INTERNATIONAL STANDARD

ISO 916

First edition
2020-02

Testing of refrigerating systems

Essais des machines frigorifiques

Reference number
ISO 916:2020(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 4, *Testing and rating of refrigerant compressors*.

This first edition of ISO 916 cancels and replaces ISO/R 916:1968, which has been technically revised.

The main changes compared to ISO/R 916:1968 are as follows:

— clarification in the Scope that this document is applicable to measurements on site;

— complete revision of the structure of the Terms and definitions clause;

— inclusion of transcritical refrigerant systems;

— new wording to the clauses “Tolerance” and “Measuring instruments”;

— deletion of “5.1.2.2, secondary cooling medium (gaseous)”;

— editorial changes;

— structured according to the current version of ISO/IEC Directives Part 2.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Testing of refrigerating systems

1 Scope

This document applies to the performance testing of compressor driven refrigerating systems (hereafter referred to as refrigerating systems) that operate according to the principle of vapour compression and consist of the circuit parts for compression, condensation, and evaporation as well as the connecting pipes and any necessary associated ancillaries required for a complete refrigeration circuit.

This document does not apply to the testing of other refrigeration systems such as absorption or steam jet refrigerating systems.

Testing of the suitability of a refrigerating system for a specific use, such as household refrigerators, refrigerated commercial and display cabinets, air conditioners, is not covered by this document.

This document includes testing outside laboratories or where specific laboratory testing standards for systems do not exist and which is performed according to agreed operating conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
overall refrigerating capacity
Q_{og}
rate at which heat is extracted from the ambient by the refrigerant

Note 1 to entry: As a rule, for single-stage refrigerating systems, the overall refrigerating capacity corresponds to the product of the mass flow and the difference between the respective enthalpies of the refrigerant at the inlet of the compressor and at the outlet of the condenser or aftercooler, if provided (see also 8.1.1).

3.2
net refrigerating capacity
Q_{on}
rate at which heat is extracted from the cooled medium in the evaporator by the refrigerant

Note 1 to entry: See also 8.1.2.

3.3
useful refrigerating capacity
Q_{oe}
rate at which heat is usefully extracted by the refrigerant or cooled medium

Note 1 to entry: The useful refrigerating capacity corresponds to the product of the flow of the refrigerant or cooled medium and its difference in enthalpy between the two points specified by agreement between which the cooling effect is made useful (see also 8.1.3).

4 Symbols and units

Parameter	Symbol	Unit
Heat-transfer area	A	m^2
Specific heat capacity	c	J/(kg·K)
Coefficient of performance	COP	—
Specific enthalpy	h	J/kg
Mass flow	m	kg/s
Absolute pressure	p	bar
Power	P	W
Heat flow	Q	W
Refrigerating capacity	Q_o	W
Temperature	t	°C
Absolute temperature	T	K
Overall coefficient of heat transfer	u	$W/(m^2·K)$
Surface coefficient of heat transfer	α	$W/(m^2·K)$
Insulation thickness	δ	m
Isentropic efficiency	η_i	—
Thermal conductivity	λ	W/(m·K)
Kinematic viscosity	ν	m^2/s
Density	ρ	kg/m^3

Indices:

Index	Parameter
amb	Ambient
cor	Corrected
e	Useful
g	Overall
K	Cooled medium, liquid
L	Heat-transfer medium
m	Mechanical
n	Net
R	Refrigerant
W	Coolant, liquid (cooling water)

Index	Location
Reference point: 1	Measuring point: compressor inlet (suction port)
Reference point: 2	Measuring point: compressor outlet (discharge port)

Index	Location
Reference point: 3	Measuring point: condenser/gas cooler refrigerant inlet
Reference point: 4	Measuring point: condenser/gas cooler refrigerant outlet or upstream of internal heat exchanger, if installed
Reference point: 5	Measuring point: upstream of the expansion valve for the evaporator
Reference point: 6	Measuring point: evaporator refrigerant inlet
Reference point: 7	Measuring point: evaporator refrigerant outlet
Reference point: 8	Measuring point: aftercooler refrigerant inlet
Reference point: 9	Measuring point: aftercooler refrigerant outlet

5 Performance warranty

5.1 General

5.1.1 Only the characteristics essential to the economic efficiency and the operation of refrigerating systems and verifiable by usual measurement methods shall be the subject of performance warranty. This requires allowances for the variations of operating conditions which are hardly avoidable in practice.

