1 SCOPE AND FIELD OF APPLICATION

1.1 Scope

This Nordtest method provides the general conditions as well as references to specific methods to be applied in field testing and presentation of performance for heat pumps and refrigeration equipment. The scope is to provide a framework of suitable test methods ranging from functional tests and simple performance check-ups of small units to accurate commissioning tests of large installations.

This test method focuses on the thermodynamic performance in terms of refrigerating and heating capacities, coefficients of performance and operating ranges (i.e. it does not pertain to e.g. mechanical safety, noise etc.).

1.2 Field of application

The primary field of application of this Nordtest method pertains to electrically driven compression heat pumps and refrigeration equipment. However, relevant parts may also be applied to the testing of equipment with other types of prime movers.

The methods described cover three specific fields of application:

- Functional test of heat pumps and refrigeration equipment;
- Performance check-ups of heat pumps and refrigeration equipment,
  - approximate level of uncertainty: ±15 %;
- Performance tests of heat pumps and refrigeration equipment,
  - approximate level of uncertainty: ±10 % (level 2),
  - approximate level of uncertainty: ±5 % (level 1).

2 REFERENCES

This Nordtest method refers to the following documents:

2.1 NT VVS 116. Refrigeration and heat pump equipment

Check-ups and performance data inferred from measurements in the refrigerant system.

2.2 NT VVS 076. Large heat pumps

Field testing and presentation of performance.

2.3 Nordtest Doc Gen 020 Nordtest handbok

Procedur för framtagning av Nordtest-metoder genom Nordtest-projekt.

2.4 EN 45 001 General criteria for the operation of testing laboratories

2.5 SS 1897 Refrigerating and heating equipment

Refrigerating and heat pump technology - Terminology.

2.6 prEN 378:1990. Refrigeration systems and heat pumps

Safety and environmental requirements - Part 1: Basic requirements and definitions.
2.7 EN 255-1:1993. Heat pumps and air conditioners
Air conditioners and heat pumps with electrically driven compressors - Heating mode - Part 1: Terms, definitions and designations.

2.8 prEN 255-2:1994. Heat pumps
Air conditioners and heat pumps with electrically driven compressors - Heating mode - Part 2: Testing and requirements for marking for space heating.

2.9 prEN 255-3:1994. Heat pumps and air conditioners
Air conditioners and heat pumps with electrically driven compressors - Heating mode - Part 3: Testing and requirements for marking for sanitary hot water.

2.10 prEN 255-4:1994. Heat pumps and air conditioners
Air conditioners and heat pumps with electrically driven compressors - Heating mode - Part 4: Requirements for space heating and sanitary hot water.

2.11 prEN 814-1:1994. Heat pumps and air conditioners
Air conditioners and heat pumps with electrically driven compressors - Cooling mode - Part 1: Terms, definitions and designations.

Air conditioners and heat pumps with electrically driven compressors - Cooling mode - Part 2: Testing and requirements for marking.

2.13 prEN 814-3:1994. Heat pumps and air conditioners
Air conditioners and heat pumps with electrically driven compressors - Cooling mode - Part 3: Requirements.

Liquid chilling packages and heat pumps with electrically driven compressors - Cooling mode - Definitions, testing and requirements for marking.

Guide to the Expression of Uncertainty in Measurement.

3 DEFINITIONS
For technical terms, specific to heat pumps and refrigerating equipment, which are not defined in this Nordtest method, reference is made to EN 255, EN 814, prEN 378, and SS 1897.

3.1 General definitions
The definitions in 3.1 may be of interest in all parts of this Nordtest method.

The definitions of coefficients of performance according to 3.1.1 - 3.1.2 are based on system boundaries for heat pumps or refrigerating equipment, heat pump or refrigerating installations and heating or refrigerating plants respectively according to Figure 1. Refrigerant states are designated according to Figure 2.

When the coefficients of performance are stated, the operating conditions must also be stated.

Figure 1. System boundaries for determination of coefficients of Performance.

Figure 2. Designation of refrigerant states.
3.1 Coefficients of performance in the heating mode

3.1.1 Carnot heating coefficient of performance, \( \Phi_C \) (\( \Phi_C \))

The ratio between the condensing temperature and the difference between the condensing temperature and evaporating temperature, given as thermodynamic (absolute) temperatures,

\[
\COP_C = \frac{T_1}{(T_1 - T_2)}
\]

3.1.2 Coefficient of performance inferred from refrigerant states, \( \Phi_1 \)

The difference in specific enthalpy of the refrigerant at the compressor outlet \( (h_3) \) and the subcooled condensate after the condenser \( (h_5) \) divided by the difference in specific enthalpy of the refrigerant at the compressor outlet \( (h_3) \) and the compressor inlet \( (h_4) \). The calculated value must be corrected by the thermal loss factor (\( f \)) of the compressor,

\[
\COP_1 = \frac{(h_3 - h_5)(1 - f)}{(h_3 - h_4)}
\]

with \( f = \frac{P_{for}}{P_{em}} \)

3.1.3 Compressor coefficient of performance, \( \Phi_{ck} \)

The ratio between the thermal power (thermal energy) released from the heat pump to the heat transfer medium and the drive input power (drive energy) at the compressor shaft,

\[
\COP_{ck} = \frac{P_1}{P_k}, \quad \COP_{ck} = \frac{Q_1}{W_k}
\]

In this standard, power inputs to ancillary devices according to 6.3.2 are included in the drive power.

3.1.4 Motor coefficient of performance, \( \Phi_{vp} \) (\( \Phi_{vp} \))

The ratio between the thermal power (thermal energy) released from the heat pump to the heat transfer medium and the drive input power (drive energy) to the compressor motor.

\[
\COP_{vp} = \frac{P_1}{P_{em}}, \quad \COP_{vp} = \frac{Q_1}{W_{em}}
\]

In this standard, power inputs to ancillary devices according to 6.3.2 are included in the drive power.

3.1.5 Total coefficient of performance, \( \Phi_{vpa} \) (\( \Phi_{vpa} \))

The ratio between the total thermal power (thermal energy) released from the heat pump installation to the heat transfer medium and the total drive input power (drive energy) to the heat pump installation,

\[
\COP_{vpa} = \frac{P_{1vpa}}{P_{em}}, \quad \COP_{vpa} = \frac{Q_{vpa}}{W_{em}}
\]

3.1.6 System coefficient of performance, \( \Phi_{va} \) (\( \Phi_{va} \))

The ratio between the total thermal power (thermal energy) released from the heating plant to the heat transfer medium, and the total input power (input energy) to the heating plant,

\[
\COP_{va} = \frac{P_{va}}{P_{eva}} = \frac{(P_{1vpa} + \eta_{va} \cdot P_{va})}{(P_{eva} + O_{va})}
\]

where \( \eta \) is the total efficiency of the supplementary heating equipment.

3.1.7 Seasonal performance factor, SPF_{vpa}

The ratio between the thermal energy released from a heat pump installation to the heat transfer medium during a whole year and the total drive energy input to the heat pump installation during the same period,

\[
\text{SPF}_{vpa} = \frac{\sum Q_{vpa}}{\sum W_{eva}}
\]

Operating conditions during the period must be stated. Stand by losses shall be considered.

3.1.8 System seasonal performance factor, SPF_{va}

The ratio between the thermal energy released from the heating plant to the heat transfer medium during a whole year, and the total energy input to the heating plant during the same period,

\[
\text{SPF}_{va} = \frac{\sum Q_{vpa}}{\sum W_{eva}} = \frac{\sum (Q_{eva} + h_{va} \cdot Q_{va})}{\sum (W_{eva} + Q_{va})}
\]

where \( \eta_{va} \) is the total efficiency of the supplementary heating equipment.

Operating conditions during the period must be stated. Stand by losses shall be considered.

