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

Part 3: Design of ceiling mounted radiant panels

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

Partie 3: Conception des panneaux radiants montés au plafond

Reference number
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Foreword

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

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

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

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

For an explanation 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

There are various types of hydronic radiant heating and cooling systems: ceiling mounted radiant panels, chilled beams, pipe embedded ceilings, walls, and floors. In those system alternatives, ceiling mounted radiant panels are widely used and frequently installed on T-bar grids designed to support the dropped acoustical ceiling. The ceiling mounted radiant panels are top loaded with thermal insulation to prevent heat gain from or loss to the plenum space. In some cases, free hanging metal panels suspended under the room ceiling by wire hangers without topside insulation are also used for space heating and cooling. Both top and bottom surfaces of the free-hanging metal panel are used as heat transfer surfaces. In principle, ceiling mounted radiant panel systems are able to accommodate varying space sensible loads by controlling panel surface temperature. Heat is transferred from the radiant panel by the heat transfer mechanisms of convection and radiation.

Generally, low temperature radiant heating and high temperature radiant cooling are classified as embedded radiant heating and cooling systems and ceiling mounted radiant 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 ASNI/ASHRAE Standard 138.

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

Part 3: Design of ceiling mounted radiant panels

1 Scope

This document specifies the design of ceiling mounted radiant panels.

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 ceiling construction with an open air gap.

This document applies to all types of prefabricated radiant panels that are part of the room periphery.

This document does not cover panels embedded into ceiling, wall or floor structures without open air gap and hybrid (combined thermal radiation and forced-convection) ceiling 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 18566-1, *Building environment design — Design, test methods and control of hydronic radiant heating and cooling panel systems — Part 1: Definition, symbols, technical specifications and requirements*

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 terms and definitions given in ISO 18566-1 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/

4 Symbols

For the purposes of this document, the symbols in ISO 18566-1 apply.

5 General design consideration

5.1 General

The ceiling mounted radiant panels work by circulating warm or cold water through a network of pipes placed on the floor, wall or ceiling. Heat is gently radiated from these radiant panels into occupied spaces, warming or cooling the objects in the area to create a comfortable environment. Radiant heating and cooling panels can be installed in a single room or throughout an entire building, and it is used for areas with normal and high ceilings. A variety of heat sources can be used, including boilers, geothermal heat pumps, solar thermal systems and electric water heaters.

Ceiling mounted radiant panels function as heat exchangers between the room air and the chilled/hot water. The ceiling panels absorb or emit heat from heat sources in a room and exchanges it with the circulating chilled/hot water. The chilled or hot water is then pumped to a chiller or boiler. With radiant panel systems, room thermal conditions are maintained primarily by direct transfer of radiant energy, rather than by convection heating and cooling. Radiation of energy takes place between objects with different surface temperatures. In order to provide acceptable thermal conditions, air temperature and mean radiant temperature should be taken into account. See Annex B for details about heat transfer by panel surfaces.

Compared with a conventional convective heating and cooling system, a radiant heating system can achieve the same level of operative temperature at a lower air temperature and a radiant cooling system at a higher air temperature. However, in all practical thermal environments, a radiation field has an asymmetric feature to some degree. If the asymmetry is sufficiently large, it can cause discomfort. Also, the thermal stratification of air may cause thermal discomfort. Therefore, these comfort criteria should be considered in the design stage of ceiling mounted radiant panels. Ceiling mounted radiant panels are generally built as an architectural finish product. Generally, the copper pipes are thermally bonded and panel piping arrangements are in a serpentine pattern or in a parallel pattern. The design of heating and cooling capacity per unit panel area is determined from the performance data rated for the test standard. The smaller the temperature difference between chilled/hot water and ceiling surface is, the more efficient the system becomes.

5.2 Panel thermal resistance

Thermal resistance in the panel to heat transfer from or to its surface will reduce the performance of the system. Thermal resistance to the heat flow may vary considerably among different panels, depending on the type of bond between the piping (wiring) and the panel material. Factors such as corrosion or adhesion defects between lightly touching surfaces and the method of maintaining contact may change the bond with time. The actual thermal resistance of any proposed system should be verified by testing. Specific resistance and performance data, when available, should be obtained from the manufacturer.

