BS EN 327:2014

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Heat exchangers — Forced convection air cooled refrigerant condensers — Test procedures for establishing performance

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National foreword

This British Standard is the UK implementation of EN 327:2014. It supersedes BS EN 327:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/30, Heat exchangers.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 80317 8

ICS 27.060.30

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2014.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 327

August 2014

ICS 27.060.30

Supersedes EN 327:2000

English Version

Heat exchangers - Forced convection air cooled refrigerant condensers - Test procedures for establishing performance

Echangeurs thermiques - Aérocondenseurs à convection forcée - Procédures d'essai pour la détermination de la performance

Wärmeübertrager - Ventilatorbelüftete Verflüssiger - Prüfverfahren zur Leistungsfeststellung

This European Standard was approved by CEN on 22 May 2014.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 327:2014 E

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Foreword

This document (EN 327:2014) has been prepared by Technical Committee CEN/TC 110 "Heat exchangers", the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by February 2015, and conflicting national standards shall be withdrawn at the latest by February 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 327:2000 and EN 327:2000/A1:2002.

The main changes with respect to the previous edition are listed below:

a) Clause 3 "Terms and definitions" is modified;

b) The revised standard takes into account the application of CO_2.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European Standard is one of a series of European Standards dedicated to heat exchangers.

1 Scope

This European Standard applies to non-ducted forced convection air cooled refrigerant condensers/gas coolers with dry air side surface within which the refrigerant changes phases or is cooled. Its purpose is to establish uniform methods of performance assessment. It does not deal with evaluation of conformity.

This European Standard does not apply to air cooled condensers/gas coolers, designed primarily for installation within the machinery compartment of packaged products or in factory-assembled condensing/gas cooling units.

This European Standard does not apply to condensers with an integral subcooling part.

This European Standard specifies methods to test and ascertain the following:

— product identification;

— standard capacity;

— nominal air flow rate;

— nominal fan power.

This European Standard does not cover technical safety aspects.

2 Normative references

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

EN 60034-1, *Rotating electrical machines - Part 1: Rating and performance (IEC 60034-1)*

EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025)*

3 Terms and definitions

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

3.1
forced convection air cooled refrigerant condenser
refrigeration system component that condenses refrigerant vapour by rejecting heat to air, which is mechanically circulated over its dry heat transfer surface by integral fans and fan drives

Note 1 to entry: The heat transfer coil includes distributing and collecting headers.

Note 2 to entry: In the following “forced convection air cooled refrigerant condenser” is referred to as “condenser”.

3.2
forced convection air cooled refrigerant gas cooler
refrigeration system component that cools the refrigerant by rejecting heat to air, which is mechanically circulated over its dry heat transfer surface by integral fans and fan drives

Note 1 to entry: In the following “forced convection air cooled refrigerant gas cooler” is referred to as “gas cooler”.

3.3
refrigerant
working fluid used for heat transfer in a cooling system, which absorbs heat at a low temperature and a low pressure and rejects heat at a higher temperature and a higher pressure usually involving changes of the state of the fluid

3.4
capacity
total heat flow rejected by the refrigerant. This total heat flow of rejection is equal to the product of the mass flow rate of the refrigerant and the difference between the enthalpies of the refrigerant at the condenser/gas cooler inlet and outlet connections

3.5
pressures
3.5.1
condensing/gas cooling pressure
pressure of the refrigerant at the inlet connection of the condenser/gas cooler

3.5.2
evaporating pressure
pressure of the refrigerant at the outlet connection of the calorimeter (applicable only to low pressure calorimeter method)

3.5.3
calorimeter pressure
pressure in the secondary fluid side of the calorimeter vessel (applicable only to low pressure calorimeter method and high pressure calorimeter with indirect heat inducement)

Note 1 to entry: All pressures are average values ascertained over the test duration, and are absolute pressures.

3.6
temperatures
Note 1 to entry: All air temperatures are dry bulb temperatures.

3.6.1
air inlet temperature
average dry bulb temperature of the air at the inlet of the condenser/gas cooler taking into consideration the local air velocities

3.6.2
ambient air temperature
average temperature of the air surrounding the calorimeter, responsible for the heat exchange with the ambient

3.6.3
inside air temperature
average temperature of the air inside the calorimeter, responsible for the heat exchange with the ambient

3.6.4
refrigerant temperatures
3.6.4.1
dew point temperature
temperature of the refrigerant corresponding to the condensing pressure

3.6.4.2
condenser/gas cooler inlet temperature
temperature of the refrigerant vapour at the inlet connection of the condenser/gas cooler

3.6.4.3
subcooled refrigerant temperature
temperature of the liquid refrigerant in the receiver

3.6.4.4
gas cooler outlet temperature
temperature of the refrigerant gas at the outlet connection of the gas cooler

3.6.4.5
evaporating temperature
dew point temperature of the refrigerant corresponding to the evaporating pressure (applicable only to low pressure calorimeter method)

3.6.4.6
vapour temperature
temperature of the refrigerant at the calorimeter outlet connection

3.6.4.7
bubble point temperature at condenser outlet
temperature corresponding to the absolute pressure of the refrigerant at the outlet connection of the condenser

3.6.5
water temperatures
(applicable only to air side calorimeter method)

3.6.5.1
water inlet temperature
temperature of the water as it enters the calorimeter

3.6.5.2
water outlet temperature
temperature of the water as it leaves the calorimeter

Note 1 to entry: All temperatures are average values ascertained over the test duration.

3.7
temperature differences
3.7.1
condenser inlet temperature difference
difference between the condensing temperature and the air inlet temperature

3.7.2
gas cooler inlet temperature difference
difference between the gas cooler inlet temperature and the air inlet temperature

3.7.3
superheating
difference between the condenser inlet temperature and the condensing temperature

3.7.4
subcooling
difference between the bubble point temperature and the subcooled refrigerant temperature

3.8
high glide
refrigerant where the difference between the condensing and bubble point temperatures at a condensing temperature of 40 °C is greater than 3 K

3.9
fan power
electrical power, absorbed by the fan motor(s) measured at the electrical terminals of the motor(s)

3.10
nominal fan power
fan power measured during the air flow test and corrected to the nominal atmospheric pressure of 1 013,25 hPa

Note 1 to entry: The fan power will also differ with the temperature at which the fan runs. As the fan power is only a small proportion of the total cooling load, the deviations are considered to be negligible.

3.11
rotational speed of the fans
average rotational speed of the fans

3.12
nominal air flow
air volume flow rate, flowing through the condenser/gas cooler

3.13
internal volume
volume of the refrigerant containing parts of the condenser/gas cooler between its two connections

3.14
fouling resistance
thermal resistance due to unwanted deposit on the heat exchanger surface reducing its heat transfer performance

Note 1 to entry: The fouling resistance for a clean surface is zero.

