
**Building environment design —
Design, test methods and control of
hydronic radiant heating and cooling
panel systems —**

**Part 1:
Vocabulary, symbols, technical
specifications and requirements**

*Conception de l'environnement des bâtiments — Conception,
méthodes d'essai et contrôle des systèmes de panneaux hydroniques
radiants de chauffage et de refroidissement —*

Partie 1: Vocabulaire, symboles, spécifications techniques et exigences

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Foreword

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

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

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

This document was prepared by Technical Committee ISO/TC 205, *Building environment design*.

A list of all parts in the ISO 18566 series can be found on the ISO website.

Introduction

The radiant heating and cooling system consists of heat emitting/absorbing, heat supply, distribution, and control systems. Typical applications are low temperature radiant heating and high temperature radiant cooling. They are classified as embedded radiant heating and cooling systems and prefabricated radiant heating and cooling panel systems.

While ISO 11855 is for embedded radiant heating and cooling systems without an open air gap, ISO 18566 is for radiant heating and cooling panel systems with an open air gap. Because the system specifications for ISO 18566 are different from those of ISO 11855, it was necessary to develop separate ISO standards regarding the design and test methods of the cooling and heating capacity and control.

ISO 18566-1 specifies the comfort criteria, technical specifications and requirements which should be considered in the manufacturing and installation of radiant heating and cooling systems. ISO 18566-2 provides the test facility and test method for heating and cooling capacity of ceiling mounted radiant panels. ISO 18566-3 specifies the design considerations and design processes of ceiling mounted radiant panels. ISO 18566-4 addresses the control of ceiling mounted radiant heating and cooling panels to ensure the maximum performance which was intended in the design stage when the system is actually being operated in a building.

ISO 18566 does not cover the panels that are embedded into the ceiling, wall or floor structure.

This document is partly based on EN 14240, EN 14037 and ANSI/ASHRAE Standard 138.

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Building environment design — Design, test methods and control of hydronic radiant heating and cooling panel systems —

Part 1:

Vocabulary, symbols, technical specifications and requirements

1 Scope

This document specifies the design, test conditions and methods for the determination of the cooling and heating capacity and control of radiant heating and cooling panels with an open air gap. This document applies to all types of prefabricated radiant panels that are part of the room periphery such as ceiling, walls and floor.

This document is applicable to water-based heating and cooling panel systems (free hanging) in residential, commercial and industrial buildings. The methods apply to systems mounted to the wall, floor or ceiling construction with an open air gap.

This document does not cover panels embedded into ceiling, wall or floor structures and hybrid (combined thermal radiation and forced-convection) ceiling panels.

This document specifies the definition, symbols, comfort criteria, technical specifications and requirements of ceiling mounted radiant panels.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18566-2, *Building environment design — Design, test methods and control of hydronic radiant heating and cooling panel systems — Part 2: Determination of heating and cooling capacity of ceiling mounted radiant panels*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

active length of the ceiling mounted radiant panel

length of the usable heating or cooling panel with identical cross section and without connection components and covers, which are bonded together with the water flow components

3.2

active surface of the ceiling mounted radiant panel

lower panel surface, of which the lateral edges are not included

3.3

asymmetric feature

difference between the plane radiant temperature of the two opposite sides of a small plane element

3.4

average unconditioned surface temperature

AUST

mean temperature value of the uncontrolled surfaces

3.5

breaking load

minimum breaking force, in kilonewtons, which is the lowest breaking strain of the rope when tested to destruction

3.6

building management system

BMS

computer-based system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as heating, cooling, ventilating, lighting, power, disaster prevention, and security systems

3.7

characteristic equation

equation that gives the thermal output and cooling capacity as a function of the temperature difference at constant water flow rate

3.8

connection component

any other component attached to the active length of the ceiling mounted radiant panel which is used for connecting to the distribution system or for venting and draining

3.9

construction dimension

dimension of ceiling mounted radiant panel after installation inside the test booth

3.10

construction length

length of the ceiling mounted radiant panel including the collectors/headers but excluding the connecting pieces to the heating pipe work

3.11

dedicated outdoor air system

DOAS

type of heating, ventilation and air-conditioning (HVAC) system that consists of two parallel systems: a dedicated outdoor air ventilation system that handles latent loads and a parallel system to handle sensible loads

3.12

dimensions of non-circular pipes

shape and all dimensions necessary to describe exactly the cross section of the pipe

3.13

direct heating or cooling surface

<wet surface> portion of the heating or cooling surface of the panel which is in contact with the water

3.14**distance between pipes**

distance between the centre lines of two pipes in parallel

3.15**draught**

unwanted local cooling of the body caused by air movement and air temperature

3.16**effective surface temperature**

design panel surface temperature based on comfort criteria

3.17**emissivity**

ratio of emissive power of a surface at a given temperature to that of the black body at the same temperature and with the same surroundings

3.18**factory test pressure**

<leak test> pressure to which the panel is submitted during the manufacturing process

3.19**free hanging sail**

element composed of one or more modules of a cooling installation which is additionally used for heating

Note 1 to entry: Depending on the use of the sails, they can be covered with thermal insulation or noise absorption material.

3.20**heated and chilled ceiling surfaces**

radiant ceiling panel surfaces which have different compositions and installation methods by manufacturers

3.21**heating appliance**

device to transfer heat in order to provide specific temperature conditions inside buildings

3.22**independent heating appliance**

self-contained heating appliance which does not need to be connected to a remote heat source (e.g. a boiler) as it contains its own heat source

3.23**indirect heating or cooling surface**

<dry surface> portion of the heating or cooling surface of the panel which is in contact with air only

EXAMPLE Radiant sheet between the pipes.

3.24**inlet water temperature**

bulk temperature of the water entering the ceiling mounted radiant panel

3.25**length of radiant sheet**

length of the heat or cold transferring sheets

Note 1 to entry: Generally identical with the active length according to ISO 18566-2.