Panel thermal resistances include:

— r_t : thermal resistance of pipe wall per unit pipe spacing in a hydronic system, m·K/W;

— r_s : thermal resistance between pipe (electric cable) and panel per unit spacing, m·K/W;

— r_p : thermal resistance of panel, m^2·K/W;

— r_c : thermal resistance of panel covers, m^2·K/W;

— r_u : characteristic panel thermal resistance, m^2·K/W.

For pipe spacing M_p,

$$r_u = r_t M_p + r_s M_p + r_p + r_c$$

When the pipes are embedded in the panel, r_s may be neglected. However, if they are attached to the panel, r_s may be significant, depending on the quality of bonding. Table A.1 gives typical r_s values for various ceiling panels. The value of r_p may be calculated if the characteristic panel thickness x_p and the thermal conductivity k_p of the panel material are known (see Annex A).

If the pipes are embedded in the panel,

$$r_p = \frac{x_p - \frac{D_o}{2}}{k_p}$$

where D_o = outside diameter of the pipe.

If the pipes are attached to the panel,

$$r_p = \frac{x_p}{k_p}$$

Thermal resistance per unit spacing of a circular pipe with an inside diameter D_i and thermal conductivity k_t is

$$r_t = \frac{\ln\left(D_o / D_i\right)}{2\pi k_t}$$

In an electric cable, $r_t = 0$.

In metal pipes, r_t is virtually the fluid-side thermal resistance.

$$r_t = \frac{1}{hD_i}$$

5.3 Panel heat loss or gain

Heat transferred from the upper surface of ceiling panels is considered as a panel heat loss. Panel heat losses are part of the building heat loss if the heat is transferred outside of the building. If the heat is transferred to another heated space, the panel loss is a source of heat for that space instead. In either case, the magnitude of panel loss should be determined. Panel heat loss to space outside the room should be kept to a reasonable amount by insulation.

5.4 Water velocity in pipes

At the design stage, attention should be given to proper water velocity. Water velocity that is too low causes laminar flow, which reduces internal heat exchange. Generally, the heat exchange coefficient within the range of turbulent flows including the transition area is different from that of laminar flows. Approximately, it can be assumed that the heat exchange coefficient of turbulent flow is about 2 200 W/m^2·K and that of laminar flow is about 200 W/m^2·K. Both values are average values. Flow characteristics can be determined by the internal diameter of the pipe, the average velocity of the flow and the kinematic viscosity of the water.

The maximum water velocity per loop depends on the selection of pumps. When the temperature differences between supply and return water are decreased, the water velocity should be increased. The higher the water velocity, the higher the friction loss, and more pump energy is required. Most loops are designed according to energy criteria with a pressure drop between 10 kPa and 25 kPa.

Noise from entrained air, high-velocity or high-pressure-drop devices, or pump and pipe vibrations should be avoided. Water velocities should be high enough to prevent separated air from accumulating and causing air binding. Where possible, avoid automatic air venting devices over ceilings of occupied spaces. In general, noise can occur at high velocities. Make sure that the ceiling's water velocities will not fall below the minimum of 0,25 m/s for the 12 mm inside diameter copper pipe. Also, the maximum velocities should not exceed 1,2 m/s for the 12 mm inside diameter copper pipe.

5.5 Surface condensation

To prevent the surface condensation problems, the surface temperature of the radiant ceiling can be controlled to be above the dew point temperature. For this purpose, it is necessary to monitor the air temperature and air humidity levels. In simple manners, the supply water temperature to the panels should be controlled to avoid the possibility of surface condensation.

To prevent condensation on the room side of cooling panels, the panel water supply temperature should be maintained at least 1 K above the room design dew point temperature. This minimum difference is recommended to allow for the normal drift of temperature controls for the water and air systems, and also to provide a factor of safety for temporary increase in space humidity.

The most frequently applied method of dehumidification uses cooling coils. If the main cooling coil is six rows or more, the dew point of the leaving air will approach the temperature of the leaving water. The cooling water leaving the dehumidifier can then be used for the panel water circuit.