Note 2 to entry: Clean, in this context, means that all production residues have been removed from the heat transfer surface and the fan(s) by the factory's cleaning process.

3.15
oil content
the proportion of oil by mass in the pure refrigerant circulating in the heat exchanger

4 Symbols

For the purposes of this document, the symbols of Table 1 apply:

Table 1 — Symbols

E	energy supply to the calorimeter (refrigerant side calorimeters)	kWh
HLF	heat loss factor from calorimeter	kW/K
h_{sup}	spec. enthalpy of superheated vapour at condenser inlet connection	kJ/kg
h_{sub}	spec. enthalpy of subcooled liquid refrigerant at condenser outlet connection	kJ/kg
h_{R1}	specific enthalpy of the refrigerant at gas cooler inlet connection	kJ/kg
h_{R2}	specific enthalpy of the refrigerant at gas cooler outlet connection	kJ/kg
h_{R4}	specific enthalpy of the refrigerant at inlet connection of the calorimeter	kJ/kg
h_{R5}	specific enthalpy of the superheated refrigerant at outlet connection of the calorimeter	kJ/kg
h_{W1}	specific enthalpy of water entering the calorimeter	kJ/kg
h_{W2}	specific enthalpy of water leaving the calorimeter	kJ/kg
N	rotational speed of the fans	min^{-1}
P_{fan}	electrical power of the fan(s)	kW
p_{atm}	atmospheric pressure	hPa
p_c	condensing or gas cooling pressure	kPa
p_{R1}	gas cooler inlet pressure	kPa
p_{R2}	gas cooler outlet pressure	kPa
p_e	evaporating pressure	kPa
p_i	pressure of the secondary fluid in the calorimeter	kPa
q_{mR}	mass flow rate of refrigerant	kg/s
q_{mW}	mass flow rate of water	kg/s
q_{va}	volumetric flow rate of the air	m^3/s
t_{A1}	air inlet temperature	°C
t_R	refrigerant temperatures	°C
t_{R1}	gas cooler inlet temperature	°C
t_{R2}	gas cooler outlet temperature	°C
t_{RM}	refrigerant temperature at flow meter	°C
t_{sup}	superheated vapour temperature	°C
t_{sub}	subcooled refrigerant temperature	°C
t_W	water temperatures	°C
t_{WM}	water temperature at flow meter	°C
t_{amb}	ambient temperature	°C
t_i	temperature inside calorimeter	°C

Δt_1	inlet temperature difference	K
Δt_{sup}	superheating	K
Δt_{sub}	subcooling	K
τ	test duration	S
U	Supply voltage	V

NOTE 1 bar = 100 kPa = 1 000 hPa

Subscripts

m mass;

v volume;

W water;

R refrigerant.

Superscripts

st standard

Numbers.

Position as defined in the annexes.

5 Standard capacity

5.1 Basis for standard capacity data

The influence of the refrigerant mass flow, the heat flux and the condensing temperature on the overall heat transfer of an air cooled condenser is low. As a result, in the range of temperature differences between 10 K and 20 K, the capacity is almost proportional to the temperature difference. The influence of superheat on the capacity is also low; it is below + 0,5 % per K superheat.

For refrigerants which are cooled but not condensed in the gas cooler the test conditions shall be observed with the greatest possible accuracy, as conversion to standard conditions can be very extensive.

The airflow through a condenser/gas cooler has great influence on its capacity. Because of the complicated relations a simple conversion to other air flows is not possible with sufficient accuracy. Therefore the electrical values which influence the fan speed (voltage and frequency) shall correspond with the standard supply conditions.

5.2 Standard capacity conditions

The standard capacity shall be based on tests performed on a clean and dry condenser/gas cooler under the following operating conditions:

Table 2 —Standard conditions for condensers

Standard condition	t_{A1}	Δt_1	Δt_{sub}
	°C	K	K
SC 1	25	15	≤ 3
SC 2	25	10	≤ 3

Table 3 — Standard conditions for gas coolers

Standard condition	t_{A1} °C	p_{R1} bar	t_{R1} °C	t_{R2} °C
SC 10	25	90	110	35

Superheating Δt_{sup} for some selected refrigerants shall be according to Table 4:

Table 4 — Superheating values

Refrigerant	Δt_{sup} K
R134a	25
R404A/R507A	25
R407C	35
R410A	40
R717 (NH_3)	50

For all other refrigerants this shall be related to superheating that results when the refrigerant is subjected to isentropic compression from – 10 °C evaporating temperature at + 10 °C superheated vapour temperature to + 40 °C condensing temperature.

5.3 Conditions for the nominal air flow rate

The nominal air volume flow rate refers to an air temperature of + 20 °C and an atmospheric pressure of 1 013,25 hPa.

NOTE 1 For refrigerant R744 (CO_2) the optimal high pressure has been taken as the basis for determining the gas cooler inlet temperature.

NOTE 2 The air volume flow is not influenced by atmospheric pressure and temperature if the fan speed is constant.

5.4 Conditions for nominal fan power

The nominal fan power refers to an air temperature of + 20 °C and to an atmospheric pressure of 1 013,25 hPa.

6 Manufacturer’s data

To identify the condenser/gas cooler and to allow its traceability the manufacturer or supplier shall provide the following minimum information for each condenser/gas cooler type:

a) manufacturer's identification;

b) model designation of unit;

c) model designation of fan;

d) rating of the fan motor(s) according to EN 60034-1;

e) standard capacity for the standard conditions in the range of application, stating the refrigerants used;

f) nominal air flow;

g) nominal fan power;

h) nominal voltage and frequency;

i) total heat transfer surface (air side);

j) fin pitch and thickness;

k) tube outside diameter and internal enhancement;

l) tube pattern;

m) circuiting arrangement;

n) internal volume including headers;

o) installation instructions;

p) maximum permissible operating pressure PS.

7 Measurements

7.1 Uncertainty of measurements

The permissible uncertainty of significant measurements is given in Table 5:

Table 5 — Uncertainty of measurements

Measured quantity	Unit	Uncertainty of measurements
Air		
— inlet temperature	°C	± 0,2 K
— other temperatures	°C	± 0,5 K
Refrigerant		
— temperature (general)	°C	± 0,2 K
— pressure for condensers and gas coolers	Pa Pa	Shall ensure that the condensing temperature to be obtained within ± 0,2 K and of the gas cooler pressure within ± 1,0 bar
— volume flow rate[a]	kg/s m^3/s	± 2 %
Liquid		
— temperature	°C	± 0,2 K
— temperature difference	K	± 0,1 K
— volume flow rate[a]	m^3/s	± 1 %
Electrical quantities		
electrical power input	W	± 1 % or at least 1 W
— Current	A	± 0,5 %
— Voltage	V	± 0,5 %
— Frequency	Hz	± 0,5 %
Oil content in the refrigerant	kg	± 20 % of the measured value
Atmospheric pressure	hPa	± 5 hPa
Fan speed	min^{-1}	± 1 %
[a] Also mass flow rate with equivalent uncertainty can be used.		

