DIRECT ACTING ELECTRIC HEATING – TESTING OF
CONTROL SYSTEMS:
PART 1: TERMINOLOGY AND EVALUATION IN A TEST
CHAMBER

Key words: Electric heating, control system, laboratory testing, test method

0 BACKGROUND

Evaluation of sophisticated control systems for electrically heated houses is time-consuming and costly. There are also practical problems regarding reproducibility and general validity. Since the difference in energy efficiency between various good systems will probably be small, it is quite important to maintain comparable test conditions. It is also important to be able to compare the systems with different test conditions to establish that the operation does not overly depend on the type of house. In order to consider these points, this Nordtest method comprises a combination of laboratory tests and computer simulation,


This part deals with part 1: Terminology and evaluation in a test chamber.
1 SCOPE AND FIELD OF APPLICATION

The test method is designed for laboratory testing of control systems for direct acting room heaters, primarily for single-family houses. This method denotes such a system as an electric-heat controller. The electric-heat controller may consist of either a central unit or several individual or co-ordinated local units.

The laboratory method may comprise one or both of the methods for climate chamber testing and computer simulation. This part deals with climate chamber testing and comprises:

- control accuracy at constant load,
- performance during a change in the outdoor temperature,
- performance during a step change in the set value for the room temperature,
- performance during a step change of an internal load,
- airing function (operation with an opened window),
- supplementary control functions.

This part also deals with terminology and different measures of control accuracy and efficiency. In principle the definitions may be used equally well for evaluation of climate chamber testing (part 1; i.e. this method) and real-time simulations (part 3).

The scope is to evaluate control systems rather than radiators/convectors with built-in thermostats. The field of application is advanced, multi-function controllers with wall-mounted indoor sensors and an optional outdoor sensor.

2 REFERENCES


2.3 CEN/TC 247 (19xx-xx V1.5): Individual Electronic Zone Control Equipment for Heating Applications.


2.5 CENELEC prEN 50193 (July 1996): Closed electrical instantaneous water heaters – Methods for measuring performance.


2.8* IEC 675 (1994-08): Household electric direct-acting room heaters – Methods for measuring the performance.

2.9* ISO 7726: Thermal environments – Specifications relating to appliances and methods for measuring physical characteristics of the environment.


2.12* Nordtest metod NT VVS 006 (1980): Electrical panel heaters: Performance testing (identical to SEN 33 06 10).

2.13 SEN 33 06 10 (1972-03-01): Elvärmepaneler – Funktionsprovning.


2.15* EAL-R2 (Edition 1, April 1997). “Expression of the Uncertainty of Measurement in Calibrations”.

*Normative references; other references are only informative.

3 DEFINITIONS

3.1 Electric-heat controller

Appliance which automatically controls the supply of electric energy for room heating to one or several zones, and/or heating of sanitary water, with respect to the required temperature and/or economy.

3.1.1 Central electric-heat controller

Electric-heat controller which has all functions, except sensors, contained in one or several centrally positioned units.

3.1.2 Local electric-heat controller

Electric-heat controller which has most of its functions contained in locally positioned units.

3.1.3 Co-ordinated local electric-heat controller

Electric-heat controller which has most of its functions contained in locally positioned units, the operation of which is co-ordinated by a central master controller.

3.1.4 Programmer

Control for regulating the room temperature according to a programme pre set by the user (c.f. ref. 2.8).
3.1.5 Set-back device
Device which allows the room temperature to be maintained at a lower value than the pre set temperature without changing the setting of the thermostat (ref. 2.8).

3.1.6 Frost protection means
Means which allows the room temperature to be maintained at a value of 7 °C ± 3 K (ref. 2.8).

3.2 Electric room heater
Device which converts electric energy to heat and transfers this heat to one or several rooms.

3.2.1 Direct acting room heater
Appliance which converts electric energy into heat after a demand for heat has arisen in a room and transfers this heat to the room without delay (ref. 2.8).

3.2.1.1 Panel heater (electric panel heater)
Direct acting heater in which the temperature rise of all surfaces in contact with the circulating air does not exceed 75 K in normal use (ref. 2.8).

3.2.1.2 Convector heater
Direct acting heater in which the temperature rise of at least one non-visible part in contact with the circulating air exceeds 75 K in normal use. The air is discharged through one or more outlets by natural convection (ref. 2.8).

3.2.1.3 Fan heater
Direct acting heater in which the movement of air through it is accelerated by a fan (ref. 2.8).

3.2.1.4 Radiant heater
Direct acting heater in which the temperature rise of at least one visible surface exceeds 75 K in normal use (ref. 2.8).

3.2.2 Central heating
Heat supply by means of a single heat source and multiple emission units in one or several zones (ref. 2.3).

3.2.3 Storage system
(for direct or central heating)
Heat supply by means of a heat source which stores energy produced during off-peak periods at a reduced price. The heater has a large thermal mass in order to store heat energy. Heat storage and demand may be indoor and/or outdoor temperature controlled (ref. 2.3).

3.2.4 Nominal mean power
Estimated mean power input, $P_{e,\text{nom}}$, required by a given room at specified temperature conditions.

3.2.5 Rated power input
Power input, $P_{e,\text{rated}}$, assigned to the heater by the manufacturer (ref. 2.8).
- In this method, rated power refers to continuous operation of the room heater.

3.2.6 Energy ratio
Ratio of the energy input ($W_{e,\text{rad}}$) during a representative period ($\tau$) of operation to the product of the rated power input ($P_{e,\text{rated}}$) and this period (ref. 2.8).

$$\varepsilon = \frac{W_{e,\text{rad}}}{P_{e,\text{rated}} \cdot \tau}.$$

3.2.7 Design energy ratio
Ratio, at design temperature conditions, of the energy input ($W_{e,\text{rad}}$) during a representative period ($\tau$) of operation to the product of the rated power input ($P_{e,\text{rated}}$) and this period.

$$\varepsilon_{\text{des}} = \frac{Q_{\text{room,des}}}{P_{e,\text{rated}} \cdot \tau}.$$

In this method, design temperature conditions refer to a room temperature of $t_{\text{room}} = +20 ^\circ \text{C}$ and an outdoor temperature of $t_{\text{out}} = -20 ^\circ \text{C}$.

3.3 Electric water heater
Appliance which converts electric energy to heat and transfers this heat to sanitary water for household use.

3.3.1 Electric storage water heater
Appliance intended for heating water electrically in a thermally well insulated container, for the long-term storage of the heated water, and provided with a device to control the water temperature (c.f. ref. 2.6).

3.3.2 Electric instantaneous water heater
Appliance intended for heating water electrically while it flows through the appliance (c.f. ref. 2.5).
3.4 Room thermostat
Thermostat, sensitive to the room temperature, which is adjustable by the user (c.f. ambient temperature thermostat in ref. 2.8).

3.4.1 Room heater thermostat
Room thermostat which is incorporated in the room heater (c.f. ambient temperature thermostat in ref. 2.8).

3.4.2 Zone thermostat
Room thermostat which is not included in a room heater and which controls one or several room heaters.

3.5 Temperature
3.5.1 Mean temperature
Arithmetic mean value of a temperature during a well defined period,
\[
\bar{t} = \frac{1}{n} \sum_{j=1}^{n} t_j \quad \text{(intermittent measurement)}
\]
\[
\bar{t} = \frac{1}{(t_1 - t_2)} \int_{t_1}^{t_2} \bar{t} \, dt \quad \text{(continuous measurement)}.
\]

3.5.2 Temperature deviation
See 3.6.15.

3.5.2.1 Deviation between maximum temperature and set value
\[
\theta_{\text{max}} = t_{\text{room, max}} - t_{\text{set}}.
\]

3.5.2.2 Deviation between minimum temperature and set value
\[
\theta_{\text{min}} = t_{\text{room, min}} - t_{\text{set}}.
\]

3.5.2.3 Range of dispersion
\[
\Delta t_{\text{max}} = t_{\text{max}} - t_{\text{min}} \quad \text{(also see 3.5.3.1)}.
\]

3.5.2.4 Mean deviation
The mean deviation is a measure of the control accuracy under specified conditions, also see 3.5.3.2 and 3.6.15 (the uncertainty of \( \theta_{\text{mdev}} \) is given by \( s_{\text{room}} \), also see 3.5.3.2),
\[
\theta_{\text{mdev}} = \bar{t}_{\text{room}} - t_{\text{set}}.
\]

The control accuracy of the electric heat controller, without consideration of the sensor position, is given by
\[
\theta_{\text{mdev,s}} = \bar{t}_s - t_{\text{set}}.
\]

3.5.3 Temperature variation
3.5.3.1 Amplitude
Difference between the maximum and the minimum room temperatures for a setting of the ambient temperature thermostat (ref. 2.8). The temperature range of dispersion with a fixed thermostat setting (also see 3.5.2.3 and compare with ref. 2.8).

3.5.3.2 Standard deviation (standard uncertainty of the mean)
The standard deviation of a single measured value,
\[
s_t = \sqrt{\frac{1}{(n-1)} \sum_{j=1}^{n} (t_j - \bar{t})^2}.
\]

The standard uncertainty of the mean,
\[
s_{\bar{t}} = \sqrt{\frac{1}{n(n-1)} \sum_{j=1}^{n} (t_j - \bar{t})^2}.
\]

3.5.3.3 Mean variation
The mean variation is a measure of the control stability (hunting) under specified conditions, also see 3.5.3.2 and 3.6.19,
\[
\Delta t_{\text{mvar}} = 2s_{\bar{t}}.
\]
The interval \( \Delta t_{\text{mvar}} \) will include approximately 95% of the temperature values.

3.5.4 Room temperature (\( t_{\text{room}} \))
The room temperature can be expressed by means of e.g. air temperature, radiant temperature, operative temperature, equivalent temperature etc. In this method the concept of room temperature refers to the operative temperature (3.5.4.3) or the globe temperature (see 3.5.4.4) in the middle of the room at a height of 1.2 m above the floor (ref. 2.8).

3.5.4.1 Air temperature (\( t_a \))
Measured air temperature with a radiation shielded sensor (heat transfer solely by convection).

3.5.4.2 Radiant temperature (\( t_r \))
Measured air temperature with a sensor without a radiation shield and with specified surface characteristics and a specified geometry (heat transfer primarily by means of radiation; measured e.g. by means of a cube thermometer, a globe thermometer, a rotational ellipsoid). The plane radiant temperature refers to a certain direction and the
mean radiant temperature refers to the mean value for all directions.