3.1.9 Coefficients of performance in the cooling mode

3.1.9.1 Carnot cooling coefficient of performance, \( \Phi_C \) (\( \Phi_C \))

The ratio between the evaporating temperature and the difference between the condensing temperature and evaporating temperature, given as thermodynamic (absolute) temperatures,

\[
\COP_C = \frac{T_2}{(T_1 - T_2)}
\]

3.1.10 System coefficient of performance, \( \Phi_{va} \) (\( \Phi_{va} \))

The ratio between the total thermal power (thermal energy) released from the heating plant to the heat transfer medium, and the total input power (input energy) to the heating plant,

\[
\COP_{va} = \frac{P_{va}}{P_{eva}} = \frac{(P_{1vpa} + \eta_{va} \cdot P_{va})}{(P_{eva} + O_{va})}
\]

where \( \eta \) is the total efficiency of the supplementary heating equipment.

Operating conditions during the period must be stated. Stand by losses shall be considered.

3.1.11 Motor coefficient of performance, \( \Phi_{vp} \) (\( \Phi_{vp} \))

The ratio between the thermal power (thermal energy) released from the heat pump to the heat transfer medium and the drive input power (drive energy) to the compressor motor.

\[
\COP_{vp} = \frac{P_1}{P_{em}}, \quad \COP_{vp} = \frac{Q_1}{W_{em}}
\]

In this standard, power inputs to ancillary devices according to 6.3.2 are included in the drive power.

3.1.12 Total coefficient of performance, \( \Phi_{vpa} \) (\( \Phi_{vpa} \))

The ratio between the total thermal power (thermal energy) released from the heat pump installation to the heat transfer medium and the total drive input power (drive energy) to the heat pump installation,
3.1.2.2 Cooling coefficient of performance inferred from refrigerant states, COP₂

The difference in specific enthalpy of the refrigerant at the compressor inlet (h₄) and the refrigerant after the expansion device (h₆ = h₅) divided by the difference in specific enthalpy of the refrigerant at the compressor outlet (h₅) and the compressor inlet (h₄). The calculated value must be corrected by the thermal loss factor (f) of the compressor (see 3.1.1.2).

\[
\text{COP}_2 = \frac{(h₄ - h₆) \cdot (1 - f)}{(h₃ - h₄)} = \text{COP}_1 - 1 + f
\]

3.1.2.3 Compressor cooling coefficient of performance, COP₂ₖ (Eₖ)

The ratio between the thermal power (thermal energy) absorbed by the refrigerant and the drive input power (drive energy) at the compressor shaft,

\[
\text{COP}_2 = \frac{P_2}{P_k}, \quad \text{COP}_2 = \frac{Q_2}{W_k}
\]

In this method, power inputs to ancillary devices according to 6.3.2 are included in the drive power.

3.1.2.4 Motor cooling coefficient of performance, COPₖₘ (Eₖₘ)

The ratio between the thermal power (thermal energy) absorbed by the refrigerant and the drive input power (drive energy) to the compressor motor,

\[
\text{COP}_k = \frac{P_2}{P_{km}}, \quad \text{COP}_k = \frac{Q_2}{W_{km}}
\]

In this method, power inputs to ancillary devices according to 6.3.2 are included in the drive power.

3.1.2.5 Total cooling coefficient of performance, COPₖₐₘ (Eₖₐₘ)

The ratio between the total thermal power (thermal energy) absorbed by the cold side heat transfer medium and the total drive input power (drive energy) to the refrigeration machinery installation,

\[
\text{COP}_k = \frac{P_{2kma}}{P_{ekma}}, \quad \text{COP}_k = \frac{Q_{2kma}}{W_{ekma}}
\]

3.1.2.6 System cooling coefficient of performance, COPₖₐ (Eₖₐ)

The ratio between the total thermal power (thermal energy) absorbed from the refrigerated space and the total drive input power (drive energy) to the refrigeration plant,

\[
\text{COP}_k = \frac{P_{2ka}}{P_{eka}} = \frac{P_{2ka}}{P_{ekma} + P_{ka}}, \quad \text{COP}_k = \frac{Q_{2ka}}{W_{eka} + Q_{bca}}
\]

3.1.2.7 Seasonal cooling performance factor, SPFₖₐₘ (Eₖₐₘ)

The ratio between the total thermal energy absorbed by the cold side heat transfer medium during a whole year and the total drive energy to the refrigeration machinery installation during the same period,

\[
\text{SPF}_k = \frac{\sum Q_{2kma}}{\sum W_{ekma}}
\]

Operating conditions during the period must be stated. Stand by losses shall be considered.

3.1.2.8 System seasonal cooling performance factor, SPFₖₐ (Eₖₐ)

The ratio between the total thermal energy absorbed from the refrigerated space during a whole year and the total energy input to the refrigeration plant during the same period,

\[
\text{SPF}_k = \frac{\sum Q_{2k}}{\sum (W_{eka} + Q_{kca})} = \frac{\sum Q_{2ka}}{\sum W_{eka} + \sum Q_{kca} - Q_{kca}}
\]

Operating conditions during the period must be stated. Stand by losses shall be considered.

3.1.3 Measuring techniques

3.1.3.1 Estimated component of the uncertainty of measurement (CIPM type A)

A component of the uncertainty of measurement estimated by applying statistical methods to the results of a series of measurements.

3.1.3.2 Expected component of the uncertainty of measurement (CIPM type B)

A component of uncertainty of measurement determined by other than statistical methods, e.g. by experience.

3.1.3.3 Combined uncertainty of measurement

Uncertainty of measurement obtained by combining all the components of the uncertainty of measurement according to the rules for combining variances.

3.1.3.4 Total uncertainty of measurement

Combined uncertainty of measurement multiplied by a given factor.

In this test method the factor to be used is 2.5.

3.1.4 Additional terminology

3.1.4.1 Operating point

Operating conditions defined by specified parameters.
3.1.4.2 Operating range
One or several intervals (e.g. temperature-humidity-voltage intervals) bounded by upper and lower limits within which the heat pump (refrigerating machinery) has guaranteed properties.

3.1.4.3 Guarantee point
Operating point stated in an agreement of guarantee or similar document.

3.1.4.4 Heat transfer medium (hot side)
Medium which transports heat from the heat pump to a heat sink (heated space).
In this document the term heat transfer medium of the hot side is used for the medium to which the heat pump (refrigerating machinery) condensor releases heat. For direct systems the heat transfer medium of the hot side corresponds to the heat sink.

3.1.4.5 Heat transfer medium (cold side)
Medium which transports heat from a heat source (refrigerated space) to the heat pump (refrigerating machinery).
In this document the term heat transfer medium of the cold side is used for the medium from which the heat pump (refrigerating machinery) evaporator extracts heat. For direct systems the heat transfer medium of the cold side corresponds to the heat source.

3.2 Definitions for performance check-ups
NT VVS 1.16 contains definitions pertaining specifically to check-ups or other situations where performance data are inferred from measurements in the refrigerant system.

3.3 Definitions for performance tests
NT VVS 076 provides further definitions to be applied in commissioning tests of large heat pumps or other examples where regular heat metering methods are used.

4 SYMBOLS
For symbols, specific to heat pumps and refrigerating equipment, which are not defined in this Nordtest method, reference is made to EN 255, EN 814, prEN 378, and SS 1897.

4.1 General symbols
The symbols in 4.1 may be of interest in all parts of this Nordtest method. for symbols not described in this document reference is made to SS 1897.

