygen flow input into the system terminal is less than the oxygen flow input into the oxygen regulator due to regulating flow consumed for establishing a small residual pressure. Therefore, Formula (3) should be transformed into the following formula for an oxygen-consuming oxygen regulator:

$$F\% = \left(21 + 79 \times \frac{Q_{oxygen} - Q_{use}}{Q_{mix}}\right)\% \quad (5)$$

It can be seen from Formula (3), (4) and (5) that there are two ways to calculate the oxygen content percentage *F* of the output gas under the condition that the oxygen regulator outputs a fixed flow:

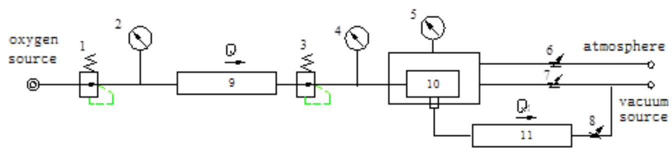
(a) Test the mixed flow Q_{mix} of the output gas and the flow Q_{oxygen} of oxygen input into the regulator, and calculate the oxygen content percentage *F* according to Formula (3) or Formula (5);

(b) Test the mixed flow Q_{mix} of the output gas and the flow Q_{air} of suction air, and calculate the oxygen content percentage F according to Formula (4).

The 'suction air flow/output mixed gas flow method' is a method used on the early oxygen equipment tester. Its characteristic is that the calibration workload only involves one curve of the outlet flow and one curve of the air flow, and the test workload only involves two parameters, i.e., the outlet flow and the air flow, the test is simple relative to the 'input oxygen flow/output mixed gas flow method', and is especially suitable for the oxygen content percentage performance test of the domestic gas-consuming type regulator, in which the test for regulating flow consumed for establishing a small residual pressure is avoided.

'Input Oxygen Flow/Output Mixed Gas Flow Method' is a method used in recent test equipment[21-23]. The oxygen content percentage test device of mixed gas uses this method to test the oxygen content percentage performance, which is characterized by direct testing of oxygen supply amount, where the oxygen flowmeter gives multiple calibration curves corresponding to the relevant altitudes, and the calibration workload is large. In the testing, for the domestic gas-consuming type regulator, it is needed to simultaneously measure three parameters such as the oxygen supply amount and the regulating flow consumed for establishing a small residual pressure as well as the outlet flow, the calibration and testing is complicated relative to ‘Suction air flow/output mixed flow method, but this method is more rigorous.

Input oxygen flow/output mixed gas flow measurement method: **Fig. 6** is a schematic diagram of the test line of the input oxygen flow/output mixed gas flow measurement method, where the function of each actuator is that the pressure reducer ‘1’ establishes the working pressure of oxygen flowmeter according to the pressure meter ‘2’; the pressure reducer ‘3’ establishes the inlet pressure of oxygen regulator according to the pressure meter ‘4’; the flow valve ‘8’ establishes the outlet flow according to the outlet flowmeter; and the vacuum valve ‘7’ and the atmospheric valve ‘6’ establishes the barometric altitude according to the altimeter ‘5’. The oxygen flowmeter displays the corresponding oxygen flow under the condition of specified outlet flow and gas pressure chamber altitude.



1. Upstream pressure reducer 2. Upstream pressure meter 3. Downstream pressure reducer 4. Downstream pressure meter 5. Altimeter of gas pressure chamber 6. Atmospheric valve 7. Vacuum valve 8. Outlet flow valve 9. Oxygen flowmeter 10. Regulator 11. Outlet flowmeter

Fig. 6 Schematic diagram of test according to input oxygen flow/output mixed gas flow measurement method

The characteristics of the input oxygen flow/output mixed gas flow measurement method are summarized as follows:

(a) The outlet flow is monitored by the outlet flowmeter downstream of the oxygen regulator outlet. This flowmeter is a damping type outlet flowmeter. The measured flow rate is independent of density of the gas medium, and the flow indicated by it is the environmental volume flow at the altitude at which the medium is located;

(b) The oxygen flow is monitored by the oxygen flowmeter upstream of the oxygen regulator inlet. The oxygen flowmeter operates at a pressure not lower than the pressure at the oxygen regulator inlet. Considering the significance of the ratio of oxygen flowmeter to the outlet flow for the test accuracy, after the outlet flowmeter is calibrated according to the scale, the outlet flowmeter is used as the standard, and the oxygen flowmeter is calibrated according to the scale graduation corresponding to each altitude of the oxygen flowmeter according to the test line to obtain the environmental flow calibration curve family as shown in **Fig. 7**;

(c) The oxygen concentration at each altitude output by the oxygen regulator is set according to the typical oxygen content percentage of the oxygen regulator, as shown in **Table 3**. After the oxygen regulator is actually calibrated with the air medium, the flow calibration curve series of 40%, 60%, 80%, and 100% mixed gas is obtained by conversion according to the coefficients given in **Table 3** below (or the air and oxygen curves are actually calibrated, and the rest are done by plotting method), as shown in **Fig. 8**.