5.1.2 For the data according to 5.2.1 to 5.2.7, it is recommended to indicate several values near the operating conditions according to 5.3, particularly for the temperature values. To avoid interpolation, these values may be presented graphically within the variation limits for each pair of values. Permissible deviations shall be subject to agreement.

5.1.3 The influence of temporary variations on other operating conditions shall be subject to agreement.

5.2 Subject of technical warranties

5.2.1 General

Subject of the technical warranties are the refrigerating capacity and the power absorbed at operating conditions which need to be agreed.

5.2.2 Refrigerating capacity

The refrigerating capacity shall be agreed as:

— overall refrigerating capacity (see 3.1);

— net refrigerating capacity (see 3.2); or

— useful refrigerating capacity (see 3.3).

5.2.3 Compressor absorbed power

The following shall be subject to agreement:

a) the power absorbed at the compressor shaft;

b) the power output at the driver shaft;

c) the power absorbed by the motor, e.g. electrical power input at the motor terminals; or

d) the fuel consumption of the engine.

5.2.4 Absorbed power of ancillaries

The power absorbed by fans, pumps, agitators, heaters, and other associated ancillaries shall be subject to agreement.

5.2.5 Absorbed power of the entire system

The drive power of the entire system shall be subject to agreement.

5.2.6 Cooling water demand

The cooling water demand may be a subject of the technical warranties.

5.2.7 Coefficient of performance

The coefficient of performance, COP, may be subject to agreement instead of the power absorbed according to 5.2.3 to 5.2.5.

5.3 Operating conditions for technical warranties

5.3.1 General

The following shall be subject to agreement:

a) refrigerant designation;

b) condition of the heat-transfer medium when entering, e.g. the condenser, aftercooler, oil cooler (if provided).

5.3.2 Overall refrigerating capacity

The following shall be subject to agreement:

a) Pressure and temperature of the refrigerant

   1) at the suction port of the compressor; and

   2) at the outlet of the condenser or of the receiver or aftercooler, respectively.

5.3.3 Net or useful refrigerating capacity

The following shall be subject to agreement:

a) the condition of the cooled medium at the inlet and outlet of the evaporator or at two defined points of the cooled medium circuit; or

b) the condition of the cooled medium at the inlet or outlet of the evaporator or at a defined point of the cooled medium circuit as well as the corresponding mass flow.

The condition of the cooled medium does not only include its temperature but also its physical data.

5.3.4 Conversion to warranty conditions

The conversion to warranty conditions requires the indication of the compressor speed or the power supply frequency (for motor compressors), respectively, the refrigerant pressures in the evaporator and the condenser or the evaporation and condensing temperature, respectively, as well as the intermediate pressures in case of multiple-stage systems.

For this purpose, the permissible deviations of the operating conditions for testing shall be specified.

Methods for correction to measured performance to indicate performance at warranty conditions shall be agreed. See also 11.5.

5.4 Tolerance

The tolerance refers to deviations from the assured property (e.g. refrigerating capacity, power absorbed, and COP) which are caused by the manufacturing process and shall be agreed separately.

5.5 Acceptance limit

The permissible deviation of measured values from the assured property is the sum of the tolerance and the overall measurement uncertainty of the applied measurement method.

In cases where zero negative tolerance has been specified in relation to manufacturing tolerances in 5.4, allowance for measurement uncertainty shall still apply.

6 Test preparation and procedure

6.1 The test shall be carried out with all values in steady-state condition and in addition particularly with the compressor and the motor at operating temperature.

6.2 Prior to any measurement, it shall be ensured that heat exchanger surfaces not in contact with the refrigerant are clean. This applies, for example, to the cooling water side of condensers and the secondary refrigerant side of the evaporator.

6.3 Readjustment of the system prior to measurements is permitted. During the actual test, only mutually agreed interventions are permitted.

6.4 The test shall be carried out at operating conditions complying as precisely as possible to those agreed in accordance with 5.3.