3.26**maximum operating pressure**

maximum system pressure to which the panel may be submitted as stated by the manufacturer

3.27

maximum surface temperature

maximum temperature permissible for physiological reasons or building fabrics, for calculation of the limit curves, which may occur at a point on the surface (floor, wall, ceiling) in the occupied or peripheral area depending on the particular usage at a temperature drop σ of the heating medium equal to 0

3.28

mean radiant temperature

MRT

uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure

3.29

mean radiant temperature of room

temperature in a defined point of the room resulting from the radiation of all surrounding surfaces and of the ceiling mounted radiant panel or heated ceiling surface

3.30

mean water temperature

arithmetical mean of inlet and outlet water temperature

3.31

minimum surface temperature

minimum temperature permissible for physiological reasons or building fabrics, for calculation of the limit curves, which may occur at a point on the surface (floor, wall, ceiling) in the occupied or peripheral area depending on the particular usage at a temperature drop σ of the heating medium equal to 0

3.32

model

ceiling mounted radiant panel or heated ceiling surface of defined construction, width and height

3.33

module

1 m of the active length of a ceiling mounted radiant panel, in relation to 1 m² active surface of a heated ceiling surface

3.34

nominal cooling capacity

cooling capacity at temperature difference of 8 K between room temperature and mean water temperature

3.35

nominal modular cooling capacity

cooling capacity of one module at temperature difference of 8 K between room temperature and mean water temperature

3.36

nominal temperature difference

temperature difference of 8 K between room temperature and mean water temperature

3.37

open or closed ceiling surface

open or closed active and non-active elements of chilled ceilings, which are additionally used for heating, which are part of suspended ceilings and generally constructed modular from industrially prefabricated elements

3.38

operative temperature

OT

uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment

3.39**outlet water temperature**

bulk temperature of the water leaving the ceiling mounted radiant panel

3.40**outside diameter of circular pipe**

nominal diameter according to standard pipe dimensions

3.41**predicted mean vote****PMV**

index that predicts the mean value of the votes of a large group of persons on the 7-point thermal sensation scale (hot, warm, slightly warm, neutral, slightly cool, cool, cold), based on the heat balance of the human body

3.42**predicted percentage of dissatisfied****PPD**

index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm

3.43**prefabricated ceiling mounted radiant panel**

heat-transmitting device in the form of a heating or cooling element with width of 0,3 m up to 1,5 m fitted with connection components and designed to operate on water flow heating facilities and/or in cooling systems

3.44**radiant output**

thermal output emitted downwards by radiation of the active length

3.45**radiant surface heating and cooling system**

heating and cooling system that controls the temperature of indoor surfaces on the floor, walls, or ceiling

3.46**radiant asymmetry**

difference between the plane radiant temperature of the two opposite sides of a small plane element

3.47**reference room temperature**

temperature measured with a globe thermometer

3.48**suspended ceiling with integrated heating elements**

single closed elements integrated in closed hanging ceilings and combined with non-active elements which are used for heating and are thermally insulated on the upper side

3.49**temperature difference**

difference between mean water temperature and reference room temperature

3.50**thermal output**

sum of the products of the heating or cooled surfaces of a space with the associated design heat flow densities

3.51

vertical air temperature difference

air temperature difference between head and ankles of a person

Note 1 to entry: 0,1 m and 1,1 m for sedentary and 0,1 m and 1,7 m above floor for standing.

3.52

water flow rate

volume of fluid passing through the ceiling mounted radiant panel per unit of time

4 Symbols

Symbol	Unit	Definition
A	m^2	surface area of the non-insulated walls
A_a	m^2	active surface of a heated ceiling surface module
A_i	m^2	installation surface area
A_{rp}	m^2	active surface area of the ceiling mounted radiant panel
c_p	J/kg K	specific heat capacity
D_i	m	inside diameter of the pipe
$D_{i/o}$	m	diameter for connection of inlet/outlet
D_o	m	outside diameter of pipe
d_{tub}	m	distance between pipes
h	J/kg	specific enthalpy
h_1	J/kg	inlet water enthalpy
h_2	J/kg	outlet water enthalpy
h_v	mm	height of the void including the height of the test sample
K	W / K^n	constant of the characteristic equation
K_{act}	$W / K^{n_{act}}$	constant of the characteristic equation of the active length/surface
K_{actM}	$W / (m^2 K^{n_{actM}})$	constant of the characteristic equation of the module
K_{Cact}	$W / (m K^{n_{Cact}})$	constant of the characteristic equation of the active length
K_{comp}	$W / K^{n_{comp}}$	constant of the characteristic equation of the connection components
K_{rto}	$W / (m K^{n_{act}})$	constant of the characteristic equation of the module based on the rated thermal output
K_{tot}	$W / K^{n_{tot}}$	constant of the characteristic equation of the construction length/surface
k_p	W/m·K	thermal conductivity of the panel material

k_t	W/m·K	thermal conductivity of the pipe material
L_{act}	m	active length of the ceiling mounted radiant panel
L_{le}	m	height of lateral edges
L_{sh}	m	length of radiant sheet
L_{tot}	m	construction length
L_{tub}	m	length of tubes
M	kg	dry mass
M_p	m	pipe spacing
m_v	m ³	water content
m_w	kg	mass of water
N	—	number of test points
n_{act}	—	exponent of the characteristic equation of the active length/surface
n_{Cact}	—	exponent of the characteristic equation of the active surface
n_{comp}	—	exponent of the characteristic equation of the connection components
n_{tot}	—	exponent of the characteristic equation of the construction length/surface
PD	%	percentage dissatisfied
p	kPa	air pressure
p_{max}	kPa	maximum operating pressure
p_s	kPa	standard air pressure defined as 101,325 kPa (1,013 25 bar)
q_m	kg/s	water flow rate
R	%	percentage of radiant output
R_a	—	active area ratio
r	%	referred percentage of radiant output for each measuring point
r_c	m·K/W	thermal resistance of panel covers
r_p	m·K/W	thermal resistance of panel
r_s	m·K/W	thermal resistance between pipe (electric cable) and panel per unit spacing
r_t	m·K/W	thermal resistance of pipe wall per unit tube spacing in a hydronic system
r_u	m·K/W	characteristic panel thermal resistance
s_i	m	thickness of upper insulation