Table 2 Oxygen content percentage performance indexes under the condition of oxygen supply system overload

Altitude (km)	Under certain accelerate rate m/s^2(g), oxygen content percentage (%) should not below:			
	29.4(3)	49.1(5)	68.6(7)	88.2(9)
2.5	23	23	22	22
4	30	29	28	26
6	40	38	37	34

Table 3 Oxygen concentration setting and flow of mixed gas output by the regulator at each altitude conversion relationship with air flow

Altitude (km)	**0**	**2～4**	**6**	**7.5～8**	**8.5～11**
Oxygen concentration of mixed gas (%)	21	40	60	80	100
Q_{mix}/Q_{air}	1	0.987	0.949	0.924	0.900

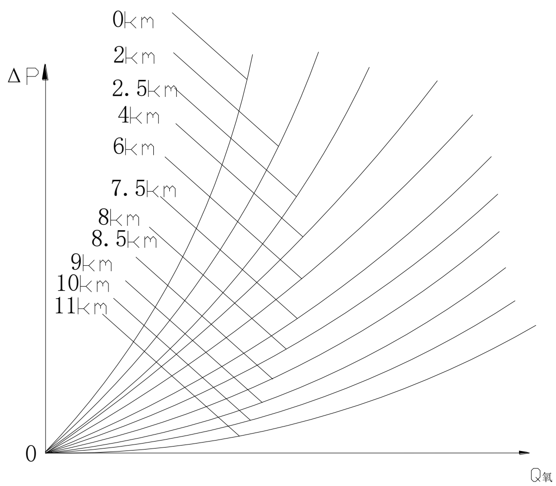


Fig. 7 Oxygen environment flow calibration curve family

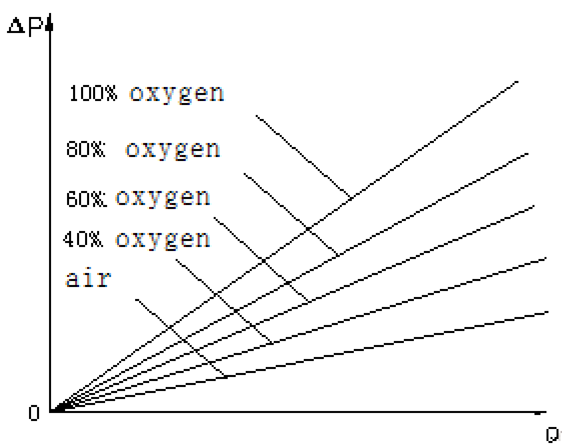


Fig. 8 Flow calibration curve family of mixed gas

In summary, the extensive use of damping cylinder as a damping element for the flow detection device meets the test requirements of the new model aviation oxygen supply equipment in terms of flow characteristics; it provides a strong logistical support for meeting the needs of new fighters in China.

IX. CALIBRATION OF MIXED GAS OXYGEN CONTENT PERCENTAGE TEST DEVICE

(1) Calibration of oxygen flowmeter and outlet flowmeter

In the test device for oxygen content percentage of mixed gas, the pressure difference meter uses a pressure sensor, and the pressure signal is converted into an electric signal. The following described is the working process for calibration of the oxygen flowmeter and the outlet flowmeter in the test device for oxygen content percentage of mixed gas.

(a) Oxygen flowmeter is calibrated for its corresponding flow value by comparison method according to the test points: 0.5V, 1.0V, 1.5V, 2.0V, 3V, 4V, 5V, 6V, 7V, 8V, 9V with a rotameter, and the correction factor is obtained according to t, P (temperature, pressure). The scale flow K_{oxygen} is calculated by the following Formula:

$$Q_{scale}=K_{oxygen}\cdot Q_{rotor} \quad (6)$$

(b) The outlet flowmeter is calibrated for the corresponding flow value $Q_{rotameter}$ by comparison method with a rotameter according to test points: 1V, 2V, 3V, 4V, 8V, 9V with a rotameter. Get the correction factor k according to t [20L/min] for (t+2) and 100L/min for (t+3) and gas pressure P. The scale flow is calculated according to the follow formula:

$$Q_{scale}=K_{export}\cdot Q_{rotor} \quad (7)$$

(c) Plot the curve;

(d) According to the corresponding table of voltage versus flow Q_{scale} given by the curve:

(1) The oxygen flowmeter gives the graduation points (V) 0.5, 1.0, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10.

