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Compressors and condensing units for refrigeration - Performance testing and test methods - Part 1: Refrigerant compressors

Compressors and condensing units for refrigeration - Performance testing and test methods - Part 1: Refrigerant compressors

Kältemittel-Verdichter und Verflüssigungssätze für die Kälteanwendung - Leistungsprüfung und Prüfverfahren - Teil 1: Kältemittel-Verdichter

Compresseurs et unités de condensation pour la réfrigération - Essais de performances et méthodes d'essai - Partie 1: Compresseurs pour fluides frigorigenes

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23.140	Kompresorji in pnevmatiļ ni stroji	Compressors and pneumatic machines
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This European Standard was approved by CEN on 9 January 2003.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Management Centre: rue de Stassart, 36 B-1050 Brussels

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Contents

Foreword

This document EN 13771-1:2003 has been prepared by Technical Committee CEN/TC 113 "Heat pumps and air conditioning units", the secretariat of which is held by AENOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2003, and conflicting national standards shall be withdrawn at the latest by October 2003.

It consists of the following parts:

Part 1: Refrigerant compressors

Part 2: Condensing units for refrigeration

Annex A is normative.

This document includes a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This part of this European Standard applies only to refrigerant compressors and describes a number of selected performance test methods. These methods provide sufficiently accurate results for the determination of the refrigerating capacity, power absorbed, refrigerant mass flow, isentropic efficiency and the coefficient of performance.

This standard applies only to performance tests conducted at the manufacturer's works or wherever the equipment for testing to the accuracy required is available.

The type of measuring instrument and the allowable uncertainty within which measurements shall be made are listed in normative annex A.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 378-1:2000, *Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1: Basic requirements, definitions, classification and selection criteria.*

EN 378-2, *Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation.*

EN ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices - Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full (ISO 5167-1:1991).*

ISO/TR 5168, *Measurement of fluid flow - Evaluation of uncertainties.*

3 Terms, definitions and symbols

For the purposes of this European Standard, the following terms and definitions apply.

3.1 Terms and definitions

3.1.1

refrigerating capacity (Φ_0)

product of the mass flow of refrigerant through the compressor and the difference between the specific enthalpy of the refrigerant at the compressor inlet and the specific enthalpy of saturated liquid. The refrigerant at the compressor inlet is superheated above the suction dew point temperature to the stated value. The saturated liquid is at a pressure corresponding to the compressor discharge dew point temperature

3.1.2

volumetric efficiency (η_v)

ratio of the actual volume rate of flow under suction conditions at the requirements specified in 4.9, to the displacement of the compressor

3.1.3

power absorbed (P)

— for externally driven compressors: the power at the compressor shaft;

— for motor compressors: the electrical power input at the motor terminals

3.1.4

refrigerant mass flow (q_m)

total refrigerant mass flow at the compressor suction inlet

3.1.5

isentropic efficiency (η_i)

ratio of the product of the mass flow and the change in isentropic enthalpy across the compressor to the power absorbed

3.1.6

coefficient of performance (COP_r)

ratio of the refrigerating capacity to the power absorbed

NOTE All the above are at the basic test condition.

3.1.7

oil circulation in the refrigerating system (x_{oil})

ratio of the measured oil mass flow to the mass flow of the circulating oil/refrigerant mixture

3.2 Symbols

For the purposes of this European Standard, the symbols of Table 1 apply.