s_m	m	reproducibility tolerance
s_o	m	repeatability tolerance
s_{sh}	m	thickness of sheet
T	K	thermodynamic temperature
θ	°C	temperature
θ_1	°C	inlet water temperature
θ_2	°C	outlet water temperature
θ_a	°C	air temperature
θ_m	°C	mean water temperature
θ_{mrad}	°C	mean radiant temperature
θ_{ref}	°C	reference room temperature
θ_{rp}	°C	mean surface temperature of the ceiling mounted radiant panel
θ_w	°C	surface temperature of the inside surfaces of the test booth
$\theta_{w,i}$		surface temperature of the i_{th} inside surface of the test booth
U_i	W/(m ² K)	heat transfer coefficient (air-insulation-wall), i.e. U -value of i_{th} surface (every wall, ceiling and floor structure) of the test booth
W_{rp}	m	width of ceiling mounted radiant panel
x_p	m	characteristic panel thickness
σ	W/(m ² K ⁴)	Stephan Boltzmann constant ($5,67 \times 10^{-8}$)
ε_{rp}	—	emissivity of the test sample
τ	s	time interval
Φ	W	heat flow or thermal output from radiant panel
Φ_{act}	W	output of the active length
Φ_B	W	total heat flow in all enclosure walls
Φ_{CLs}	W	standard modular cooling capacity
Φ_{Cme}	W	measured cooling capacity of a ceiling mounted radiant panel
Φ_{CN}	W	nominal cooling capacity of a ceiling mounted radiant panel
Φ_{comp}	W	output of connection components
Φ_{CS}	W	standard cooling capacity of a ceiling mounted radiant panel, cooling capacity at standard temperature difference and standard air pressure
Φ_D	W	rated thermal output

Φ_L	W/m W/m ²	modular thermal output
Φ_{LS}	W/m W/m ²	standard modular thermal output
Φ_{me}	W	measured output
$\Phi_{M,s}$	W	standard output of a master panel of the primary set for interlaboratory comparisons
$\Phi_{O,s}$	W	standard output of a master panel
Φ_{rad}	W	radiant output
Φ_S	W	total thermal output of simulators
Φ_{tot}	W	total output
$\Delta\theta$	K	temperature difference
$\Delta\theta_{cn}$	K	nominal temperature difference (8 K) of a ceiling mounted radiant panel when cooling
$\Delta\theta_{cs}$	K	standard temperature difference (15 K) of a ceiling mounted radiant panel when cooling, reference room temperature 32 °C and mean water temperature 17 °C
$\Delta\theta_{me}$	K	measured temperature difference
$\Delta\theta_{pr}$	K	radiant temperature asymmetry
$\Delta\theta_s$	K	standard temperature difference of a ceiling mounted radiant panel when heating (55 K), mean water temperature 75 °C and reference room temperature 20 °C

5 Comfort criteria

5.1 General

Room thermal environment with ceiling mounted radiant panels is different from that with the conventional all-air HVAC system. Compared with conventional all-air HVAC system, ceiling mounted radiant panels can reduce the uncomfortable environment caused by draught and air temperature differences between the human head and foot. The human head, which emits much of the body's heat, can more effectively emit that energy with the cool ceiling above. And the cooled ceiling can increase the thermal comfort by making a radiatively cool face and temperate feet.

It is possible to maintain the space dry-bulb temperature higher with radiant panels and achieve the desired thermal comfort. For example, a space at 26 °C with radiant cooling can give the perception of a space at about 24 °C without radiant panels. This results in a reduction in the building cooling loads. It also means that the conditioned ventilation supply air can remove more sensible cooling load since there is a larger temperature rise as the air passes through the space.

With ceiling mounted radiant panel cooling, the heat rejection from the human body by radiation can be increased from about 35 % without radiant panels to 50 % with radiant panels. Likewise, the heat loss due to convection decreases from about 40 % without the radiant panels to about 30 % with. The net effect is that less heat is rejected by perspiration in the presence of the radiant cooling field. Also, the radiant asymmetry can be experienced by the occupant with radiant panels. With most of the

