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Air compressor for fuel cell system

燃料电池发动机用空气压缩机

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Table of Contents

Foreword.....	3
1 Scope	4
2 Normative references	4
3 Terms and definitions	6
4 Equipment and instrument requirements.....	10
5 Operating modes.....	11
5.1 Operating mode 1	11
5.2 Operating mode 2	11
6 Technical requirements	12
6.1 General items	12
6.2 Operating characteristics and mechanical characteristics	12
6.3 Electrical characteristics.....	15
6.4 Environmental adaptability	16
6.5 Safety and prohibited substances	19
6.6 Durability	20
7 Test methods	21
7.1 Test conditions	21
7.2 Working characteristics and mechanical characteristics	22
7.3 Electrical characteristics.....	29
7.4 Environmental adaptability	31
7.5 Safety and prohibited substances	35
7.6 Durability	36
8 Inspection	40
8.1 Inspection items	40
8.2 Type inspection	42
8.3 Exit-factory inspection.....	42
8.4 Random inspection.....	42
9 Marks, packaging, transportation and storage requirements	42
9.1 Marks	42
9.2 Packaging	43
9.3 Transportation	43
9.4 Storage	43
Annex A (normative) Calculation formulas	44
Annex B (informative) Examples of operating characteristic diagrams for air compressors	49
Annex C (informative) Data record of air compressor operating points.....	53

Air compressor for fuel cell system

1 Scope

This document specifies the technical conditions, test methods, inspection rules and marking, packaging, transportation and storage requirements for air compressors for fuel cell systems (hereinafter referred to as air compressors).

This document applies to air compressors for fuel cell systems, including centrifugal air compressors, positive displacement air compressors, etc.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 755-2019, *Rotating electrical machines -- Rating and performance*

GB/T 2408-2021, *Plastics -- Determination of burning characteristics -- Horizontal and vertical test*

GB/T 2423.3-2016, *Environmental testing -- Part 2: Testing method -- Test Cab: Damp heat, steady state*

GB/T 2423.4-2008, *Environmental testing for electric and electronic products -- Part 2: Test method -- Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

GB/T 2423.18-2021, *Environmental testing -- Part 2: Test methods -- Test Kb: Salt mist, cyclic (sodium chloride solution)*

GB/T 2423.22-2012, *Environmental testing -- Part 2: Test methods -- Test N: Change of temperature*

GB/T 2423.56-2018, *Environmental testing -- Part 2: Test methods -- Test Fh: Vibration, broadband random and guidance*

GB/T 4208, *Degrees of protection provided by enclosure (IP code)*

GB/T 6908, *Analysis of water used in boiler and cooling system -- Determination of electrical conductivity*

GB/T 13277.1-2008, *Compressed air -- Part 1: Contaminants and purity classes*

NOTE: The physical meaning of the compressor adiabatic efficiency is the ratio of the adiabatic compression power to the actual compression power when the gas is compressed to a certain pressure, which represents the degree of closeness between the gas compression process inside the compressor and the isentropic process.

3.13 compressor inlet mass flow

The mass flow of air entering the compressor.

3.14 compressor effective inlet mass flow

The air mass flow that can be effectively used by the fuel cell system.

NOTE: For compressors using air bearings, compressed air is required to cool the bearings and motors. This part of the gas is usually not used by the fuel cell engine. The compressor effective inlet mass flow can be used to deduct the cooling air flow, or the compressor outlet flow can be used as the compressor effective inlet mass flow.

3.15 air compressor rotational speed

The number of revolutions of the air compressor motor shaft per unit time.

NOTE: If the compressor, expander and motor are coaxial and there is no speed change device, the compressor and expander speed is consistent with the motor shaft speed. If there is a speed change device, the motor shaft speed is used.

3.16 minimum rotational speed

The minimum speed specified by the manufacturer for stable operation of the air compressor.

NOTE: The minimum rotational speed of the air compressor is usually limited by bearing stability (for air bearings), motor speed stability, etc.

3.17 maximum rotational speed

The maximum operating speed of the air compressor specified in the product technical documents.

3.18 compressor pressure ratio

The ratio of the total pressure (absolute pressure) of the gas at the compressor outlet to the total pressure (absolute pressure) of the gas at the compressor inlet.

NOTE: The total pressure can be calculated using the static pressure plus dynamic pressure method, see A.1 in Annex A.

3.19 operating characteristic margin

The percentage of the difference between the work point and the work boundary line to the boundary point characteristics.

