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**The performance testing method of bi-circulation unit for
low-temperature waste heat recovery and utilization**

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The performance testing method of bi-circulation unit for low-temperature waste heat recovery and utilization

1 Scope

This Standard specifies the performance testing method of bi-circulation unit for low-temperature waste heat recovery and utilization, including terms and definitions, symbols, test specifications, test preparation, testing, test data collation and test report.

This Standard is applicable to the performance test of bi-circulation unit for low-temperature waste heat recovery and utilization (hereinafter referred to as "the device"). The performance test of other similar devices can be performed by using this Standard as reference.

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, *Rotating electrical machines - Rating and performance*

GB/T 2624 (all parts), *Full differential pressure device installed in a pipe of circular cross-section measuring fluid flow*

GB/T 5773-2016, *The method of performance test for positive displacement refrigerant compressors*

GB/T 10870, *The methods of performance test for water chilling (heat pump) packages using the vapour compression cycle*

GB/Z 18039.1, *Electromagnetic compatibility - Environment - Description and classification of electromagnetic environments*

GB/T 18430.1-2007, *Water chilling (heat pump) packages using the vapor compression cycle - Part 1: Water chilling (heat pump) packages for industrial and commercial and similar application*

GB/T 37819-2019, *Bi-circulation power generation unit for low-temperature waste heat recovery*

GB/T 50050, *Code for design of industrial recirculating cooling water treatment*

c_p - the constant pressure specific heat capacity of the cold source or heat source medium at the average temperature, in joules per kilogram Celsius [$\text{J}/(\text{kg}\cdot^\circ\text{C})$];

h_a - the specific enthalpy of the organic working medium at the outlet of the evaporator, in joules per kilogram (J/kg);

h_d - the specific enthalpy of the organic working medium at the inlet of the evaporator, in joules per kilogram (J/kg);

h_1 - the inlet enthalpy value of the heat source medium on the evaporator side, in joules per kilogram (J/kg);

h_2 - the outlet enthalpy of the heat source medium on the evaporator side, in Joules per kilogram (J/kg);

K_c - the heat transfer coefficient between the outer surface of the condenser and the ambient air, in watts per square meter Celsius [$\text{W}/(\text{m}^2\cdot^\circ\text{C})$];

K_e - the heat transfer coefficient between the outer surface of the evaporator and the ambient air, in watts per square meter Celsius [$\text{W}/(\text{m}^2\cdot^\circ\text{C})$];

K_f - the heat transfer coefficient between the outer surface of the auxiliary equipment and the ambient air from the evaporator to the expander and from the expander to the condenser, in units of watts per square meter Celsius [$\text{W}/(\text{m}^2\cdot^\circ\text{C})$];

M_g - the mass flow rate of the gas organic working medium and lubricating oil mixture measured by the flow meter, in kilograms per second (kg/s);

M_l - the mass flow rate of the mixture of liquid organic working medium and lubricating oil measured by the flow meter, in kilograms per second (kg/s);

P_{in} - the electric power input of the device, in watts (W);

P_{out} - the electric power output of the device, in watts (W);

P_s - the shaft power output of the device, in watts (W);

Q_c - the heat release on the condenser side of the device, in watts (W);

$Q_{c,r}$ - the heat correction value of the condenser into the environment, in watts (W);

Q_e - the heat absorption on the evaporator side of the device, in watts (W);

$Q_{e,r}$ - the heat correction value of the evaporator into the environment, in watts (W);

$Q_{s,r}$ - the total heat released to the ambient air by the auxiliary equipment from the evaporator to the expander and from the expander to the condenser, in watts (W);

q_v - the volume flow, in cubic meters per second (m^3/s);

t_a - the ambient air temperature, in degrees Celsius ($^{\circ}\text{C}$);

$t_{c,m}$ - the average value of the inlet and outlet temperatures of the cooling source medium on the condenser side, in degrees Celsius ($^{\circ}\text{C}$);