7.2 Measurement criteria

7.2.1 Pipe side temperature measurement

Refrigerant temperatures shall be measured using one of the following methods:

a) Method A

When the temperature is measured on the outside of the connecting pipe it shall be measured at two opposite points of the same cross-section and, if the pipe is horizontal, there shall be one point above and one below.

The pipe shall be insulated on each side of the temperature measuring point for a length of at least 10 times of its outside diameter. It shall be ensured, that good thermal contact exists between the sensor and the pipe at the measuring point.

The measured value is the arithmetic mean of both individual values.

b) Method B

When the temperature is measured by a sensor immersed in the pipe, care shall be taken that temperature stratifications and flow patterns do not influence the accuracy of the measurements.

7.2.2 Condenser and gas cooler inlet temperature

The inlet temperature shall be measured as near as possible to the inlet connection provided by the manufacturer ensuring that no liquid is present at the measuring point. Method B is preferred.

7.2.3 Subcooled refrigerant temperature

The subcooled refrigerant temperature shall be measured in the liquid of the receiver. Method B is required, ensuring that the device is permanently immersed in the liquid.

To achieve this, the temperature sensing element shall be placed in the liquid part of the liquid receiver required for free drainage.

NOTE This is especially significant as the refrigerant coming from the condenser does not have a uniform temperature and therefore needs mixing.

7.2.4 Water temperatures (Balancing air cooler - Air side calorimeter)

Water temperatures shall be measured as the water enters or leaves the air side calorimeter. Method B is required.

7.2.5 Gas cooler outlet temperature

The outlet temperature shall be measured as near as possible to the outlet connection provided by the manufacturer.

NOTE Method B is preferred.

7.2.6 Air temperatures

7.2.6.1 Air inlet temperature

The air inlet temperature shall be measured in the centre of equal sections of the face area. These sections shall not be larger than 0,2 m^2 and be square if possible. There shall be at least 6 sections. Temperature sensing elements shall be shielded against radiation and any other form of heat transfer affecting the accuracy of the measurement.

If the air inlet area is orientated vertically, an additional temperature sensor shall be placed on the lower and upper verge of the inlet area in order to check that there is no significant temperature stratification.

7.2.6.2 Ambient air temperature for high and low pressure - calorimeter method

The ambient air temperature shall be the arithmetic mean of temperatures measured in the centre of six rectangular planes surrounding the insulated calorimeter and within a distance of 400 mm to 500 mm.

7.2.6.3 Air temperatures - air calorimeter room method

Air temperatures shall be measured 0,15 m perpendicular to the surface of the calorimeter.

If the calorimeter is in direct contact with the floor the temperature shall be measured on the outer surface of the insulation.

NOTE The quantity and location of temperature measuring points will be dependent on the calorimeter design and the variation in inside and ambient temperatures.

There shall be at least one inside and ambient temperature measuring point on each of the six surrounding surfaces.

7.2.7 Pressure measuring points

The pressure measuring points shall be located in the middle of a straight part of pipe of constant diameter, equal to the condenser/gas cooler connections, having a length of not less than 10 times its diameter ensuring that there is no restriction involved. They shall be placed between the temperature measuring points and the connections of the condenser/gas cooler.

The flow rates of refrigerants and water shall be measured according to the recommendations of the installation instructions for the flow measuring devices.

7.2.8 Refrigerant flow rate

When the liquid flow rate is measured, the refrigerant shall be sufficiently subcooled to prevent the generation of flashgas which causes inaccurate measurements. In order to check that there is no flashgas, a sight glass shall be placed immediately after the flow measuring section.

NOTE 1 With refrigerants it is practical to measure the flow rate on the liquid side.

NOTE 2 For gas coolers it is practical to measure the flow rate on the gas cooler outlet side.

NOTE 3 Flow rates usually fluctuate over time. Therefore, to measure these, integrated devices are more suitable than instantaneous indicators.

7.2.9 Water flow rate

NOTE As with refrigerants, integrating devices are more suitable than momentary indicators.

7.2.10 Oil content

The oil content shall be measured unless it can be guaranteed that it is below 1 % by mass.

For a recommended measurement procedure see Annex D (informative).

7.2.11 Non-azeotropic refrigerant

For high glide refrigerants the refrigerant mixture shall be measured unless it can be guaranteed that the mass fraction varies by less than 2 % from the refrigerant manufacturer’s data.

8 Testing methods and equipment

8.1 Testing methods for capacity

8.1.1 General

Two methods of determining the capacity shall be used simultaneously as follows:

— The primary method shall determine the capacity by use of a calorimeter;

— The confirming method shall determine the capacity by use of a refrigerant flow meter;

— The result of the confirming method shall agree with that of the primary method within ± 4 %:

— The standard capacity shall be based on the arithmetic mean of the results of the primary and secondary methods;

— The testing arrangements are shown in Annexes A, B and C.

NOTE If the deviation between both methods is greater, it can be assumed that there is an error either in the testing arrangement or in the execution of the tests.

The methods given in 8.1.2, 8.1.3, 8.1.4, 8.1.5 and 8.1.6 are applicable.

8.1.2 High pressure calorimeter (primary method)

8.1.2.1 General

In this method the refrigerant, condensed by the condenser is re-evaporated and superheated in a calorimeter approximately at the condensing temperature by a known heat input. The refrigerant is circulated either by natural convection or pump circulation (see Figures A.1 and A.2).

NOTE 1 Any subcooling in an air cooled condenser is a sign for non-condensables in the test cycle or a refrigerant accumulation in the condenser. To achieve subcooling there may only be a liquified refrigerant phase in the tube. In case of accumulations the header or outlet connection is too small and the condenser will never work properly. The outlet connection will be totally filled with liquid. As long as there is a liquid and a gaseous refrigerant phase at the outlet connection (this is the usual case), subcooling is physically impossible. If there are non-condensables in the test cycle, the determined condensing temperature over a pressure measurement is higher than the actual condensing temperature. This is effected by the additional partial pressure of the non-condensables. For accurate testing these non-condensables have to be purged from the test cycle.

NOTE 2 This method is not suitable for high glide refrigerants and is not practical where high operating pressures are required.

8.1.2.2 Direct capacity measurement

In this method the heat flow induced into the calorimeter corresponds to the capacity of the condenser, taking into account any heat loss and possible heat inducement by the pump.

8.1.2.3 Flow rate measurement method

This method determines the refrigerant flow rate indirectly by dividing the heat flow rate, indeed into the calorimeter, by the difference of the specific enthalpies at the connections of the calorimeter. In order to obtain the capacity, the refrigerant flow rate is multiplied by the difference of the specific enthalpies at the connections of the condenser.