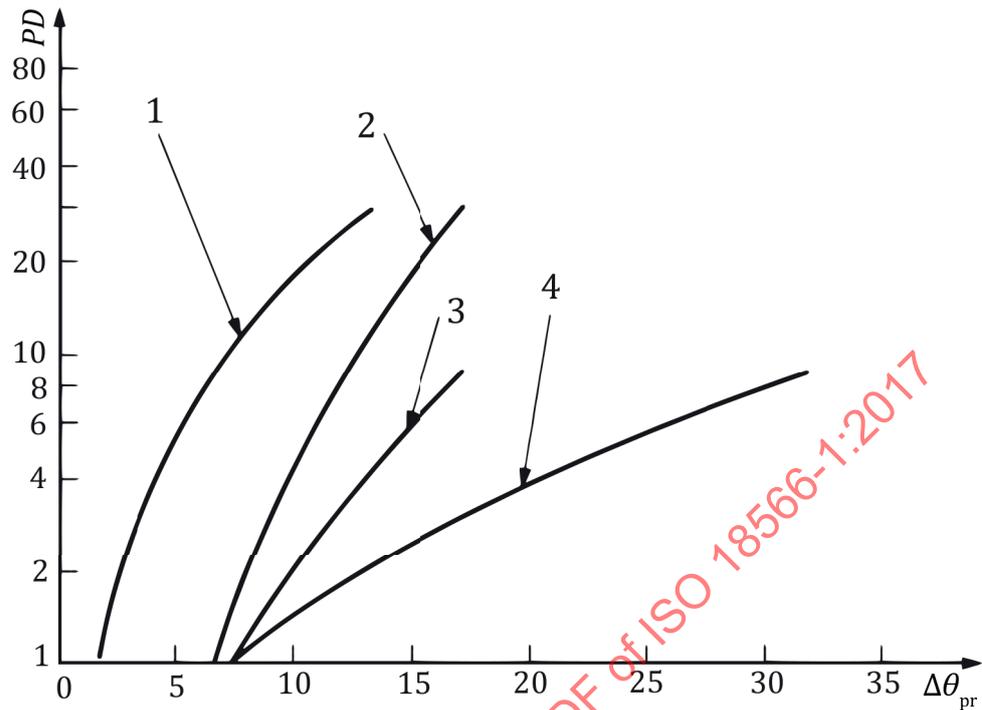
enclosure at 26 °C or below and the radiant panels at approximately 16 °C, up to 10 K radiant asymmetry temperature differential exists.

People may be dissatisfied due to general thermal comfort and/or local thermal comfort parameters. Thermal comfort requirements may limit the capacity and use of radiant surface heating and cooling systems. According to ISO 7730, for the thermal comfort requirements in winter for people with mainly sedentary activity (1,2 met, 1,0 clo), the operative temperature range is between 20 °C and 24 °C. In summer, for people with mainly sedentary activity (1,2 met, 0,5 clo), it is between 23 °C and 26 °C.

This document presents the prediction methods for the general thermal sensation and degree of discomfort (thermal dissatisfaction) of people exposed to moderate thermal environments. It enables the analytical determination and interpretation of thermal comfort using calculation of predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) and local thermal comfort, giving the environmental conditions considered acceptable for general thermal comfort as well as those representing local discomfort. Especially for designing of the radiant heating and cooling panel system, it is important that thermal comfort is specified with regard to the radiant temperature asymmetry and vertical air temperature difference. According to ISO 7730, the predicted per cent of dissatisfied occupancy is less than 6 % as a result of 8 K or less radiant asymmetry. For most cases, only about 50 % of the ceiling is chilled, so the effective mean radiant ceiling temperature of the two nearly equal areas is close to 21 °C, resulting in a radiant asymmetry of only about 5 K.

5.2 Radiant temperature asymmetry

The human body is most sensitive to radiant asymmetry caused by warm ceiling or cool walls. In case of ceiling mounted radiant panel for heating, the radiant temperature asymmetry should be maintained less than 5 K in relation to a small horizontal plane 0,6 m above the floor. [Figure 1](#) shows discomfort level (percentage dissatisfied) due to radiant temperature asymmetry in case of ceiling cooling/heating and walls-windows cooling/heating.

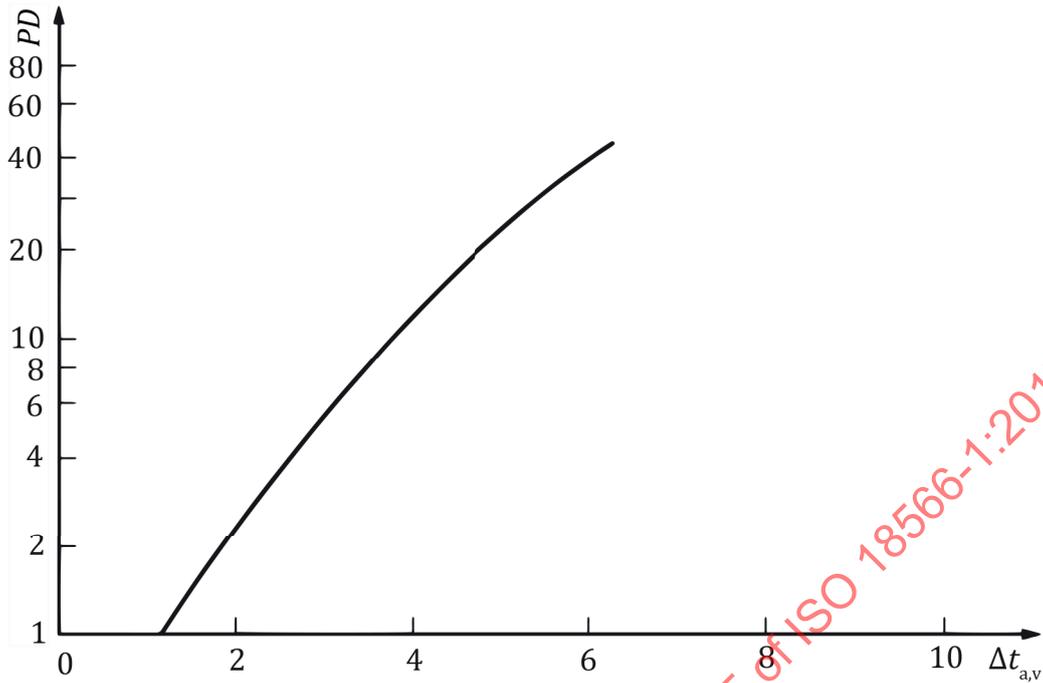
**Key**

- PD percentage dissatisfied, %
 $\Delta\theta_{pr}$ radiant temperature asymmetry, K
 1 warm ceiling
 2 cool wall
 3 cool ceiling
 4 warm wall

Figure 1 — Local thermal discomfort caused by radiant temperature asymmetry

5.3 Vertical air temperature difference

One of the important features of radiant heating and cooling system is that it is possible to get the uniform temperature conditions from floor to ceiling. Thermal stratification that results in the air temperature at the head level being warmer than at the ankle level may cause thermal discomfort. The differences in air temperature from the ankle level to the head level are recommended to be within 3 K. [Figure 2](#) can be used in conjunction with the PPD limit for vertical temperature differences to determine the allowable ranges of vertical temperature differences.



