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**The method of performance test for positive displacement
refrigerant compressors**

容积式制冷剂压缩机性能试验方法

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The method of performance test for positive displacement refrigerant compressors

1 Scope

This Standard specifies the terms and definitions, test regulations, test methods, as well as calculation of input power, cooling (heating) coefficient of performance, volume efficiency, isentropic efficiency and test deviation for positive displacement refrigerant compressors.

This Standard applies to the performance test for single-stage positive displacement refrigerant compressor (hereinafter referred to as “single-stage compressor”), positive displacement refrigerant compressor equipped with economizer (hereinafter referred to as “compressor equipped with economizer”) and positive displacement refrigerant compressor equipped with flash-tank (hereinafter referred to as “compressor equipped with flash-tank”). It applies as a reference to the tests for other types of compressors.

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 2624.1, Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 1: General principles and requirements

GB/T 2624.2, Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 2: Orifice plates

GB/T 2624.3, Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 3: Nozzles and Venturi nozzles

GB/T 2624.4, Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full - Part 4: Venturi tubes

GB 9237, Refrigerating systems and heat pumps - Safety and environmental requirements

GB/T 29030-2012, Positive displacement CO₂ refrigerant compressor (unit)

4.1.6 Provide equipment for sampling the refrigerant-oil mixture to measure the oil content.

4.2 Test regulations

4.2.1 The compressor refrigerating capacity performance test of a single-stage compressor includes two test methods, namely, method X and method Y. The two methods shall be tested simultaneously; the deviation between the test results of method X and method Y shall be within $\pm 4\%$; the average value of the measurement and calculation results of method X and method Y shall prevail.

4.2.2 For the compressor heating capacity test of the compressor and the compressor refrigerating capacity test of the compressor equipped with economizer or flash-tank, only one test method (method X or method Y) may be used for measurement.

4.2.3 During the test of a compressor, the system shall establish a thermal equilibrium state, and the test time shall generally be no less than 1 hour. The measurement data shall be recorded once every 15 minutes after the test conditions have stabilized for half an hour, until the four measurement data meet the requirements of Table 2, 4.2.1 and 4.2.2. If the test data is automatically collected by computer, the continuous measurement data collection time shall not be less than 30 minutes. Minor adjustments to pressure, temperature, flow and liquid level are allowed during the test data recording period.

4.2.4 Types of test methods

The compressor test shall comply with the requirements of 4.2.1 and 4.2.2. During each test cycle, the data specified in the test report (see 4.5.2) shall be measured, together with any additional data required for each test method.

a) Test methods for subcritical cycle compressors

The nine different test methods are as follows:

Method A: Second refrigerant calorimeter method (see 5.1.1);

Method B: Fully liquid refrigerant calorimeter method (see 5.1.2);

Method C: Dry refrigerant calorimeter method (see 5.1.3);

Method D1: Suction pipe refrigerant gas flow meter method (see 5.1.4);

Method D2: Exhaust pipe refrigerant gas flow meter method (see 5.1.4);

Method F: Refrigerant liquid flow meter method (see 5.1.5);

Method G: Water-cooled condenser calorimeter method (see 5.1.6);

Method J: Refrigerant gas cooling method (see 5.1.7);

4.3.2 The temperature difference between the inlet and outlet of the cooling or heating medium of the calorimeter shall not be less than 6 °C during calibration or testing.

4.4 Provisions for measuring instruments and accuracy

4.4.1 General provisions

4.4.1.1 The types of instruments for testing may be one or more.

4.4.1.2 The instruments for testing shall be calibrated and within the valid use period.

4.4.2 Temperature measurement

4.4.2.1 Instrumentation

Instruments for measuring temperature include: glass mercury thermometer, thermocouple, resistance thermometer, semiconductor thermometer and differential thermometer.

4.4.2.2 Accuracy

The accuracy requirements of the measuring instrument are as follows:

- a) Inlet and outlet temperatures of the heating or cooling medium and refrigerant of the calorimeter: accuracy ± 0.1 °C;
- b) Temperature of cooling water in condenser: accuracy ± 0.1 °C;
- c) Compressor suction temperature, temperature before flow throttling device: accuracy ± 0.1 °C;
- d) Other temperatures: accuracy ± 0.2 °C.