In designations used below the index "kb" is consistently used for the heat transfer medium on the cold side, "vb" for the heat transfer medium on the hot side and "i" for air. In some cases "in" or "out" are added to indicate inlet or outlet. The high pressure side (condensor) is designed by the index "1" and the low pressure side (evaporator) by the index "2".
P
Power

P_1  
Total thermal power released from a heat pump to heat transfer medium  
(P_1 = P_1 + P_2 + P_3 or P_1 = P_1 + P_2 + P_3)

P_{1vpa}  
Total thermal power released from a heat pump installation to the heat transfer medium  
(P_{1vpa} = P_{1} + P_{2} + P_{3} + P_{distr})

P_{1va}  
Total thermal power released from a heating plant to the heat transfer medium  
(P_{1va} = P_{1vpa} + P_{1va} + P_{1va})

P_2  
Thermal power absorbed by the refrigerant circuit

P_{2kma}  
Net thermal power absorbed by the cold side heat transfer medium  
(P_{2kma} = P_{2} - P_{e} - P_{distr} or P_{2kma} = P_{2} - P_{e} - P_{distr})

P_{2ka}  
Net thermal power absorbed from the heat source/refrigerated space  
(P_{2ka} = P_{2} - P_{e} - P_{distr} or P_{2ka} = P_{2} - P_{e} - P_{distr})

P_k  
Shaft drive power to compressor

P_em  
Drive power to compressor motor

P_{eva}  
Total power input to a heat pump installation

P_{eva}  
Total power input to a heat pump installation

P_{eva}  
Total power input to a refrigeration plant  
(P_{eva} = P_{eva} + P_{eva})

P_{ekma}  
Total drive power input to a refrigerating plant  
(P_{ekma} = P_{ekma} + P_{ekma})

P_{ekka}  
Total drive power input to a refrigerating plant  
(P_{ekka} = P_{ekka} + P_{ekka})

P_ef  
Drive power to fan(s)

P_ep  
Drive power to pump(s)

P_{for}  
Thermal power loss from the compressor

P_{distr}  
Thermal power loss from the distribution system  
(a heat loss is given a negative sign and a heat gain a positive sign)

P_{iva}  
Power input to a supplementary heating plant

P_{ika}  
Power input to a supplementary cooling plant

P_{1(korr)}  
Measured thermal power output (heating) corrected for deviations in the operating conditions relative to the stated operating point

P_{2(korr)}  
Measured thermal power input (cooling) corrected for deviations in the operating conditions relative to the stated operating point

P_{e(korr)}  
Measured electric power input corrected for deviations in the operating conditions relative to the stated operating point

P_{1(f)}  
Stated (reference) thermal power output (heating)

P_{2(f)}  
Stated (reference) thermal power input (cooling)

P_{e(f)}  
Deviation (reference) electric power input

P_{1(avv)}  
Deviation between measured and stated thermal power output (heating);  
(P_{1(avv)} = P_{1(f)} - P_{1(f)})

P_{2(avv)}  
Deviation between measured and stated thermal power input (cooling);  
(P_{2(avv)} = P_{2(f)} - P_{2(f)})

P_{e(avv)}  
Deviation between measured and stated electric power input;  
(P_{e(avv)} = P_{e(f)} - P_{e(f)})

ΔP_1  
Uncertainty in the determination of P_1 due to uncertainties in determining the operating point

ΔP_1 (drift)  
Uncertainty in the determination of P_1 due to measurement uncertainties

ΔP_2  
Uncertainty in the determination of P_2 due to uncertainties in determining the operating point

ΔP_2 (drift)  
Uncertainty in the determination of P_2 due to measurement uncertainties

ΔP_e  
Uncertainty in the determination of P_e due to uncertainties in determining the operating point

ΔP_e (drift)  
Uncertainty in the determination of P_e due to measurement uncertainties

Heat (thermal energy)

Heat (thermal energy)

Q  
Thermal energy released from the heat pump to the hot side heat transfer medium  
(Q_1 = Q_1 + W_{ep} + Q_{distr} or Q_{1yva} = P_{1} + P_{ef} + P_{distr})

Q_{1va}  
Total thermal energy released from a heat pump installation to the hot side heat transfer medium  
(Q_{1va} = Q_{1va} + Q_{1va} + Q_{1va})

Q_2  
Thermal energy absorbed by the refrigerant circuit

Q_{2kma}  
Net thermal energy absorbed by the cold side heat transfer medium  
(Q_{2kma} = Q_{2} - Q_{e} - Q_{distr} or Q_{2kma} = Q_{2} - Q_{e} - Q_{distr})

Q_{2ka}  
Net thermal energy absorbed from the heat source/refrigerated space  
(Q_{2ka} = Q_{2} - W_{ep} - Q_{distr} or Q_{2ka} = Q_{2} - W_{ep} - Q_{distr})

Q_{iva}  
Energy input to a supplementary heating plant

Q_{ikka}  
Energy input to a supplementary cooling plant

Q_{distr}  
Thermal energy loss from the distribution system  
(a heat loss is given a negative sign and a heat gain a positive sign)

q  
Flowrate

q  
Flowrate

q_{m}  
Volume flow  
(q_{m} = \rho \cdot q_{m})

q_{vb}  
Volume flow, heat transfer medium, cold side

q_{vbb}  
Volume flow, heat transfer medium, hot side

q_{vwb}  
Volume flow, air, heat transfer medium, cold side

q_{vkb}  
Volume flow, air, heat transfer medium, hot side

SPF  
Seasonal performance factor

SPF_{vpa}  
Seasonal performance factor in the heating mode

SPF_{va}  
System seasonal performance factor in the heating mode

SPF_{kma}  
Seasonal performance factor in the cooling mode
System seasonal performance factor in the cooling mode

Thermodynamic (absolute) temperature

Thermodynamic condensing temperature

Thermodynamic evaporating temperature

Celsius temperature

Temperature, incoming cold side heat transfer medium to the heat pump

Temperature, outgoing cold side heat transfer medium from the heat pump

Temperature, incoming hot side heat transfer medium to the heat pump

Temperature, outgoing hot side heat transfer medium from the heat pump

Condensing temperature

Evaporating temperature

Work done (mechanical or electric)

Drive energy to the compressor shaft

Drive energy to the compressor motor

Total drive energy input to the heat pump plant

Total energy input to the heating plant \( (W_{eva} = W_{evpa} + Q_{vva}) \)

Transformer ratio for current transformers

Transformer ratio for voltage transformers

Scale reading on instruments for electric power

Density

Density, heat transfer medium, cold side

Density, heat transfer medium, hot side

Efficiency

Efficiency of supplemental heating equipment

Efficiency of pumps

Efficiency of fans

Half the range of a B-type uncertainty

The range of uncertainty is the maximum range of the B-type uncertainty for the measured quantity.

Thermal loss factor of the compressor,

Index for designation of sequential numbers of elements in a series of measurements

Index for designation of sequential numbers of variables

Numeric factor (coverage factor) for multiplication of the combined uncertainty of measurement

Number of measured values in a series of measurements

Estimated standard deviation of a single measurement (A-type uncertainty, 3.1.3.1)

Estimated standard deviation of the arithmetic mean of a series of measurements (A-type uncertainty, 3.1.3.1)

Expected standard deviation (B-type uncertainty, 3.1.3.2)

Total uncertainty of measurement.

Symbols for performance check-ups

NT VVS 116 contains symbols pertaining to performance check-ups or other situations where performance data are inferred from measurements in the refrigerant system.

Symbols for performance tests

NT VVS 076 provides the symbols to be applied in commissioning tests of large heat pumps or other examples where regular heat metering methods are used.

5 GENERAL CONDITIONS

There general conditions apply in all tests and evaluations of heat pumps and refrigeration equipment covered by this Nordtest method. When further, particular conditions are required by specific tests, these conditions are described in the relevant test method.

5.1 Environmental and safety aspects

Obligatory, standard safety equipment shall be fitted and in use during testing unless it constitutes an impediment to the test, see 2.8.