6.5 The steady-state condition must be proven over a sufficiently long time period, while the initial and the final values of all quantities relevant to the test shall be within previously agreed limits.

6.6 Values deviating strongly from the arithmetic mean of the readings are not taken into account.

6.7 Readings are acceptable as long as the steady-state condition can be maintained.

6.8 All measurements shall be carried out in accordance with applicable standards, e.g. ISO 5167 (all parts). The measuring instruments shall be chosen in accordance with Clause 7.

6.9 The refrigerating system under test shall be provided with the required connections for pressure and temperature measurements. These connections shall not impair the intended function of the system.

6.10 For measuring the overall refrigerating capacity, it shall be ensured that the liquid refrigerant is free from bubbles downstream of the condenser or the aftercooler, respectively. Proper purging of the refrigerating system is additionally required.

6.11 Two consecutive measurement series shall be conducted.

7 Measuring instruments

7.1 General

7.1.1 The condensing and evaporating temperatures are derived from the absolute pressure readings, where the sources according to 12.1 are used and the purging measures according to 6.10 are followed.

7.1.2 Only measuring instruments with fully verifiable indications shall be used. It is essential that the measurement uncertainty can be determined by calibration and does not vary during testing. Measuring instruments whose condition may vary during the test shall be verified both before and after testing. The measurement uncertainty values indicated below refer to the extended measurement uncertainty with a confidence interval of 95 % corresponding to twice the standard deviation.

7.1.3 Besides the types of measuring instruments indicated below, other generally accepted measuring instruments or devices may be used provided they comply with the indicated measurement uncertainties.

7.2 Temperature measuring instruments

The measurement uncertainty of the temperature measuring instrument shall be within the following limits while 7.1 shall be taken into account:

a) for measuring the temperatures of cooled medium in the evaporator or cooling water in the condenser ±0,1 K;

a) for all other temperature measurements ±0,5 K.

7.3 Pressure gauges

The measuring range shall be chosen such that the measurement uncertainty does not exceed 2 % of the indicated value.

a) if Bourdon-tube, diaphragm or bellows manometers are used, classes 0,6 to 0,1 (precision manometers) shall be chosen;

b) if pressure transducers are used, they shall be calibrated prior to measurement;

c) if liquid filled pressure gauges are used for measuring the pressure differences, it shall be ensured that the uncertainty of the measurement does not exceed 1 % of the indicated value. The medium to be measured shall not be absorbed by the barrier liquid.

7.4 Measuring instruments for electric power

The measurement uncertainty shall not exceed:

a) 0,5 % of the full scale value for indicating measuring instruments;

b) 1 % of the measured value for integrating measuring instruments.

7.5 Flow meters

The measurement uncertainty of flow meters shall be within 2 % of the indicated value.

7.6 Speed measuring devices

The measurement uncertainty shall not exceed 0,75 % of the indicated value.

7.7 Torque measuring devices

The measurement uncertainty shall not exceed 1 % of the rated load.

7.8 Time measuring devices

The measurement uncertainty shall not exceed 0,1 % of the measured value.

7.9 Mass measuring devices

The measurement uncertainty shall not exceed 0,2 % of the measured value.

8 Determination of the refrigerating capacity

8.1 Direct methods

8.1.1 Overall refrigerating capacity

8.1.1.1 General

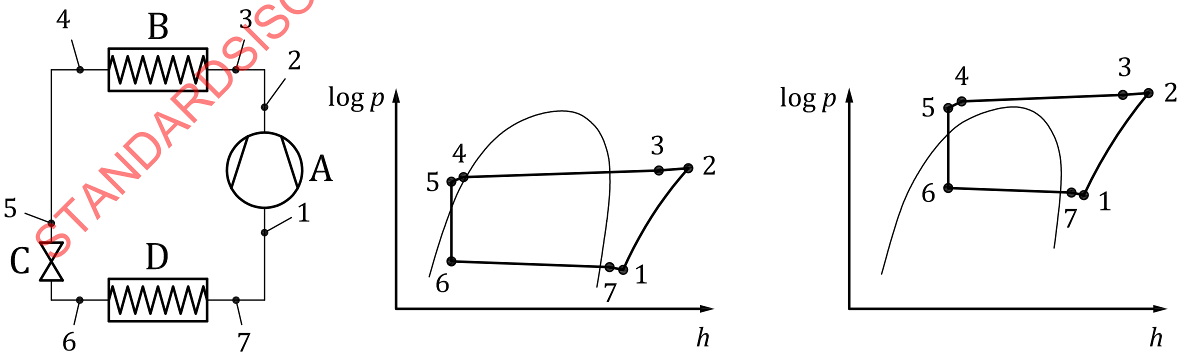
The refrigerating capacity is calculated from the refrigerant mass flow and a difference of enthalpy.