4.4.2.3 Measurement regulations

The following requirements shall also be met during measurement:

- a) The thermometer sleeve is made of thin-walled steel pipe or stainless steel thin-walled pipe or copper pipe, and is inserted vertically into the fluid (the size of the thermometer sleeve shall not significantly affect the airflow). If the pipe diameter is small, it can be inserted obliquely in reverse flow or a temperature measuring tube can be used, and the insertion depth is 1/2 the pipe diameter. Heat-conducting medium is injected into the sleeve, and the thermometer shall not be pulled out when reading.
- b) Where possible, when measuring the inlet and outlet temperature difference of the heating or cooling medium and refrigerant in the calorimeter, the inlet and outlet thermometers shall be exchanged after each reading to improve the measurement accuracy.

Electrical measuring instruments include: power meter (including indicating and integrating types), ammeter, voltmeter, power factor meter, frequency meter and transformer.

4.4.5.2 Accuracy

The accuracy requirements of the measuring instrument are as follows:

- a) Power meter: the indicating type shall have an accuracy not less than Class 0.5, and the integrating type shall have an accuracy not less than Class 1; digital power meter: $\pm 0.2\%$ of the range;
- b) Ammeter, voltmeter, power factor meter and frequency meter: accuracy not less than Class 0.5;
- c) Transformer: accuracy not less than Class 0.2.

4.4.5.3 Measurement regulations

The power meter measurement value shall be above 1/3 of the full scale (when using the “two-power meter” method for measurement, the measured value of one of the power meters can be less than 1/3 of the full scale). When using the “two-power meter” method or the “three-power meter” method to measure the power of a three-phase AC motor, the indicated current and voltage values shall not be less than 60% of the rated current and voltage values of the power meter.

For digital power meters: If a current transformer is used, the actual displayed current value shall not be less than 20% of the transformer range.

4.4.6 Compressor power measurement

4.4.6.1 Instrumentation

Power measuring instruments include: torque tachometer, dynamometer, standard motor and other dynamometers.

4.4.6.2 Accuracy

The accuracy is within $\pm 1.5\%$ of the measured shaft power.

4.4.6.3 Measurement regulations

The following requirements shall also be met during measurement:

- a) The input power of three-phase AC motors is measured using the “two-power meter” method or the “three-power meter” method;
- b) When there is a belt or external gear transmission, the transmission efficiency is as follows:

the calorimeter, and the suction temperature is controlled by the heat input to the superheater.

5.1.2.3.2 The exhaust pressure of the compressor refrigerant is adjusted by changing the condenser cooling water volume, heat exchange area or cooling water temperature, or by the pressure control valve in the exhaust pipe.

5.1.2.3.3 When testing the compressor equipped with economizer or flash-tank, the refrigerant liquid temperature before expansion of the air supply circuit shall be adjusted by an auxiliary subcooling or heating device.

5.1.2.3.4 If liquid is used for heating, the inlet and outlet temperature fluctuation shall not exceed ± 0.3 °C, the flow rate shall be controlled so that the temperature difference between inlet and outlet is not less than 6 °C, and the heating liquid flow rate fluctuation shall not exceed $\pm 0.5\%$. If electric heating is used, the fluctuation of input power shall not exceed $\pm 1\%$.

5.1.2.3.5 During the test period, the change in the compressor refrigerating capacity caused by the fluctuation of the input heat shall not exceed 1%. If the heater is working intermittently, the change in the saturation temperature (or dew point temperature) corresponding to the refrigerant liquid shall be less than ± 0.5 °C.

5.1.2.3.6 Additional data include:

- a) Refrigerant gas pressure and temperature at the evaporator outlet;
- b) Refrigerant liquid pressure and temperature before the main circuit expansion valve;
- c) Calorimeter ambient temperature;
- d) Flow rate and inlet and outlet temperatures of the calorimeter heating liquid;
- e) Electrical heating capacity input to the calorimeter;
- f) Exhaust temperature of the compressor;
- g) Refrigerant pressure at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- h) Refrigerant mass flow rate at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- i) Or refrigerant liquid mass flow rate in the liquid injection branch (for compressor with suction or intermediate cavity liquid injection cooling).

5.1.2.4 Refrigerant flow rate calculation

The refrigerant flow is regulated by an expansion valve installed close to the calorimeter on the main circuit. In order to reduce the influence of external heat, the pipe between the main circuit expansion valve and the calorimeter shall be insulated.

The heat leakage of the calorimeter shall not exceed 5% of the compressor refrigerating capacity.

When the heater is heating the outer surface of the calorimeter, more than 10 temperature measurement points distributed at equal distances shall be installed on the electrically insulating outer surface of the heater to determine the average surface temperature required for calculating the heat leakage.

The temperature of the heated liquid shall be measured and the pressure shall be ensured not to exceed the safety limit of the equipment.

