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Non-metallic chemical equipment - Test method for heat transfer coefficient and flow resistance performance of impervious graphite heat exchanger

非金属化工设备 不透性石墨换热器传热系数和流阻性能测试方法

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3 Terms and definitions

3.1 Average heat transfer area: the arithmetic mean of the heat transfer area of the longitudinal holes and the heat transfer area of the transverse holes of an impervious graphite block-hole heat exchanger.

3.2 Residual volume: the total volume of the heat transfer block of an impervious graphite block-hole heat exchanger less the volume of the heat transfer holes. 3.3 Equivalent thickness: the ratio of the residual volume of such a block to the average heat transfer area.

4 Symbols

The clause lists the symbols used, each with its quantity and unit. Areas and geometry: heat transfer area of the exchanger under test in square metres; inner diameter of the pressure or differential pressure tapping in millimetres; length of the straight section of the impulse line in millimetres; distance between the temperature instrument and the sealing face of the inlet and outlet flanges in millimetres.

Thermophysical properties and flows: specific heat capacity at constant pressure of the cold fluid, of the hot fluid and of the precooler cold fluid, in joules per kilogram kelvin; density of the cold fluid, of the hot fluid and of the precooler cold fluid, in kilograms per

cubic metre; dynamic viscosity of the cold and hot fluids in pascal seconds; thermal conductivity of the cold and hot fluids in watts per metre kelvin; latent heat of vaporization of steam in joules per kilogram; volume flow of the cold fluid, of the hot fluid and of the precooler cold fluid in cubic metres per second; mass flow of the cold fluid, of the steam, of the condensate of the exchanger under test and of the condensate of the preheater in kilograms per second; velocity of the cold and hot fluids in metres per second.

Heat, temperature and pressure: heat duty of the cold fluid, of the hot fluid, of the condensate of the exchanger under test, of the condensate of the preheater and of the precooler cold fluid, in watts; relative error of the heat balance, dimensionless; inlet and outlet temperatures of the cold and hot fluids of the exchanger under test, inlet and outlet temperatures of the precooler and preheater cold fluids, steam temperature and vaporization temperature on the evaporating side of the exchanger under test, in degrees Celsius; temperature difference between the cold and hot sides at the inlet end and at the outlet end, logarithmic mean temperature difference and effective logarithmic mean temperature difference, in kelvin; temperature difference correction factor, dimensionless; inlet and outlet pressures of the cold side and of the hot side in pascals, and the corresponding inlet-to-outlet pressure differences, connecting-pipe pressure drops and cold-side and hot-side flow resistance performances, also in pascals; local resistance coefficients of the cold-side and hot-side connecting pipes, dimensionless.

Heat transfer coefficients and dimensionless numbers: condensing-side and evaporating-side heat transfer coefficients and the overall heat transfer coefficient, in watts per square metre kelvin; Euler number, Nusselt number, Prandtl number and Reynolds number for the cold and hot fluids and the liquid-phase Reynolds number, all dimensionless; Martinelli number, dimensionless; inlet, mean and outlet vapour quality, dimensionless.

5 Test systems

5.1 The test system for the liquid-liquid condition without phase change is shown in Figure 1 and its main equipment does the following: the cooling tower cools the fluid leaving the cooler to room temperature; the cooler cools the cold fluid entering the exchanger under test to the set temperature; the heater heats the hot fluid entering the exchanger under test to the set temperature; the separator separates the condensate from the steam; and the subcooler cools the condensate discharged from the heater.

5.2 The test system for the vapour-liquid condensing condition is shown in Figure 2 and adds a precooler train: the precooler cooling tower cools the fluid leaving the precooler cooler to room temperature; the precooler cooler cools the fluid leaving the precooler to the set temperature; the precooler condenses the fluid entering the condensing side of the exchanger under test to the set vapour quality; the precooler separator separates the condensate from the steam; the subcooler cools the condensate discharged from the

separator of the exchanger under test; that separator separates the condensate from the condensing-side fluid; and the cooler and cooling tower of the exchanger under test cool the cold fluid to the set temperature and then to room temperature.

5.3 The test system for the liquid-vapour evaporating condition is shown in Figure 3. Besides the cooling tower and cooler, it has a separator and a subcooler for the exchanger under test, a steam separator for the exchanger under test that separates the condensate from the steam entering it, a steam separator, a subcooler and a separator for the preheater, and the preheater itself, which heats the fluid entering the evaporating side of the exchanger under test to the set vapour quality.