If the refrigerant vapour at the compressor inlet is dry, saturated or superheated (i.e. free from entrained liquid), the overall refrigerating capacity is given by Formula (1)

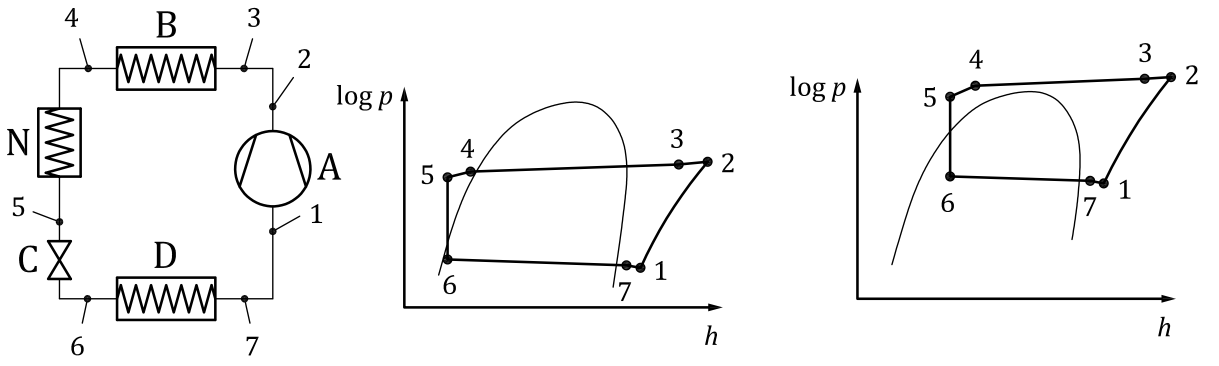
$$Q_{og} = m_R \left(h_1 - h_5 \right) \tag{1}$$

Condition 1 corresponds to the condition at the compressor inlet, condition 5 corresponds to the condition upstream of the expansion valve before the evaporator (see Figures 1 and 2).

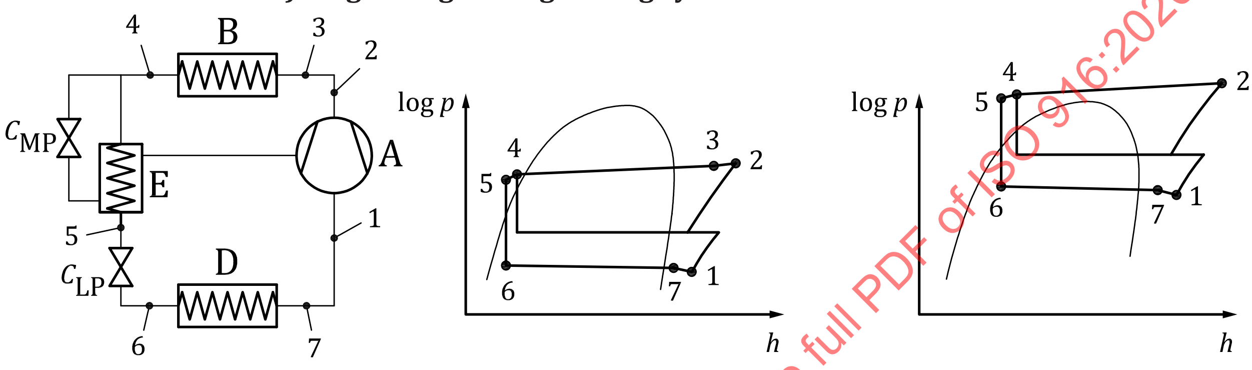
The refrigerant mass flow is determined either from the heat balance in accordance with 8.1.1.2 or from the flow measurement in accordance with 8.1.1.3. This method is suitable for various designs of refrigerating systems. Figures 1 and 2 show representations of refrigerating system schematics and their characteristic in the *p*–*h* diagram.