5.2 Documentation

All documents and information necessary for testing and assessment must be available prior to the test.

5.2.1 Principle of operation

The principle of operation of the heat pump or refrigeration system shall be described briefly in writing. This description shall be supported by the following documents:

- A general layout drawing of the total system (preferably according to ISO 4067-1, see Appendix A5).
- A general drawing of the refrigerant system (preferably according to ISO 4067-4, see Appendix A6) as well as a list of components (make or type) and materials including the quantity and type of refrigerant.
- General drawings of piping and ductwork regarding the hot and cold side heat transfer systems.
- An electrical wiring diagram of the power supply, plus information regarding rated voltage, rated power for all electric motors and ancillary devices, and the total rated power for the system.
- An electrical wiring diagram of the control system (preferably according to ISO 3511-1, see Appendix A4 and DS 5009).
- Background documents regarding the design and sizing of connections to external systems. This includes, among other things, the temperature differences, flow-rates and pressure drops in the heat exchangers.

5.2.2 Instructions

Documented information must be available regarding:
- Instructions for operation. This comprises automatic as well as manual control systems including any defrost system.
- Instructions for use and maintenance.

The documentation must contain information regarding the range of operation of the system in terms of temperature, flowrate, pressure etc.

5.2.3 Measuring equipment

For the purpose of testing there must be appropriately designed connections for sensors concerning all quantities which are to be measured (see the respective test method). This may refer to:
- Thermometer wells for temperature sensors,
- Adapting pieces (including sufficient straight lengths of piping) for the installation of flowmeters,
- Connecting points for installation of meters for electric energy or power (it must be possible to measure separately each electric power input which is to be presented individually),
- Pressure tabs for measurement of the refrigerant pressure or the pressure difference in the heat transfer systems of the hot and cold side respectively.

The location of sensors shall be documented in the general drawings. Descriptions of the measuring equipment must also be available. The status of all measuring equipment that is required for the test must be documented by appropriate calibration certificates prior to the test. This applies both to permanently attached measuring equipment and to equipment which is only used during the test.

5.2.4 Technical data

Pertinent technical data shall be documented in accordance with Chapter 6. If the purpose of the test is to compare measured and stated performance data, a complete presentation of these data is required prior to the test. In cases where fouling of heat exchanger surfaces is considered to affect the performance, the state of these surfaces shall be investigated and documented (c.f. ENV 305, see Appendix A1).

6 PRESENTATION OF PERFORMANCE

Performance data may be presented by manufacturers or suppliers on the basis of theoretical information or tests. Tests may have been conducted by e.g. a manufacturer, a user or by a third party. Such performance data shall always be presented with specified operating conditions.

6.1 General presentation of performance

Depending on the type of heat pump/refrigerating equipment the operating conditions are stated according to Table 6.1 in terms of the temperature conditions.

Table 6.1. Definition of the operating conditions in terms of temperature.

<table>
<thead>
<tr>
<th>Type of equipment</th>
<th>Temperature of the heat transfer medium (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cold side</td>
</tr>
<tr>
<td>Brine/Water</td>
<td>$t_{\text{bin}}$</td>
</tr>
<tr>
<td>Water/Water</td>
<td>$t_{\text{bin}}$</td>
</tr>
<tr>
<td>Air/Water</td>
<td>$t_{\text{bin}}$ ($t_{\text{wb}}$)</td>
</tr>
<tr>
<td>Air/Air</td>
<td>$t_{\text{bin}}$</td>
</tr>
<tr>
<td>Brine/Air</td>
<td>$t_{\text{bin}}$</td>
</tr>
<tr>
<td>Water/Air</td>
<td>$t_{\text{bin}}$</td>
</tr>
<tr>
<td>Air/Sanitary hot water</td>
<td>$t_{\text{bin}}$ ($t_{\text{wb}}$)</td>
</tr>
</tbody>
</table>

The following data shall be stated:
- Thermal power (heating and/or cooling capacity),
- Drive power (electric power input),
- Coefficient of performance (not mandatory),
- Operating range.

If a coefficient of performance in the heating or the cooling mode is stated, this should be in accordance with the definitions given in 3. First priority is given to the total coefficient of performance, second priority to the motor coefficient of performance or compressor coefficient of performance, depending on whether the heat pump/refrigerating equipment is delivered with or without the drive motor.

Furthermore, in some instances information is also required concerning
- The type of cold side heat transfer medium,
- The type of hot side heat transfer medium,
- Flowrates,
- Fouling resistance,
- Pressure difference,
- Mains frequency and voltage,
- The type of refrigerant,
- The type of defrosting system.

Concerning general performance presentations, such as catalogues or pamphlets, it is often suitable to base these data on the outgoing cold side heat transfer medium temperature (as opposed to the incoming temperature recommended in Table 6.1). Performance data will then be relatively independent of the hot and cold side heat transfer media flowrates within the range of operation where the heat pump/refrigeration equipment can operate at full power.
6.2 Thermal power

6.2.1 General
Thermal power shall always be stated for the same system boundaries (Figure 1) as drive power and a possible coefficient of performance. For heat pumps operating with frosting surfaces the thermal power is stated for frostfree surfaces together with the necessary information to estimate the thermal power during one complete frosting and defrosting cycle.

6.2.2 Heat pumps
The stated thermal power, $P_1$, relates to the sum of all individual powers supplied to the hot side heat transfer medium from the different heat producing components of the heat pump. If these components are intended to be connected to separate hot side heat transfer media systems, data are to be stated for each system separately (see Figure 1).

6.2.3 Heat pump installations
The stated thermal power of a heat pump installation, $P_{1\text{p}}$, also includes heat power supplied to the hot side heat transfer medium by pumps or fans incorporated in the heat pump installation (see Figure 1).

6.3 Drive power

6.3.1 General
Drive power shall always be stated for the same system boundaries (Figure 1) as thermal power and a possible coefficient of performance. For heat pumps operating with frosting surfaces the drive power is stated for frostfree surfaces together with the necessary information to estimate the drive power during one complete frosting and defrosting cycle.

6.3.2 Heat pumps
For heat pumps powered by electric motors the electric power input to the compressor drive motor, $P_{\text{em}}$, is stated when the motor is part of the heat pump delivery. If the motor is not part of the delivery the shaft power of the compressor, $P_{\text{ek}}$, is stated. The heat pump power input includes any necessary supplementary power, e.g. to oil pumps, refrigerant pumps and defrosting systems. These supplementary power inputs are preferably stated separately.

6.3.3 Heat pump installations
The stated power input of a heat pump installation, $P_{1\text{p}}$, includes, in addition to the drive power of the heat pump (according to 6.3.2), the following supplementary power inputs:
- Power to pumps or fans in the cold side heat transfer system.
- Power to pumps or fans in the hot side heat transfer system.

Note: Concerning heat pump installations where the drive power and supplementary power have the same rated voltage, total power can be stated without being split into drive power and supplementary power.

6.4 Pressure difference
Pressure difference shall be stated for specified system boundaries concerning external connections of heat transfer media systems and shall be stated at nominal values of temperature and flowrate. Depending on possible internal pumps or fans, pressure differences may be positive or negative.

6.5 Operating range
The operating range shall be defined in terms of a full load range as well as a part load range where it is at all possible for the heat pump (refrigerating machinery) to operate. For further details, see NT VVS 076.

6.6 Presentation of performance for performance check-ups
NT VVS 116 contains requirements regarding specific performance data pertaining to check-ups or other situations where performance data are inferred from measurements in the refrigerant system.

6.7 Presentation of performance for performance tests
NT VVS 076 provides the requirements regarding specific performance data to be applied in commissioning tests of large heat pumps or other examples where regular heat metering methods are used.