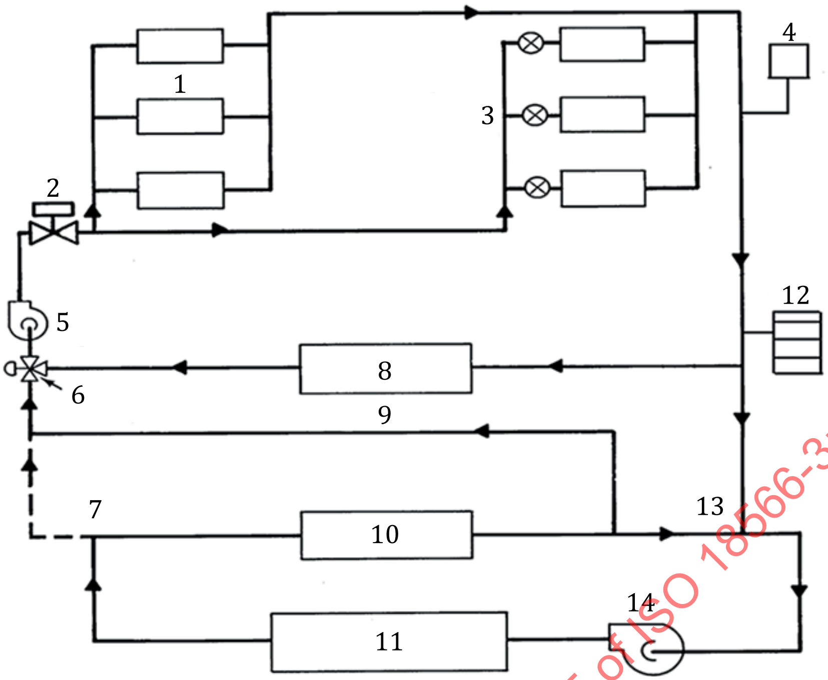
Several chemical dehumidification methods are available to control latent and sensible loads separately. In one application, cooling tower water is used to remove heat from the chemical drying process, and additional sensible cooling is necessary to cool the dehumidified air to the required system supply air temperature.

When chemical dehumidification is used, hygroscopic chemical-type dew point controllers are required at the central apparatus and at various zones to monitor dehumidification.

When cooled ceiling panels are used with a variable air volume (VAV) system, the air supply rate should be near the maximum volume to assure adequate dehumidification before the cooling ceiling panels are activated.

5.6 Water distribution and piping system

Hydronic radiant panels can be used with two-pipe, three-pipe and four-pipe distribution systems. Figure 1 shows the arrangement of a typical system. It is common to design for a 10 K temperature drop for heating across a given grid and a 3 K rise for cooling, but larger temperature differentials may be used, if applicable.



Key

1	panels	8	water heater
2	choke valve	9	supply
3	zone valves (optional)	10	primary cooling coil
4	air sep.	11	refrigeration chiller
5	secondary water pump	12	exp. tank
6	secondary water mixing valve	13	return
7	supply (alternate connection)	14	primary water pump

Figure 1 — Primary/secondary water distribution system with mixing control

As with any hydronic system, look closely at the piping system design. Piping should be designed to ensure that water of the proper temperature and in sufficient quantity is available to every grid or coil at all times. Proper piping and system design should minimize the detrimental effects of oxygen on the system. Reverse-return systems should be considered to minimize balancing problems.

Individual panels can be connected for parallel flow using headers, or for sinuous or serpentine flow. To avoid flow irregularities within a header-type grid, the water channel or lateral length should be greater than the header length. If the laterals in a header grid are forced to run in a short direction, this problem can be solved by using a combination series-parallel arrangement. Serpentine flow will ensure a more even panel surface temperature throughout the heating or cooling zone.

Design piping systems to accept thermal expansion adequately. Do not allow forces from piping expansion to be transmitted to panels. Thermal expansion of the ceiling panels should be considered.

In circulating water systems, plastic, rubber, steel, and copper pipes are used widely in ceiling, wall, or floor panel construction. Steel pipe should be the all-welded type. Copper tubing should be soft-drawn coils. Fittings and connections should be minimized. Changes in direction should be made by bending.

Solder-joint fittings for copper pipe should be used with a medium-temperature solder of 95 % tin, 5 % antimony, or capillary brazing alloys. All piping should be subjected to a hydrostatic test of at least three times the working pressure.

Pressure test should be tested to determine the long-term hydrostatic strength of the pipe. The designer should properly determine the maximum operating pressure, taking operating temperature and pressure ranges within the piping system into account. Also, the designer can refer to the recommendations of the heat source manufacturer as well as the local code requirements to ensure that proper clearances are incorporated into the design layout. Failure to follow pressure and temperature limits may damage the pipe, resulting in leaks and operational failures. The designer should incorporate proper controls into the system to ensure the pressure and temperature capability of the pipe is not exceeded. For example, temperature and pressure relief valves can be a safety mechanism in case the system overheats. This valve acts quickly to relieve excess temperature or pressure if either one of the conditions is reached.