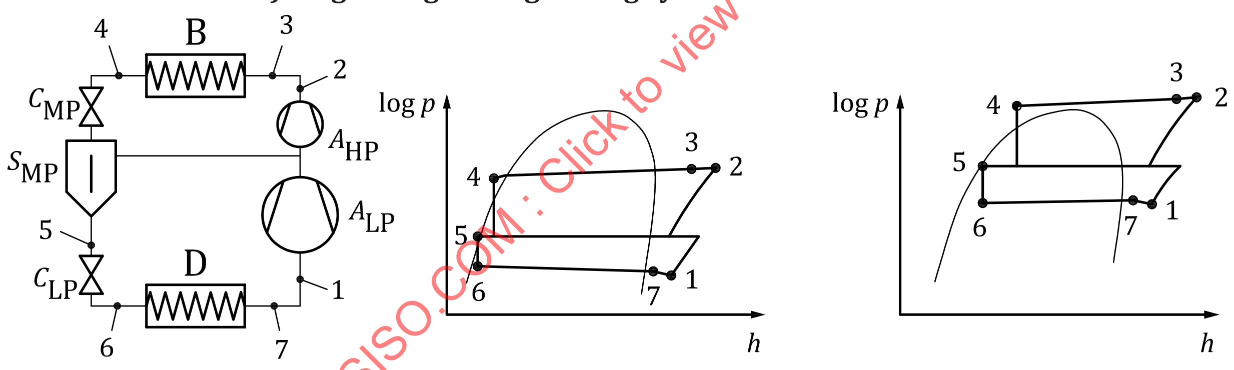
a) Single-stage refrigerating system



b) Single-stage refrigerating system with aftercooler



c) Single-stage refrigerating system with economiser



d) Two-stage refrigerating system with intermediate pressure separator

Key

A compressor, A_{LP} from low pressure to intermediate pressure, A_{HP} from intermediate pressure to high pressure

B condenser

C expansion valve, C_{MP} to intermediate pressure, C_{LP} to evaporator pressure