7 METHOD OF TEST

7.1 General
This Nordtest method covers three specific fields of application:
- Functional tests of heat pumps and refrigeration equipment;
- Performance check-ups of heat pumps and refrigeration equipment;
  - approximate level of uncertainty: ±15 % (level 3);
- Performance tests of heat pumps and refrigeration equipment;
  - approximate level of uncertainty: ±10 % (level 2);
  - approximate level of uncertainty: ±5 % (level 1);
7.1.1 Method of performance check-ups

NT VVS 116 describes the method pertaining to check-ups or other situations where performance data are inferred from measurements in the refrigerant system. This method can be used in situations where a measuring uncertainty of ±15 % is satisfactory. Performance check-ups comprise:
- Determination of the coefficient of performance in the heating mode (COP1),
- Determination of the coefficient of performance in the cooling mode (COP2),
- Determination of the electric power input to the compressor motor \( (P_{em}) \).

From these results the following thermal capacities can be inferred:
- The heating capacity \( (P_1) \),
- The cooling capacity \( (P_2) \).

7.1.2 Method of performance tests

NT VVS 076 describes the methods to be applied in the commissioning tests of large heat pumps or other examples where regular heat metering methods are used. The methods can be used in situations where measuring uncertainties of ±5 % (level 1) or ±10 % (level 2) are satisfactory. The performance tests of large heat pumps comprise:
- Determination of the heating capacity \( (P_{1vpa} \text{ or } P_1) \),
- Determination of the total electric power input to the heat pump installation \( (P_{evp}) \),
- Determination of the electric power input to the heat pump \( (P_{evp}) \),
- Determination of the electric power input to the compressor motor \( (P_{em}) \),
- Determination of the coefficient of performance in the heating mode \( (COP_{1vpa}, COP_{1vp} \text{ or } COP_{1k}) \),
- Determination of the cooling capacity \( (P_{2vpa} \text{ or } P_2) \),
- Pressure differences in the heat transfer medium systems,
- Pressures and temperatures in the refrigerant system,
- Comparison of stated and measured performance data.

7.2 Measurements

7.2.1 General requirements

The aim of the method of test is to achieve an overall uncertainty of measurement which is less than ±5 % (level 1), ±10 % (level 2), or ±15 % (level 3). The uncertainty of measurement, which is actually achieved as a result of a test, can only be decided after an estimation of uncertainty according to 7.4.

Requirements concerning permissible uncertainties of measurement in 7.2.3 - 7.2.4 apply to the overall uncertainty of measurement including uncertainties due to installation effects, measuring instruments, transducers, readings, calibration etc. Uncertainties due to fluctuations in the system during testing are not included but are treated separately.

Further recommendations measurements are contained in Appendix C. In case shaft power input is measured the same requirements concerning uncertainty of measurement apply as for measurement of electric power input according to 7.2.4.5.

Measurements shall be performed during a period of at least 30 minutes, with readings taken at maximum intervals of 3 minutes during the measuring period.

For heat pumps (refrigerating machinery) operating under frosting conditions the performance test is carried out with defrosted heat exchanger surfaces and during the most stable 30 minute period possible.

If the requirements for measuring techniques, which are stated in 7.2, cannot be fulfilled for some reason, the deviations from this method of test must be clearly stated in the test report. Furthermore, a separate investigation shall be made of the possible influence of this deviation on the uncertainty of measurement. Deviations may concern, e.g., calibration, stability etc.

7.2.2 Requirements for stability

Prior to the test the plant must have operated under stable conditions for a minimum period of 30 minutes. For heat pumps (refrigerating machinery) operating under frosting conditions the performance test is carried out when the unit has attained a regular frosting-defrosting sequence. Measurements are made during the most stable 30 minute period possible starting at least 10 minutes after a defrost cycle has been terminated. The conditions of testing are considered stable when the following requirements are fulfilled (not applicable to operation with frosting):

<table>
<thead>
<tr>
<th>Temperature, flowrate</th>
<th>Maximum permissible deviation from the mean value (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
</tr>
<tr>
<td>Temperature of heat transfer medium, cold side</td>
<td>0.5 K</td>
</tr>
<tr>
<td>Flowrate of heat transfer medium, cold side</td>
<td>5 %</td>
</tr>
<tr>
<td>Temperature of heat transfer medium, hot side</td>
<td>1 K</td>
</tr>
<tr>
<td>Flowrate of heat transfer medium, cold side</td>
<td>5 %</td>
</tr>
</tbody>
</table>

Conditions of operation shall remain stable within the above limits during the entire test. A check of the operating conditions is preferably performed by monitoring the parameters continuously or at intervals at least 10 times shorter than the measuring interval.

If the conditions of stability cannot be achieved by any means, measurements are performed with the prevailing conditions of operation but the actually measured fluctuations of temperatures and flowrates are stated.
7.2.3 Requirements for measuring instruments

Transducers and measuring instruments shall have a certificate of calibration traceable to a national or international primary standard. The certificate of calibration shall not be older than 1 year at the time of testing.

Instruments and transducers shall be checked immediately prior to and after the test in order to see if there is any need for recalibration.

Calibrations shall apply to the specific output signal being used at the time of measurement. Otherwise there must be a traceable calibration of the conversion between the calibrated output and the measured output.

If the measuring instrument is calibrated in other conditions than those prevailing at the time of test (e.g. concerning pressure or temperature) verified expressions for the influence of these quantities on the calibration shall be available.

7.2.4 Measurement of different quantities

For the presentation of performance data and operating points according to 6.6 - 6.8 measurement of some or all of the following quantities is required. The quantities required for determination of the operating point and calculation of power output or input shall be chosen according to the specific type of test.

For checking the heat pump operation and tracing technical problems it may be useful to know the following quantities:
- Evaporating pressure.
- Condensing pressure.

<table>
<thead>
<tr>
<th>Quantities always to be measured:</th>
<th>Quantities measured for specific purposes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Incoming temperature of heat transfer medium, cold side</td>
<td>- Flowrate of heat transfer medium, hot side</td>
</tr>
<tr>
<td>- Incoming temperature of heat transfer medium, hot side</td>
<td>- Flowrate of heat transfer medium, cold side</td>
</tr>
<tr>
<td>- Outgoing temperature of heat transfer medium, hot side</td>
<td>- Outgoing temperature of heat transfer medium, cold side</td>
</tr>
<tr>
<td>- Power input to compressor(s)</td>
<td>- Refrigerant pressures</td>
</tr>
<tr>
<td></td>
<td>- Refrigerant temperatures</td>
</tr>
<tr>
<td></td>
<td>- State of humid air</td>
</tr>
<tr>
<td></td>
<td>- Pressure difference in the heat transfer system, cold side</td>
</tr>
<tr>
<td></td>
<td>- Pressure difference in the heat transfer system, hot side</td>
</tr>
<tr>
<td></td>
<td>- Power input to ancillary devices</td>
</tr>
</tbody>
</table>

In 7.2.4.1 - 7.2.4.5 requirements concerning measuring equipment are stated. If the measuring equipment has no indicators for individual quantities (e.g. when using heat meters) the requirements apply to the corresponding internal signals.

7.2.4.1 Measurement of temperature and temperature difference

Temperatures in hot or cold side heat transfer media shall be measured with a sufficient number of sensors in the liquid or air flows. In particular, problems concerning thermal stratification shall be considered, e.g. by increasing the number of temperature sensors. Positioning of sensors is described in Appendix C.

The rise time of a temperature sensor shall not exceed 120 seconds. The time relates to a change from 0 % to 90 % of the real temperature change and includes any thermometer wells or casings.

Temperature and temperature difference shall be measured with an overall uncertainty not exceeding ±0.1 K (level 1) or ±0.3 K (level 2 and 3) for liquids and ±0.2 K (level 1) or ±0.5 K (level 2 and 3) for air.