Table 1 — Symbols

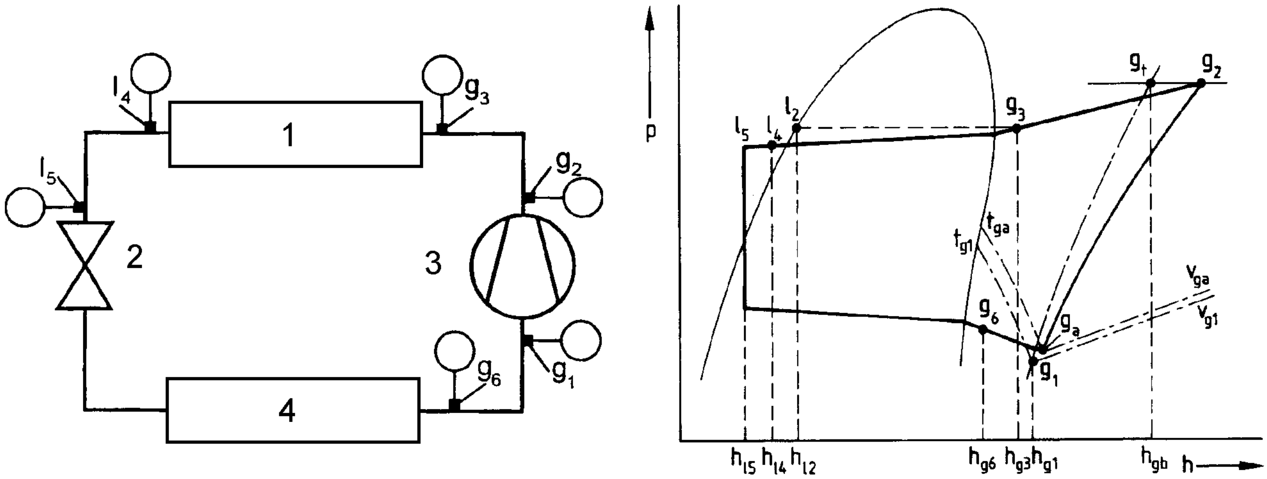
Symbol	Designation	SI unit
c	Specific heat capacity of liquid	J/(kg K)
c_{oil}	Specific heat capacity of oil	J/(kg K)
f	Nominal electrical frequency	Hz
f_a	Actual electrical frequency	Hz
F	Heat leakage factor	W/K
$h_{l\,2}$	Specific enthalpy of liquid refrigerant at bubble point corresponding to the pressure at the compressor outlet according to the basic test conditions	J/kg
$h_{l\,4}$	Specific enthalpy of liquid refrigerant at the outlet of the condensor	J/kg
$h_{l\,5}$	Specific enthalpy of liquid refrigerant at the inlet in the expansion device	J/kg
h_{gt}	Specific enthalpy of refrigerant vapour at the compressor outlet having the same entropy as the refrigerant vapour at the compressor inlet (basic test conditions)	J/kg
$h_{g\,1}$	Specific enthalpy of the refrigerant vapour at the compressor inlet at the basic test conditions	J/kg
$h_{g\,3}$	Specific enthalpy of the refrigerant vapour at the inlet of the condenser	J/kg
$h_{g\,6}$	Specific enthalpy of the refrigerant vapour at the outlet of the calorimeter	J/kg
n	Nominal compressor speed	1/min
n_a	Actual compressor speed	1/min
P	Power absorbed	W
P_0	Power absorbed at the basic test conditions	W
P_a	Actual power absorbed	W
$p_{g\,1}$	Absolute pressure, compressor inlet	MPa
$p_{g\,2}$	Absolute pressure, compressor outlet	MPa
$p_{g\,3}$	Pressure of the refrigerant vapour entering the condenser	MPa
$p_{g\,6}$	Pressure of the refrigerant vapour of the evaporator outlet	MPa
$p_{l\,4}$	Pressure of the refrigerant liquid leaving the condenser	MPa
$p_{l\,5}$	Pressure of the refrigerant liquid entering the expansion device	MPa