6 Design processes of hydronic panel systems

6.1 General

This clause provides a basic design process, including highlighting key points to consider while designing a ceiling mounted radiant panel system. The layout of the ceiling mounted radiant panels in buildings can be determined by using calculated thermal output from the panel surfaces. The design of radiant panel system can be done with a software program, but it is important for the designer to understand how to design a system manually in order to optimize the system.

Ceiling mounted radiant panels can be integrated into an HVAC system that heats and cools. In such a system, a source of dehumidified ventilation air is required in summer, so the system is classed as an air-and-water system. Also, various amounts of forced air are supplied year round. When radiant panels are applied for heating only, a ventilation system may be required, depending on local codes. Radiant panel systems are an outgrowth of the perforated metal, suspended acoustical ceilings. These radiant ceiling systems are usually designed into buildings where the suspended acoustical ceiling can be combined with panel heating and cooling. The panels can be designed as small units to fit the building module, which provides extensive flexibility for zoning and control, or the panels can be arranged as large continuous areas for maximum economy. Some ceiling installations require active panels to cover only a portion of the room and compatible matching acoustical panels for the remaining ceiling area. Panel design requires determining panel area, panel type, supply water temperature, water flow rate, and panel arrangement. Panel performance is directly related to room conditions. Air-side ventilation and dehumidification system also should be designed. Heating and cooling loads may be calculated by procedures in accordance with standards for heating and cooling load calculation, e.g. ISO 52016-1, based on an index such as operative temperature.

6.2 Cooling operation

(A) Determine room design dry bulb temperature, relative humidity, and dew point. Also, specify the outdoor design conditions for buildings.

A thermal comfort condition in an air-conditioned space is defined by the desired dry bulb temperature and relative humidity. The designer specifies the inside design conditions in air-conditioned spaces for some of the building applications according to the local standards or building code. Especially at a given room design dry bulb temperature and relative humidity in summer, the designer determines the room dew point temperature to prevent the surface condensation problems. Design dew point temperature is the basis on the determination of design and operation strategies during cooling period.

When designing an HVAC system, it is also important to use the correct outdoor climate data (outdoor design conditions) for the locality in which the building is located. These data are used when calculating the building component heating load and component cooling load, which in turn are used to determine the required heat supply or removal rate for each room, design the appropriate panel area and duct work, and select the optimal equipment for the application. Evidently, there can be some errors that will propagate throughout the system design process in case of using the irrelevant outdoor design conditions. The results are an uncomfortable indoor environment, energy inefficiency, and avoidable expenses.

(B) Calculate room sensible and latent heat gains.

Based on the indoor and outdoor design conditions, sensible and latent heat loads could be specified.

Refer to the building drawings and specifications.

(C) Establish minimum supply air quantity for ventilation. Calculate latent and sensible cooling available from supply air, respectively. After that, determine remaining sensible cooling load to be satisfied by the ceiling mounted radiant panel system.

All occupied buildings require a supply of outdoor air. The fresh air supply is required to maintain an acceptable indoor air quality and especially to dilute the carbon dioxide exhaled. The quantity may be added per person and is related to the occupant density and activity within the air-conditioned space. Depending on outdoor conditions, the air may need to be cooled before it is distributed into the occupied space.

As outdoor air is drawn into the building, indoor air is exhausted or allowed to escape, thus removing air contaminants. The minimum ventilation rate, which is to be maintained in air-conditioned spaces, shall conform to the minimum ventilation rates recommended in breathing zone according to the local standards or building code. The outdoor fresh air is necessary in an air-conditioned environment to maintain good indoor air quality, but since this air is still at higher temperature and humidity as compared to the return air temperature and humidity from the air-conditioned space, it adds to the cooling and dehumidification demand of the space. Therefore, in order to prevent the surface condensation at panel surface, to maximize the benefit of outdoor fresh air and to minimize its impact on the cooling load and subsequently on energy use in an air-conditioned system, precooling and dehumidification of outdoor fresh air before it gets mixed up with the return air from the air-conditioned space are recommended.