Heat losses and possible heat inducement by the pump are taken into account.

8.1.3 Low pressure calorimeter (primary method)

This method determines the flow rate of the refrigerant, circulated by a compressor, by use of a calorimeter on the low pressure side of the refrigerating cycle (see Figure B.1). To obtain the refrigerant flow rate, the heat flow, induced into the calorimeter, is divided by the difference of the specific enthalpies at the connections of the calorimeter. In order to obtain the capacity, the refrigerant flow rate is multiplied by the difference of the specific enthalpies at the connections of the condenser/gas cooler.

In order to keep the heat gain or loss of the calorimeter vessel at a negligible proportion of the heat input, its temperature is kept at ambient air temperature.

8.1.4 Air side calorimeter (primary method)

This method determines the capacity of the condenser/gas cooler on the air side in a calorimeter room (see Figure C.1).

The principle is to measure the capacity rejected by the condenser/gas cooler by measuring the capacity of a water cooled air cooler balancing the calorimeter room air temperature. The cooling capacity corresponds to the capacity of the condenser/gas cooler, taking into account the heat exchanged between the air inside the calorimeter room and the ambient as well as the heat input by the condenser of the condenser/gas cooler fan motors and other auxiliary devices. The cooling capacity is obtained by multiplying the measured water flow rate through the balancing cooler with the difference of the specific enthalpies of the water leaving and entering the calorimeter room.

8.1.5 Refrigerant flow method (confirming method)

The confirming test method determines the capacity on the refrigerant side.

The principle is to measure the refrigerant flow rate directly and to multiply it by the difference between the specific enthalpies at the inlet and outlet connections of the condenser/gas cooler.

The specific enthalpy difference of the refrigerant is determined from the temperature and pressure measurements and physical properties of the refrigerant.

Only refrigerants with well documented physical properties shall be used.

8.1.6 Air flow method

The air flow method for determining the capacity is considered not to be sufficiently accurate and therefore its use is not permitted in this standard.

NOTE Because of the difficulty of measuring the temperature of the air leaving the condenser/gas cooler with sufficient accuracy due to the quick mixing of the air coming from the condenser/gas cooler with the ambient air, it is not possible to determine the temperature difference between the air inlet and outlet.

8.2 Air flow measurement

Condensers/gas coolers create a very turbulent air flow, therefore the measurement of air speeds at individual points cannot be used to determine air volume flow. The testing method shall be capable of measuring the overall air volume flow. It is recommended that EN ISO 5801, with an inlet or outlet chamber arrangement, be used. An auxiliary fan shall be used which provides atmospheric pressure in the chamber at the pressure measuring points adjacent to the connection of the condenser/gas cooler. Other methods are acceptable provided that the required accuracy is achieved.

For the measurement of air temperature one point at the inlet or outlet is sufficient.

During the air volume flow measurement it is not necessary for refrigerant to be circulating through the condenser/gas cooler.

8.3 Equipment for capacity measurement

8.3.1 General

The test installation shall be capable of maintaining steady-state conditions as required by this standard.

NOTE Heat inducement into a refrigerant side calorimeter is preferably executed by electric power supply.

The testing arrangement shall be designed in such a way that the condenser/gas cooler under test can be placed under conditions as in practical operation. In particular the following shall be ensured:

— free drainage of the liquid refrigerant from the condenser to the liquid receiver shall be provided;

— with non azeotropic refrigerants care shall be taken, that there are no liquid refrigerant accumulations in the refrigerant cycle.

Non-azeotropic refrigerants are mixtures of more than one refrigerant with different individual boiling temperatures. If the mixture is separated at a two phase state e.g. in a vessel, one of the two phases can accumulate affecting the concentration of each refrigerant within the rest of the system. While testing, it should be ensured that the concentration of the individual refrigerants within the mixture circulating through the condenser is identical with the concentration with which it was originally filled.

— the air flow through the condenser/gas cooler being tested shall not be modified;

— the air flow around the condenser/gas cooler shall not be influenced. Recirculation of air shall neither be created nor prevented if it is a normal feature.

Therefore the condenser/gas cooler shall be installed so that, where *A* and *B* are the air inlet dimensions of the condenser/gas cooler:

a) no obstacle is positioned within a distance of 1,5 × $\sqrt{A \times B}$ away from the discharge of the condenser/gas cooler;

b) no obstacle is positioned within a distance of 0,75 × $\sqrt{A \times B}$ parallel to the sides of the condenser/gas cooler;

c) all distances correspond to the minimum requirements of the installation instructions provided by the manufacturer, particularly the distance of the air inlet from the floor or next wall;

d) the volume in m^3 of the compartment, housing the condenser/gas cooler under test, shall be at least 1/600 of the air flow rate in m^3/h produced by the condenser/gas cooler under test together with all auxiliary air moving devices.

The calorimeter shall be designed such, that the heat exchange with the ambient does not influence the accuracy of the test result by more than ± 1 %.

This means that the heat loss should be known with an uncertainty of less than ± 10 % if it amounts to 10 % of the measured capacity.

The total heat input of the calorimeter shall be chosen such that it does not vary by more than ± 0,5 % of the capacity measured during the test duration.

The heat loss of the liquid receiver and the connecting pipe to the condenser/gas cooler shall be small enough to prevent condensation in the vessel, equivalent to more than 0,25 % of the measured capacity.

The liquid receiver shall be equipped with a sight glass in order to check that the temperature sensing element is immersed in the liquid refrigerant and that constant flow is achieved.

8.3.2 High pressure calorimeter

The calorimeter consists of a well-insulated pressure vessel inside which the refrigerant is evaporated and superheated in a consecutive superheating zone. The heat may be supplied directly or indirectly via a secondary fluid.

When the heating elements are in direct contact with the refrigerant, their temperature shall be low enough to prevent decomposition of the refrigerant.

When the heat is supplied indirectly, the heating elements are immersed into a secondary fluid surrounding an evaporator coil. The secondary fluid is heated up approximately to the superheating temperature. It consists preferably of a volatile liquid and the evaporator coil is placed in the vapour zone of the vessel. The refrigerant itself is evaporated and superheated in the evaporator coil.

NOTE 1 The coil needs to be sized only for maximum requirements and can be used also for lower capacities

When calculating the total heat content of the calorimeter, the mass of the secondary fluid and the refrigerant in the calorimeter vessel shall be considered.

When a circulation pump is used, it shall not induce measurable heat into the refrigerant.

NOTE 2 The heat induced by the pump is a variable which can only be verified with great difficulty in the calibration test. Furthermore it mostly causes flashgas which falsifies the measured value of the flow meter and influences the performance of the pump itself adversely.

This normally requires a variable speed pump, thermally separated from the refrigerant cycle. A throttling device for flow control causes flashgas in the pump and the flow meter. The circulation pump should be placed between the liquid receiver and the flow meter in order to obtain maximum subcooling in the meter. A short equalising line between the pump and the meter can be useful.