Key

PD percentage dissatisfied, %

$\Delta t_{a,v}$ vertical air temperature difference between head and feet, °C

Figure 2 — Local thermal discomfort caused by vertical air temperature difference

6 Technical specifications and requirements

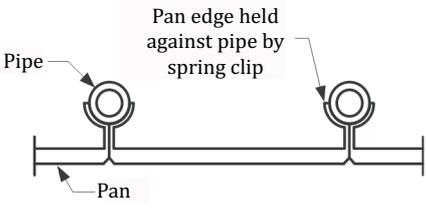
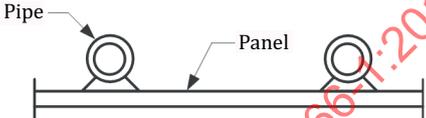
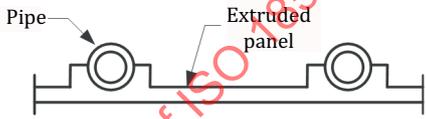
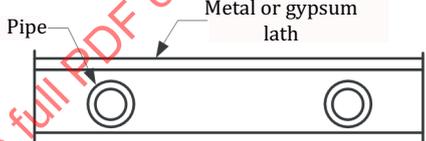
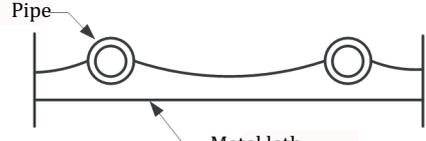
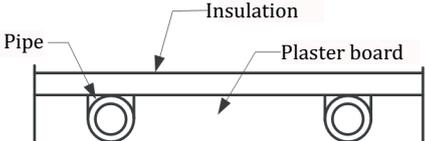
Technical specifications include the system types, specifications which are considered in manufacturing stage and the considerable details for installation stage. Technical requirements include the thermal and hydronic performances, safety and maintenance.

6.1 Technical specifications and installation

6.1.1 Major types of radiant panels

The radiant panel system is characterized by open air gap. The major components of radiant panel system are a radiant panel and pipes. The types of radiant panels are determined by the arrangement of major components: a panel and pipes. For each type, the heat transfer characteristics are different. Insulation is necessary to prevent heat losses to unoccupied space. In addition, a heat transfer layer, fixing equipment (hangers, wire net, etc.) and finishing material (plaster, etc.) are necessary as the case may be. The major types of radiant panels are stated in [Table 1](#).

Table 1 — Major types of a radiant panel

Description	Shape
Pipes fixed to pan edge	
Pipes secured to panel	
Pipes fixed to extruded panel	
Pipe fixed under metal/gypsum lath	
Pipe fixed on metal lath	
Plaster board	

Details of the different types of ceiling panels are stated in [Annex A](#).

6.1.2 Specification

The thermal output of a radiant panel is mainly transferred to the space by radiation. The thermal output to the unoccupied space shall be minimized by insulation. The maximum surface temperature of the lateral edges shall not exceed the minimum surface temperature of the radiant sheet between the last two wet surfaces. Air flow across the panel is to be prevented. The specifications for a radiant panel, pipes, insulation and dimensional tolerances are shown below.

a) Radiant panel

If the material in use requires protection, measures for protection against corrosion should be provided. The paint used for protection shall not contain any chemical substances the use of which is not allowed in building products. The compliance with the relevant domestic regulations shall be stated by the manufacturer of the radiant panel.

The radiating heating/cooling surface shall have an emissivity not lower than 0,8.

The manufacturers shall declare the materials used for producing the radiant panels, including surface protection (see [Annex B](#)).

b) Pipes

The dimensions of plastic pipes should comply with the requirements of the following: ISO 15875-1 for PE-X, ISO 15876-1 for PB and ISO 15874-1 for PP. Copper piping should comply with the requirements of EN 1057 (for pipes) and EN 1254-1 (for fittings).

Minimal pipe thickness should comply with the requirements for service conditions, operation pressure (higher than 4 bar) and durability (more than 50 years). The use of pipes with an oxygen-barrier layer is recommended to reduce corrosion problems. The oxygen permeability should be less than or equal to 0,1 g/m³·d at a water temperature of 40 °C, where d is the average outer diameter of the pipe.

The manufacturers shall declare the pipe materials used for the radiant panel (see [Annex B](#)).

c) Insulation

The non-heated or non-cooled side of the radiant panels shall be provided with insulation. The thermal resistance of the insulation has a substantial influence on the thermal output to non-space.

For the insulation of the radiant panel used by the manufacturer, the following information shall be given (see [Annex B](#)):

- thermal resistance in m² K/W and specific mass in kg/m³ at 40 °C;
- material for cover of the insulation;
- reaction to fire.

The major purpose of insulation is to prevent thermal output to non-space. In addition, acoustic performance can be considered.

d) Dimensional tolerances

The dimensional tolerances of parts of the panel having an influence on the thermal output shall not be greater than those indicated in the manufacturer's drawings supplied to the laboratory with the testing samples. Under no circumstances shall they be greater than those stated in [Tables 2](#) and [3](#).