3.5.4.3 Operative temperature \( (t_{op}) \)
Calculated or measured temperature with a specified weighting of the air and radiant temperatures. Directional operative temperature refers to weighting of the air temperature and plane radiant temperature. This method uses the weighting factor 0.5, and the air and weighted mean radiant temperature in the centre of the room, i.e.
\[
t_{op} = 0.5 \cdot (t_A + \bar{t}_r)
\]

3.5.4.4 Globe temperature \( (t_{globe}) \)
Measured air temperature using a sensor mounted inside a thin-wall black globe having a diameter of approximately 10 cm (ref. 2.8).

3.5.4.5 Equivalent temperature \( (t_{equi}) \)
Calculated or measured temperature taking into consideration specified weightings of air temperature, radiant temperature and air velocity.

3.5.4.6 Comfort temperature \( (t_{com}) \)
Equivalent temperature which during specified activities and with specified clothing provides a certain thermal comfort. This method refers to the calculated air temperature needed to yield the minimum frequency of complaints \( (PMV = 0) \) during existing conditions with clothing of 1 Clo and an activity of 1 Met. The air temperature can be calculated with the aid of ISO 7730 (ref. 2.10).

3.5.4.7 Temperature asymmetry \( (\theta_{ass}) \)
Difference between the plane radiant temperatures in two opposite directions in the room.

3.5.4.8 Temperature gradient \( (g_t) \)
Difference between the air temperatures at two specified positions in the room divided by the distance between these positions.

3.6 Control technology
3.6.1 Control device
Generic designation of controller – controlling element – actuator.

3.6.2 Controller
Functional unit which is included in the control equipment and which contains a comparing element and also performs some other function of the control equipment, e.g. amplification, compensation (ref. 2.14).
– Hence the unit transforms the error signal of the comparing element to a control signal with specified characteristics (e.g. proportional and integrating action, also known as PI-controller).

3.6.3 Controlled object
Generic designation of a process which is to be controlled in a specified way (e.g. the indoor temperature of a building).
– In this part of the method, the controlled object is the standardized test chamber.

3.6.4 Control with fixed set point (constant control action)
Function of a control system when the objective is to minimize the influence of disturbance variables \( (v) \) on the actual value or output signal \( (y) \), while the desired value is constant.

3.6.5 Follow-up control (servo action)
Function of a control system when the objective is to minimize the deviation between the desired value or reference value \( (r) \) and the actual value or output signal \( (y) \), while the desired value varies.

3.6.6 Adaptive control
Control (feedback control) such that the properties of the control equipment (feedback control equipment) are automatically adapted to the characteristics of the control object or the input signals of the system (ref. 2.14).

3.6.7 Command variable
Variable which after conversion provides the reference variable (ref. 2.14).
– C.f. the definitions of desired value and reference variable (3.6.8).

3.6.8 Reference variable
Input variable to a system which the controlled variable is to follow (ref. 2.14).
– C.f. the definitions of set point (3.6.14) and command variable (3.6.7).

3.6.9 Manipulated variable
Variable which constitutes the output variable from the control equipment and input variable to the controlled object (ref. 2.14).
The manipulated variable normally consists of a signal from the controller, which influences the controlled object in order to lower the error signal.

3.6.10 Controlled variable
Output variable from the object which is controlled (ref. 2.14).

3.6.11 Disturbance variable, \( v \)
Variable which may cause an unwanted influence on the controlled object (ref. 2.14).

3.6.12 Actual value (of controlled variable), \( y \)
Value of a variable at a given moment. If nothing else is said the value of the controlled variable is intended (ref. 2.14).

3.6.13 Desired value
Desired value of a variable at a given time. If nothing else is said the desired value of the controlled variable is intended (ref. 2.14).

3.6.14 Set point
Signal which corresponds to the reference variable (ref. 2.14).

3.6.15 System (control) deviation
Difference between desired value and actual value of the controlled variable.
It is presumed that desired value and actual value are expressed in the same units (ref. 2.14).

3.6.16 Error signal (difference quantity), \( e \)
Output signal (output quantity) from the comparing element of a control system (ref. 2.14). C.f. the definition of system (control) deviation (see 3.6.15).

3.6.17 Set point drift
Change in the mean value of the thermostatically controlled air temperature when the heat demand changes (ref. 2.13; corresponds to 3.6.18: thermostat drift).

3.6.18 Thermostat drift
Difference between the average room air temperatures obtained at different energy ratios for a fixed setting of the room thermostat (c.f. ref. 2.8; corresponds to 3.6.17: set point drift).

3.6.19 Hunting
Normally unwanted, self-induced, periodic variations of a control system (ref. 2.14). Also see 3.5.3.3. In this method (ref. 2.13): Variation around a mean value of the thermostatically controlled room temperature.

3.6.20 Unit impulse response
Time response of a system which is affected by a unit impulse function (Dirac function) on one of its inputs (ref. 2.14).

– This is used e.g. during transient analysis (a unit impulse has the surface = 1 but infinitesimal width and infinite height).

3.6.21 Step response
Time response of a system which is affected by a stepwise change of one of its input variables (ref. 2.14).

– This is used e.g. during transient analysis (a step function increases the amplitude of the input signal instantaneously from zero to a constant value).

3.6.22 Ramp response
Time response of a system which is affected by a ramp function on one of its inputs (ref. 2.14).

– This is used e.g. during transient analysis (a ramp function increases the amplitude of the input signal linearly with time).

3.6.23 Time constant, \( \tau_c \)
Time interval, after which a variable that varies according to an exponential function would reach its final value if it were to retain its original rate of change (ref. 2.14).

– This corresponds to the time required for the output signal to change from 0 to 63 % of the final value of a step response in a 1st order system (\( y = y_\infty [1 - e^{-t/\tau_c}] \)).

3.6.24 Rise time, \( \tau_r \)
Time interval, in connection with a step response, from the moment the output signal, having started form zero, reaches a small specified percentage (e.g. 10 %) to the moment it first reaches a large specified percentage (e.g. 90 %) of the same steady state value (ref. 2.14).
3.6.25 Dead time, delay time, lag time, \( \tau_L \)
Time interval from the execution of a change in the input variable to the start of the induced change in the output variable (ref. 2.14).
– A lag time may correspond to e.g. a transport delay caused by the finite velocity in air and water systems.

3.6.26 Settling time, \( \tau_S \)
Time interval from the application of a unit step change in the input variable until the moment the induced variation in the output variable permanently lies within a defined tolerance, e.g. 5 % of the difference between final and original steady state value (ref. 2.14).
– A tolerance of \( \pm 0.5 \) K applies in this method.

3.6.27 Transient analysis
Method for determination of the dynamic characteristics of a system by recording its output signal as a function of a sudden change of a given type in the input signal (e.g. impulse, step).

4 DESIGNATIONS

4.1 Abbreviations
ACH Air Changes per Hour
CEN Comité Européen de Normalisation
CENELEC Comité Européen de Normalisation Electrotechnique
D Derivative (control action)
EMC Electromagnetic Compatibility
IEC International Electrotechnical Commission
ISO International Organization for Standardization
P Proportional (control action)
PI Proportional and integral (control action)
PID Proportional, integral and derivative (control action)
PMV Predicted Mean Vote
SPC Set-Point Control

4.2 Symbols for physical quantities

Latin letters
A area (m²)
\( c_p \) isobaric specific heat capacity (J/kg/K)
e error (in a time domain)
F view factor (–)
g gradient (a temperature gradient is stated in K/m)
H height above floor level (m)
j running numerical index
L loss factor (W/K)
M mass (kg)
N largest numerical value of running index
P power (W)
q flow rate (m³/s or m³/h)
Q heat (J or Wh)
r relative set point drift
t temperature according to a Celsius scale (°C)
T thickness (m)
U absolute temperature (K)
u manipulated (controlled) variable (in a time domain)
v velocity (m/s)
W energy, work (J or Wh)
W width (m)
y actual value (in a time domain)

Greek letters
\( \delta \) deviation from a steady state value (K)
\( \Delta T \) temperature change, temperature variation (°C)
\( \Delta T \) temperature change, temperature variation (K)
\( \varepsilon \) energy ratio (Wh/Wh)
\( \eta \) efficiency
\( \lambda \) thermal conductivity (W/m²/K)
\( \theta \) temperature difference, temperature deviation (K)
\( \rho \) density (kg/m³)
\( \tau \) time (s or h)

4.3 Subscripts
A air
As air at sensor
act actual value
amb ambient
ass asymmetry
b back
c constant (time constant)
c convection
cp control point
cdev control deviation
com comfort
con controller
d door
des design conditions
dev deviation
EA exhaust air
e electric
equiv equivalent
exc excess temperature
5 GENERICS

5.1 Selection of test objects

Testing is normally carried out on an electric-heat controller which is selected in agreement between the client and the testing institute. The client is responsible for compliance of the electric-heat controller with current safety regulations. Prescribed and normally fitted safety equipment shall, unless it is a hindrance for the test procedure, be mounted and in use during testing.

5.2 Documentation

Prior to testing, the following documents and information shall be conveyed to the testing institute:

- Instructions for suitable location and installation. Installation work shall be described step by step in such a way that the intended function of the installation can be achieved. International Protection class shall be stated for individual units.
- Instructions for use including basic descriptions of all functions, any proposed settings as well as informative texts and advice for locating faults.
- Descriptions of the different control functions. Functions may for instance include day/night set-back of temperature in different zones, change of temperature by means of remote control, time control of a water heater, airing control, frost protection etc. Any imbedded functions for detecting faults shall be described. Prerequisites for self-tuning or self-adaptive functions shall be clearly stated.
- Description and technical data of input and output units. This may comprise types of sensors, types of signals and communication protocols etc. of incoming signals, types of signals and communication protocols of output signals, types and capacities of current controlling elements (triacs, contactors etc.) etc. In particular, external communication regarding remote control should be described in detail (e.g. load control signals from a utility).
- Flowchart which gives an overview of the operation of the electric-heat controller and its communication with the surroundings. In the case of programmable systems, flowcharts shall also be provided for those functions which have been realized in software.
- List of components with a drawing or a sketch clearly showing the position of different components.