Table 1 *(continued)*

Symbol	Designation	SI unit
p_s	Absolute pressure of the secondary fluid	MPa
q_m	Refrigerant mass flow as determined by the test	kg/s
$q_{m\ 0}$	Refrigerant mass flow at the basic test conditions	kg/s
q_{mf}	Fluid mass flow	kg/s
q_{moil}	Oil mass flow	kg/s
q_{mx}	Mass flow of liquid refrigerant/oil mixture	kg/s
q_v	Refrigerant volume flow	m^3/s
q_{vx}	Volume flow of refrigerant/oil mixture	m^3/s
t_a	Ambient temperature	°C
t_c	Mean surface temperature of the calorimeter (basic test conditions)	°C
t_{ga}	Actual temperature at the compression inlet	°C
$t_{g\ 1}$	Refrigerant vapour temperature at the compressor inlet (basic test conditions)	°C
$t_{g\ 3}$	Temperature of the refrigerant vapour entering condenser	°C
$t_{g\ 6}$	Temperature of the refrigerant vapour at the evaporator outlet	°C
$t_{l\ 2}$	Saturation temperature of the liquid refrigerant corresponding to the pressure at the compressor outlet	°C
$t_{l\ 4}$	Temperature of the refrigerant liquid leaving the condenser	°C
$t_{l\ 5}$	Temperature of the refrigerant liquid entering the expansion device	°C
t_r	Average bubble point temperature of the refrigerant	°C
t_s	Saturation temperature of the secondary fluid	°C
t_x	Reference temperature	°C
t_1	Inlet temperature of the fluid	°C
t_2	Outlet temperature of the fluid	°C
U	Nominal electrical voltage	V
V_{sw}	Compressor displacement	m^3/s
x_{oil}	Oil circulation in the refrigerating system, expressed in kilogram per kilogram of mixture	kg/kg
COP_r	Coefficient of performance	—
η_i	Isentropic efficiency	—
η_v	Volumetric efficiency	—
v_{ga}	Actual specific volume of refrigerant vapour at the inlet of the compressor	m^3/kg
$v_{g\ 1}$	Specific volume of refrigerant vapour at the inlet of the compressor at the basic test conditions	m^3/kg
ρ_m	Density of refrigerant corresponding to pressure and temperature at which the flow rate is measured	kg/m^3
Φ_i	Heat input to the calorimeter	W
Φ_n	Electrical input to the heater	W
Φ_0	Refrigerating capacity of the compressor at the basic test conditions	W

3.3 Refrigerant circuit state points

Figure 1 illustrates the state of the refrigerant as it passes through the system



a) Circuit diagram b) Pressure vs enthalpy diagram

Key

1 Condenser

2 Expansion device

3 Compressor

4 Evaporator

Figure 1 - Refrigerant circuit

4 General requirements

4.1 Calculation methods

4.1.1 Principle

The determination of the refrigerating capacity of a compressor at the basic test conditions comprises:

— the evaluation of the actual mass flow of refrigerant through the compressor when operating within the limits allowed to the basic test conditions in 4.9;

— the correction of this mass flow to that, at the basic test conditions using the ratio of the actual specific volume (v_{ga}) of the refrigerant vapour at the compressor suction to the specific volume of the vapour at the basic test conditions ($v_{g\,1}$);

— the product of the corrected mass flow and the difference between the specific enthalpies at the basic test conditions of the refrigerant vapour at the compressor suction ($h_{g\,1}$) and the liquid refrigerant at a pressure corresponding the compressor discharge dew point temperature ($h_{l\,2}$).

NOTE For the purposes of this standard it is assumed that the volume flow rate is constant when the compressor is operating within the limits allowed in 4.9.

4.1.2 Specific enthalpy

The value of the specific enthalpy is taken from recognised data of the thermodynamic properties of the refrigerant used. The determining parameters are: the pressure and the temperature at the compressor inlet and the pressure at the compressor outlet. If operation with an oil separator is specified by the manufacturer, the pressure is measured at the oil separator outlet.

4.1.3 Refrigerant mass flow

The refrigerant mass flow is either measured directly or calculated from measured values.