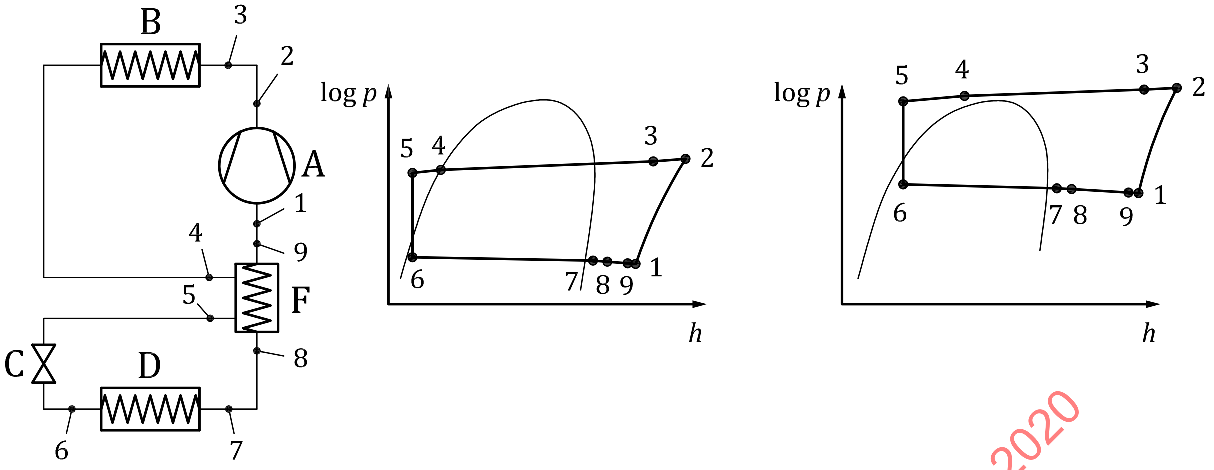
D evaporator

E economiser

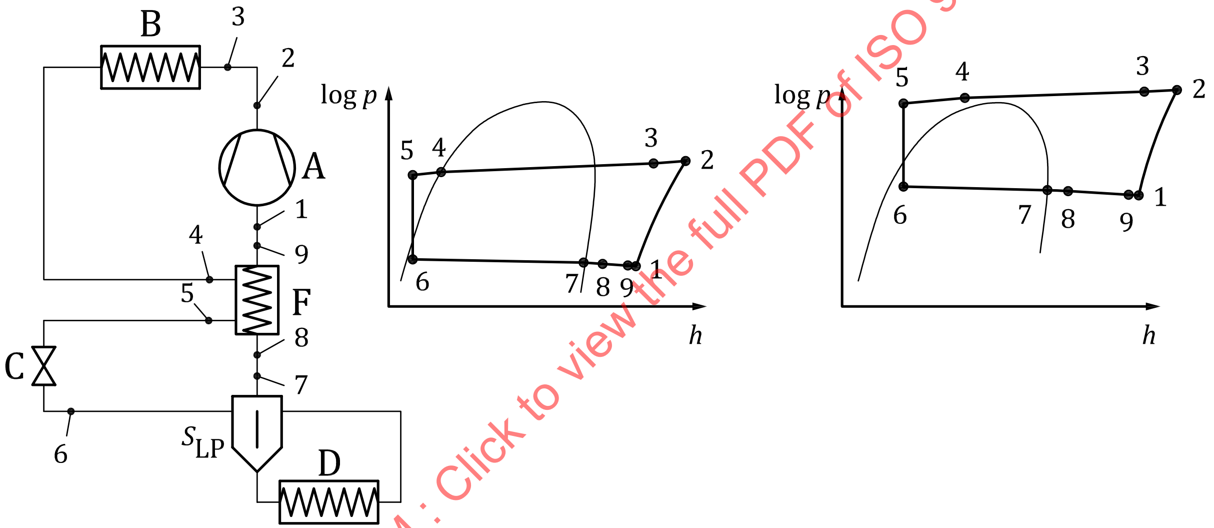
N aftercooler

S liquid separator, S_{MP} at intermediate pressure

Figure 1 — Schematics and log-p-h diagrams of subcritical and trans-critical refrigerating systems



a) Single-stage refrigerating system with internal heat exchanger and dry evaporation



b) Refrigerating system with internal heat exchanger and flooded evaporator

Key

A compressor

B condenser

C expansion valve

Internal heat transfer, $\Delta h_{4-5} \approx \Delta h_{8-9}$

D evaporator

F internal heat exchanger

S_{LP} liquid separator at evaporation pressure

Figure 2 — Schematics and log-p-h diagrams of single-stage refrigerating systems with internal heat exchanger

8.1.1.2 Determination of the refrigerant mass flow from the heat balance

8.1.1.2.1 The refrigerant mass flow can be determined by using the heat balance at each component of the circuit through which it passes. Any case of previously branching off partial flows shall be taken into account.

8.1.1.2.2 For single-stage systems, the condenser is the most suitable circuit component for establishing a heat balance provided it is operated with liquid cooling without mass transfer (evaporation). The refrigerant mass flow is then determined by using Formula (2).

$$m_R = \frac{m_W \cdot c_W \cdot \Delta t_W + Q_{cor}}{\Delta h_R} \tag{2}$$

where

$\Delta h_R = (h_3 - h_4)$ is the decrease of the refrigerant enthalpy in the condenser.

The liquid mass flow m_w is determined by means of the usual methods, e.g. with measuring vessel, volume meter, pressure differential device.

The heat flow Q_{cor} is a correction required whenever the temperature of the external condenser surface deviates from the ambient temperature. This correction is determined from Formula (3).

$$Q_{cor} = u \cdot A(t_m - t_{amb}) \tag{3}$$

where

u is the overall heat transfer coefficient between the medium flowing along the internal surface of the external wall of the condenser and the ambient.

Since Q_{cor} merely represents a correction, the following approximation is sufficient:

$u = 7\ W/(m^2 \cdot K)$ if the condenser is not thermally insulated and not installed outdoors;

A is the area of the external condenser surface in contact with the ambient;

t_m is the mean temperature of the external condenser wall which in this correction can be considered equal to the temperature of the medium flowing along the internal surface of the external wall;

t_{amb} is the ambient temperature.