The tabulated requirements for measurement of temperature (+K):  

<table>
<thead>
<tr>
<th>Item</th>
<th>Liquid</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall uncertainty of measurement for temperature or temperature difference</td>
<td>Level 1</td>
<td>Level 2 and 3</td>
</tr>
<tr>
<td>Calibration of the measuring instrument</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Reproducibility of the measuring instrument</td>
<td>0.05</td>
<td>0.1</td>
</tr>
<tr>
<td>Resolution of the indicator</td>
<td>0.05</td>
<td>0.1</td>
</tr>
</tbody>
</table>

7.2.4.2 Measurement of flowrate

Flowrates in the hot side heat transfer system shall be measured by means of volume or mass flowmeters measuring the total flowrate. Measurements according to level 2 may also be performed using other methods such as velocity-area methods, tracer gas or other inferential methods.

The same requirements concerning measurement of flowrates in the hot side heat transfer system are recommended also for the cold side flowrate if this is included in the test.

Flowmeters shall be installed in such a way that the manufacturer's requirements concerning straight lengths of piping, minimum or maximum operating pressure, mounting position etc can be fulfilled (also see Appendix C1.2). For flowrate measurements in liquids it shall be checked that the system operating pressure is sufficiently large to prevent cavitation in the flowmeter and that the liquid is sufficiently free from entrained gases in order not to significantly affect the uncertainty of measurement. Tightness of ducts and cabinets shall be checked when measuring air flowrates in ducts.

Flowrates shall be measured with an overall uncertainty not exceeding ±2 % (level 1) or ±5 % (level 2 and 3) for liquids and ±5 % (level 1) or ±10 % (level 2 and 3) for air.
7.2.4.3 Measurement of pressure or pressure difference

Pressure taps shall be designed in such a way that the fluid velocity does not affect the measurement results (no contribution by dynamic pressure components).

Transmission lines between pressure taps and pressure sensors shall be designed in such a way that measurement uncertainties due to flows in the transmission line are avoided. The transmission line shall be installed in such a way that no pockets (where gases may accumulate) are formed between the tap and the sensor. Valves shall be included in the line to facilitate shut off, purging etc. (also see Appendix C1.3).

7.2.4.3.1 Cold and hot side heat transfer systems

Pressures are determined as static gauge pressures.

Pressure differences are determined as the difference in static pressure between two specified positions. When determining pressure differences the flow must always be determined simultaneously with a relative uncertainty which is less than 0.5 times the relative uncertainty of the pressure difference.

Pressures and pressure differences shall be measured with an overall uncertainty not exceeding ±5 % (level 1) or ±10 % (level 2 and 3) for liquids and ±5 Pa/% (level 1) or ±10 Pa/% (level 2 and 3) for air.

Tabulated requirements for measurement of pressure or pressure difference (±):

<table>
<thead>
<tr>
<th>Item</th>
<th>Liquid (%)</th>
<th>Air (Pa or %)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
<td>Level 2 and 3</td>
</tr>
<tr>
<td>Overall uncertainty of measurement for pressure or pressure difference</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Calibration of the measuring instrument</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Reproducibility of the measuring instrument</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Resolution of the indicator</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

* Use Pa in the range 0-100 Pa and % for pressures exceeding 100 Pa

7.2.4.3.2 Refrigerant systems

In NT VVS 116 measurements in the refrigerant system are used for determination of performance data. Measurement of refrigerant pressures may also be of interest in applying methods NT VVS 076, e.g. to check:

- Operating stability.
- Pressures limiting the operating range.

Pressures shall be determined as absolute static pressures (relative to vacuum). When measurements are performed in the refrigerant system it is particularly important to state exactly where in the system the pressure taps are located.

Refrigerant pressures shall be measured with an overall uncertainty not exceeding ±2 % (level 1) or ±5 % (level 2 and 3). Regarding performance measurements, refer to NT VVS 116.

Tabulated requirements for measurement of refrigerant pressures (± %). Regarding performance measurements, refer to NT VVS 116:

<table>
<thead>
<tr>
<th>Item</th>
<th>Level 1</th>
<th>Level 2 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall uncertainty of measurement for pressure</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Calibration of the measuring instrument</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Reproducibility of the measuring instrument</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Resolution of the indicator</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

7.2.4.4 Measurement of humidity

Humidity is expressed as wet bulb temperature (°C).

Humidity shall be measured by direct measurement of wet bulb temperature (minimum air velocity 2.5 m/s), measurement of dew point temperature or measurement of relative humidity. When measuring dew point temperature or relative humidity the requirements below apply to the result recalculated to be expressed as wet bulb temperature.

Humidity shall be measured with an overall uncertainty not exceeding 0.2 K (level 1) or 0.5 K (level 2 and 3).

Tabulated requirements for measurement of wet bulb temperature (±K):

<table>
<thead>
<tr>
<th>Item</th>
<th>Level 1</th>
<th>Level 2 and 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall uncertainty of measurement for wet bulb temperature</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Calibration of the measuring instrument</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Reproducibility of the measuring instrument</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Resolution of the indicator</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>
7.2.4.5  Measurement of electric power

Electric power shall be measured by means of current and voltage transformers connected to meters for electric power or energy.

Power measurements in 3-phase systems shall be performed using 2 or 3 watt meter methods. If energy meters are used the measuring time shall be determined with an uncertainty of measurement not exceeding ±0.1%.

At the time of measurement it must be checked that the maximum permissible load of the transformers is not exceeded (otherwise the uncertainty of measurement will be affected).

Voltage and frequency are checked and if possible corrections are made for deviations from rated voltage or rated frequency.

Electric power shall be measured with an overall uncertainty not exceeding ±1% (level 1) or ±2% (level 2 and 3).

Tabled requirements for measurement of electric power (± %):

<table>
<thead>
<tr>
<th>Item</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall uncertainty of measurement for electric power</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Calibration of the measuring instrument</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Reproducibility of the measuring instrument</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Resolution of the indicator</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Uncertainty of measuring transformers</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

7.2.4.6  Measurement of thermal power

Thermal power output is determined by measuring the flow-rate and temperature rise of the hot side heat transfer medium. In particular circumstances, better accuracy may be achieved using an indirect method to measure the cooling power and drive power input.

Thermal power input (cooling power) is determined by measuring the flowrate and temperature drop of the cold side heat transfer medium.

The aim is to determine the thermal power with an overall uncertainty not exceeding ±5% (level 1), ±10% (level 2) or ±15% (level 3). In the case of level 3, NT VVS 116 provides the details regarding measurement of the refrigerant state and the inferred COP and thermal power.

When using measuring instruments with a direct display of thermal power, or energy, the resolution of the indicator (scale division) shall not exceed ±0.5% (level 1) or ±1% (level 2 and 3) of the measured value.

For integrating heat meters, the measuring period must be sufficiently long to satisfy the above requirements. Sensors for checking the stability criteria are also required.

Tabulated overall requirements for performance measurements:

<table>
<thead>
<tr>
<th>Measured quantity</th>
<th>Unit</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal power</td>
<td>W</td>
<td>(5%)*</td>
<td>(10%)*</td>
<td>(15%)*</td>
</tr>
<tr>
<td>Liquid temperature, difference</td>
<td>°C</td>
<td>0.1 K</td>
<td>0.3 K</td>
<td></td>
</tr>
<tr>
<td>Dry bulb air temperature, wet bulb air temperature difference</td>
<td>°C</td>
<td>0.2 K</td>
<td>0.5 K</td>
<td></td>
</tr>
<tr>
<td>Liquid flowrate, air flowrate</td>
<td>m³/s</td>
<td>5%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Liquid pressure difference</td>
<td>Pa</td>
<td>5%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Air pressure, pressure difference</td>
<td>Pa</td>
<td>5%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Electric power, density, specific heat capacity</td>
<td>W/kg/m³</td>
<td>1%</td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

* Target values for upper limits of the uncertainty.
** Use Pa in the range 0–100 Pa and % for pressures exceeding 100 Pa.
*** In the case of level 3, NT VVS 116 provides the details regarding measurement of the refrigerant state and the inferred COP and thermal power.