3.20 mass flow margin

The percentage of the difference between the working point flow and the maximum (small) flow of the air compressor at the corresponding working point pressure ratio to the maximum (small) flow.

NOTE: For centrifugal air compressors, the mass flow margin is the margin between the operating point and the surge line and the blocking line. For positive displacement air compressors, the mass flow margin is the margin between the operating point and the inefficient zone protection line. The maximum (minimum) flow of the air compressor is the maximum (minimum) flow that can be stably operated under the pressure ratio specified by the manufacturer.

3.21 rotational speed margin

The percentage of the difference between the operating point speed and the highest (low) speed of the air compressor to the highest (low) speed.

3.22 pressure ratio margin

The percentage of the difference between the working point pressure ratio and the maximum pressure ratio of the air compressor at the working point flow.

3.23 compressor corrected mass flow

Convert the compressor inlet mass flow to the mass flow under standard ambient conditions.

NOTE: To compare the performance of the compressor, when the test (actual measurement) environment is different from the standard ambient conditions, the compressor effective inlet mass flow is converted according to the standard ambient conditions.

3.24 compressor corrected rotational speed

Convert the air compressor rotational speed to the speed under standard ambient conditions.

NOTE: To compare the performance of the compressor, when the test (actual measurement) environment is different from the standard ambient conditions, the compressor speed is converted according to the standard ambient conditions.

3.25 compressor corrected input power

Convert the compressor input power to the power under standard ambient conditions.

NOTE: To compare the performance of the compressor, when the test (actual measurement) environment is different from the standard ambient conditions, the compressor input power is

the rotational speed margin shall not be less than 3%.

For positive displacement compressors, after converting the rated point and the minimum steady point to the standard conditions, the mass flow margin shall not be less than 5%, the pressure ratio margin shall not be less than 5%, and the rotational speed margin shall not be less than 3%.

6.2.3 Dynamic response

Test the dynamic response of the air compressor in accordance with the provisions of 7.2.2. The load-up time of the air compressor shall not exceed 3 s, and the load-down time shall not exceed 2 s.

6.2.4 Startup and shutdown response

Test the startup and shutdown response of the air compressor in accordance with the provisions of 7.2.3. The startup and shutdown response time of the air compressor shall not exceed 1 s.

6.2.5 Noise

Test the overall noise of the air compressor in accordance with the provisions of 7.2.4. The overall noise of the air compressor shall meet the following requirements, or be determined by the manufacturer and the user after consultation:

- a) The noise level under the rated point and dynamic response conditions specified in 6.2.3 shall not exceed 75 dB(A);
- b) The noise level under the minimum steady point shall not exceed 70 dB(A).

6.2.6 Cooling water channel flow resistance characteristics

For the water-cooled parts of the air compressor (such as the air compressor as a whole, compressor, motor or controller), the cooling water channel flow resistance shall be tested separately in accordance with 7.2.5. The flow resistance of the cooling water channel shall comply with the provisions of the product technical documents. The flow resistance deviation value under the same flow shall not exceed $\pm 10\%$.

6.2.7 Air path sealing

Test the air circuit for tightness according to 7.2.6.

The leakage value (mL/min) of the air circuit shall not exceed 0.5 power of the rated power (kW) of the air compressor, or be determined by consensus between the manufacturer and the user.

6.2.8 Cooling channel sealing

For the water-cooled parts of the air compressor (such as the air compressor as a whole,

compressor, motor or controller), test the sealing of the cooling water channel in accordance with 7.2.7.

The leakage of cooling water channel shall not exceed 1 mL/min.

6.2.9 Air path cleanliness

Test the cleanliness of the air path in accordance with 7.2.8. The cleanliness of the air path shall comply with the following provisions, or be determined by consensus between the manufacturer and the user:

- a) The total mass of metal particles with a size of 0 μm ~200 μm shall not exceed 40 mg per square meter of air path surface area;
- b) Metal particles with a diameter greater than 200 μm are not allowed;
- c) The length of non-metallic fibers shall not exceed 1000 μm .

6.2.10 Cleanliness of cooling water channels

Test the cleanliness of cooling water channels in accordance with 7.2.8. The cleanliness of cooling water channels shall comply with the following provisions, or be determined by consensus between the manufacturer and the user:

- a) The total mass of 1 m^2 of metal particles with a size of 0 μm ~500 μm per square meter of air path surface area shall not exceed 40 mg;
- b) Metal particles with a diameter greater than 500 μm are not allowed;
- c) The length of non-metallic fibers shall not exceed 1000 μm .