6 PRINCIPLES OF TEST METHOD

A comprehensive laboratory test of an electric-heat controller comprises control characteristics, comfort, energy efficiency, noise and electrical characteristics.

6.1 Control characteristics

Control characteristics are tested according to 6.1.1–6.1.6.

6.1.1 Settings

Optional manual settings, temporary as well as permanent, are checked. As regards temporary settings, a check is made when the system returns to the normal setting. Stable, adaptive values are included in the term permanent setting.

6.1.2 Room temperature control

Room temperature control functions of the electric-heat controller are tested concerning:
• System (control) deviation at a steady state outdoor temperature,
• Influence of a change in outdoor temperature,
• Influence of a change in the desired indoor temperature,
• Influence of internal loads,
• Influence of airing (opening of windows).

6.1.3 Supplementary control functions
Supplementary control functions of the electric-heat controller are tested concerning:
• Frost protection,
• Airing (opening of windows),
• Water heater,
• Load control,
• Load limitation,
• External communication.

6.1.4 Interruption of power supply
The electric-heat controller is checked regarding its operation after an interruption of the power supply. In particular, any changes in permanently modified settings are checked.

6.1.5 Comfort
The thermal comfort during operation with the electric-heat controller is compared with the best possible comfort in the same room.

6.1.6 Power and efficiency
Power input and energy input during operation with the electric-heat controller are compared with the minimum possible inputs of power and energy in the same room and a given comfort temperature.

6.2 Sound emission
Sound emission from the electric-heat controller is tested in a reverberation chamber in accordance with ISO 3741. Sounds of long and short duration are investigated separately and accounted for using A-, B-, as well as C-filters. Sound power is reported as $L_{WA}$, $L_{WB}$, and $L_{WC}$ respectively in the unit Bel (1 B = 10 dB).

When the electric-heat controller emits pulse sounds, e.g. from the action of electro-mechanical switchgear, the test set-up is arranged so that the sound pulses are repeated with a steady frequency (interval between on-switches: $\tau$ = 2 min). Sound emission will not be covered any further in this method.

6.3 Electrical characteristics
Series produced electric-heat controllers, including any optional modules or supplementary equipment, shall be tested and approved according to current requirements concerning electrical safety. This method does not comprise testing of electrical characteristics. For such testing, reference is made primarily to national, CENELEC or IEC standards. Examples of applicable test methods for electric-heat controllers can be found in ref. 2.4 regarding e.g. power supply, voltages, protection by enclosures, electromagnetic compatibility (emissions, immunity) etc.

7 TEST EQUIPMENT
Test equipment shall be designed so that all requirements in this method can be fulfilled, e.g. concerning set values, stability and uncertainty of measurement. Section 10 provides requirements concerning measuring uncertainties. Measuring equipment shall be calibrated with traceability to national or international standards.

7.1 Equipment for testing of settings
Equipment for testing different settings consists of a test chamber in accordance with 7.1.2.

7.2 Equipment for testing room temperature control functions
Testing is carried out in a test chamber of the type used for testing radiators (ref. 2.8: IEC 675, ref. 2.12: NT VVS 006 = ref. 2.13: SEN 33 06 10). The chamber shall consist of two parts, one simulating the outdoor climate ("out") and one simulating a heated room ("room"). The outdoor and room parts shall be separated by a partition wall with a window (see Figure 7.1). It shall also be possible to adjust a suitable ventilating airflow with the outdoor air supplied to the room through two symmetrically placed openings above the window and the exhaust air extracted from a position a maximum of 0.4 m above floor level at the opposing wall.

It shall be possible for the outdoor climate to be controlled between +15 and –15 °C and to increase or decrease linearly with time (ramp function).

The room shall be equipped with an electric convector heater which can be operated by the electric-heat controller. The heater shall give an energy ratio between 0.7–0.8 at the

![Figure 7.1. Test chamber for evaluation of control functions.](image-url)
design temperature conditions of the room ($t_{\text{out}} = -20 \, ^\circ\text{C}$, $t_{\text{room}} = +20 \, ^\circ\text{C}$). By adjusting air flow and exterior wall, the ratio of the heat losses $P_{\text{wall}}/P_{\text{vent}}$ shall be adjusted to $1.2 \pm 0.2$ at the design conditions.

It shall be possible for the room to be equipped with an internal heat load which can be controlled from the outside. It shall be possible for the load to be varied and it must not include a fan. A suitable type of heat source is a radiation shielded light bulb or a panel heater.

The chamber shall have access to a stabilized voltage of 230/400 V for the supply of the electric-heat controller and the convector heater.

Appendix 1 provides design values for the test chamber and radiator, Appendix 2 provides guidelines for checking and presenting the characteristics of the test chamber and Appendix 3 provides guidelines regarding measuring positions.

The heating requirement of the room is characterized by three loss factors:

– the heat loss: room ⇒ outdoor, $P_{\text{room1}} = L_1 \cdot (t_{\text{room}} - t_{\text{out}})$

– the heat loss: room ⇒ other surroundings, $P_{\text{room2}} = L_2 \cdot (t_{\text{room}} - t_{\text{amb}})$

– the heat loss: due to ventilation, $P_{\text{vent}} = L_{\text{vent}} \cdot (t_{\text{room}} - t_{\text{out}})$. The loss factors $L_1$ and $L_2$ are determined by means of measurements and calculations whereas $L_{\text{vent}}$ is given by: 

$$L_{\text{vent}} = q_{\text{vent}} \cdot \rho A \cdot c_p A.$$

8 PREPARATION OF TEST SAMPLES

When installing the electric-heat controller, a check is made that prescribed and series fitted safety equipment is installed and in use. If something is missing, this is noted and a special check is made to minimize personal hazard.

The electric-heat controller is photographed and compared with accompanying documentation. It is determined whether stated measurements and components in the accompanying documentation agree with the test object. Type designation and any serial numbers are noted.

If the test is intended for some kind of product certification, programmable systems are to be documented by a read-out and storage of the contents of the memory circuits for future comparisons with manufactured units.

The electric-heat controller is mounted at the designated position in the test chamber and any sensors are connected. Unless otherwise prescribed by the manufacturer/supplier, the room sensor is mounted at the middle of one of the long sides of the chamber at the same height as the comfort sensor (1.2 m above floor level, also see Figure 9.2). Thereafter the electric-heat controller is connected to the convector heater and an initial functional check is made.

Controllers with self-tuning or adaptive functions shall run through the full test procedure of 9.2 below at least once before the actual test is carried out. This provides a learning period of at least 72 h which should be adequate for systems not using seasonal learning periods.

9 TEST PROCEDURE AND EXPRESSION OF RESULTS – Control characteristics

A comprehensive laboratory test of an electric-heat controller comprises control characteristics, comfort, energy efficiency, sound emissions and electrical characteristics. Testing of sound emissions and electrical characteristics are superficially dealt with in 6.2 and 6.3 and will not be further discussed in this test method.

Sensors and the electric-heat controller are installed in a test chamber according to Figure 7.1 and Appendix 3. The system is tested to check its real behaviour, with sensors and a convector heater connected. Furthermore, this test may be used to provide data for verifying results from tests on sensors according to Nordtest method NT VVS 124 and systems by means of real-time simulation according to Nordtest method NT VVS 125.

9.1 Settings

Different alternative manual settings, temporary as well as permanent, are checked. As regards temporary settings, the time of return to the normal setting is checked. Permanent settings also include stable, adaptive settings.

The desired value for the room temperature is set at $+20.0 \, ^\circ\text{C}$. If the measured mean value of the room temperature in the middle of the test chamber, at a height of 1.2 m above the floor, is $20.0 \pm 0.5 \, ^\circ\text{C}$ at an outdoor temperature of $-5 \pm 0.5 \, ^\circ\text{C}$, then the setting is unchanged. Otherwise the setting of the
desired value is adjusted to bring the temperature inside the tolerance and the new setting is noted. The mean value of the room temperature refers to a minimum of 50 measurements, evenly spaced in time during a period of at least 1 h. This setting is fixed for the remainder of the test.

N.B. If the set value is modified, as described above, then the nominal set values 20 and 18 °C shall be modified accordingly in all mathematical formulations of deviations, variations etc. below.

The following quantities are reported (also see Chapter 11):
- room temperature (actual value $t_{\text{room,ref}}$ and setting of desired value $t_{\text{room,set}}$),
- all tested manual settings.

### 9.2 Room temperature control

The closed-loop control characteristics of the electric-heat controller are checked concerning accuracy of room temperature control, influence of a change in outdoor temperature, influence of a changed setting of the desired value and influence of internal heat loads. Figure 9.1 and Table 9.1 describe the testing sequence.

![Figure 9.1. Test sequence during evaluation of the control function.](image)

Table 9.1 Sequence of events during evaluation of the control function.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Time (h)</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau_0$</td>
<td>0</td>
<td>Stabilization period</td>
</tr>
<tr>
<td>$\tau_1$</td>
<td>8</td>
<td>Constant conditions ($t_{\text{ref}} = +20 , ^\circ\text{C}$, $t_{\text{out}} = -5 , ^\circ\text{C}$, $P_{\text{int}} = 0 , \text{W}$)</td>
</tr>
<tr>
<td>$\tau_2$</td>
<td>10</td>
<td>New constant outdoor temperature ($t_{\text{out}} = +5 , ^\circ\text{C}$)</td>
</tr>
<tr>
<td>$\tau_3$</td>
<td>15</td>
<td>Ramp decrease of the outdoor temperature (5 K/h)</td>
</tr>
<tr>
<td>$\tau_4$</td>
<td>17</td>
<td>Original constant outdoor temperature ($t_{\text{out}} = -5 , ^\circ\text{C}$)</td>
</tr>
<tr>
<td>$\tau_5$</td>
<td>26</td>
<td>New reference value for the room temperature ($t_{\text{ref}} = +18 , ^\circ\text{C}$)</td>
</tr>
<tr>
<td>$\tau_6$</td>
<td>34</td>
<td>Original reference value for the room temperature ($t_{\text{ref}} = +20 , ^\circ\text{C}$)</td>
</tr>
<tr>
<td>$\tau_7$</td>
<td>50</td>
<td>Internal heat load ($P_{\text{int}} = 0.9P_{\text{room}}$)</td>
</tr>
<tr>
<td>$\tau_8$</td>
<td>55</td>
<td>Original internal heat load ($P_{\text{int}} = 0 , \text{W}$)</td>
</tr>
<tr>
<td>$\tau_9$</td>
<td>72</td>
<td>Airing (opening of the window)</td>
</tr>
<tr>
<td>$\tau_{10}$</td>
<td>72.25</td>
<td>Original conditions (closed window)</td>
</tr>
<tr>
<td>$\tau_{11}$</td>
<td>74</td>
<td>Interruption of the power supply ($t_{\text{out}} = -5 , ^\circ\text{C}$)</td>
</tr>
<tr>
<td>$\tau_{12}$</td>
<td>74.25</td>
<td>Original conditions (connected power supply)</td>
</tr>
<tr>
<td>$\tau_{13}$</td>
<td>77</td>
<td>Termination of the test</td>
</tr>
</tbody>
</table>