If no flashgas is present the heat input by the pump should be negligible.

8.3.3 Low pressure calorimeter

The calorimeter consists of a well insulated pressure vessel inside which the refrigerant is evaporated and superheated in a consecutive superheating zone. The heat is supplied indirectly via a secondary fluid. The heating elements are immersed into the secondary fluid surrounding an evaporator coil. The secondary fluid is heated up approximately to the ambient temperature. It consists preferably of a volatile liquid and the evaporator coil is placed in the vapour zone of the vessel. The refrigerant itself is evaporated and superheated to the ambient temperature within ± 1 °C in the evaporator coil.

The coil should be sized only for maximum requirements and can be used also for lower capacities.

In order to keep the oil content in the condenser/gas cooler within the specified limits it is recommended to fit an oil separator between the compressor and the condenser/gas cooler under test.

The line from the measuring point of the subcooled refrigerant temperature or the gas line between gas cooler and expansion valve, the expansion valve, the line connecting it to the calorimeter, the calorimeter itself and the suction line to the measuring point of the vapour temperature shall be well insulated to reduce heat gain or heat loss to less than 2 % of the measured capacity and to prevent any moisture condensation. When calculating the total heat content of the calorimeter, the mass both of the refrigerant and the secondary fluid in the calorimeter vessel shall be considered.

8.3.4 Air side calorimeter

The condenser/gas cooler is installed in a well insulated calorimeter room together with a balancing air cooler. The room shall be designed and arranged such that verification of the heat exchange with the ambient according to the requirements of this standard is possible.

All equipment in the refrigerant cycle, except for the measuring points at the condenser/gas cooler and the liquid receiver shall be placed outside the calorimeter room. The liquid receiver may be positioned outside the calorimeter if unrestricted refrigerant drainage is guaranteed.

The refrigerant pipes within the calorimeter room, shall be insulated sufficiently well for the heat emission in the calorimeter room to lie below 0,5 % of the cooling capacity to be measured. Thus it is negligible.

The balancing air cooler shall be designed and installed such, that the general requirements, specified above, are met. The water inlet and outlet temperature measuring points shall be positioned immediately outside the calorimeter wall.

All power input into the calorimeter shall be measured.

The calorimeter room shall be located in an ambient than average temperature of which can be held constant. There shall be no significant heat radiation to the test room. The clearance between the calorimeter room and the walls of the enclosing space shall be sufficient to allow the reproducible measurement of the ambient temperature.

Ambient conditions of the calorimeter room shall be such that the same air conditions, particularly air movements, prevail during the calibration test as during the capacity test.

The heat exchange of the calorimeter with the ambient shall not exceed 20 % of the measured capacity.

The total heat flow of the calorimeter room is calculated from the mass and specific heat of the objects in the room, the interior covering of the walls and floor and half the insulation thickness.

8.3.5 Refrigerant flow method

The following measuring installation is recommended as it has proven to be simple and reliable. Other ways of measuring the refrigerant flow rate directly can be used, provided they meet the limits for uncertainty specified in this standard.

The flowmeter is placed in the liquid line or in the gas line between gas cooler and the expansion valve of the refrigerant cycle.

NOTE 1 When using the high pressure calorimeter the flow meter will preferably be placed outside the calorimeter insulation in order to supply maximum subcooling.

NOTE 2 When using the low pressure calorimeter the flow meter will preferably be placed just before the expansion valve in order to supply maximum subcooling.

For preliminary runs a by pass parallel to the flow meter may be used in order not to change the flow rate by shutting it before the test, it should have the same pressure drop as the meter.

8.3.6 Liquid receiver

For high glide refrigerants the internal volume of the liquid receiver shall be less than 4 % of the total system volume.

9 Test procedures

9.1 General

The condenser/gas cooler shall be installed in accordance with the manufacturer's specification.

All components supplied by the manufacturer as part of the condenser/gas cooler shall be included in the test setup and used in accordance with the manufacturer's instructions.

The difference between any individual air inlet temperatures should not exceed 1 K. For any deviations greater than 1 K it shall be ascertained that this is not due to the test equipment and this shall be mentioned in the test report.

The condenser/gas cooler itself may generate recirculation of air and thus cause a greater deviation. The liquid receiver shall be connected to the condenser outlet in a way that there is no restriction to the liquid flow from the condenser. Gas shall be prevented from leaving the receiver with the liquid.

9.2 Heat loss measurement - calibration

9.2.1 General

If not otherwise specified the difference between the inside and ambient temperatures shall be as high as possible but not exceed 40 K.

When selecting the temperatures, the effect they may have on the insulation material shall be taken into account.

The test duration shall be chosen such that any deviation from steady-state conditions cannot influence the uncertainty of the test result by more than ± 0,5 %.

The test duration shall continue for at least 6 h after steady-state conditions have been reached. Then temperatures and temperature differences shall not change by more than ± 2,5 % of the measured temperature difference during the test duration.

Measurements shall be taken at regular intervals small enough to monitor all significant fluctuations. At least 7 sets of measurements are required.

9.2.2 High pressure calorimeter - direct heat inducement into refrigerant

The calibration test shall determine the heat loss from the system under the same subcooling and superheating values as in standard capacity test.

The system comprises:

a) for the direct capacity measurement method the calorimeter side of the circuit between the pressure measuring points at the condenser;

b) for the flow rate measurement method the calorimeter side of the circuit between the measuring points for the temperatures needed for determining the significant enthalpy difference.

For calibration, a well insulated water-cooled condenser shall be connected in place of the air cooled condenser to be tested. The heat shall be induced by electric heaters. The difference between the heat input into the calorimeter and the heat removed by the water is the heat loss.

The internal temperature is the saturation temperature corresponding to the pressure inside the calorimeter. For the purposes of this standard the inside temperature corresponds to the condensing temperature. The temperature conditions shall correspond to the standard conditions for the refrigerant used.

Maximum difference between two individual ambient air temperatures shall be 1 K.

Data to be recorded:

— Individual ambient air temperatures.

— p_c, t_{sup} and t_{sub} *or* t_{R4} and t_{R5} as required.

— E, τ.

All data required for determining the water cooled condenser capacity.

9.2.3 Low and high pressure calorimeters - heat inducement into secondary fluid

The calorimeter shall be disconnected from the circuit at the measuring points for the significant refrigerant temperatures for determining the enthalpy difference. For a low pressure calorimeter, the expansion device shall be connected during calibration. The heat input under steady-state conditions is the heat loss.

When the secondary fluid inside the calorimeter is volatile, the inside temperature is the saturation temperature corresponding to its pressure.

In the case of a non volatile refrigerant a measuring point shall be placed both in the lower and upper part of the calorimeter.

Maximum difference between two individual ambient air temperatures shall be 1 K.