$t_{e,m}$ - the average value of the inlet and outlet temperatures of the heat source medium on the evaporator side, in degrees Celsius ($^{\circ}\text{C}$);

t_f - the average surface temperature of auxiliary equipment from the evaporator to the expander and from the expander to the condenser, in degrees Celsius ($^{\circ}\text{C}$);

t_1 - the inlet temperature of the heat source medium on the evaporator side, in degrees Celsius ($^{\circ}\text{C}$);

t_2 - the outlet temperature of the heat source medium on the evaporator side, in degrees Celsius ($^{\circ}\text{C}$);

t_3 - the inlet temperature of the cooling source medium on the condenser side, in degrees Celsius ($^{\circ}\text{C}$);

t_4 - the outlet temperature of the cooling source medium on the condenser side, in degrees Celsius ($^{\circ}\text{C}$);

α_f - the surface heat transfer coefficient of auxiliary equipment, in watts per square meter in degrees Celsius [$\text{W}/(\text{m}^2 \cdot ^{\circ}\text{C})$];

δ_f - the thickness of the thermal insulation material on the surface of the auxiliary equipment, in meters (m);

η_{out} - the thermoelectric conversion efficiency;

η_s - the thermal efficiency;

λ_f - the thermal conductivity of the thermal insulation material on the surface of the auxiliary equipment, in watts per meter Celsius [$\text{W}/(\text{m} \cdot ^{\circ}\text{C})$];

ρ - the density of cold source or heat source medium at average temperature, in kilograms per cubic meter (kg/m^3);

ω - In the mixed solution of organic working fluid and lubricating oil, the mass ratio of organic working fluid and mixed solution.

5 Test regulations

5.1 When testing the device, two different methods shall be used to measure at the same time, defined as Method X and Method Y, respectively. See 7.3 for the selection principles of Method X and Method Y.

- The maximum ambient temperature does not exceed 40°C;
- When the test is carried out at an altitude of more than 1000m or the ambient air temperature is higher than 40°C, it shall be carried out in accordance with the provisions of GB/T 755.

6.2 Device status and requirements

6.2.1 The general requirements of the device shall comply with the provisions of 5.1.2~5.1.15 in GB/T 37819-2019.

6.2.2 The safety requirements of the device shall comply with the provisions of 5.3 in GB/T 37819-2019.

6.2.3 The air tightness requirements of the device shall comply with the provisions in GB/T 18430.1-2007.

6.3 Test system requirements

6.3.1 The test system shall use qualified measuring instruments to complete the measurement of temperature, pressure, flow, electrician, time, quality, noise, speed, power. The measuring instrument shall comply with the provisions of 6.4.

6.3.2 The test equipment and instruments of the test system shall not interfere with the normal operation and operation of the device.

6.3.3 The cleanliness and corrosiveness of the heat source and cold source medium used in the test system shall meet the requirements of the device. The water quality shall meet the requirements of GB/T 50050.

6.3.4 The test system shall have the functions of safe grid connection and splitting of power. Its power system design standards shall comply with the provisions of Chapter 12 of GB 50588-2017.

6.3.5 The test system shall be equipped with an electric energy measurement device. Its design shall meet the requirements of DL/T 5137.

6.3.6 There shall be no interference around the test system. The electromagnetic environment of the test site shall meet the requirements of GB/Z 18039.1.

6.3.7 The test system shall be protected from freezing when it is out of service.

6.4 Test instrument requirements

6.4.1 General provisions

6.4.1.1 The type of instrument used for the test can be one or more to measure.

6.4.1.2 The test instrument shall be tested and calibrated by the national metrology

department within the valid period of use.

6.4.1.3 The installation and use of measuring instruments shall comply with the provisions in GB/T 10870.

6.4.2 Temperature measuring instruments and requirements

6.4.2.1 Temperature measuring instruments

Temperature measuring instruments include glass mercury thermometer, resistance thermometer, thermocouple and semiconductor thermometer.