4.1.4 Power absorbed

The value for the power absorbed includes the power absorbed by such ancillaries that are necessary for operation of the compressor. Within a superheat range of ± 5 K it is assumed that the power consumption will stay constant.

4.1.5 Basic equations

The refrigerant mass flow q_m determined by measurement is converted to the basic test conditions using the following equation:

$$q_{m\,0} = q_m \cdot \frac{v_{ga}}{v_{g\,1}} \cdot \frac{n}{n_a} \qquad (1)$$

For motor compressors, the correction factor n/n_a is replaced by f/f_a.

The refrigerating capacity as defined in 3.1.1 for compressors is calculated using the following equation:

$$\Phi_0 = q_{m\,0} \cdot (h_{g\,1} - h_{l\,2}) \qquad (2)$$

The power absorbed as defined in 3.1.3 is converted from the measured power absorbed to the basic test conditions using the following equation:

$$P_0 = P_a \cdot \frac{n}{n_a} \qquad (3)$$

For motor compressors, the correction factor n/n_a is replaced by f/f_a.

The volumetric efficiency η_v as defined in 3.1.2 is calculated using the following equation:

$$\eta_v = \frac{q_m}{V_{sw}} \cdot \frac{v_{ga}}{v_{g\,1}} \cdot v_{g\,1} = \frac{q_m}{V_{sw}} \cdot v_{ga} \qquad (4)$$

NOTE Within the limits specified in this European Standard, it is assumed that the volumetric efficiency is constant.

The isentropic efficiency η_i as defined in 3.1.5 is calculated using the following equation:

$$\eta_i = q_{m\,0} \frac{h_{gt} - h_{g\,1}}{P_0} \qquad (5)$$

The coefficient of performance COP_r as defined in 3.1.6 is calculated using the following equation:

$$COP_r = \frac{\Phi_0}{P_0} \qquad (6)$$

4.2 Requirements for the selection of test methods

4.2.1 General

Generally two different test methods from those taken from clause 5 shall be used at the same time. The results of the two methods shall correlate within 4 %. The test result is the mean value of the two methods.

4.2.2 Second concurrent test

Where testing devices are in constant use and are subject to periodical calibration in accordance with the recommended EN ISO 9001 a second concurrent test is not necessary.

4.3 Test period

4.3.1 General

The tests described relate exclusively to those refrigerant compressors and test installations which permit continuous operation and which can hold the fluctuations of all influencing factors within the specified limits for a certain time.

These conditions are described as steady states and are defined precisely in 4.9.

4.3.2 Steady state conditions

After the compressor has been started, adjustments shall be made during a preliminary run until the major readings required for the test are within the allowable deviations.

Steady state conditions shall be reached for at least 15 min before each test.

4.3.3 Recording of measured data

Once steady state has been reached, the measured data shall be registered on recording instruments. At least one complete measuring cycle shall be carried out every minute. The test period shall be at least 15 min and the average shall be formed from all measured values.

4.4 Pressure and temperature measuring points

The pressure and temperature measuring points for the compressor shall be mounted at the same place which is located at a distance of at least 4 times the diameter of a straight pipe but not less than 150 mm from the shut-off valves or connections to the compressor. The diameter of the pipe shall be consistent with that of the flange on the compressor for a length of at least 8 times the pipe diameter.

4.5 Oil circulation

The circulating quantity of oil is determined after the test.

From the liquid phase of the refrigerant circuit the refrigerant/oil mixture is poured into a collecting device intended for this specific purpose and the oil fraction is determined.

For repeated testing of one compressor model, the oil circulation of which is known, random sampling is sufficient. Alternative procedures with the same accuracy may be used. The collecting device shall be constructed with due regard to EN 378-2.

4.6 Fractionation

The composition of zeotropic refrigerants shall be analysed when a new batch sample is delivered.

When leaks are found the composition of the refrigerant charge shall be adjusted in order to ensure that the refrigerant is in accordance with the correct specification or the charge shall be replaced and the test repeated.