Data to be recorded:

— Individual ambient air temperatures;

— p_i or t_i;

— E, τ.

9.2.4 Air calorimeter room

With the water flow to the balancing cooler off, the calorimeter room is heated electrically. The electrical power input, including fan motors, under steady-state conditions, is the heat loss.

The heat flow through the calorimeter room shall be measured when the air circulation in the calorimeter room is at the maximum achievable value and another value approximately 50 % lower. If fitted, fans on the balancing cooler shall be on to correspond to test conditions as closely as possible.

When the calorimeter room floor is in contact with the floor of the site, additionally the heat inducement into the calorimeter room shall be varied such, that the higher value lies at least 50 % above the lower.

NOTE It is desirable that the ambient air temperature is varied additionally as this will give a hint on the relative proportions of the heat flow through the floor and the other surrounding surfaces.

A theoretical evaluation of the heat transfer shall be established and compared to the measured results.

Individual inside air temperatures or ambient air temperatures shall not differ from each other by more than 10 % of the difference between the inside and ambient temperature.

Data to be recorded:

— Individual inside and ambient temperatures;

— air flow rates of the condenser/gas cooler and balancing cooler fans;

— E, τ.

9.3 Capacity measurement

9.3.1 Steady-state

Measurement of condenser/gas cooler capacity shall be carried out in steady-state conditions. These shall be reached half an hour before the test commences.

Steady-state conditions are assumed to have been reached and maintained when all changes and periodic fluctuations during test duration remain within the following ranges:

a)	air inlet temperatures	t_{A1}	± 0,3 K;
b)	inlet temperature difference	Δt_1	± 0,3 K;
c)	superheated vapour temperature	t_{sup}	± 1 K;
d)	gas cooler inlet temperature	t_{R1}	± 2 K;
e)	gas cooler inlet pressure	p_{R1}	± 1,0 bar;
f)	refrigerant and water flow rate	q_{mR}, q_{mW}	± 3 %;
g)	electrical power input into the calorimeter	P	± 1,0 %;
h)	ambient temperature	t_{amb}	± 1 K;
i)	fan speed	n	± 2 %.

In order to ensure that steady-state conditions are maintained, all important values are to be continuously monitored at intervals small enough to identify all significant fluctuations.

9.3.2 Test duration

The test duration shall be chosen such that any deviation of temperatures will not influence the uncertainty of the test result by more than ± 0,5 %.

The test duration shall be a minimum of one hour.

At least five sets of measurements shall be taken at regular intervals during the test period.

NOTE The heat capacity (water equivalent) of the calorimeter has considerable influence on the accuracy of the measurements when the temperatures are not completely constant.

As the uncertainty caused in this way shall not be more than 0,5 % when constant conditions are not maintained exactly, the test duration depends on the heat capacity and on the relative deviation from constant conditions. The following formula gives an estimation of the testing time:

$$\tau \geq \left(200 \times \Delta t_i \times C\right) / P$$

where

τ	is the test duration required for an uncertainty ≤ 0,5 % in s;
Δt_i	is the temperature difference between the highest and the lowest inside air temperature during the test period in K;
C	is heat capacity of the calorimeter and equipment in kJ/K;
P	is the measured capacity in kW.

The total heat content of the calorimeter room is calculated from the mass and specific heat of the objects in the room, the interior covering of the walls and floor and half the insulation thickness.

9.3.3 Conducting the test

To retain sufficient accuracy when converting the measured capacity to the standard conditions, the average values shall be within the deviations from the standard conditions given in Table 6:

Table 6 — Tolerances

Condenser		Gas cooler	
t_{A1}	± 3 K	t_{A1}	± 1 K
Δt_1	± 1 K	p_{R1}	± 1 bar
Δt_{sup}	± 10 % of nominal value	t_{R1}	± 1 K
		t_{R2}	± 1 K
U	± 2 % of nominal value	U	± 2 % of nominal value
Frequency	± 1 % of nominal value	Frequency	± 1 % of nominal value

With the refrigerant side calorimeters the maximum difference between two individual ambient air temperatures shall be 1 K.

9.3.4 Data to be recorded

9.3.4.1 General

With air side temperatures the values at individual measuring points shall be recorded.

If the difference between any individual air inlet temperatures exceeds 1 K, this difference, and the reason for it, shall be given in the test report.

Data to be recorded: U, t_{sup}, t_{A1}, P_{fan}, n, τ, energy input into the calorimeter E.

9.3.4.2 High pressure calorimeter

t_{sup}, t_{sub}, t_{A1}, t_{amb},

for flow rate measurement additionally t_{R4}, t_{R5},

p_c, (p_i if required), p_{atm}, P_{fan}, n, τ, energy input into the calorimeter E,

refrigerant used.

9.3.4.3 Low pressure calorimeter

t_{sup}, t_{sub}, t_{R4}, t_{R5}, t_{A1}, t_{amb}, t_{R1}, t_{R2}

p_c, p_i, p_e, p_{R1}, p_{R2}, p_{atm}, P_{fan}, n, τ ,

energy input into the calorimeter E,

refrigerant used, oil content.

9.3.4.4 Air side calorimeter

t_{sup}, t_{sub}, t_{R1}, t_{R2}, t_{A1}, t_{amb}, t_i, t_{W1}, t_{W2}, t_{WM}, p_c

p_{R1}, p_{R2}, $P_{fan,}$ n, q_{mW} or q_{vW}, n, τ,

energy input into the calorimeter *E*,

refrigerant used, oil content.

9.3.4.5 Confirming method

Additionally: q_{mR} or q_{vR}, t_{RM}

9.4 Measuring the fan performance

The condenser/gas cooler shall be tested without influencing the air resistance at air inlet and outlet.

The air temperature shall be (20 ± 5) °C.

The air flow rate and fan power shall be measured under steady-state conditions, which are assumed to exist when the fan speed does not change by more than 0,5 % within 15 min.

The following data shall be recorded: P_{fan}, n, t_{air}, p_{atm} and supply voltage. For measuring the air flow rate, all data required by the test method shall be recorded.

10 Capacity calculation

10.1 General

Consistent units shall be used.

10.2 Heat loss factor: calibration test

10.2.1 High pressure calorimeter - direct heat inducement into the refrigerant

$$HLF = \frac{\left(\frac{E}{\tau} - q_{mW} \ x \left(h_{W2} - h_{W1}\right)\right)}{\left(t_i - t_{amb}\right)}$$

where

h_{W1}	is the enthalpy of the water at the water cooled condenser inlet connection;
h_{W2}	is the enthalpy of the water at the water cooled condenser outlet connection;
t_i	is the condensing temperature at the water cooled condenser inlet connection;
t_{amb}	is the arithmetic mean of the individual ambient air temperature measurements.