7.3  Evaluation

7.3.1  General

Derived quantities, such as heating power and cooling power, shall be evaluated either by using mean values of the measured parameters or by calculation of the instantaneous value for every sample of measured parameters and forming the arithmetic mean of individually calculated derived quantities. Thermal power is then calculated from the ‘simultaneously’ measured values of flowrate and temperature difference according to:

\[
P_i = \sum_{i=1}^{n} \frac{P}{\tau}
\]

where \( P \) is the thermal power output or input, \( i \) is the sequential number of the measurement and \( n \) is the total number of measurements.

All quantities belonging to measurement number \( i \) shall be determined within an interval of time not exceeding the rise time of the sensor with the shortest rise time. This method shall only be used if all sensors have rise times shorter than 60 s.

When variations during the measuring period are large, this alternative provides a more correct value provided that the measuring frequency is sufficiently high.

If integrating heat meters or electric energy meters are used, the average power is formed by means of the measured energy \( (Q, W_c) \) during a defined interval of time (c).
Whenever possible a power balance calculation shall be performed. In such a case it is important that measuring equipment of similar quality is used for all measured quantities and that the same system boundaries are used for both power input and power output.

The power balance is stated as a percentage of the measured thermal power.

7.3.2 Determination of power

The determinations of thermal power output and input as well as electric power input are described in the respective performance test methods NT VVS 116 and NT VVS 076.

7.3.3 Recalculation between tested and stated operation points

To make a comparison possible between tested and stated performance values, measured values have to be corrected for deviations between the actually tested and the stated operating points. When deviations are small, it is assumed that linear interpolation can be used within the full load operating range of the heat pump (refrigerating machinery) regarding all parameters.

In case coefficient of performance or cooling power are stated, these quantities are treated in a similar manner.

To permit the method of correction mentioned above the following maximum deviations from the stated operating point are allowed:

- Incoming temperature of heat transfer medium, cold side: \( t_{\text{in, r}} \), ±2 K,
- Outgoing temperature of heat transfer medium, hot side: \( t_{\text{out, r}} \), ±5 K,
- Flowrate of heat transfer medium, cold side: \( q_{\text{kb, r}} \), ±10 %
- Flowrate of heat transfer medium, hot side: \( q_{\text{vb, r}} \), ±20 %

These limits also stipulate the operating points where performance data shall be stated in order to facilitate this method of correction.

When corrections are made for operating points at part load or close to boundaries of the operating range a special investigation concerning the method of correction must be made for each individual case before commencing the test.

7.3.4 Deviations between measured and stated performance data

Deviations between measured and stated performance data are calculated according to

\[
P_1(\text{avv}) = P_1(\text{korr}) - P_1,r, \\
P_2(\text{avv}) = P_2(\text{korr}) - P_2,r, \\
P_e(\text{avv}) = P_e(\text{korr}) - P_e,r, \\
\]

where

\[
P_1(\text{avv}) = \text{deviation between measured and stated thermal power output}, \\
P_2(\text{avv}) = \text{deviation between measured and stated thermal power input}, \\
P_e(\text{avv}) = \text{deviation between measured and stated electric power input}, \\
P_1(\text{korr}) = \text{measured thermal power output corrected for deviations in the operating conditions relative to the stated operating point}, \\
P_2(\text{korr}) = \text{measured thermal power input corrected for deviations in the operating conditions relative to the stated operating point}, \\
P_e(\text{korr}) = \text{measured electric power input corrected for deviations in the operating conditions relative to the stated operating point}, \\
P_1,r = \text{stated thermal power output (reference value)}, \\
P_2,r = \text{stated thermal power input (reference value)}, \\
P_e,r = \text{stated electric power input (reference value)}.
\]

For a deviation to be considered relevant, it must exceed the stated total uncertainty of measurement for the test.

According to this test method a deviation shall therefore be stated as the difference between the measured and stated values with the uncertainty of measurement subtracted.

7.4 Uncertainties

7.4.1 General

Statements of uncertainty shall be based on ISO guidelines (reference 2.17). When measurements are carried out with accuracy level 1 (see methods NT VVS 076), a regular determination of uncertainty is required. In this case, type A and type B components of uncertainty shall be stated separately for each quantity and shall then be combined to an overall uncertainty of measurement of this particular quantity. For details and examples of calculation reference is made to NT VVS 076.

7.4.2 Propagation of uncertainties

A quantity \( Y(x_1, ..., x_i, ..., x_n) \), which is calculated from \( n \) input values, will attain an uncertainty \( \Delta Y \) from the \( n \) individual input uncertainties \( \Delta x_j \) according to:

\[
\Delta Y = \sum_{j=1}^{n} \frac{\partial Y}{\partial x_j} \Delta x_j
\]

The input quantities \( x_j \) may be measured values (e.g. \( t_{vb} \), \( q_{vb} \) or values of physical properties from tables (e.g. \( \rho_{vb} \), \( c_{vb} \) and \( Y \) may be the calculated power or COP.

Note: When a quantity \( Y \), such as thermal capacity \( P_1 \), is calculated from measured values it attains an uncertainty \( \Delta P_{1(\text{m\text{\tiny{a}}/\text{t})}} \) from the uncertainties of measurement. When \( P_1 \) is compared with a reference value \( P_{1,r} \), there will be an additional uncertainty in the exact reference value to compare with since there is an uncertainty in the measured operating conditions. This translates into an additional uncertainty of the capacity, \( \Delta P_1(\text{drift}) \), from the operating conditions.
7.4.3 Component uncertainties

In paragraph 7.4.2 the differentials $\Delta x_j$ (e.g. $\Delta t$, $\Delta q$, etc), expressing the uncertainty of measured or tabulated values, may refer to either the estimated (type A, reference 2.17) component of uncertainty or the expected (type B, reference 2.17) component of uncertainty. Calculations shall be made separately for each type.

Type A uncertainties are stated as the standard deviation of the arithmetic mean of a number $n$ of measured values,

$$s_x = \frac{s_x}{\sqrt{n}}$$

Type B uncertainties are stated by means of symmetric uncertainty limits $a_j$, where $a_j$ is the estimated maximum uncertainty of variable $x_j$. The uncertainty of measurement is stated as the standard deviation of a rectangular distribution,

$$u = \frac{a_j}{\sqrt{3}}$$

Variances from several type B components of uncertainty are combined according to

$$u = \sqrt{\frac{1}{3} \sum_{j=1}^{m} a_j^2}$$

Accuracy level 1 (methods NT VVS 076) requires a regular determination of uncertainty. In this case, type A and type B components of uncertainty shall be stated separately for each quantity.

7.4.4 Total uncertainty

For accuracy level 1 (methods NT VVS 076 and NT VVS 116), type A and type B components of uncertainty shall be stated separately for each quantity and shall be combined into an overall uncertainty of measurement of this particular quantity.

$$U = \sqrt[2]{s_x^2 + u^2}, \quad k = 2.5$$

The numerical factor mostly corresponds to a confidence level which is better than 95 % for the type A component of uncertainty assuming a normal distribution. The overall uncertainty of measurement for each respective quantity calculated in this way is entered into the formulas for determination of uncertainty for derived quantities ($P_1$, $P_2$, $P_e$, COP).