The correction Q_{cor} may be positive or negative. Since it is determined only by approximation, it must be small in comparison to the other heat flows of the balance. Therefore, it shall not exceed the maximum permissible error given in 10.4.1. Thermal insulation shall be provided, if required; in which case the value u is determined by using the following approximation formula for flat walls:

$$\frac{1}{u} = \frac{1}{\alpha} + \frac{\delta}{\lambda} \tag{4}$$

where

$\alpha = 7\ W/(m^2 \cdot K)$ is the approximate value for free convection;

δ and λ are the thickness of the insulation and its coefficient of thermal conductivity at operating conditions.

8.1.1.2.3 If an aftercooler is installed downstream of the condenser, the heat balance is preferably established for both parts of the circuit together.

8.1.1.2.4 Since the uncertainty of the external heat balance of evaporative condensers is too high, the heat balance will be established on a different part of the circuit, usually on the aftercooler alone. Therefore, it is recommended to provide the required temperature measuring points on this aftercooler. While taking into account the measurement uncertainty, the mass flow of the heat-transfer medium will be limited such as to generate a minimum difference of 5 K between the inlet and the outlet of that aftercooler.

Considering the tolerances given in Clause 9, this method requires a particularly precise measuring device. Additionally, it shall be ensured that the refrigerant is free from any vapour bubbles at the aftercooler inlet. This usually requires a subcooling of 2 K. If the aftercooler is operated with a heat-transfer fluid other than water, precise data on its specific heat capacity are required.

8.1.1.3 Determination of the refrigerant mass flow by means of a flow meter

The refrigerant mass flow can be determined for both the entirely liquid state and the entirely gaseous state by means of a flow meter in accordance with Clause 7 if the piping is provided with anti-pulsation devices or if it is free from pulsation and provided the measured values are not impaired by unacceptably large amounts of oil.

8.1.2 Net refrigerating capacity for a liquid cooled medium

It is expedient to determine the net refrigerating capacity from the flow of the cooled fluid.

This measurement method is based on Formula (5):

$$Q_{on} = m_K \cdot c_K \cdot \Delta t_K + Q_{cor} \tag{5}$$

The cooled liquid mass flow m_K is determined by the usual methods, e.g. measuring vessel, pressure differential device, volume meter, at either the inlet or the outlet of the evaporator.

The values of the specific heat capacity c_K for secondary refrigerant shall be obtained from the values given by the manufacturer:

The temperature decrease Δt_K of the secondary refrigerant between the inlet and outlet of the evaporator shall not be less than 5 K. Therefore, this method is not applicable if such a difference is inconsistent or impracticable with the given data.

Q_{cor} is a generally minor correction which therefore can be determined by approximation provided the measurement uncertainties are taken into account (see Clause 10). This correction is the sum of:

a) the heat equivalent of the power output generated by the auxiliary equipment positioned between the measuring locations in the cooled medium circuit (e.g. circulating pumps, agitators);

b) the heat flow Q'_{cor} which is to be applied whenever the cooled medium in the evaporator is not fully insulated against the ambient; this term can be calculated by using Formula (6):

$$Q'_{cor} = u \cdot A (t_{amb} - t_m) \tag{6}$$

where

u is the overall heat transfer coefficient between the environment and the cooled medium. This value is calculated by using Formula (4);

A is the area of the external evaporator surface in contact with the ambient;

t_m is a mean temperature equal to

— the arithmetic mean of the inlet and outlet temperatures of the cooled medium for evaporators with forced circulation of the cooled medium (counterflow apparatus, parallel flow apparatus, etc.);

— the outlet temperature for brine tanks with an adequately strong agitator;

t_{amb} is the ambient temperature.

It is essential to note that the term Q'_{cor} only refers to the heat flow from the environment to the cooled medium being cooled down and not to the heat flow from the ambient to the refrigerant. In case the latter occurs, e.g. at evaporators with refrigerant in the shell, it shall not be taken into account in the determination of the net refrigerating capacity according to the definition (see 3.2).

8.1.3 Useful refrigerating capacity

8.1.3.1 General

It is expedient to determine the useful refrigerating capacity, as for net refrigerating capacity, from the flow of the cooled medium, while omitting, however, the correction Q_{cor} according to 8.1.2.