**Measurements:**

The following quantities shall be measured and reported (also see Chapter 11):
- Test object: reference/set value for the room temperature, $t_{\text{room,ref}}$/$t_{\text{room,set}}$.
- Air flow: exhaust air flow rate in the ventilation duct, $q_{\text{EA}}$.
- Temperature: incoming supply air, $t_{\text{SA}} = t_{\text{out}}$;
- outgoing exhaust air, $t_{\text{EA}}$;
- radiation shielded air temperature at the room sensor, $t_{\text{ASroom}}$;
- radiation shielded air temperatures in the room, $t_{\text{A1-3room}}$;
- globe temperature in the middle of the room, $t_{\text{globe}}$;
- comfort temperature in the middle of the room, $t_{\text{com}}$;
- operative temperature in the middle of the room, $t_{\text{op}}$;
- temperatures on the inside of walls, ceiling, floor, $t_{\text{surf}}$–$t_{\text{surf}}$. 
– temperatures on the outside of walls, roof, floor, \( t_{t_{amb}} - t_{s_{amb}} \),
– temperatures on the window and radiator.

**Power/energy:**
– electric-heat controller and radiator (electric convector heater).

**Time:**
– test duration and clock times for events.

**Reporting:**
Reporting is to be in a descriptive form as well as by means of diagrams of the temporal variations during the period 0 h to 74 h of:
– temperatures on window (twin), radiator (trad), in room (troom) and outdoors (tout),
– other surface temperatures \( t_{j,sur} \),
– air temperatures \( t_{A1}, t_{A2}, t_{A3} \), operative temperature \( t_{op} \) and temperature at the control sensor \( t_{s} \),
– system (control) deviation \( q_{cdev} = t_{set} - t_{room} \) and deviation between the temperature at the control sensor and the temperature in the room \( q_{s_{cdev}} = t_{s} - t_{room} \),
– electric power input to the radiator \( P_{erad} \) and the internal heat load \( P_{int} \).

Furthermore, a number of quantities are derived according to 9.2.1–9.2.5.

### 9.2.1 System (control) deviation at constant outdoor temperature

The following quantities are calculated for the period \( \tau_{0} \) to \( \tau_{1} \):
– system (control) deviation (see 3.6.15),
– mean variation (hunting; see 3.6.19, 3.5.3.2–3),
– mean deviation between the room temperature and the temperature at the control sensor.

#### 9.2.1.1 Evaluation and reporting: system (control) deviation

The system (control) deviation is a measure of the control accuracy and is calculated as

\[
\theta_{cdev1} = \frac{1}{(\tau_{1} - \tau_{0})} \int_{\tau_{0}}^{\tau_{1}} \left[ f_{\text{set}} - t_{\text{room}} \right] \, dt = \frac{1}{8} \left[ 20 - t_{\text{room}} \right] \, dt
\]

or

\[
\theta_{cdev1} = 20 - \frac{1}{n} \sum_{j=1}^{n(8h)} t_{\text{room},j} - t_{\text{room}} \, \rightarrow 0 - 8.
\]

#### 9.2.1.2 Evaluation and reporting: mean variation

The mean variation is a measure of the control stability and is calculated as

\[
\Delta t_{mvart} = 2s_{i} = 2 \cdot \sqrt{\frac{1}{n-1} \sum_{j=1}^{n(8h)} (t_{\text{room},j} - t_{\text{room}})^{2}}
\]

where \( n \) is the number of measurements during the 8 h period \( \tau_{0} \) to \( \tau_{1} \) (also see 3.5.1, 3.5.3.2 and 3.5.3.3).

### 9.2.2 Influence of a change in the outdoor temperature

The control function during a change in the outdoor temperature is tested by changing the outdoor temperature from \(-5 \degree C\) to \(+5 \degree C\) at the time 8 h and a return at the time 15 h. The change is made as a ramp at a rate of 5 K/h. Figure 9.1 illustrates the sequence. The following quantities are derived for the period \( \tau_{1} \) to \( \tau_{4} \):
– system (control) deviation (see 3.6.15),
– set point drift (see also 3.6.17 and 3.6.18),
– mean variation (hunting; see 3.5.3.2 and 3.6.19),
– mean deviation between the room temperature and the temperature at the control sensor.

#### 9.2.2.1 Evaluation and reporting: system (control) deviation

System (control) deviation during a change in outdoor temperature is calculated as

\[
\theta_{cdev2} = \frac{1}{(\tau_{2} - \tau_{1})} \int_{\tau_{1}}^{\tau_{2}} \left[ f_{\text{set}} - t_{\text{room}} \right] \, dt = \frac{17}{8} \left[ 20 - t_{\text{room}} \right] \, dt
\]

or

\[
\theta_{cdev2} = 20 - \frac{1}{n(17h)} \sum_{j=1}^{n(17h)} t_{\text{room},j} - t_{\text{room}} \, \rightarrow 0 - 8.\]

#### 9.2.2.2 Evaluation and reporting: relative set point drift

The relative set point drift during a change in outdoor temperature is calculated as

\[
r = \frac{\Delta t_{sp}}{\Delta t_{out}} = \frac{1}{(5-(-5))} \left[ \int_{\tau_{1}}^{\tau_{2}} t_{\text{room}} \, dt - \int_{\tau_{3}}^{\tau_{4}} t_{\text{room}} \, dt \right]
\]

i.e.

\[
r = \frac{\Delta t_{sp}}{\Delta t_{out}} = \frac{1}{10} \left[ \int_{7}^{15} t_{\text{room}} \, dt - \int_{14}^{17} t_{\text{room}} \, dt \right].
\]
### 9.2.2.3 Evaluation and reporting: mean variation

The mean variation during a change in the outdoor temperature is calculated as

\[ \Delta t_{\text{var}} = \frac{2s_t}{n} \cdot \sqrt{\frac{1}{n-1} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - \bar{t}_{room})^2} \]

where \( n \) is the number of measurements during the 9 h period \( \tau_1 \) to \( \tau_4 \) (also see 3.5.1, 3.5.3.2 and 3.5.3.3).

### 9.2.2.4 Evaluation and reporting: mean deviation between the temperature of the control sensor and the room temperature

The deviation is a measure of the influence of the positioning of the control sensor on the control result and is calculated as

\[ \theta_{\text{dev}} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - \bar{t}_{room})^2 \]

or

\[ \theta_{\text{dev}} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - \bar{t}_{room})^2 \]

where \( n \) is the number of measurements during the 1 h period \( \tau_6 \) to \( \tau_7 \).

### 9.2.3 Influence of a changed set point

The control function during a changed set point of the indoor temperature is tested by changing the set point from +20 °C to +18 °C at the time 26 h with a return at the time 34 h. The change is made instantaneously (a step change). Figure 9.1 illustrates the sequence. The following quantities are calculated for given intervals of the period \( \tau_5 \) to \( \tau_6 \):
- system (control) deviation (see 3.6.15),
- mean deviation (also see 3.5.2.4),
- overshoot \( M \) (also see 3.6.28),
- settling time \( \tau_s \) (\( \pm 0.5 \) K; also see 3.6.26),
- mean deviation between the room temperature and the temperature at the control sensor.

### 9.2.3.1 Evaluation and reporting: system (control) deviation

The remaining system (control) deviation after a decreased set point of the room thermostat is calculated as

\[ \theta_{\text{dev},5} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - \bar{t}_{room})^2 \]

and that related to the increased set point as

\[ \theta_{\text{dev},6} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - \bar{t}_{room})^2 \]

where \( n \) is the number of measurements during the 1 h period \( \tau_6 \) to \( \tau_7 \).

### 9.2.3.2 Evaluation and reporting: mean deviation

The mean deviation with a decreased set point of the room thermostat is calculated as

\[ \theta_{\text{dev},5} = \sqrt{\frac{1}{t_5} \int_{t_5}^{t_6} (t_{room} - t_{set})^2 \, dt} = \sqrt{\frac{1}{27} \int_{t_5}^{t_6} (t_{room} - 18)^2 \, dt} \]

or

\[ \theta_{\text{dev},5} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - 18)^2 \]

where \( n \) is the number of measurements during the 1 h period \( \tau_6 \) to \( \tau_7 \).

The mean deviation with an increased set point of the room thermostat is calculated as

\[ \theta_{\text{dev},6} = \sqrt{\frac{1}{t_6} \int_{t_6}^{t_7} (t_{room} - t_{set})^2 \, dt} = \sqrt{\frac{1}{35} \int_{t_6}^{t_7} (t_{room} - 18)^2 \, dt} \]

or

\[ \theta_{\text{dev},6} = \frac{1}{n} \sum_{j=(t\text{h})}^{(t\text{h}+26h)} (t_{room,j} - 18)^2 \]

where \( n \) is the number of measurements during the 1 h period \( \tau_7 \) to \( \tau_8 \).