Note: When derived quantities are calculated as the mean of the products of instantaneous values, the formulas for $\Delta P_{1(\text{mät})}$, $\Delta P_{e(\text{mät})}$ etc only apply to the type B uncertainty components of the respective variable. The type A component of uncertainty is calculated as the standard deviation of the mean of the derived quantity and the overall uncertainty of measurement is determined by combination in the same way as for the measured quantities.

8 TEST REPORT

8.1 General lay-out of the test report

The general lay-out of the test report shall be based on NORDTEST DOC GEN 020 (see 2.5) and EN 45 001 (see 2.6).

8.2 Test report for performance check-ups

NT VVS 116 contains specific items pertaining to reports from check-ups or other situations where performance data are inferred from measurements in the refrigerant system.

8.3 Test report for performance tests

NT VVS 076 provides the specific items to be applied in reports from commissioning tests of large heat pumps or other examples where regular heat metering methods are used.
APPENDIX A: ADDITIONAL INFORMATION

Additional useful information may be found in the following standards:

**A1 ENV 305 Heat exchangers**
Definitions of performance of heat exchangers and the general test procedure for establishing performance of all heat exchangers.

**A2 ENV 306 Heat exchangers**
Heat exchangers - Methods of measuring the parameters necessary for establishing the performance.

**A3 IEC 751**
Industrial platinum resistance thermometer sensors.

**A4 ISO 3511:1-4**
Process measurement control functions and instrumentation symbolic representation.

**A5 ISO 4067:1**
Technical drawings - Installations - Part 1: Graphical symbols for plumbing, heating, ventilation, and ducting.

**A6 ISO-DIS 4067:4**
Technical drawings - Installations - Part 4: Graphical symbols for refrigerating plants.

**A7 ISO Standards Handbook 15:1983**
Measurement of fluid flow in closed conduits.

**A8 VDI/VDE 3511**
Technische Temperaturmessungen.
APPENDIX B: LIST OF ORIGINAL INDICES

The following list provides a background to the origin of the indices by given the original Swedish designations and the corresponding translated English terminology.

**LIST OF ORIGINAL INDICES**

<table>
<thead>
<tr>
<th>Index</th>
<th>Swedish</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>avv</td>
<td>avvikelse pga driftpunkt</td>
<td>deviation due to the operating point</td>
</tr>
<tr>
<td>e</td>
<td>elektrisk</td>
<td>electric</td>
</tr>
<tr>
<td>ef</td>
<td>elektrisk, fläkt</td>
<td>electric, fan</td>
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<tr>
<td>em</td>
<td>elektrisk, motor</td>
<td>electric, motor</td>
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<td>ep</td>
<td>elektrisk, pump</td>
<td>electric, pump</td>
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<tr>
<td>evpa</td>
<td>elektrisk, värmepumpanläggning</td>
<td>electric, heat pump installation</td>
</tr>
<tr>
<td>eva</td>
<td>elektrisk, värmeanläggning</td>
<td>electric, heating plant</td>
</tr>
<tr>
<td>ekma</td>
<td>elektrisk, kylmaskinanläggning</td>
<td>electric, refrigerating machinery installation</td>
</tr>
<tr>
<td>eka</td>
<td>elektrisk, kylanläggning</td>
<td>electric, refrigerating plant</td>
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<td>fläkt</td>
<td>fan</td>
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<td>inkommande</td>
<td>incoming</td>
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<td>kompressor</td>
<td>compressor</td>
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<td>kb</td>
<td>köldbärare</td>
<td>heat transfer medium, cold side</td>
</tr>
<tr>
<td>km</td>
<td>kylmaskin</td>
<td>refrigerating machinery</td>
</tr>
<tr>
<td>kma</td>
<td>kylmaskinanläggning</td>
<td>refrigerating machinery installation</td>
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<tr>
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<td>kylanläggning</td>
<td>refrigerating plant</td>
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<td>corrected</td>
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<td>Luft, köldbärare</td>
<td>air, heat transfer medium, cold side</td>
</tr>
<tr>
<td>lvb</td>
<td>Luft, värmebärare</td>
<td>air, heat transfer medium, hot side</td>
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<td>mät</td>
<td>mätsäkerhet</td>
<td>uncertainty of measurement</td>
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<td>presented</td>
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<td>utgående</td>
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<td>tillsatsvärmeanläggning</td>
<td>supplementary heat supply</td>
</tr>
<tr>
<td>tka</td>
<td>tillsatskylanläggning</td>
<td>supplementary cooling supply</td>
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</table>
APPENDIX C: RECOMMENDATIONS

In this section directions and recommendations are given concerning measuring equipment and the performance of the test. These recommendations should be adhered to if the requirements set up in Chapter 7 are to be fulfilled. Further recommendations may be found in ENV 306 (Reference A2).

C.1 Measurement of temperature

Sensors for measurement of liquid temperatures in pipes or air temperatures in ducts should be installed in accordance with Figure C1 (see for instance VDI/VDE 3511, Reference A8) in the order 1-3 below.

1. In bends, against the direction of flow.
2. In narrow pipes, at an angle against the direction of flow.
3. Perpendicular to the direction of flow.

Figure C1. Installation of thermometer wells.

In certain circumstances (e.g. large, poorly insulated air ducts), when the difference in temperature between the fluid and the duct or pipewall is large, temperature sensors have to be equipped with radiation shields (see Fig. C2). Radiation shields are normally required when temperatures are measured close to non ducted air heat exchangers.

When selecting sensor types the first choice should be platinum resistance transducers (e.g. Pt-100 sensors according to IEC 751, Reference A3). Measurements should be taken using 4-wire connections and a sufficiently low measuring current to avoid heating of the sensor element.

Thermal contact paste or the equivalent must always be used when sensors are inserted in wells.

C.2 Measurement of flowrate

Installation of flowmeters shall always be carried out in straight sections of pipework of the same internal dimensions as the inlet and outlet of the flowmeter. In particular, sections directly after 90° bends in different geometrical planes, after T-joints, after pumps or fans etc should be avoided.

Irrespective of information obtained from the flowmeter supplier minimum undisturbed straight lengths of piping of at least 10*D before the meter and 5*D after the meter should be aimed for where D is the inlet diameter of the flowmeter (exceptions can be made for displacement meters such as piston meters etc).

In many instances, and in particular where swirl is anticipated, the above straight lengths may prove insufficient (see ISO Standards Handbook 15, reference A7, in particular standards ISO 4064/2, ISO 5167, ISO 5168 and ISO/TR 6817). In special cases the use of flow straighteners may be required if the stated accuracy of the flowmeter is to be achieved.

C.3 Measurement of pressure and pressure difference

Pressure taps should be located on the inlet and outlet pipes of the measured component and they should be positioned in such a way that the measuring points agree with the definitions of pressure or pressure drop in the stated performance data.

In particular when pressures are low and flow velocities high pressure taps must be designed with great care. Detailed instructions are given in the standards ISO 2186 and ISO R541 (ISO Standards Handbook 15, reference A7). Taps may consist of one or several connected holes in the pipe. Holes are to be drilled perpendicularly to the pipe axis and no burrs or radii may remain on the flow side of the hole. The diameter of the holes should be smaller than the wall thickness of the pipe but not so small as to risk clogging of the holes. Taps on horizontal pipes should be...
placed on the top for pipes carrying gas or steam, between 0-45° below the horizontal plane for clean liquids and between 0-45° above the horizontal plane for liquids with a large content of entrained solid particles.

The pressure sensor should be placed close to the pressure tap. For liquid systems the sensor is placed directly below the tap and for gas systems directly above the tap. When necessary, compensation is made for the static pressure of any liquid columns.

Sometimes the use of gas separators, condensation chambers, settling chambers, purging systems etc may be required, depending on the type of application.

Heating or cooling of pressure transmission lines may be necessary if these lines are long and there is a risk of condensation or evaporation (in particular for measurements in refrigerant systems).