The precooling and dehumidification of outdoor fresh air can be carried out with the combination of general air handling units (AHU) such as dedicated outdoor air system (DOAS) and energy recovery wheel (ERV). Before determining the required sensible cooling output of ceiling mounted radiant panel system, latent and sensible cooling load from supply air shall first be specified.

(D) Determine AUST (average unconditioned surface temperatures). Also, calculate the mean radiant temperature and the operative temperature.

Any surface that is warmer than the cooling panel will draw energy out of that cooling panel. All of the unconditioned surfaces represent the radiant cooling load on the conditioned panel. These unconditioned surfaces along with the conditioned surface represent the mean radiant temperature (MRT) calculated as an area weighted average. The value of the MRT averaged out with the dry bulb temperature (t_{db}) represents the operative temperature [t_{op} = (MRT + t_{db})/2]. Determine optimum operative temperature in conditioned space. From the comfort range of operative temperature, establish optimum design indoor air temperature.

(E) Determine minimum permissible effective cooling panel surface temperature that will not lead to surface condensation and thermal discomfort at design conditions.

The greater the cooling load in room space, the greater the temperature differential required between the panel and space temperature. Panel surface temperatures are regulated by ISO 18566-1 based on health and comfort research. Especially examine the radiant temperature asymmetry. Acceptable ranges of radiant temperature asymmetry are less than 5 K for warm ceilings, 15 K for cool ceilings, 10 K for cool walls, and 27 K for warm walls at 10 % local discomfort dissatisfaction. Also, according to the design dew point temperature, minimum permissible effective cooling panel surface temperature should be determined.

(F) Determine necessary panel area for remaining sensible cooling.

Determine the thermal output of the ceiling panel by using the test results according to ISO 18566-2 for the given conditions and calculate the necessary panel area for cooling.

(G) Determine average panel cooling water (brine) temperature for given pipe spacing. Also, determine the flow rate and temperature increase of cooling water in flow calculation.

Ceiling mounted radiant panels are generally fabricated in a factory and installed on site. The operating temperatures of the fluid are a function of efficiency of the panel which is related to the resistance of the finishing layers, conductivities of the pipe and encasing materials, pipe surface area, fluid flow characteristics, and log mean temperature differences. Pipe spacing plays a significant role in the effectiveness and efficiency of the radiant panel. For a given pipe spacing of prefabricated ceiling panel, determine average panel cooling water (brine) temperature. After determining the average panel cooling water (brine) temperature, the designer can determine the flow rate and temperature increase (Δt) of the cooling water (brine) in the flow calculation and then establish the return temperature, which is related to the efficiency of the heat sources, such as heat pump, solar system or chiller. Also, it is related to the operation and control strategies of radiant panel. All of these factors affect the initial cost and operating cost of the whole system, the quality of the indoor environment and efficacy of the surface temperature.

(H) Design the panel arrangement. Also, determine the size and location of manifold.

Ceiling mounted radiant panels can also be integrated into the ceiling design. They provide several functions such as heating, cooling, sound absorption, insulation, and unrestricted access to the plenum space. They should be easily maintained during the operation. In determining the panel arrangement, the designer should consider the ceiling design and the size and location of manifold. Generally, the manifolds could be installed near the conditioned space. Allow sufficient space above the ceiling for installation and connection of the piping that forms the panel ceiling. Manifolds are selected according to the pipe size, number of circuits and circuit flow rates. The designer should consider the effect of manifold location on the ceiling mounted radiant panel layout and the impact of bringing many pipes in to one area. Determine the appropriate number of circuits for each manifold. Zoning the building increases the number of circuits in manifolds with outlets. Calculate the distribution flow rate of the manifold for the selected number of circuits. Select the proper manifolds which do not exceed the maximum allowable range of flow rates. As with any hydronic system, piping should be designed to ensure that water with proper temperature and sufficient quantity is available to every circuit at all times.

6.3 Heating operation

(A) Designate room design dry bulb temperature for heating.

(B) Calculate room heat loss.

Based on the indoor and outdoor design conditions, sensible heat loads could be specified.

Refer to the building drawings and specifications.

(C) Determine AUST (average unconditioned surface temperatures). Also, calculate the mean radiant temperature and the operative temperature.