### 9.2.3.3 Evaluation and reporting: overshoot

The overshoot with an increased set point of the room thermostat is calculated as

\[ M = \frac{t_{room,max} - t_{room}}{t_{room,set} - t_{out}} \]

during the period \( 34 \leq \tau \leq 42 \) h, where

\[ f_{\text{room}} = \int_{t_7}^{t_8} \frac{t_{room}}{1} \, dt = \int_{t_7}^{t_8} 1 \, dt \]

and

\[ f_{\text{out}} = \int_{t_7}^{t_8} \frac{t_{out}}{1} \, dt = \int_{t_7}^{t_8} 1 \, dt \]

and

\[ f_{\text{room}} = \int_{t_7}^{t_8} \frac{t_{room}}{1} \, dt = \int_{t_7}^{t_8} 1 \, dt \]
9.2.3.4 Evaluation and reporting: settling time

The settling time is calculated as the time it takes for the electric-heat controller to control the temperature to a steady state value ±0.5 K after returning to the nominal set point, i.e.

\[ \tau_\delta \text{ such that } |t_{\text{room}} - T_{\text{room}}|_{\tau_6} < 0.5 \text{ K} . \]

9.2.3.5 Evaluation and reporting: mean deviation between the temperature of the control sensor and the room temperature

The deviation is a measure of the influence on the control result of the positioning of the control sensor and is calculated during a decrease in set point as

\[ \theta_{\text{dev5}} = \frac{1}{n} \sum_{j=1}^{n} (f_s - t_{\text{room}})_{26 \to 27} . \]

During an increase in the set point the deviation is given by

\[ \theta_{\text{dev6}} = \frac{1}{n} \sum_{j=1}^{n} (f_s - t_{\text{room}})_{34 \to 35} . \]

9.2.4 Influence of internal heat loads

The control function during the influence of internal heat loads is tested by switching on a load which totals around 90 % of the heat demand of the room at –5 °C at the time 50 h and switching it off at the time 55 h (positive internal heat load; for negative loads, c.f. 9.2.5),

\[ \int_{t_1}^{t_2} P_{\text{int}} = \frac{0.9}{(t_1 - t_0)} \int_{t_0}^{t_1} P_{\text{read}} \, dt . \]

Figure 9.2. Positioning of internal heat loads and room thermostat of the electric-heat controller (view from above).

The change is made instantaneously (a step change). Figure 9.1 illustrates the sequence and the positioning of the internal heat loads. The following quantities are calculated for the period \( \tau_7 \) to \( \tau_8 \):

- system (control) deviation (see 3.6.15),
- mean deviation (also see 3.5.2.4),
- mean variation (hunting; see 3.5.3.2, 3.5.3.3 and 3.6.19),
- settling time \( \tau_\delta \) (d = ±0.5 K; also see 3.6.26)
- mean deviation between the room temperature and the temperature at the control sensor.

9.2.4.1 Evaluation and reporting: system (control) deviation

The remaining system (control) deviation after switching on the internal heat load is calculated as

\[ \theta_{\text{dev8}} = \frac{1}{n} \sum_{j=1}^{n} (20 - t_{\text{room}})_{54 \to 55} . \]

The control deviation related to the switching on of the heat load is calculated as

\[ \theta_{\text{dev8}} = \frac{1}{n} \sum_{j=1}^{n} (20 - t_{\text{room}})_{50 \to 51} . \]

and that related to the switching off as

\[ \theta_{\text{dev8}} = \frac{1}{n} \sum_{j=1}^{n} (20 - t_{\text{room}})_{55 \to 56} . \]

9.2.4.2 Evaluation and reporting: mean deviation

The mean deviation during the switching on of the internal heat load is calculated as

\[ \theta_{\text{dev7}} = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (t_{\text{room}} - f_{\text{set}})^2} \]

or

\[ \theta_{\text{dev7}} = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (t_{\text{room}} - 20)^2} . \]

where \( n \) is the number of measurements during the 1 h period \( \tau_7 \) to \( \tau_7 + 1 \).

The mean deviation during switching off of the internal heat load is calculated as

\[ \theta_{\text{dev8}} = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (t_{\text{room}} - f_{\text{set}})^2} . \]
or
\[
\theta_{\text{mdev}8} = \frac{1}{n} \sum_{j=51}^{56} (t_{\text{room},j} - 20)^2
\]
where \( n \) is the number of measurements during the 1 h period \( \tau_8 \) to \( \tau_8 + 1 \).

9.2.4.3 Evaluation and reporting: mean variation

The mean variation during switching on of the internal heat load is calculated as
\[
\Delta t_{\text{mvar}7} = 2s_t = 2 \left( \frac{1}{n-1} \sum_{j=51}^{56} (t_{\text{room},j} - \bar{t}_\text{room})^2 \right)
\]
where \( n \) is the number of measurements during the 5 h period \( \tau_7 \) to \( \tau_8 \) (also see 3.5.1 and 3.5.3.2-3).

9.2.4.4 Evaluation and reporting: settling time

The settling time is calculated as the time it takes for the electric-heat controller to control the temperature to a steady state value within \( \pm 0.5 \) K after switching off of the internal heat load, i.e.
\[
\tau_\delta \text{ such that } |t_{\text{room}} - \bar{t}_\text{room}| < 0.5 \text{ K}.
\]

9.2.4.5 Evaluation and reporting: mean deviation between the temperature of the control sensor and the room temperature

The deviation is a measure of the influence on the control result of the positioning of the control sensor and is calculated during a switching on of the internal heat load as
\[
\theta_{\text{scdev}7} = \frac{1}{n} \sum_{j=51}^{56} (t_s - t_{\text{room}}) \, dt = \frac{1}{n} \sum_{j=51}^{56} (t_s - t_{\text{room}}) \, dt
\]
or
\[
\theta_{\text{scdev}7} = \frac{1}{n} \sum_{j=51}^{56} (t_s - t_{\text{room}}) \, dt
\]
During a switching-off of the internal heat load the deviation is calculated as
\[
\theta_{\text{scdev}8} = \frac{1}{n} \sum_{j=51}^{56} (t_s - \bar{t}_\text{room}) \, dt
\]
or
\[
\theta_{\text{scdev}8} = \frac{1}{n} \sum_{j=51}^{56} (t_s - t_{\text{room}}) \, dt
\]
where \( n \) is the number of measurements during the 1 h period \( \tau_8 \) to \( \tau_8 + 1 \).

9.2.5 Airing (opening of windows; heat rejection)

The control function during airing (negative internal load; for positive loads, c.f. 9.2.4) is tested by opening the window for 15 min (0.25 h) at the time 72 h and hence closing at the time 72.25 h. The change is instantaneous (step change). Figure 9.1 illustrates the sequence. The following quantities are calculated during the period \( \tau_9 \) to \( \tau_{11} \):
- system (control) deviation (see 3.6.15),
- mean deviation (also see 3.5.2.4),
- mean variation (hunting; see 3.5.3.2 and 3.6.19),
- settling time \( \tau_\delta \) (\( d = \pm 0.5 \) K; also see 3.6.26),
- mean deviation between the room temperature and the temperature at the control sensor.

9.2.5.1 Evaluation and reporting: system (control) deviation

The remaining system (control) deviation after airing is calculated as
\[
\theta_{\text{scdev}11} = \frac{1}{n} \int_{\tau_{11}}^{\tau_{10}} (t_{\text{room}} - t_{\text{ref}}) \, dt = \frac{1}{n} \int_{\tau_{10}}^{\tau_{11}} (t_{\text{room}} - 20) \, dt
\]
or
\[
\theta_{\text{scdev}11} = \frac{1}{n} \sum_{j=10}^{11} (20 - t_{\text{room},j})
\]
The deviation in connection with the closing of the window is calculated as
\[
\theta_{\text{dev}10} = \frac{1}{n} \sum_{j=10}^{11} (t_{\text{room},j} - 20)
\]

9.2.5.2 Evaluation and reporting: mean deviation

The mean deviation during opening of the window is calculated as
\[
\theta_{\text{mdev}8} = \frac{1}{n} \int_{\tau_9}^{\tau_{10}} (t_{\text{room}} - t_{\text{ref}})^2 \, dt = \frac{1}{n} \int_{\tau_9}^{\tau_{10}} (t_{\text{room}} - 20)^2 \, dt
\]
or
\[
\theta_{\text{mdev}8} = \frac{1}{n} \sum_{j=10}^{11} (t_{\text{room},j} - 20)^2
\]
where \( n \) is the number of measurements during the 1 h period \( \tau_9 \) to \( \tau_{10} \).
The mean deviation during closing of the window is calculated as
\[
\theta_{\text{mdev}10} = \frac{1}{n} \int_{\tau_{10}}^{\tau_{11}} (t_{\text{room}} - t_{\text{set}})^2 \, dt = \frac{1}{n} \int_{\tau_{10}}^{\tau_{11}} (t_{\text{room}} - 20)^2 \, dt
\]
or
\[
\theta_{\text{mdev}10} = \frac{1}{n} \sum_{j=10}^{11} (t_{\text{room},j} - 20)^2
\]
where \( n \) is the number of measurements during the 1 h period \( \tau_{10} \) to \( \tau_{10} + 1 \).

9.2.5.3 Evaluation and reporting: mean variation

The mean variation after airing is calculated as

\[
\Delta t_{\text{mean}10} = 2\sigma = 2 \sqrt{\frac{1}{(n-1)} \sum_{j=\lfloor 72.25 h \rfloor}^{n} (f_{\text{room},j} - f_{\text{room}})^2}
\]

where \( n \) is the number of measurements during the 2.75 h period \( \tau_{10} \) to \( \tau_{11} \) (also see 3.5.1, 3.5.3.2 and 3.5.3.3).

9.2.5.4 Evaluation and reporting: settling time

The settling time is calculated as the time it takes for the electric-heat controller to control the temperature to a steady state value \( \pm 0.5 \) K after closing the window, i.e.

\[\tau_{510} \text{ such that } \left| f_{\text{room}} - t_{\text{room}}^{73 \to 74} \right|_{\tau_{10}}^{\tau_{10} + 5} < 0.5 \text{ K.}\]

9.2.5.5 Evaluation and reporting: mean deviation between the temperature of the control sensor and the room temperature

The deviation is a measure of the influence on the control result of the positioning of the control sensor and is calculated during an opening of the window as

\[
\theta_{\text{scdev}9} = \frac{1}{\tau_{9}} \int_{\tau_{9}}^{\tau_{10}} \left[ f_{s} - f_{\text{room}} \right] \, dt = \frac{1}{0.25} \int_{72}^{72.25} \left[ f_{s} - t_{\text{room}} \right] \, dt
\]

or

\[
\theta_{\text{scdev}9} = \frac{1}{n} \sum_{j=\lfloor 72.25 h \rfloor}^{j=73.25} \left( f_{s} - t_{\text{room}} \right)_{\tau_{72} \to \tau_{72.25}}
\]

During closing of the window the deviation is calculated as

\[
\theta_{\text{scdev}10} = \frac{1}{\tau_{10}} \int_{\tau_{10}}^{\tau_{10} + 1} \left[ f_{s} - f_{\text{room}} \right] \, dt = \frac{1}{72.25} \int_{73.25}^{73.25} \left[ f_{s} - t_{\text{room}} \right] \, dt
\]

or

\[
\theta_{\text{scdev}10} = \frac{1}{n} \sum_{j=\lfloor 72.25 h \rfloor}^{j=73.25} \left( f_{s} - f_{\text{room}} \right)_{\tau_{72} \to \tau_{73.25}}
\]

9.3 Supplementary control functions

Supplementary control functions of the electric-heat controller are tested regarding:

- frost protection,
- airing (opening of windows),
- water heater control,
- load control,
- load limitation
- external communication.