10.2.2 High and low pressure calorimeter - indirect heat inducement into the refrigerant

$$HLF = \frac{\frac{E}{\tau}}{\left(t_i - t_{amb}\right)}$$

where

t_i is the condensing temperature corresponding to the calorimeter inside pressure;

t_{amb} is the arithmetic mean of the individual ambient air temperature measurements.

10.2.3 Air side calorimeter

10.2.3.1 Air side calorimeter totally enclosed by air

$$HLF = \frac{\frac{E}{\tau}}{\left(t_i - t_{amb}\right)}$$

where

t_i is the arithmetic mean of the individual inside air temperature measurements;

t_{amb} is the arithmetic mean of the individual ambient air temperature measurements.

10.2.3.2 Air side calorimeter in contact with the floor

The heat loss/gain shall be calculated by use of a calculation model which shall be verified using the different calibration test results considering also the air flow inside the calorimeter.

10.3 Capacity measurement test

10.3.1 High and low pressure calorimeter - flow rate measurement methods

The measured capacity is calculated by the following formula:

$$P_1 = \left(\frac{E}{\tau} - \text{HLF} \times \left(t_\text{i} - t_\text{amb}\right)\right) \text{ x } \frac{\left(h_\text{sup} - h_\text{sub}\right)}{\left(h_\text{R5} - h_\text{R4}\right)} \text{ or}$$

$$P_1 = \left(\frac{E}{\tau} - \text{HLF} \times \left(t_\text{i} - t_\text{amb}\right)\right) \text{ x } \frac{\left(h_\text{R1} - h_\text{R2}\right)}{\left(h_\text{R5} - h_\text{R4}\right)}$$

where

h_{R4} is the enthalpy of the saturated liquid at t_{R4}.

10.3.2 High pressure calorimeter method - direct capacity measurement

$$P_1 = \frac{\text{E}}{\tau} - \text{HLF} \times \left(t_\text{i} - t_\text{amb}\right)$$

10.3.3 Air side calorimeter

$$P_1 = q_\text{mW} \times \left(h_\text{W2} - h_\text{W1}\right) + \text{E}/\tau + \text{HL}$$

where

HL is the heat flow from the calorimeter to the ambient calculated by a calculation model verified at the calibration test results.

E is the total power input into the calorimeter room, e.g. by the fan power measured during the capacity test.

10.3.4 Confirming method

$$P_2 = q_{mR} \times \left(h_{\sup} - h_{sub}\right) \text{ or}$$

$$P_2 = q_{mR} \times \left(h_{R2} - h_{R1}\right)$$

11 Conversion to Standard Conditions

11.1 General

11.1.1 Introduction

The standard capacity shall be obtained from the average capacity measured (primary and confirming) and corrected for inlet temperature difference and atmospheric pressure.

11.1.2 Correction for atmospheric pressure

For each test a correction factor for the deviation from standard atmospheric pressure (1 013,25 hPa) shall be determined according to:

$$F = 1 + (1013{,}25 - p_{atm}) \times 6{,}5 \times 10^{-4}$$

This formula should allow for the influence of atmospheric pressure on the capacity of the condenser/gas cooler. It is assumed that the capacity increases approximately 0,065 % per hPa of higher air pressure and decreases approximately 0,065 % per hPa of lower air pressure compared to 1 013,25 hPa.

11.1.3 Standard capacity

Within the permissible deviations the following relationships shall apply:

$$P^{(st)} = \frac{P_1 + P_2}{2} \times \frac{15}{\Delta t_1} \times F \text{ (SC1) and}$$

$$P^{(st)} = \frac{P_1 + P_2}{2} \times \frac{10}{\Delta t_1} \times F \text{ (SC2)}$$

11.2 Nominal air flow

For the purposes of this standard the measured air flow rate shall be the nominal air flow rate. No correction to nominal conditions is necessary.

11.3 Nominal fan power

For the purposes of this standard the fan power, measured during the air flow test and corrected to the standard atmospheric pressure of 1013,25 hPa shall be the nominal fan power. The following formula shall apply:

$$P_{fan}^{(st)} = P_{fan} \; x \; \frac{1013{,}25}{p_{atm}}$$

where

P_{fan} and p_{atm} are the values measured during the air flow rate test.

No correction to standard temperature conditions is required.

NOTE For the purposes of this standard a conversion of both the nominal air flow and standard fan power to standard capacity measuring conditions is considered not to change the values significantly, as air side conditions do not differ significantly and will not cause a significant difference in fan speed. Moreover this standard is intended to be used as basis for the certification of product ranges with numerous models, which not all can be capacity tested.

12 Test report

The test report shall be in accordance with EN ISO/IEC 17025. The test report shall at least contain:

a) date;

b) test institute;

c) test location;

d) test method;

e) test supervisor;

f) test object designation:

   1) type;

   2) serial number;

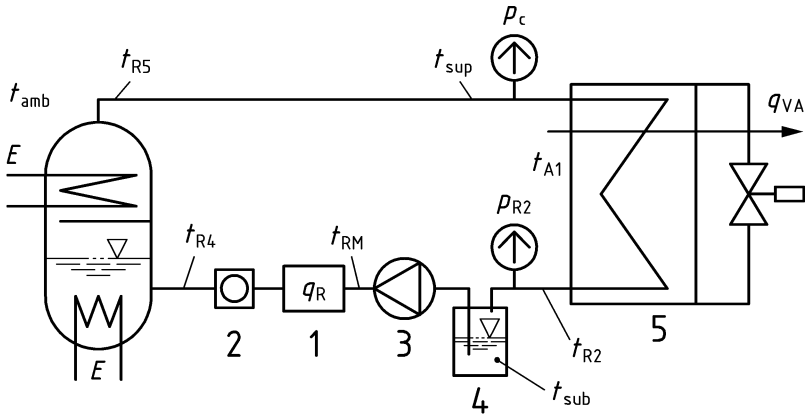
   3) name of the manufacturer;

g) the reference of the refrigerant properties including version number;

h) reference to this European Standard;

i) relevant measured values, see 9.3.4 and 9.4.