Table 2 — Dimensional tolerances (metal)

Parts of the panel	Tolerances
Outside diameter of pipes	±0,50 mm
Distance between pipes	±1 % of the distance
Length of pipes	±3,00 mm
Length of radiant sheet	±3,00 mm
Width of ceiling mounted radiant panel	±6,00 mm
Thickness of sheet	±0,08 mm
Height of lateral edges	±3,00 mm

Table 3 — Dimensional tolerances (plasterboard)

	Type P	Types A, D, E, F,H, I, R or combined
Tolerance on width	-8 mm to approximately 0 mm	-4 mm to approximately 0 mm
Tolerance on length	-6 mm to approximately 0 mm	-5 mm to approximately 0 mm
Tolerance thickness	-0,6 to approximately +0,6 mm	-0,5 mm to approximately +0,5 mm
Squareness of ends	—	Not exceeding 2,5 mm per metre of width
Edge and end profiles	—	Depth of taper: between 0,6 mm and 2,5 mm; width of taper: between 40 mm and 80 mm

— Type A: Plasterboard with a face to which suitable gypsum plasters or decoration may be applied. For the purposes of identification, these boards are designated Type A.

— Type D (gypsum plasterboard with controlled density): These boards have a controlled density, with a face to which suitable gypsum plasters or decoration may be applied. This enables improved performance in certain applications to be obtained. For the purposes of identification, these boards are designated Type D.

— Type E (gypsum sheathing board): Boards especially manufactured to be used as sheathing board in external walls. They are not intended to receive decoration. They are not designed to be permanently exposed to external weather conditions. This type of wallboard has reduced water absorption rate. They shall have a minimum water vapour permeability. For the purposes of identification, these boards are designated Type E.

— Type F (gypsum plasterboard with improved core adhesion at high temperature): Plasterboard with a face to which suitable gypsum plasters or decoration may be applied. These boards have mineral fibres and/or other additives in the gypsum core to improve core cohesion at high temperatures. For the purposes of identification, these boards are designated Type F.

— Type H (plasterboard with reduced water absorption rate): Types of boards which have additives to reduce the water absorption rate. They may be suitable for special applications in which reduced water absorption properties are required to improve the performance of the board. For the purposes of identification, these boards are designated Type H1, H2 and H3, with different water absorption performance.

— Type P: Boards which have a face intended to receive gypsum plaster or to be combined by collage with other materials in form of boards or panels. In case of boards intended to receive gypsum plaster, the edges are either square or round. For the purpose of identification, these boards are designated Type P.

— Type I (gypsum plasterboard with enhanced surface hardness): Boards which are used for applications where higher surface hardness is required. They have a face to which suitable gypsum plasters or decoration may be applied. For the purposes of identification, these boards are designated Type I.

— Type R (gypsum plasterboard with enhanced strength): These boards for special applications where higher strength is required have both increased longitudinal and transverse breaking loads. They have a face to which suitable gypsum plasters or decoration may be applied. For the purposes of identification, these boards are designated Type R.

6.1.3 Installation

During the installation of the panel system, it is necessary to ensure that the fixing point can bear the load of panels and ensure that the coupling should be installed to prevent leakage.

The fixing points on the radiant panel shall be designed to withstand a load of five times the allocated mass of the panel, including water, without failure. A loading up to three times of the allocated filled mass shall be achieved without any occurrence of permanent deformation. The manufacturer shall submit a statement for the suitability and stability of the fixing points in accordance with national regulations, if these exist, rather than recommended values.

When coupling a panel to other panel, the bending radius shall not be less than the minimum bending radius defined in the relevant product standards. This operation should be carried out in accordance with the manufacturer's instructions.

6.2 Technical performance

6.2.1 Thermal performance

The rated thermal output and the thermal output in different operating conditions (characteristic curve) are to be determined in a test laboratory according to ISO 18566-2. Thermal performance is influenced by insulation which prevents thermal output to non-space. The specification of insulation is described in [6.1.2](#). The manufacturers shall inform the rated thermal output of the radiant panels (see [Annex B](#)).

6.2.2 Hydronic performance

The manufacturer shall provide the means to calculate water flow resistance for the different types of unit with connections and internal pipe layout, and the water flow for panels should be balanced. When manifold is not applied, the distribution method by piping like reverse return should be used. When manifold is applied, headers, flow control valves, actuators and air escape valves should be used. The installation specification should be carried out in accordance with the manufacturer's instructions.

The water flow within a pipe is necessary to be turbulent to enhance the thermal performance. Therefore, the Reynold's number is needed to be over 4 000. However, laminar flow may be involved in some cases (e.g. at low load situation). So laminar flow is considered in ISO 18566-2 and ISO 18566-3. The lower end of velocity range is based in the ability of flowing water to move air bubbles along a vertical pipe. Average flow velocity of 0,6 m/s or higher can entrain air bubbles that are in a downward water flow. The upper end of velocity range is 1,2 m/s which is based on minimizing noise generated by the flow.

6.2.3 Acoustic performance

Noise can be occurred when too much water is flowing inside the pipes. To minimize the noise generated by the flow, the upper end of velocity range is 2 m/s when determining the rate of water flow. In principle, it is necessary to adapt the domestic acoustic regulations.

6.3 Safety

6.3.1 Durability of the panel system

System durability aims to promote building practices that prolong the useful service life of buildings, reduce maintenance and promote serviceability.

Rehabilitation and/or replacement of damaged components and structures results in the inefficient use of resources. Improper moisture control can lead to premature failure of building components and can contribute to poor environmental conditions for occupants. In order to provide long operation cycle of the system, the durability of system components (heat source/sink, piping, fitting, garnitures, and electronic equipment) have to be considered.

For safety reasons, a safety device, independent of the control unit, and which operates even in the absence of electric power, should cut off the heat supply in the surface heating circuit in such a way that the temperature around the heating elements does not exceed the specified temperature limits^[13].

In addition, the pressure and fire related situation should be considered to certify the durability of the system as follow.

a) Pressure

The headers and their connections to the pipes of the active length (wet surface) of all products leaving the factory shall be tested for leaks with a test pressure equal to at least 1,3 times the maximum operating pressure stated by the manufacturer.