9.3.1 Frost protection

A frost protection device is tested by checking how low the ambient temperature of the control sensor can be made before the controller delivers its maximum output.

Describe the function, measure the output and the ambient temperature.

9.3.2 Airing (heat rejection)

Describe the operation. Concerning control characteristics, see 9.2.5.

9.3.3 Water heater control

Describe the operation.

9.3.4 Load control

Describe the operation.

9.3.5 Load limitation

Describe the operation.

9.3.6 External communication

Describe the operation.

9.4 Interruption of power supply

The electric-heat controller is checked regarding its operation after an interruption of the power supply. In particular, any changes to permanent custom settings are checked after the interrupt. If permanent custom settings cannot be maintained, a check is made whether the system returns to its default setting or any other setting. Permanent custom settings also include stable, adaptively generated control settings. The operation is also checked when using any normal off-switch, e.g. for summer operation.

Reporting:

A descriptive report is made in addition to diagrams of temporal variations during the period 74 h to 77 h of:

- temperatures on window \( (t_{\text{win}}) \) and radiator \( (t_{\text{rad}}) \), in room \( (t_{\text{room}}) \) and outdoors \( (t_{\text{out}}) \),
- other surface temperatures \( (t_{\text{sur}}) \),
- air temperatures \( (t_{A1}, t_{A2}, t_{A3}) \), operative temperature \( (t_{op}) \) and temperature at the control sensor \( (t_{s}) \),
- system (control) deviation \( (\theta_{\text{scdev}} = t_{\text{set}} - t_{\text{room}}) \) and deviation between temperature at the control sensor and the room \( (\theta_{\text{scdev}} = t_{s} - t_{\text{room}}) \),
- power input to the radiator \( (P_{\text{erad}}) \).
9.5 Comfort

The thermal comfort is evaluated by means of the measurements in 9.2.1–5. The thermal comfort is estimated by comparing the room temperature at a height of 1.2 m with the calculated room temperature for optimum comfort (PMV = 0). Appendix 3 provides the designations for surface temperatures used in the determination of thermal comfort.

Reporting:

Mean values of the following quantities are calculated for the period 0–72 h:

- room temperature, \( t_{\text{room}} \),
- mean radiant temperature, \( \bar{t}_r \),
- operative temperature, \( t_{\text{op}} \),
- comfort temperature, \( t_{\text{com}} \),
- radiant asymmetry, \( \theta_{\text{asy}} \),
- temperature gradient, \( \Delta t \),
- floor temperature, \( t_{\text{floor}} \).

In addition, diagrams of temporal variations during the period 0 h to 77 h are made for:

- room temperature \( t_{\text{room}} \), mean radiant temperature \( t_{\text{r}} \),
- operative temperature \( t_{\text{op}} \) and floor temperature \( t_{\text{floor}} \),
- radiant asymmetry \( \theta_{\text{asy}} = t_{\text{r}} - t_{\text{floor}} \) and temperature gradient \( \Delta t = (t_{\text{A3}} - t_{\text{A1}})/\Delta H \).

9.5.1 Room temperature

The room temperature is determined during the following periods:

- mean value during \( \tau_{0} - \tau_{9} \) (the entire normal period),
- mean value during \( \tau_{1} - \tau_{4} \) (change in outdoor temperature),
- mean value during \( \tau_{5} - \tau_{6} \) (change in indoor temperature),
- mean value during \( \tau_{7} - \tau_{8} \) (change in outdoor temperature),
- mean value during \( \tau_{9} - \tau_{11} \) (airing period).

The room temperature is measured and/or calculated by means of the measured globe and air temperature at the centrally located comfort position in the room, \( t_{\text{room}} = t_{\text{globe}} \).

9.5.2 Mean radiant temperature

The mean radiant temperature is compared with the room temperature during the following periods:

- mean value during \( \tau_{0} - \tau_{9} \) (the entire standard period),
- mean value during \( \tau_{1} - \tau_{4} \) (change in outdoor temperature),
- mean value during \( \tau_{5} - \tau_{6} \) (change in indoor temperature),
- mean value during \( \tau_{7} - \tau_{8} \) (change in outdoor temperature),
- mean value during \( \tau_{9} - \tau_{11} \) (airing period).

The mean radiant temperature is calculated by means of measured surface temperatures and view factors in relation to the comfort position of the room (all walls, floor, ceiling, window and radiator; \( F_j \) = view factor between surface \( j \) and a small, parallel surface element at the location of the comfort sensor),

\[
\bar{t}_r = F_{\text{win}} \cdot t_{\text{win}} + F_{\text{rad}} \cdot t_{\text{rad}} + \sum_{j=1}^{6} F_j \cdot t_{\text{sur},j}.
\]

9.5.3 Operative temperature

The operative temperature is compared with the room temperature during the following periods:

- mean value during \( \tau_{0} - \tau_{9} \) (the entire standard period),
- mean value during \( \tau_{1} - \tau_{4} \) (change of outdoor temperature),
- mean value during \( \tau_{5} - \tau_{6} \) (change of indoor temperature),
- mean value during \( \tau_{7} - \tau_{8} \) (change of outdoor temperature),
- mean value during \( \tau_{9} - \tau_{11} \) (airing period).

Operative temperature is calculated as

\[
\bar{t}_{\text{op}} = \frac{1}{2}(F_{A2} + \bar{t}_r).
\]

9.5.4 Comfort temperature

The comfort temperature is the calculated temperature which under the prevailing conditions would give a PMV index = 0 according to ISO 7730 (see 3.5.4). The comfort temperature is compared with the room temperature during the normal period (mean value during \( \tau_{0} - \tau_{9} \), i.e. the entire normal period).

9.5.5 Radiant asymmetry

The radiant asymmetry is determined for the following periods:

- mean value during \( \tau_{0} - \tau_{9} \) (the entire standard period),
- mean value during \( \tau_{1} - \tau_{4} \) (change of outdoor temperature),
- mean value during \( \tau_{5} - \tau_{6} \) (change of indoor temperature),
- mean value during \( \tau_{7} - \tau_{8} \) (change of outdoor temperature),
- mean value during \( \tau_{9} - \tau_{11} \) (airing period).

Radiant asymmetry is calculated by means of measured surface temperatures and view factors in relation to the comfort position of the room for the direction window-wall and opposing gable (the surfaces 2–5 are neglected as the contributions will be approximately the same in both directions; regarding designations, see Appendices 1–3),

\[
\theta_{\text{asy}} = F_{\text{win}} \cdot t_{\text{win}} + F_{\text{rad}} \cdot t_{\text{rad}} + F_1 \cdot t_{\text{sur},1} - F_6 \cdot t_{\text{sur},6}.
\]

9.5.6 Temperature gradient

The temperature gradient is determined for the following periods:

- mean value during \( \tau_{0} - \tau_{9} \) (the entire standard period),
- mean value during \( \tau_{1} - \tau_{4} \) (change in outdoor temperature),
- mean value during \( \tau_{5} - \tau_{6} \) (change in indoor temperature),
- mean value during \( \tau_{7} - \tau_{8} \) (change in outdoor temperature),
- mean value during \( \tau_{9} - \tau_{11} \) (airing period).
The temperature gradient is calculated as the difference between the upper and lower room temperature,

\[ g_t = \frac{\theta_{\text{grad}}}{\Delta H} = \frac{t_{A3} - t_{A1}}{H_3 - H_1} = \frac{1.6}{[K/m]} \, . \]

9.5.7 Floor temperature
The floor temperature is determined for the following periods,

- mean value during \( t_0 - t_9 \) (the entire standard period),
- mean value during \( t_1 - t_8 \) (change in outdoor temperature),
- mean value during \( t_7 - t_8 \) (change in indoor temperature),
- mean value during \( t_9 - t_11 \) (airing period).

9.6 Power input and efficiency
The power input and the efficiency of the electric-heat controller are evaluated by means of the measurements from 9.2.1–5. The following quantities are calculated:

- nominal mean power input at \( t_{\text{room}} = +20 \, ^\circ\text{C} \) (see 9.5.1),
- power input during opening of windows,
- efficiency of the electric-heat controller.

All evaluations of power and energy inputs are referred to nominal conditions, i.e. \( t_{\text{out}} = -5 \, ^\circ\text{C} \) and \( t_{\text{out}} = +5 \, ^\circ\text{C} \) respectively and \( t_{\text{amb}} = t_{\text{room}} \). Hence the corrected energy input, with no ambient losses, for a certain period will be

\[ W_{\text{net}} = W_0 + \sum_j \Delta W_{\text{nom},j} \]

with

\[ \Delta W_{\text{nom},j} = \int_{t_j}^{t_{j+1}} \left[ L_1 + L_{\text{vent}} + (L_2 \cdot (t_{\text{amb}} - t_{\text{room}})) \right] dt \, . \]

Thereafter the power/energy deviation caused by the deviation of the controlled room temperature from the nominal set value is estimated, i.e.

\[ W_{\text{nom}} = W_0 + \sum_j \Delta W_{\text{nom},j} \]

with

\[ \Delta W_{\text{nom},j} = \int_{t_j}^{t_{j+1}} (L_1 + L_{\text{vent}}) \cdot (t_{\text{room,set}} - t_{\text{room}}) \right] dt \, . \]

For temperatures higher as well as lower than the nominal room temperature, \( \Delta W_{\text{nom},j} \) corresponds to an energy related comfort deviation.

9.6.1 Nominal mean power input
The nominal mean power input is a measure of the power requirement at a given air temperature \( t_{\text{room}} = +20 \, ^\circ\text{C} \) in a given test room and it is determined as

\[ \bar{P}_{e,\text{nom}} = \frac{W_{e,\text{nom}}}{(t_9 - t_0)} = \frac{W_{e,\text{nom}}}{72} \, . \]

All power inputs refer to the total input to the electric-heat controller, i.e. both the controlled power and the internal power requirement of the controller (also see Appendix 3.3). The internal power requirement is also determined and reported separately.