Annex A
(normative)
Flow meter method



Key

1 refrigerant flow meter

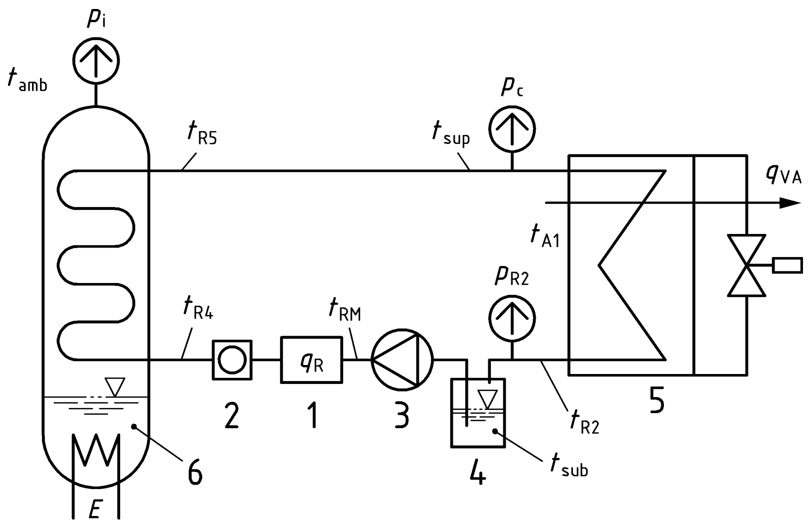
2 sight glass

3 pump or gravity

4 receiver (not required for gas coolers)

5 condenser/gas cooler

Figure A.1 — Arrangement for direct heat inducement method (for single substance and azeotropic refrigerants)



Key

1 refrigerant flowmeter

2 sight glass

3 pump or gravity

4 receiver

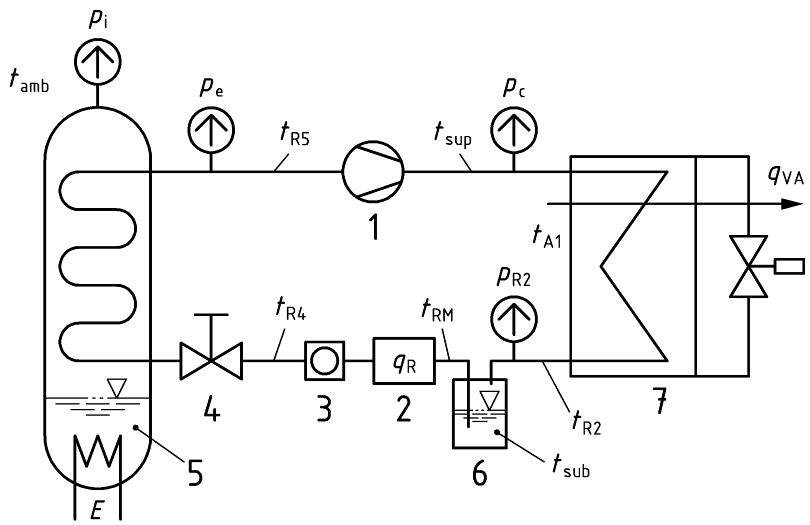
5 condenser

6 secondary fluid (volatile)

Figure A.2 — Arrangement for indirect heat inducement method

For gas coolers tests no receiver is needed.

Annex B
(informative)
Low pressure calorimeter



Key

1 compressor

2 refrigerant flowmeter

3 sight glass

4 expansion device

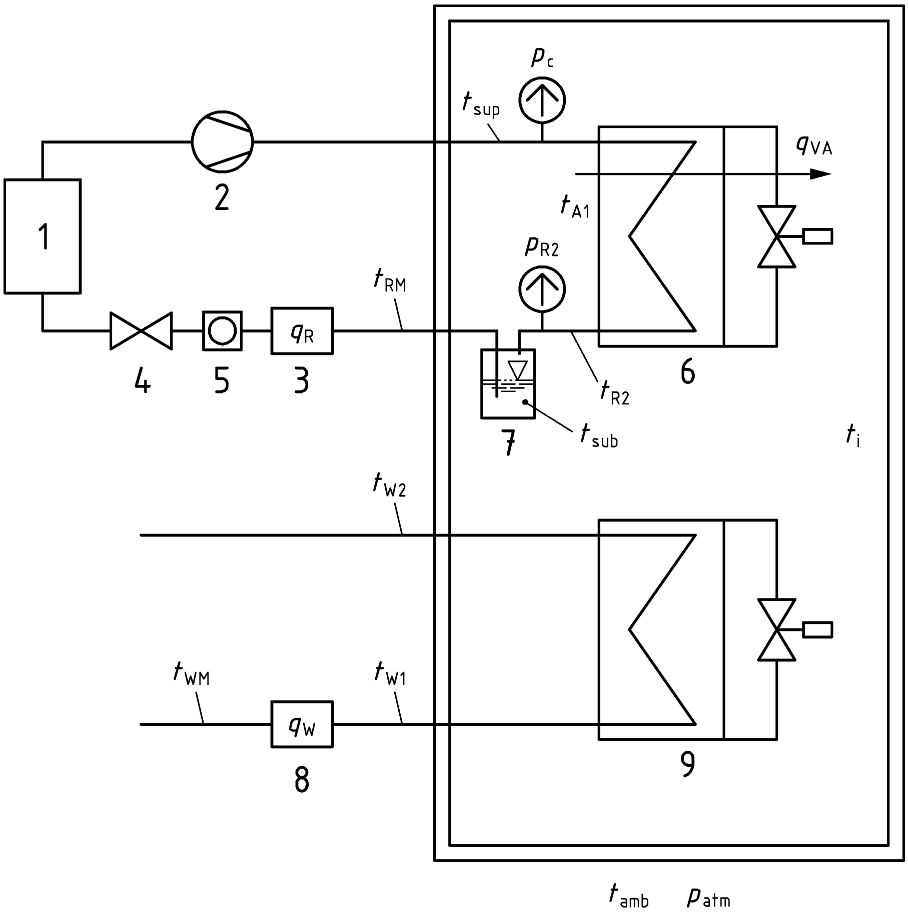
5 secondary fluid (volatile)

6 receiver

7 condenser

Figure B.1 — Arrangement for low pressure calorimeter method

Annex C
(informative)
Air-Side calorimeter



Key

1 calorimeter room
2 compressor
3 refrigerant flowmeter
4 evaporator
5 sight glass
6 condenser
7 receiver
8 water flowmeter
9 balancing air cooler

Figure C.1 — Arrangement for air-side calorimeter method

Annex D
(informative)
Procedure to measure the oil content

The source of the refrigerant properties used shall be indicated including version number.

a) Weigh the empty vessel with an accuracy of ± 0,1 g;

b) Connect this vessel to the liquid cooler at the appropriate position;

c) Weigh the vessel filled with the test sample with an accuracy of ± 0,1 g;

d) Evaporate the refrigerant carefully in order to prevent any escape of oil with the refrigerant and evacuate the vessel. The refrigerant is to be recovered;

e) Add a solvent to the remaining oil (e.g. methylchloroform) in the vessel. Shake the mixture carefully and put it into an evaporating pan which has been weighed accurately to ± 1 mg. Following this, rinse the vessel twice with the solvent and put this mixture into the pan also;

f) Evaporate the solvent by means of a boiling water bath;

g) Weigh the evaporation pan with the oil accurately to ± 1 mg.

The oil content is obtained by dividing the difference of the weights of the evaporating pan with and without the remaining oil by the difference of the weights of the pressure vessel with and without the refrigerant/oil test sample.

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EN ISO 5801, *Industrial fans - Performance testing using standardized airways (ISO 5801)*

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