Protective measures shall be adopted and, in accordance with the provisions of GB 9237, the refrigerant pressure shall not exceed the safety limit of the equipment.

5.1.3.2 Calibration of heat leakage

5.1.3.2.1 When the calorimeter is a tube-type, pass a heating liquid between the tubes, and adjust its flow rate and inlet temperature so that its inlet temperature is 15 °C higher than the ambient temperature and the fluctuation does not exceed ± 0.3 °C; control the flow rate so that the temperature difference between the inlet and outlet is not less than 6 °C. When the calorimeter is a tubular container, input the electric heating capacity so that its average surface temperature is 15 °C higher than the ambient temperature. When the ambient temperature is below 43 °C, maintain the temperature fluctuation within ± 1 °C.

5.1.3.2.2 If liquid heating is used, under the condition of stable flow rate, measure the inlet and outlet temperatures of the heated liquid every hour until the fluctuation of the inlet and outlet temperatures for four consecutive measurements does not exceed ± 0.3 °C. If electric heating is used, the fluctuation of input power shall not exceed $\pm 1\%$. Measure the refrigerant saturation temperature (or dew point temperature) every hour until the fluctuation of four temperature values does not exceed ± 0.5 °C.

5.1.3.2.3 The heat input to the calorimeter is calculated as follows:

- a) When heating with liquid, calculate according to Formula (7):

$$\Phi_i = C(t_1 - t_2)q_{mc} \dots\dots\dots (7)$$

- b) When heating with electricity, Φ_i is the power input to the electric heater.

5.1.3.2.4 The heat leakage coefficient is calculated as follows:

- a) When heating with liquid, calculate according to Formula (8):

The flow meter shall also be equipped with a bypass pipe, in which the resistance of the stop valve and pipeline on the bypass pipe shall be roughly equal to the resistance of the flow meter. Except for the time of measuring the flow, the bypass pipe shall be unobstructed.

Arrange the temperature measurement points at the refrigerant liquid inlet of the subcooler and the flow meter to measure the refrigerant liquid temperature. Install the pressure gauge at the outlet of the flow meter.

5.1.5.2 Calibration

The flow meter shall be calibrated regularly, and the viscosity of the calibration liquid shall be 0.5 ~ 2 times the viscosity of the refrigerant used. The flow rate during calibration shall be measured at least three points within the flow meter scale range, including the minimum, median, and maximum values.

5.1.5.3 Test procedure

5.1.5.3.1 Open the stop valve on the bypass pipe to operate the system. After reaching the specified value of the working condition, close the stop valve to allow the refrigerant liquid to pass through the flow meter. The temperature of the refrigerant entering the flow meter shall be at least 3 °C lower than the saturation temperature (or bubble point temperature) corresponding to the outlet pressure of the flow meter.

5.1.5.3.2 Additional data include:

- a) Refrigerant liquid mass flow rate in the main circuit;
- b) Refrigerant liquid temperature at the subcooler inlet and flow meter inlet;
- c) Refrigerant saturation temperature (or bubble point temperature) corresponding to the flow meter outlet pressure;
- d) Exhaust temperature of the compressor;
- e) Refrigerant pressure at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- f) Refrigerant mass flow rate at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- g) Refrigerant liquid mass flow rate in the liquid injection branch (for compressor with suction or intermediate cavity liquid injection cooling).

5.1.5.4 Refrigerant flow rate calculation

After correction for heat leakage, the ratio of the mass of condensed refrigerant entering the gas cooler to the mass of uncondensed refrigerant is equal to the inverse of the ratio of the changes in the specific enthalpy of the two vapors in the gas cooler.

The gas cooler is connected to the compressor exhaust pipe through a flow control valve that is manually or automatically controlled by the exhaust pressure. There shall be a liquid flow meter at the condenser outlet, and the flow meter outlet is connected to the gas cooler through an expansion valve.

The gas cooler consists of a container (which can heat the refrigerant liquid during heat leakage calibration), into which the refrigerant liquid is sprayed and directly mixed with the uncondensed refrigerant vapor from the compressor exhaust pipe and then evaporated. The refrigerant vapor coming out of the gas cooler shall not contain refrigerant droplets and be at least superheated by 8 °C.

The gas cooler shall be insulated so that its heat leakage is no more than 5% of its heat exchange capacity.

There shall be a liquid reservoir in front of the liquid flow meter, which is equipped with a stop valve and a bypass valve so that it can be completely isolated from the circulation loop or can receive liquid from the circulation loop and supply liquid to the system.