6.2.11 Cooling water channel conductivity

For the water-cooled parts of the air compressor (such as the air compressor as a whole, compressor, motor or controller), if the cooling water channel shares cooling water with the fuel cell stack, the conductivity of the cooling water channel shall be tested in accordance with 7.2.9. The conductivity of the cooling water channel shall not exceed 10 $\mu\text{S}/\text{cm}$.

6.2.12 Compressed air purity

Compressed air purity test shall be carried out in accordance with 7.2.10. The purity of compressed air shall meet the following requirements or be determined by consensus between the manufacturer and the user:

- a) The particle purity of compressed air at the outlet of the air compressor shall comply with the provisions for Grade 2 in 7.1 of GB/T 13277.1-2008;
- b) The oil content of compressed air at the outlet of the air compressor shall comply

not be longer than 3 s.

6.3.9 High voltage cables

All high-voltage cables of air compressors shall have 360° shielding and heat-resistant temperature shall not be lower than 150°C.

6.3.10 Feed characteristics

For air compressors with power feeding function, test the power feeding characteristics of the air compressor according to 7.3.9.

The feeding voltage range, feeding current and feeding efficiency shall comply with the provisions of the product technical documents.

6.3.11 Electromagnetic compatibility

Test the electromagnetic compatibility of the air compressor according to 7.3.10.

For the tests in 7.3.10a), b), c) and d), the limits for different frequency bands shall comply with the specifications of the air compressor manufacturer.

For the tests in 7.3.10e), f), g), h), i) and j), the functional characteristics of the air compressor during and after the test shall comply with the manufacturer's specifications.

6.3.12 Speed control accuracy

Test the air compressor speed control accuracy according to 7.3.11. It shall be less than ± 200 r/min or 0.2% of the maximum rotational speed (whichever is greater).

6.4 Environmental adaptability

6.4.1 General inspection items

After all environmental adaptability tests are completed, the air compressor is restored to normal operation and shall meet the following requirements:

- a) Visually check that there are no cracks or damage on the outer surface of the air compressor, and that the bolts are not loose;
- b) The air path sealing complies with the provisions of 6.2.7;
- c) The cooling water channel sealing complies with the provisions of 6.2.8;
- d) The insulation resistance complies with the provisions of 6.3.3;
- e) Visually check that there is no leakage of lubricating oil (if any) and coolant (if any);

- f) The air compressor can operate stably for not less than 1 h under rated point;
- g) Compared with before the test, the rated flow deviation rate of f) does not exceed 3%.

6.4.2 Low temperature storage

Perform low temperature storage test in accordance with 7.4.1.

The insulation resistance retest in the box shall comply with the provisions of 6.3.3.

After the test is completed, restore the air compressor to normal operation, which shall comply with the provisions of 6.4.1.

6.4.3 High temperature storage

Perform high temperature storage test in accordance with 7.4.2.

The insulation resistance retest in the box shall comply with the provisions of 6.3.3.

After the test is completed, the air compressor shall be restored to normal and shall comply with the provisions of 6.4.1.

6.4.4 Low temperature performance

Conduct low temperature working performance test according to 7.4.3.

The insulation resistance re-measured in the box shall comply with the provisions of 6.3.3.

After the test is completed, restore the air compressor to normal state and comply with the provisions of 6.4.1.

6.4.5 High temperature working performance

Conduct high temperature working performance test in accordance with 7.4.4.

The insulation resistance re-tested in the box shall comply with the provisions of 6.3.3.

After the test is completed, the air compressor shall be restored to normal and shall comply with the provisions of 6.4.1.

6.4.6 Plateau adaptability

Perform the plateau adaptability test in accordance with 7.4.5.

The insulation resistance re-tested in the box shall comply with the provisions of 6.3.3.

After the test is completed, the air compressor shall be restored to normal and shall comply with the provisions of 6.4.1.

After the test, restore the air compressor to normal operation and comply with the provisions of 6.4.1.

6.4.13 Mechanical shock

Perform mechanical shock test in accordance with 7.4.12.

After the test, restore the air compressor to normal operation and comply with the provisions of 6.4.1.