In case of plastic pipes, the minimum allowed thickness is defined by ISO 15875-1 for PE-X, ISO 15876-1 for PB and ISO 15874-1 for PP pipes. The plastic pipes should include an oxygen barrier layer to ensure tightness. Principally, PB is very stable and prohibits oxygen infiltration through the pipe wall. With other plastic materials such as PE-X, it is necessary to include the foil layer known as the oxygen barrier in the pipe wall. Minimal pipe thickness should comply with the requirements for service conditions, operation pressure higher than 4 bar and durability of more than 50 years.

A sample of a complete panel shall be tested to ensure that no leakage or permanent deformation will occur at the maximum test pressure, which is a factor of 1,69 times the maximum operating pressure stated by the manufacturer (see [Annex B](#)).

b) Reaction to fire

In principle, domestic fire regulations should be adapted. The materials from which the appliances are made (steel, aluminium, plaster board, etc.) should be considered to meet required fire class.

In EU countries, the appliances made from steel or aluminium are considered to be reaction to fire class A1 without the need for testing (provided that any organic part of the paint or coating is less than 1 % by mass or volume). If the organic part of the paint or coating exceeds 1 % by mass or volume, the material should be tested and classified according to DIN EN 13501-1 and the resulting class stated.

6.3.2 Indoor environment impact

Occupants are affected by the surface temperature of floor or wall panels, the exposed pipe works and dangerous substances from panels.

With wall and floor heating systems, surface temperatures of heating elements seldom go over 30 °C, so hand burning is not an issue (also the case with air heating systems in general). As the risk of hand burning can be introduced when surface temperatures exceed 40 °C to 45 °C, it is necessary to consider in this case.

The laboratory shall verify the manufacturer's statement that the painting used in the protective coating does not release dangerous substances, under normal operating conditions, in compliance with domestic regulations concerning painting materials to be used in building products.

6.4 Maintenance of conformity

The manufacturer shall establish a system of quality assurance to ensure that the products maintain conformity with the requirements in [Table 4](#). The initial attestation of conformity shall be valid until any change is made to the design of the model or type or any change is made to the manufacturing process having an influence on the thermal output.

Table 4 — Conformity checklist

Category		Contents
System specification and installation	Radiant panel	Panel material Surface coating materials to prevent corrosion Emissivity at panel surface
	Pipes	Pipe material Pipe thickness Operation pressure Water temperature during heating and cooling operation Durability Oxygen permeability to reduce corrosion problems
	Insulation	Thermal resistance Specific mass Cover material Reaction to fire
	Dimensional tolerances	Dimension of panel
	Installation	Suitability and stability of the fixing points
	Technical performance	Thermal performance
Technical performance	Hydronic performance	Water flow resistance Water flow balancing according to the distribution system Reynold's number
	Acoustic performance	Noise level at the maximum design water flow rate
Safety	Durability of the system	Leakage test results Reaction to fire
	Indoor environment impact	Surface temperature distribution Release of dangerous substances from radiant panel

Annex A (informative)

Descriptions of different types of radiant heating and cooling ceiling panels

Radiant heating and cooling panels are the prefabricated panels integrated with pipes which are generally suspended below the concrete slab or other horizontal building construction. The radiant ceiling panels are primarily used for large spaces such as open plan offices, storages, malls. The radiant ceiling panel can be installed by means of hangers after the construction of building structure. The radiant ceiling panel is composed of insulation, hangers, pipes, wire net, plaster, etc. Suspended radiant panel systems may cover the whole ceiling surface or can be used as a supplement to embedded system to allow for fast changes in heating and cooling. The insulation above the radiant panel is used to avoid the heat loss to the unconditioned space. Mostly, this panel system is made of aluminium or steel sheet with copper pipes (see [Figure A.1](#)).

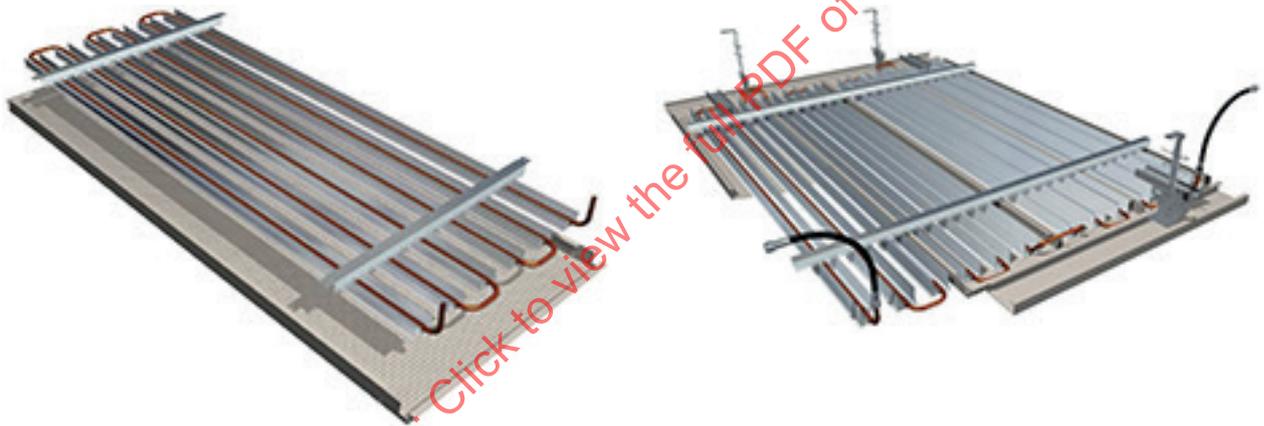
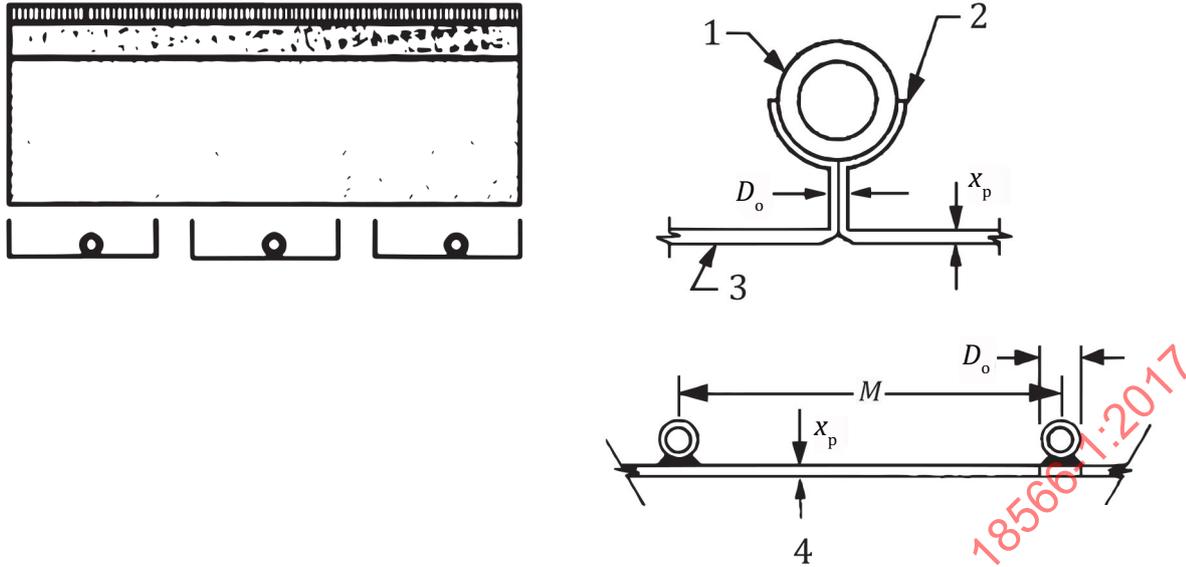