5.1.7.2 Calibration of heat leakage

5.1.7.2.1 Fill the gas cooler with sufficient refrigerant liquid; close the inlet and outlet stop valves; heat the refrigerant; keep its temperature about 15 °C higher than the ambient temperature; ensure that the refrigerant liquid in the gas cooler is not completely evaporated. When the ambient temperature is below 43°C, maintain the temperature fluctuation within ± 1 °C.

After thermal equilibrium is established, measure the refrigerant saturation temperature (or dew point temperature) once every hour until the temperature fluctuation does not exceed ± 0.5 °C for four consecutive times.

5.1.7.2.2 The heat leakage coefficient is calculated according to Formula (16):

$$F_1 = \frac{\Phi_i}{t_r - t_a} \dots\dots\dots (16)$$

5.1.7.3 Test procedure

5.1.7.3.1 Adjust the refrigerant liquid flow rate of the gas cooler by a control valve so that its evaporation rate is equal to the condensation rate of the condenser.

5.1.7.3.2 The condensing pressure can be adjusted by the pressure control valve between the exhaust pipe and the condenser, or by changing the cooling water volume, heat exchange area or cooling water temperature.

5.1.7.3.3 The compressor suction pressure is regulated by the gas cooler inlet flow control valve on the exhaust line. The compressor suction superheat is regulated by the liquid flow control valve entering the gas cooler.

5.1.7.3.4 When testing the compressor equipped with economizer or flash-tank, the refrigerant liquid temperature before expansion of the air supply circuit shall be adjusted by an auxiliary subcooling or heating device.

5.1.7.3.5 After reaching the suction and exhaust pressures and temperatures specified in the test conditions, start recording data.

During the test, the change in the calculated refrigeration capacity caused by flow fluctuations of the partially condensed refrigerant liquid shall be less than 1%.

5.1.7.4 Additional data

Additional data includes:

- a) Refrigerant gas pressure and temperature at the gas cooler outlet;
- b) Refrigerant liquid pressure and temperature before entering the expansion valve of the gas cooler;
- c) Pressure and temperature of refrigerant gas entering the gas cooler;
- d) Refrigerant gas pressure in the gas cooler;
- e) Ambient temperature of the gas cooler;
- f) Mass flow rate of condensed refrigerant liquid entering the gas cooler;
- g) Exhaust temperature of the compressor;
- h) Refrigerant pressure at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- i) Refrigerant mass flow rate at the outlet of the economizer or flash-tank air supply circuit (for compressor equipped with economizer or flash-tank);
- j) Or refrigerant liquid mass flow rate in the liquid injection branch (for compressor with suction or intermediate cavity liquid injection cooling).

5.1.7.5 Refrigerant flow rate calculation

5.1.7.5.1 The flow rate of refrigerant entering the evaporator of the refrigeration cycle where the compressor is located measured by the test is calculated according to Formula (17):

Appendix A

(Informative)

Oil content measurement method

A.1 Operating conditions

The oil content measurement conditions are operated according to the relevant standards or regulations. When the working conditions are stable and meet the requirements in Table 2 for four consecutive measurements, measure the oil content.

A.2 Sampling location

Take a sample of the refrigerant-oil mixture on the refrigerant liquid pipeline between the liquid reservoir and the expansion valve.

A.3 Measurement procedure and calculation method

A.3.1 Empty the sampling container and weigh it accurately.

A.3.2 Connect the sampling container to the refrigerant pipeline and remove the gas in the connecting pipeline. Draw a sample of the refrigerant-oil mixture.

A.3.3 Weigh the container containing the sample.

A.3.4 Weigh a clean, empty flask with a loose cotton plug in the neck.

A.3.5 Use a tube to pass through the cotton plug and extend it under the mouth of the flask; slowly pour the refrigerant-oil mixture liquid in the container into the flask.

A.3.6 Reweigh the empty container. Take the average of this mass and the container mass determined according to A.3.1 as the mass of the empty container. Subtract the mass of the empty container from the mass of the container containing the sample measured according to A.3.3 to obtain the mass of the refrigerant-oil sample.

A.3.7 Slowly evaporate the refrigerant in the flask.

A.3.8 Reweigh the flask with the cotton plug. Subtract the mass of the empty flask determined in A.3.4 from this mass, to obtain the mass of the oil.

A.3.9 The oil content is the quotient obtained by dividing the mass of oil determined in accordance with A.3.8 by the mass of refrigerant-oil determined in accordance with A.3.6, multiplied by 100%.

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