Any surface that is cooler than the heating panel will draw energy out of that heating panel. All of the unconditioned surfaces represent the radiant heating load on the conditioned panel. These unconditioned surfaces along with the conditioned surface represent the mean radiant temperature (MRT) calculated as an area weighted average. The value of the MRT averaged out with the dry bulb temperature (t_{db}) represents the operative temperature [t_{op} = (MRT + t_{db})/2].

(D) Determine the required effective surface temperature of panel.

The greater the heating load in room space, the greater the temperature differential required between the panel and space temperature. Panel surface temperatures are regulated by ISO 18566-1 based on health and comfort research. Excessively high surface temperatures over the occupied zone will cause the occupant to experience a “hot head effect”.

(E) Determine the panel area for sensible heating.

Determine the thermal output of the ceiling panel by using the test results according to ISO 18566-2 for the given conditions and calculate the necessary panel area for heating.

(F) Determine average panel heating water (brine) temperature for given pipe spacing. Also, determine the flow rate and temperature increase of heating water in flow calculation.

(G) Design the panel arrangement. Also, determine the size and location of manifold.

Annex A
(informative)

Thermal resistance of ceiling panels and thermal conductivity of typical pipe material

A.1 Thermal resistance of ceiling panels

Table A.1 — Thermal resistance of ceiling panels

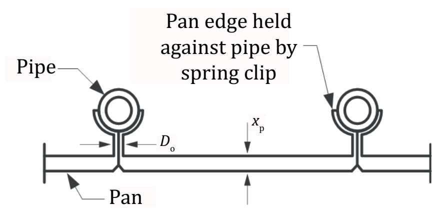
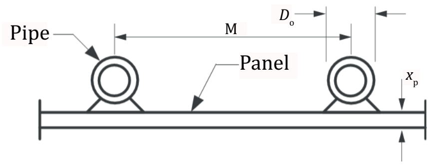
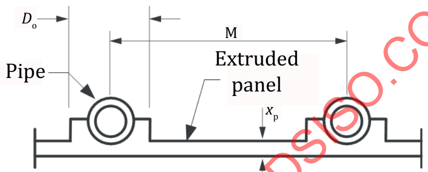
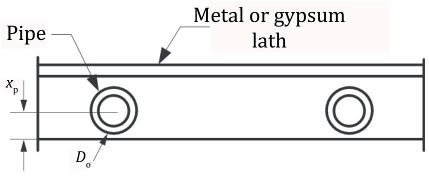
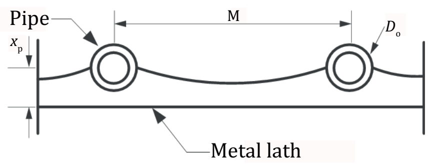
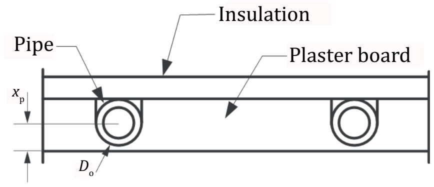
Type of panel	Thermal resistance	
	r_p m²·K/W	r_s m·K/W
	$\frac{x_p}{k_p}$	0,32
	$\frac{x_p}{k_p}$	0,38
	$\frac{x_p}{k_p}$	0,10

Table A.1 *(continued)*

Type of panel	Thermal resistance	
	r_p m²·K/W	r_s m·K/W
	$\dfrac{x_p - \dfrac{D_o}{2}}{k_p}$	≈ 0
	$\dfrac{x_p - \dfrac{D_o}{2}}{k_p}$	≤ 0,12
	$\dfrac{x_p - \dfrac{D_o}{2}}{k_p}$	≈ 0

A.2 Thermal conductivity of typical pipe material

Table A.2 — Thermal conductivity of typical pipe material

Material	Thermal conductivity k_t W/m·K
Carbon steel (AISI 1020)	52
Copper (drawn)	390
Red brass (85 Cu-15 Zn)	159
Stainless steel (AISI 202)	17
Low-density polyethylene (LDPE)	0,31
High-density polyethylene (HDPE)	0,42
Cross-linked polyethylene (VPE or PEX)	0,35
Textile-reinforced rubber heat transfer hose (HTRH)	0,29
Polypropylene block copolymer (PP-C)	0,22
Polypropylene random copolymer (PP-RC)	0,22
Polybutylene (PB)	0,22
Polyethylene raised temperature (PE-RT)	0,35

