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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.

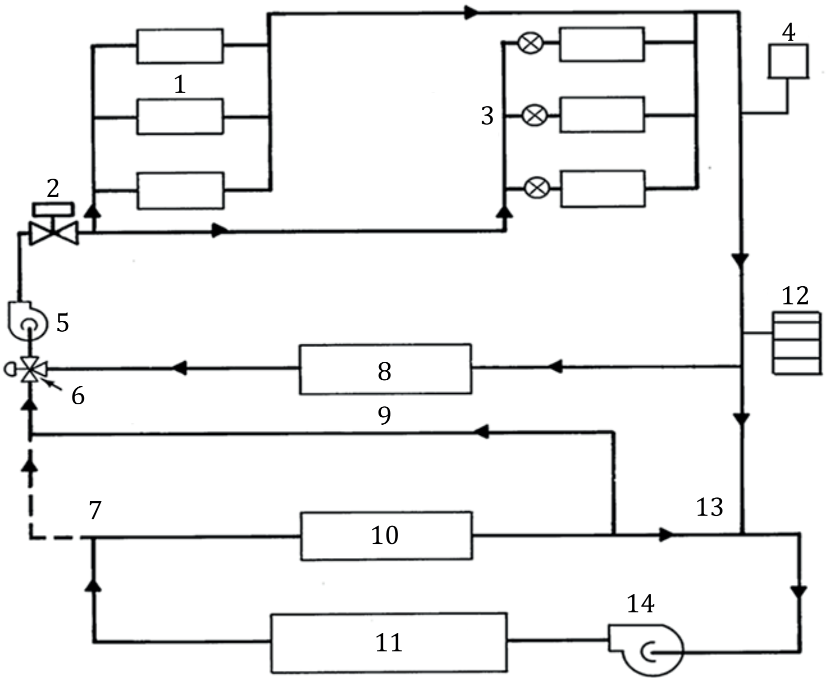
Several chemical dehumidification methods are available to control latent and sensible loads separately. In one application, cooling tower water is used to remove heat from the chemical drying process, and additional sensible cooling is necessary to cool the dehumidified air to the required system supply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