(2) The outlet flowmeter gives the graduation points (V) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

(e) A correspondence table of voltage and flow is given to form the solidification data, which is saved in the test device through the chip and becomes the initial data of the test device.

In the paper, **Fig. 9** is the calibration curve diagram of the oxygen flowmeter, **Fig. 10** is the calibration curve diagram of the outlet flowmeter, mark out the curve diagrams of 0.1MPa, 0.6MPa and 1.5MPa for 20L/min step of oxygen, and the curve diagram of 3MPa at 20L/min step of oxygen is similar to the curve diagrams of 1.5MPa and 3MPa at 100L/min raised step of oxygen, which will not be repeated here.

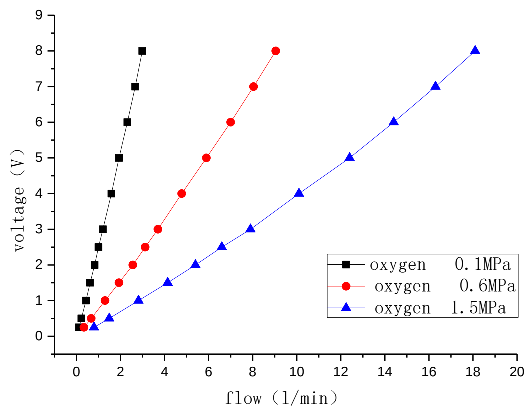


Fig. 9 Calibration curve of oxygen flowmeter

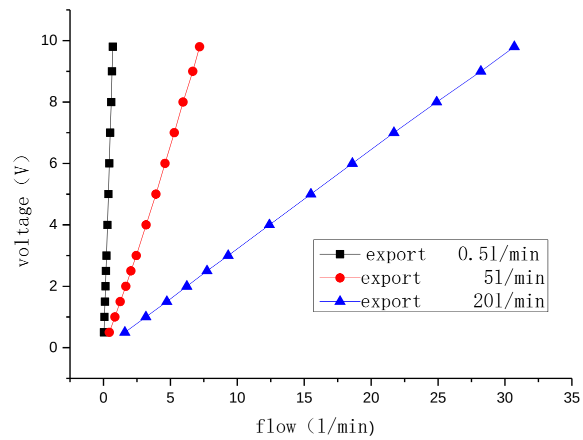


Fig. 10 Calibration curve of outlet flowmeter

(2) Oxygen content percentage calibration of the test device

The test device for oxygen content percentage of mixed gas uses this method to test the oxygen content percentage performance, which is characterized by direct testing of the oxygen supply amount, where the oxygen flowmeter gives multiple calibration curves corresponding to the relevant altitudes, the calibration workload is large, but this method is very rigorous. The following describes the working process of its calibration.

(a) Press the 'Oxygen' key of '20L/min' step of the outlet flowmeter. 'F52' key is established by pressing 'Oxygen' key of '1.5L/min' step and the corresponding altitude key and 'Input 2' key, and is displayed on the 'Function' display bar.

(c) After pressing the 'Set' and 'Run' keys, the zero value of flow (O2) is displayed on the outlet flowmeter (13) display bar, and the oxygen flowmeter (14) displays the zero value of voltage.

(d) Calibrate the corresponding table of voltage and flow by comparison method with the outlet flowmeter as the reference. The corresponding table of flows for each altitude graduation point is given according to 0.5, 1.0, 1.5, 2, 3, 4, 5, 6, 7, 8, 9V.

(e) A corresponding table of voltage and flow is given to form the solidification data, which is saved in the test device through the chip and becomes the initial data of the test device.

Fig. 11 is the calibration curve diagram of oxygen content percentage showing the calibration values for oxygen content percentage at different altitudes.