9.6.2 Power input during airing (opening of windows)
The power input during airing is reported separately as it is primarily a limitation function which has a relatively small influence on the energy input during normal use. Figure 9.1 describes the airing sequence. The mean power input during the actual airing is calculated as

\[ P_{\text{erad,10}} = \frac{1}{(t_{10} - t_9)} \int_{t_9}^{t_{10}} P_{\text{erad}} \cdot dt = \frac{1}{0.25} \int_{t_9}^{72.25} P_{\text{erad}} \cdot dt \]

or

\[ P_{\text{erad,10}} = \frac{1}{n} \sum_{j=1}^{n} P_{\text{erad},j} \, . \]

The mean power input during the entire airing sequence is given by

\[ P_{\text{erad,11}} = \frac{1}{(t_{11} - t_9)} \int_{t_9}^{t_{11}} P_{\text{erad}} \cdot dt = \frac{74}{2} \int_{t_9}^{72} P_{\text{erad}} \cdot dt \]

or

\[ P_{\text{erad,11}} = \frac{1}{n} \sum_{j=1}^{n} P_{\text{erad},j} \, . \]

9.6.3 Efficiency of the electric-heat controller
The efficiency of the electric-heat controller can be determined by comparing the energy input when it is in use with an estimated net input for the 72 hour test period, \( W_{e,\text{net}} \). To minimize uncertainties due to differences between test chambers and uncertainties of the loss factors of the chambers it is preferred to define the efficiency in terms of temperature deviations. The excessive temperature is defined as

\[ \theta_{\text{exc}} = \frac{1}{n} \sum_{j=1}^{n} (t_{\text{room,j}} - t_{\text{ref}}) \text{ for all } t_{\text{room,j}} > t_{\text{ref}} \, . \]

The reference temperature corresponds to the room temperature set values +20 °C and +18 °C respectively during the different periods. In order not to include calibration errors regarding the settings of the electric-heat controller, the following definitions are made:
Period Definition of $t_{ref}$

$t_0 \rightarrow t_5 \quad t_{ref1} = t_{room0} - 26 h$
$t_5 \rightarrow t_6 \quad t_{ref2} = t_{room, min26} - 34 h$ if $< 18 \degree C$, else $t_{ref2} = 18$
$t_6 \rightarrow t_9 \quad t_{ref3} = t_{room34} - 72 h$ if $t_{room34} - 72 h < t_{ref1}$, else $t_{ref3} = t_{ref1}$.

The efficiency is determined as

$$\eta_f = 1 - \left( \frac{t_{out} - t_{room}}{t_{room} - t_{out}} \right)_{0 \rightarrow 72 h} = 1 - \left( \frac{t_{exc}}{23.8} \right)_{0 \rightarrow 72 h}$$

where the approximation refers to nominal values of $t_{room}$ and $t_{out}$. This definition will favour efficient control strategies as well as close room temperature control.

10 MEASURING UNCERTAINTIES AND STABILITY

10.1 Measuring uncertainties

Measuring uncertainties shall be estimated according to EAL-R2 (ref. 2.15) and may not exceed values according to Table 10.1.

### Table 10.1. Maximum permissible measuring uncertainties.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Measuring uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature:</td>
<td></td>
</tr>
<tr>
<td>- air temperature</td>
<td>±0.2 K</td>
</tr>
<tr>
<td>- surface temperature of walls</td>
<td>±0.5 K</td>
</tr>
<tr>
<td>- surface temperature of window and radiator</td>
<td>±2 K</td>
</tr>
<tr>
<td>Flow rate:</td>
<td>±5 %</td>
</tr>
<tr>
<td>- exhaust air flow rate</td>
<td></td>
</tr>
<tr>
<td>Voltage:</td>
<td>±0.5 %</td>
</tr>
<tr>
<td>- supply voltage of the electric-heat controller</td>
<td>±1 %</td>
</tr>
<tr>
<td>Power and energy:</td>
<td>±1 %</td>
</tr>
<tr>
<td>- electric power and energy input to the electric-heat controller and the internal load</td>
<td></td>
</tr>
<tr>
<td>Time interval:</td>
<td>±0.1 %</td>
</tr>
<tr>
<td>Length:</td>
<td>±1 %</td>
</tr>
<tr>
<td>View factor:</td>
<td>±0.01</td>
</tr>
</tbody>
</table>

In the case of derived quantities the uncertainty is estimated by sums of the squares of variances according to the following example:

$$L_{vent} = q_{EA} \cdot \rho_A \cdot c_{PA}$$

which, after logarithmic differentiation, yields

$$\frac{\Delta L_{vent}}{L_{vent}} = \left[ \left( \frac{\Delta q_{EA}}{q_{EA}} \right)^2 + \left( \frac{\Delta \rho_A}{\rho_A} \right)^2 + \left( \frac{\Delta c_{PA}}{c_{PA}} \right)^2 \right]^{1/2}$$

where the individual contributions within brackets constitute the combined variances of types A and B according to EAL-R2.

10.2 Stability

Table 10.2 provides the conditions of stability and the maximum permissible deviations between stated set-values and actual values during testing.

### Table 10.2. Permissible deviations from set-values.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Set-value</th>
<th>Permissible deviation between mean value and set-value</th>
<th>Permissible deviation of individual values from the set-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- room temperature*</td>
<td>+20 °C</td>
<td>±0.5 K</td>
<td>±1 K</td>
</tr>
<tr>
<td>- ambient temperature</td>
<td>+20 °C</td>
<td>±1 K</td>
<td>±2 K</td>
</tr>
<tr>
<td>- outdoor temperature**</td>
<td>±5 °C</td>
<td>±0.5 K</td>
<td>±1 K</td>
</tr>
<tr>
<td>Flowrate:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- exhaust-air flowrate</td>
<td>0.5V_{room}</td>
<td>±20 %</td>
<td>±20 %</td>
</tr>
<tr>
<td>Voltage:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- supply voltage to the electric-heat controller</td>
<td>230/400 V</td>
<td>±5 %</td>
<td>±5 %</td>
</tr>
<tr>
<td>Power and energy:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- electric power to the internal load</td>
<td>0.9P_{eroom}</td>
<td>±10 %</td>
<td>±15 %</td>
</tr>
</tbody>
</table>

* This only applies to the initial period $t_0$ to $t_1$.
**This does not apply during the ramp periods.

11 TEST REPORT

The test report shall comprise the following items, whenever relevant to the actual test:

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organization or individual who commissioned the test
d) Purpose of the test
e) Reference to the test method and statement of any deviations from this method. The actually used test chamber shall be specified (e.g. by reference to a standard and to given dimensions)
f) Method for selecting the test object
g) Condition of the test object on arrival and the date of arrival
h) Date of the test
i) Manufacturer’s name, type designation and serial number of test object
j) Description of the test object, stating any special functions
k) Agreement with accompanying documentation (Ch. 8)
l) Description of any special functions
m) Settings of desired values (set-values) etc. (Ch. 8 and 9.1)
n) Installation (voltage supply, positioning of controller and sensors; Ch. 8)
o) Conditioning of the test object (e.g. warming-up period, adjustments, test-runs)

p) Test results from:
   - functional checks (Ch. 8)
   - control functioning during changes of outdoor temperature, set value for the indoor temperature, internal loads and opening of windows (Ch. 9.2)
   - additional control functions such as frost protection, airing load-limitation, load control, load limitation and external communication (Ch. 9.3)
   - functioning during an interruption of the power supply (Ch. 9.4)
   - comfort (Ch. 9.5)

   - energy efficiency and internal power used by the controller (Ch. 9.6)
   - sound emission (when applicable, testing is reported separately; this report only notes if a sound test has been carried out and if so, identification of the report and the results in Bel)
   - electrical characteristics (when applicable, testing is reported separately; this report only notes if a test has been carried out and if so, identification of the report)

q) Measuring uncertainties and stability (Ch. 10)

r) Identification of test equipment and instruments

s) Date of the report and signatures.
APPENDIX 1. DESIGN DATA FOR TEST CHAMBER AND HEATER

The test chamber shall be designed according to the test standards for electric radiators NT VVS 006 (ref. 2.12) or IEC 675 (ref. 2.8). Since IEC 675 has recently been updated, this international standard is recommended. Recommendations from the radiator test methods notwithstanding, the following requirements on the airtightness and ventilation of the room apply:

Ventilation: \( q_{EA} = 0.5–1.0 \, \text{ACH/h (0.35–0.70 dm}^3/\text{s/m}^2 \). Airtightness: Leakage flow rate \(<0.1 q_{EA} \) at \( \pm 50 \, \text{Pa} \).

### A1.1 ACCORDING TO NT VVS 006

**Volume of test chamber:** \( V_{room} = 25–35 \, \text{m}^3 \).

**Surface of test chamber:** \( A_{room} = 55–65 \, \text{m}^2 \) (total surface exposed to the room air).

**Radiator position:** 0.1 m above floor, symmetrically positioned under the window.

**Window position:** 0.8 m above floor, symmetrically positioned on the wall.

**Ventilation:** \( q_{EA} < 0.5 \, \text{ACH/h} \), see the overriding requirement above.

**Thermal insulation:** \( \lambda = 0.13–0.17 \, \text{W/m/K} \) in a surface layer of at least 5 mm and such that the requirements of the table regarding heat coefficients are fulfilled for this layer (excluding the window).

![Table](image)

### A1.2 ACCORDING TO IEC 675

**Volume of test chamber:** \( V_{room} = 30–40 \, \text{m}^3 \).

**Surface of test chamber:** \( A_{room} = – \).

**Radiator position:** According to directions for installation, symmetrically positioned under the window.

**Window position:** \( >0.8 \, \text{m above floor, symmetrically positioned on the wall.} \)

**Ventilation:** \( q_{EA} \approx 1.0 \, \text{ACH/h (} \approx 0.70 \, \text{dm}^3/\text{s/m}^2 \). \)

**Thermal insulation:** See table.

### A1.3 HEATER

The heater should be a convector heater with the following characteristics:

- **Height:** \( 0.2 < H < 0.5 \, \text{m} \).
- **Design energy ratio:** \( 0.7 < \epsilon_{des} < 0.8 \) (approx. 0.9–2.2 kW depending on the chamber).