5.4 The pressure vessels, pressure piping and fittings of the test systems meet the applicable technical regulations and standards. Safety valves are fitted on the tube-side and shell-side inlet lines of the exchanger under test and meet the applicable technical regulations and standards. The piping and fittings carrying the fluid and the exchanger under test are insulated.

6 Measuring instruments and their installation

6.1 Liquid flow is preferably measured with an orifice plate, turbine or electromagnetic flowmeter and steam flow with a vortex flowmeter; the range suits the test and the accuracy class is not lower than class 0.5. The straight lengths upstream and downstream meet GB/T 27698.1 and the instrument manual. The flowmeter is installed close to the exchanger under test and there is no leakage or diversion of test fluid between the measuring point and the exchanger. Condensate mass flow is preferably measured by weighing with an electronic weighing instrument of the high accuracy class of GB/T 7724 or better. Instruments are used within their period of verification or calibration.

6.2 Temperature is preferably measured with a thermocouple or a platinum resistance thermometer with a permissible error of 0.5 °C and a range suiting the test; the mounting direction and immersion depth meet GB/T 27698.1, and the distance between the instrument and the sealing face of the inlet and outlet flanges of the exchanger under test, shown in Figure 4, is not greater than 150 mm.

6.3 Pressure and differential pressure are preferably measured with pressure or differential pressure transducers whose range suits the test and whose accuracy class is not lower than class 0.2. The tappings are close to the exchanger under test and the straight lengths upstream and downstream of the instrument meet GB/T 27698.1. The tapping is perpendicular to the pipe wall, its inner diameter is 2 mm to 4 mm, and the straight length of the impulse line, shown in Figure 4, is at least twice that inner diameter. The instruments are installed at the same height and are used within their period of verification or calibration.

7 Structural parameters of the heat exchanger under test

7.1 For an impervious graphite shell-and-tube heat exchanger the client supplies the inner diameter, outer diameter, effective length and number of the graphite tubes, their arrangement and pitch, the number of tube passes, the shell inner diameter, the tube bundle limit circle diameter, the baffle cut, spacing and thickness, and the thermal conductivity of the graphite. A note states that the effective length of a tube is the tube length less the bonded length, the auxiliary tubesheet thickness and the baffle thickness.

7.2 For an impervious graphite block-hole heat exchanger the client supplies the diameter, length and number of the transverse holes, the number of shell passes, the diameter, length and number of the longitudinal holes, the number of tube passes, the thermal conductivity of the graphite, and the residual volume and equivalent thickness of the block. A note states that the length of a transverse hole is the length of its centre line. 7.3 The testing body confirms the structural parameters supplied by the client.

8 Test methods

8.1 For the liquid-liquid condition without phase change the parameters measured and recorded are the volume flows of the cold and hot fluids, their inlet and outlet temperatures, and their inlet and outlet pressures or the inlet-to-outlet pressure differences. Before the test the equipment, lines and instruments are securely connected and the safety valve set pressure is below the design pressure of the exchanger under test; during the test the exchanger is completely filled with the test fluid and the air is purged from the impulse lines. In the first run the hot fluid velocity is held constant and the cold fluid velocity varied: both velocities are preferably set to 1.0 m/s, the hot fluid inlet temperature to 60 °C +/- 1 °C and the cold fluid inlet temperature to 30 °C +/- 2 °C; after at least 5 min of stable running, once the relative error of the heat balance is not greater than +/- 5 %, at least three sets of data are collected simultaneously; the cold fluid velocity is then varied over the range 0.5 m/s to 1.5 m/s in not fewer than six steps, with a test and data collection after each step. In the second run both velocities are varied by equal amounts over the same range, again in not fewer than six steps. The test procedure may be adjusted at the user's request or according to the features of the equipment.

8.2 For the vapour-liquid condensing condition the parameters measured are the steam mass flow, the precooler cold fluid volume flow, the cold fluid volume flow of the exchanger under test and its condensate mass flow; the precooler cold fluid inlet and outlet temperatures, the cold fluid inlet and outlet temperatures of the exchanger under test and the steam temperature; and the condensing-side inlet and outlet pressures or the inlet-to-outlet pressure difference. With the steam mass flow held constant, the cold-side velocity is preferably set to 1.5 m/s and held throughout, the condensing-side inlet vapour quality is set to 0.5 through the precooler, and after at least 5 min of stable running with a