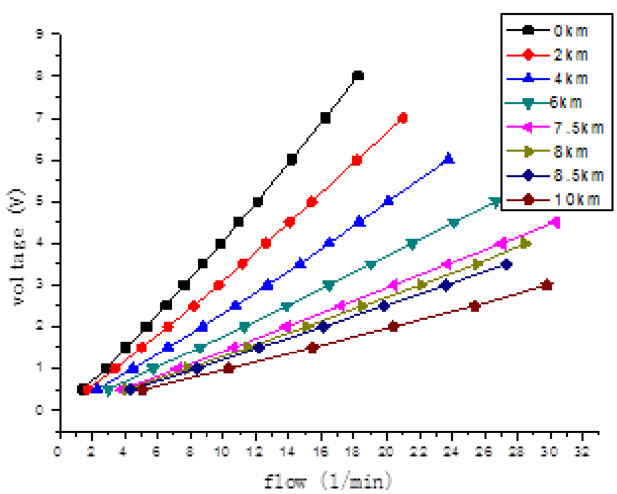
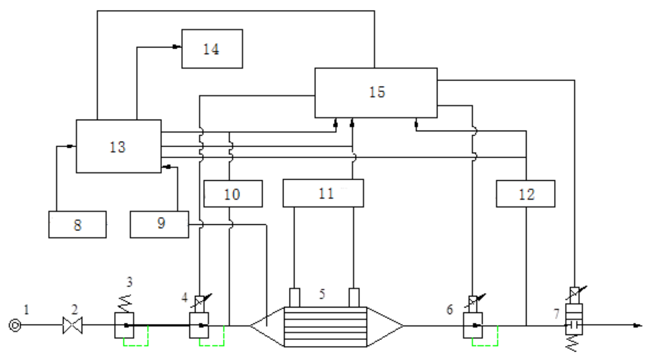


Fig. 11 Calibration curve of oxygen content percentage

X. INTELLIGENT DEVELOPMENT OF TEST DEVICE

In the oxygen supply system, the high-pressure oxygen is decompressed to a rated pressure (for example, 0.5 MPa, 1 MPa, etc.) by a pressure reducer, and then enters the oxygen regulator. Since the oxygen flow supplied to the oxygen regulator cannot be collected separately from the low pressure outlet end of the regulator (the regulator outlet flow also includes the air flow introduced by the air inhaler mechanism, and there is still a very small portion of oxygen supplied into the regulator discharged into atmosphere as the regulating flow of the residual pressure mechanism of the regulator), the oxygen flow can only be measured in the section upstream of the regulator inlet section. **Fig. 12** provides a schematic operating diagram of an intelligent flow test device. The inlet pressure of the damping cylinder and inlet pressure of the regulator are controlled by electric proportional pressure valves ‘4’ and ‘6’, respectively, and the pressure values are monitored by piezoresistive sensors. When it is necessary to establish a set value flow, the flow adjustment is realized by the electric proportional pressure valve ‘7’, and the capacitive differential pressure transducer measures the differential pressure formed by the pressure tapping section of the damping cylinder; the temperature sensor senses the temperature when the gas medium flows through the damping cylinder, the barometric sensor senses the atmospheric pressure of the test environment, both sensors provide data for flow temperature correction and barometric correction.



1-Oxygen source 2-switch 3-pressure reducer 4-electric proportional pressure valve 5-damping cylinder 6-electric proportional pressure valve 7-electric proportional flow valve 8-altitude sensor 9-temperature sensor 10-inlet pressure sensor 11-pressure differential transducer 12 - Outlet pressure sensor 13 - microprocessor 14 – display unit 15 - proportional valve controller

Fig. 12 An intelligent flow test device

In summary, the popularization and application of the damping tube as a flow detection device for the damping tube meets the test requirements for the new type of aviation oxygen supply equipment in terms of flow characteristics; in order to meet the needs of China’s new fighter aircraft, it provides a powerful logistical support.

XI. CONCLUSION

The flow measurement method with the damper tube as the damping element is a measurement method for volume flow at high altitude in present paper, and researches have been carried out in the aspects of range setting, measurement principle, certification/calibration method, example verification of the measurement device, etc., showing that this measurement method is feasible. At present it is applied for measurement of volume flow of aviation oxygen supply equipment at high altitude without the need for correction of medium density, which provides a new way for flow measurement, and provides a guarantee for measurement of volume flow of aviation oxygen supply system. The application of flow detection devices with damping cylinders as damping elements, such as mixed gas medium flow test, dynamic instantaneous flow test, and mixed gas oxygen percentage test, have further enriched the flow detection using damping tubes as damping elements.

In the test device for oxygen content percentage of mixed gas, the structural style of two tandem damping cylinder flowmeters is adopted. In order to improve the measuring accuracy of the oxygen flowmeter at the location of inlet high pressure, the outlet flowmeter is used as a standard device to calibrate the oxygen flowmeter by comparison, which meets the oxygen content percentage test of the oxygen regulator, and develops the flow measurement method which uses the damping cylinder as the damping element from single application to multiple applications.

The application of the intelligent test device will develop the flow measurement method using the damping cylinder as the damping element towards intelligence in order to satisfy the requirements of the test device.

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