Figure A.1 — Examples of construction of radiant panels

The pipe installation to the panel significantly influences the thermal output. If poorly installed, the temperature differences between the panel surface and the cooling fluid may be increased. Generally, in the case of panels suspended below a concrete slab, approximately 90 % of the thermal output is available to cool/heat the room. The remaining 10 % cools or heats the slab of the room (see [Figure A.2](#)).



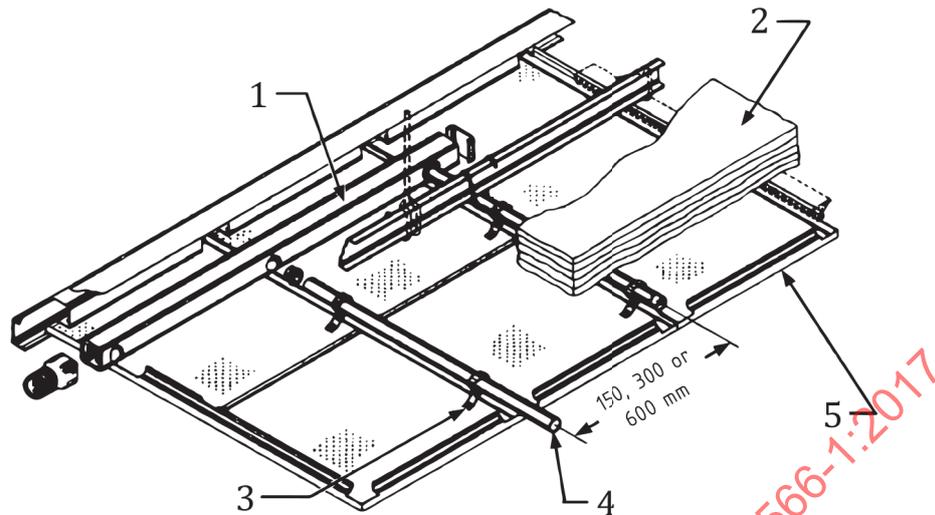
Key

- 1 steel pipe
- 2 pan edge held against pipe by spring clip
- 3 aluminium pan
- 4 copper tube secured to aluminium sheet

Figure A.2 — Example of construction details in ceiling panels

In ASHRAE fundamentals, three types of metal ceiling systems are addressed.

The first consists of light aluminium panels, usually 300 mm by 600 mm, attached in the field to 15 mm galvanized pipe coils. [Figure A.3](#) illustrates a metal ceiling panel system that uses 15 mm pipe laterals on 150 mm, 300 mm, or 600 mm centres, hydraulically connected in a sinuous or parallel-flow welded system. Aluminium ceiling panels are clipped to these pipe laterals and act as a heating panel when warm water is flowing or as a cooling panel when chilled water is flowing. This type can be classified as the type of “Pipes secured to panel” in this document.

**Key**

- 1 38 mm square header
- 2 thermal blanket
- 3 panel clip
- 4 15 mm pipe lateral
- 5 aluminium panel

Figure A.3 — Metal ceiling panels attached to pipe laterals

The second type of panel consists of a copper coil secured to the aluminium face sheet to form a modular panel. Modular panels are available in sizes up to about 910 mm × 1 520 mm and are held in position by various types of ceiling suspension systems, most typically a standard suspended T-bar 600 mm × 1 200 mm exposed grid system. [Figure A.4](#) illustrates metal panels using a copper pipe pressed into an aluminium extrusion, although other methods of securing the copper pipe have proven equally effective. Metal ceiling panels can be perforated so that the ceiling becomes sound absorbent when acoustical material is installed on the back of the panels. The acoustical blanket is also required for thermal reasons, so that reverse loss or upward flow of heat from the metal ceiling panels is minimized. This type can be classified as the type of “Pipes secured to panel” or “Pipes contacted to panel embedded in insulation” in this document.