Where the measurement is taken on the side of a cooled gas flow, e.g. high-pressure process gas, the calculation of the refrigeration capacity has to take into account the Joule-Thompson effect caused by a pressure drop, depending on the gas.

8.1.3.2 Direct measurement

The measurement complies with the methods described in 8.1.2 while taking into account the corrections according to 8.1.2.

8.1.3.3 Calorimetric measurement

This method is used for measuring the useful refrigerating capacity for cooling media and will be applied whenever the steady-state condition cannot be realized during a test. The natural heat source will be replaced by an artificial source, if required. This can consist of e.g. steam, hot water, electric heating. Then, the heat flow supplied by the artificial heat source is measured which corresponds to the useful refrigerating capacity.

8.2 Indirect methods

8.2.1 General

Indirect methods are recommended for cases where the direct methods are impracticable or less precise than the indirect methods or when applied for verifying the direct methods (according to 8.1).

8.2.2 Determination of the overall refrigerating capacity by means of a calibrated compressor

This means a test for the determination of the power absorbed by the compressor (compressor power) usually carried out prior to the installation of the compressor into the refrigerating system at the manufacturer's premises under conditions representative of those in later operation, in particular regarding the evaporation and condensing temperatures. The overall refrigerating capacity can be determined from the compressor power by multiplying the latter with the difference of enthalpy assigned to the overall refrigerating capacity according to 3.1 and dividing by the difference of enthalpy assigned to the compressor power.

The refrigerant mass flow is determined by testing the compressor on a compressor capacity test rig. For this purpose, the test conditions shall comply as closely as possible with the operating conditions in the system. Any differences between the operating conditions during the compressor capacity measurements at the manufacturer's premises and those during the measurements on the refrigerating system shall be taken into account in accordance with Clause 11. The overall refrigerating capacity is determined according to 8.1.

Where the compressor was tested at the manufacturer with a different gas, e.g. dry nitrogen, and at conditions differing much from the system test conditions, a conversion method shall be agreed. Using a proven recalculation based on manufacturers description or own experience, the refrigerant mass flow and power absorbed can be determined with the manufacturers' performance data. The uncertainty of this method is higher, compared to the above described.

8.2.3 Determination of the net refrigerating capacity

By determination of insulation losses between the control valve and the compressor inlet, it is also possible to derive the net refrigerating capacity according to 8.1.2 via determination of the overall refrigerating capacity in accordance with 8.1.1.

8.2.4 Determination of the useful refrigerating capacity

The useful refrigerating capacity can be determined from the net refrigerating capacity according to 8.2.3 while taking into account the corrections in accordance with 8.1.2.

8.2.5 Determination of the overall refrigerating capacity from the overall energy balance

This method is listed among the indirect methods as a procedure for the verification of direct measurements only.

Where substantial deviations occur within the balance, the corresponding causes shall be investigated.

For a refrigerating system with throttling expansion and a water-cooled condenser, without water evaporation, the balance is established by using Formula (7):

$$Q_{og} = Q_I + Q_{II} + Q_{III} - P + Q_{IV} \quad (7)$$

or in case of single-stage compression, Formula (8):

$$Q_{og} = \frac{h_1 - h_5}{h_2 - h_1} (P - Q_{II} - Q_{IV}) \quad (8)$$

where

Q_I is the heat flow transferred to the water or ambient air in the condenser and the aftercooler;

Q_{II} is the heat flow transferred to the heat-transfer medium (cooling water or air) from the compressor and, if applicable in case of multiple-stage systems, in the intercoolers;

Q_{III} is the heat flow transferred from the hot discharge gas lines, including the oil separator, between the compressor outlet and the condenser inlet;

P is the power absorbed at the compressor shaft or the motor terminals;

Q_{IV} is the heat flow transferred from the compressor, including oil cooler and auxiliary equipment, not included in Q_{II}.

The ratio $Q_o/(h_1 - h_5)$ is equal to the average mass flow of the refrigerant m_R.

Since Q_{II}, Q_{III}, Q_{IV} are general corrections, their approximate determination is sufficient; this, however, does not apply to compressors with oil coolers.