6.4.2.2 Temperature measuring instrument accuracy

The accuracy of the instrument for measuring the following parameters is:

- a) The inlet and outlet temperatures of the cold and heat sources of the device: $\pm 0.1^{\circ}\text{C}$;
- b) Liquid organic working fluid temperature: $\pm 0.1^{\circ}\text{C}$;
- c) Other temperature: $\pm 0.2^{\circ}\text{C}$.

6.4.2.3 Temperature measuring requirements

The following requirements shall be met during temperature measurement:

- a) Thermometer casing is made of thin-walled steel pipe or stainless steel thin-walled pipe. Insert fluid vertically (thermometer sleeve is sized so that airflow is not significantly affected). When the diameter of the pipe is small, it can be obliquely inserted into the reverse flow or use a temperature measuring pipe. Insertion depth is $1/2$ pipe diameter;
- b) When it is used to measure the temperature difference between the inlet and outlet of cold and heat sources, it is advisable to exchange the inlet and outlet thermometers for measurement after each reading, so as to improve the measurement accuracy;
- c) When measuring the temperature outside the pipe wall, insulation measures shall be set, so as to improve the measurement accuracy.

6.4.3 Pressure measuring instruments and requirements

6.4.3.1 Pressure measuring instruments

Pressure measuring instruments include spring tube pressure gauges, pressure sensors, U-tube differential pressure gauges and mercury barometric pressure gauges.

6.4.3.2 Pressure measuring instrument accuracy

For all pressure measuring instruments, the accuracy of the absolute pressure reading

in DL/T 448-2016. In which:

- a) Power meter: level 0.5 for indicating type, level 1 for accumulating type;
- b) Ammeter, voltmeter, power factor meter and frequency meter: level 0.5;
- c) Transformer: level 0.2;
- d) Voltage proof test device: level 2.

6.4.6 Time measuring instrument accuracy

The accuracy of the time measuring instrument is $\pm 0.1\%$.

6.4.7 Weight (mass) measuring instrument accuracy

The accuracy of the weight (mass) measuring instrument is $\pm 0.2\%$.

6.4.8 Noise measuring instrument accuracy

The accuracy of the noise measuring instrument is $\pm 2\%$.

6.4.9 Speed measuring instruments and accuracy

6.4.9.1 Speed measuring instruments

Speed measuring instruments include speed counter, tachometer, flash frequency meter.

6.4.9.2 Speed measuring instrument accuracy

The accuracy of speed measuring instrument is $\pm 2\%$.

6.4.10 Shaft power measuring instruments and accuracy

6.4.10.1 Shaft power measuring instruments

Shaft power measuring instruments include torque tachometer, balance dynamometer, standard motor.

6.4.10.2 Shaft power measuring instrument accuracy

The accuracy of the shaft power measuring instrument is $\pm 1.5\%$.

7 Testing

7.1 Testing requirements

There are 4 test methods for the device. Two of them shall be selected during the test, denoted as Method X and Method Y. The data specified in the measurement report (see

The parameter values of the physical properties of the organic working medium shall be based on the current tables and diagrams of the thermophysical properties of the organic working medium.

8.1.2 Test data

All measurement data shall be the average value of three consecutive measurements during the test period and shall be used for uncertainty analysis.

8.2 Test report

8.2.1 General data includes:

- a) Test date, location, personnel, start time, end time and measurement time;
- b) Device model and exit-factory serial number;
- c) Rated electric power output of the device;
- d) Types of cold and heat sources;
- e) Organic working fluid and lubricating oil;
- f) Ambient temperature.

8.2.2 The test conditions are:

- a) Inlet temperature on the heat source side;
- b) Inlet temperature on the cold source side.

8.2.3 The test method is:

- a) Method X;
- b) Method Y.

8.2.4 Test results and averages include:

- a) Inlet and outlet temperature and flow rate of heat source medium;
- b) Inlet and outlet temperature and flow rate of cold source medium;
- c) Evaporation pressure, condensation pressure and circulating flow of organic working medium circulation side;
- d) Input voltage, current and power of the device;
- e) Generator output current, voltage, frequency or output shaft power of the device;

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