At the design conditions of \( t_{in} = +20 \, ^\circ\text{C} \) and \( t_{out} = -20 \, ^\circ\text{C} \), the heat loss through the window wall is in the range 0.4–0.9 kW.

With \( \text{ACH} = 1.0 \), \( P_{\text{vent}} \) is in the range 0.3–0.6 kW and hence the total \( P_{e,rad} \) is between 0.7–1.5 kW. By adjusting air flow and exterior wall, the ratio \( P_{e,rad}/P_{\text{vent}} \) should be adjusted to 1.2±0.2 at the design conditions.
A2.3 THERMOGRAPHY
Thermography is not a normative part of the assessment of the characteristics of the test chamber, but it is a very useful tool.

A2.3.1 Exterior walls
The exterior walls are thermographed in connection with the determination of the loss factor \( L_{1\text{trans}} \) (excessive temperature inside the chamber).

A2.3.2 Partition wall
The partition wall and the window are thermographed in connection with the determination of loss factor \( L_{2\text{trans}} \) (–15 °C in the outdoor part).

A2.3.3 Radiator
The radiator is thermographed in connection with the determination of the loss factor \( L_{2\text{trans}} \) (–15 °C in the outdoor part). The result is used to analyze the suitability of the selected surface sensor positions.

A2.4 AIR-TIGHTNESS
The test chamber is pressurized with ±50 Pa. Leakage flow rate <0.1 \( q_{\text{vent}} \).

A2.5 OUTDOOR TEMPERATURE
Set \( t_{\text{out}} = -5 \) °C. The control accuracy (stability) is checked, Range of dispersion: \( t_{\text{out,max}} - t_{\text{out,min}} < 1.0 \) K,
Standard deviation: \( s_{\text{out}} = \frac{s_{\text{out}}}{\sqrt{n}} < 0.1 \) K for \( n > 100 \) and a (of the mean) measuring interval > 1 min, i.e. a measuring period > 100 min.
The temperature is changed to \( t_{\text{out}} = +5 \) °C with a rate of change of 5 K/h. The accuracy of the follow-up control (servo) is checked (i.e. how closely the temperature change follows the desired ramp function).

### APPENDIX 2. RECOMMENDATIONS FOR CHECKING AND REPORTING THE PROPERTIES OF THE TEST CHAMBER

The following measurements shall be documented (values given in the tables are only examples):

#### A2.1 MEASURED VALUES AND VALUES FROM TABLES OF PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th>Element</th>
<th>Height ( H ) (m)</th>
<th>Width ( W ) (m)</th>
<th>Thickness ( t ) (mm)</th>
<th>Density ( \rho ) (kg/m(^3))</th>
<th>Sp. heat ( c_p ) (J/kg/K)</th>
<th>Thermal cond. ( \lambda ) (W/m/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall 1, Glass:</td>
<td>1.20</td>
<td>0.90</td>
<td>2x3, 40</td>
<td>2600, 1.188</td>
<td>840, 1005</td>
<td>0.8, 0.0254</td>
</tr>
<tr>
<td>Wall 1, Insulation:</td>
<td>2.50</td>
<td>3.00</td>
<td>100</td>
<td>– 50, – 1.60</td>
<td>0.040*, 0.14*</td>
<td></td>
</tr>
<tr>
<td>Wall 2, Floor</td>
<td>3.00</td>
<td>3.50</td>
<td>90</td>
<td>– 30</td>
<td>1.45</td>
<td>0.040</td>
</tr>
<tr>
<td>Wall 3, Ceiling</td>
<td>3.00</td>
<td>3.50</td>
<td>90</td>
<td>– 30</td>
<td>1.45</td>
<td>0.040</td>
</tr>
<tr>
<td>Wall 4, Rear wall</td>
<td>2.50</td>
<td>3.50</td>
<td>80</td>
<td>– 30</td>
<td>1.45</td>
<td>0.040</td>
</tr>
<tr>
<td>Wall 5, Front wall</td>
<td>2.50</td>
<td>3.50</td>
<td>80</td>
<td>– 30</td>
<td>1.45</td>
<td>0.040</td>
</tr>
<tr>
<td>Wall 6, Gable</td>
<td>2.50</td>
<td>3.00</td>
<td>80</td>
<td>– 30</td>
<td>1.45</td>
<td>0.040</td>
</tr>
</tbody>
</table>

* The wall consists of approx. 70 % insulation and approx. 30 % timber frame.

#### A2.2 CALCULATED AND MEASURED VALUES*

<table>
<thead>
<tr>
<th>Element</th>
<th>Surface ( A ) (m(^2))</th>
<th>Volume ( V ) (m(^3))</th>
<th>Mass ( M ) (kg)</th>
<th>((M\rho c_p)/A) (kJ/K/m(^2))</th>
<th>(U)-value ( U ) (W/m(^2)/K)</th>
<th>Loss factor, ( L ) (W/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall 1, Glass:</td>
<td>1.08</td>
<td>0.0065, 0.0430</td>
<td>16.8, 0.05</td>
<td>13.07, 0.047</td>
<td>3.30</td>
<td>3.56</td>
</tr>
<tr>
<td>Wall 1, Wall part</td>
<td>6.42</td>
<td>0.64, 32.10</td>
<td>8.00</td>
<td>0.74</td>
<td>4.75</td>
<td></td>
</tr>
<tr>
<td>Wall 2, Floor</td>
<td>10.50</td>
<td>0.94, 28.35</td>
<td>3.92</td>
<td>0.44</td>
<td>4.66</td>
<td></td>
</tr>
<tr>
<td>Wall 3, Ceiling</td>
<td>10.50</td>
<td>0.94, 28.35</td>
<td>3.92</td>
<td>0.44</td>
<td>4.66</td>
<td></td>
</tr>
<tr>
<td>Wall 4, Rear wall</td>
<td>8.75</td>
<td>0.70, 21.00</td>
<td>3.48</td>
<td>0.50</td>
<td>4.38</td>
<td></td>
</tr>
<tr>
<td>Wall 5, Front wall</td>
<td>8.75</td>
<td>0.70, 21.00</td>
<td>3.48</td>
<td>0.50</td>
<td>4.38</td>
<td></td>
</tr>
<tr>
<td>Wall 6, Gable</td>
<td>7.50</td>
<td>0.60, 18.00</td>
<td>3.48</td>
<td>0.50</td>
<td>3.75</td>
<td></td>
</tr>
<tr>
<td>Sum:</td>
<td>53.50</td>
<td>4.50, 165.70</td>
<td>C(_1) = 13.12, C(_2) = 8.00, C(_3) = 18.28</td>
<td>L(_1) = 8.31, L(_2) = 21.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* It shall be clarified which values have been calculated and which have been measured.
APPENDIX 3. RECOMMENDATIONS FOR POSITIONING OF SENSORS

The following measurements are included: Temperature, electric power/energy and air flow rate. The Figures A3.1 and A3.2 provide an overview of the measuring positions.

Walls 2–6: $t_{2i}$ and $t_{2\text{amb}}$, $t_{3i}$ and $t_{3\text{amb}}$, $t_{4i}$ and $t_{4\text{amb}}$, $t_{5i}$ and $t_{5\text{amb}}$, and $t_{6i}$ and $t_{6\text{amb}}$, according to the example of wall 2 in Figure A3.4 (also see Figures A3.1–A3.2).

A3.1 TEMPERATURES

A3.1.1 Temperature of the ventilation air

Exhaust air: $t_{\text{EA}}$ according to Figure A3.1.
Supply air: $t_{\text{SA}}$ according to Figure A3.1.

A3.1.2 Wall temperatures

Wall 1: $t_{1l}$ and $t_{1r}$ according to Figure A3.3 (also see Figures A3.1–A3.2).

A3.1.3 Window temperature

Window: $t_{\text{win}}$ according to Figure A3.3 (also see Figures A3.1–A3.2).

A3.1.4 Radiator temperature

Radiator: $t_{\text{radlf}}$, $t_{\text{radrf}}$, $t_{\text{radmf}}$ and $t_{\text{radmb}}$ according to Figure A3.3 (also see Figures A3.1–A3.2).

A3.1.5 Room air temperature

Room: $t_{A1}$, $t_{A2}$, and $t_{A3}$ according to Figure A3.5 (also see Figures A3.1–A3.2).

By means of these temperatures, the temperature gradient can be calculated.
A3.1.6 Comfort temperature
Comfort: \( t_{\text{com}} \), \( t_{\text{globe}} \), and \( t_{\text{top}} \) according to Figure A3.5 (also see Figures A3.1–A3.2).

The operative temperature is calculated by means of the room temperature according to A3.1.5 plus the surface temperatures according to A3.1.2–4. The comfort temperature is calculated in a similar manner or directly measured, e.g. by means of a globe thermometer or an instrument adapted to ISO 7730 (ref. 2.10). By means of the surface temperatures the radiant asymmetry can also be determined.

A3.1.7 Temperature at the control sensor
Control sensor: \( t_{\text{sout}} \) and \( t_{\text{srroom}} \) according to Figure A3.1.

The outdoor sensor is placed in the middle of the outdoor room and the control sensor is positioned according to the manufacturer’s directions for installation. Radiation protected temperature sensors are placed as near as possible to the respective control sensor without disturbing their operation.

A3.2 AIR FLOW RATE
Exhaust air: \( q_{\text{EA}} \) is measured in the ventilation duct between the exhaust air outlet at floor level in the indoor room and the inlet to the outdoor room according to Figure A3.1. Requirements on straight lengths must be adhered to.

A3.3 ELECTRICAL POWER/ENERGY
Total: \( P_{\text{etot}} \) is determined according to Figure A3.6.

A3.3.1 Electric power input to radiators
Radiator: \( P_{\text{erad}} \) is determined according to Figure A3.6.

If the current controlling device is a triac, it may not be possible to determine \( P_{\text{erad}} \) directly in a satisfactory manner and one may have to settle for measuring only \( P_{\text{etot}} \).

A3.3.2 Internal electric power of the electric-heat controller
The internal electric power used by the electric-heat controller is determined as the difference between \( P_{\text{etot}} \) and \( P_{\text{erad}} \) or as \( P_{\text{etot}} \) with a switched-off radiator.

A3.3.3 Internal load
Internal load: \( P_{\text{int}} \) is determined according to Figure A3.6.