6.5 Safety and prohibited substances

6.5.1 Inclusiveness

For centrifugal air compressors, the containment test shall be carried out in accordance with the provisions of 7.5.1 and shall meet the following requirements:

The housing shall be able to completely contain any debris that may be generated:

- a) Run the air compressor at a speed not less than 1.2 times the rated speed. The compressor impeller hub breaks at this speed. The loose pieces shall be completely contained in the compressor housing. No impeller loose pieces are allowed to fly outward;
- b) For air compressors with expanders, run the air compressor to a speed not less than 1.2 times the rated speed. The expander impeller hub breaks at this speed. The loose pieces shall be completely contained in the expander housing. No impeller loose pieces are allowed to fly outward.

6.5.2 High voltage safety

All high-voltage connectors shall have connection terminals for determining the high-voltage interlock function and shall meet the safety requirements of 5.1 in GB 18384-2020.

6.5.3 Combustion characteristics

The horizontal and vertical combustion performances of exposed plastic parts in the air compressor shall meet the Grade HB specified in 8.4 and Grade V-0 specified in 9.4 of GB/T 2408-2021 respectively.

6.5.4 Prohibited substances

Test prohibited substances in accordance with 7.5.2.

The air compressor shall meet the prohibited substance requirements specified in GB/T 30512. Asbestos shall not be detected.

6.6 Durability

6.6.1 Start-stop durability

Carry out the start-stop durability test of the air compressor in accordance with 7.6.1.

After the test is completed, the air compressor shall be restored to normal operation and shall comply with the provisions of 6.4.1.

After the test, the air compressor components are disassembled and confirmed. There shall be no abnormal phenomena such as wear, breakage, deformation, looseness, etc. that affect the function.

6.6.2 Temperature cycle durability

Carry out the temperature cycle endurance test according to 7.6.2.

After the test is completed, the air compressor shall be restored to normal operation and shall comply with the provisions of 6.4.1.

After the test, the air compressor components are disassembled and confirmed. There shall be no abnormal phenomena such as wear, breakage, deformation, looseness, etc. that affect the function.

6.6.3 Variable load cycle durability

Carry out the variable load cycle endurance test according to 7.6.3.

After the test is completed, the air compressor shall be restored to normal operation and shall comply with the provisions of 6.4.1.

After the test, the air compressor components are disassembled and confirmed. There shall be no abnormal phenomena such as wear, breakage, deformation, looseness, etc. that affect the function.

6.6.4 High load endurance

Carry out high load endurance test according to 7.6.4.

After the test, restore the air compressor to normal operation, which shall comply with the provisions of 6.4.1.

After the test, the air compressor components are disassembled and confirmed. There shall be no abnormal phenomena such as wear, breakage, deformation, looseness, etc. that affect the function.

7.2.1.2 Test preparation

Carry out the test preparation as follows:

- a) Install the air compressor on the test bench. The installation method shall comply with the provisions of the product technical documents;
- b) Set the coolant flow and temperature according to the requirements of the product technical documents;
- c) Run the air compressor to operating mode 2.3. During the load-up process, if there are safety problems such as air leakage, water leakage, electric leakage and pipe burst, the test shall be stopped immediately. Check that there shall be no air leakage, water leakage, electric leakage and other phenomena at each connection. There shall be no abnormal sound during the operation of the air compressor;
- d) After the coolant temperature stabilizes, start the test.

7.2.1.3 Working characteristic diagram (map diagram) test

Follow the steps below to test the air compressor operating characteristic diagram:

- a) Fix the reduced speed of the air compressor. After finding the surge point and the choke point of the speed line, evenly divide the flow of the two intervals into more than 6 points for testing. During the test, the value of each measuring point shall be stable for no less than 3 min after the control parameter reaches the specified value (the time can be shortened appropriately for the surge point). Measure each point 5 times. Take the average value when calculating (or take the average value within 1 min after stabilization);
- b) After completing one speed line, continue to test the next speed line until the map is completed. There shall be no less than 7 speed lines and they shall include the minimum rotational speed and the rated speed. The speed interval shall not be greater than 15% of the maximum rotational speed;
- c) After the test is completed, turn off the air compressor and the test bench.

7.2.1.4 Rated point performance test

Follow the steps below to perform the rated point performance test of the air compressor:

- a) The reduced speed of the fixed air compressor is the rated speed. The speed deviation shall not exceed the provisions of 6.3.12;
- b) Adjust the throttle valve so that the reduced mass flow of the air compressor is equal to the rated flow;
- c) Make the air compressor run stably under rated point for no less than 10 min. The

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