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**Energy performance of building
systems — Underfloor air
distribution systems —**

**Part 1:
General overview**

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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.

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This document was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods*.

A list of all parts in the ISO 7615 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Energy performance of building systems — Underfloor air distribution systems —

Part 1: General overview

1 Scope

This document provides a general overview, including terms and definitions and technical specifications for an underfloor air distribution (UFAD) system. A UFAD system includes a raised floor, a zone air handling unit (AHU), an underfloor plenum and underfloor air diffusers. This document is applicable to all types of systems which utilize underfloor plenum to supply conditioned air into the occupied space.

This document is not applicable to AHUs, ceiling-based air diffusers or displacement ventilation systems.

2 Normative references

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

ISO 7730, *Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*

ISO 13731, *Ergonomics of the thermal environment — Vocabulary and symbols*

ISO 16818, *Building environment design — List of test procedures for heating, ventilating, air-conditioning and domestic hot water equipment related to energy efficiency*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7730, ISO 13731 and ISO 16818 and the following apply.

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

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

3.1 underfloor air distribution system UFAD system

forced air delivery system which takes advantage of the underfloor plenum to supply the conditioned air produced from the air handling unit into the occupied space through underfloor air diffusers mounted on the raised floor

3.2 raised floor

elevated interior floor composed of modular panels above the structural slab to form the underfloor plenum for the passage of conditioned air supplied from the air handling unit

3.3

underfloor plenum

void space between raised floor and the slab, where technical services are placed, and the conditioned air is supplied from the air handling unit before being supplied into the occupied space

3.4

underfloor air diffuser

air supply outlet mounted on the raised floor through which the conditioned air produced from the air handling unit is supplied into the occupied space

3.5

thermal plume

movement of the occupied space air in the upward direction caused by the buoyancy effect above the internal heat gain components

Note 1 to entry: Internal heat gain usually includes occupants, lighting and electric equipment.

3.6

space air stratification

formation of a stratified environment in the air in the occupied space, having an elevated temperature with height caused by the thermal buoyancy

3.7

personal thermal comfort system

device, under the control of the occupant, to either heat or cool, or both, the immediate thermal environment of an individual occupant, without affecting the thermal environment of the other occupants

3.8

thermal decay

increase or decrease in temperature of the conditioned air supplied from the air handling unit as it travels through the underfloor plenum, mainly caused by the convective heat transfer from/into the upper surface of the slab and lower surface of the raised floor

3.9

pressurized plenum

underfloor plenum configuration where the conditioned air is blown from the air handling unit into the underfloor plenum to maintain positive pressure in the underfloor plenum relative to the occupied space

3.10

neutral plenum

underfloor plenum configuration where the conditioned air is blown from the air handling unit into the underfloor plenum to maintain almost the same pressure as the occupied space

3.11

ducted plenum

underfloor plenum configuration where the conditioned air is blown from the air handling unit into air ducts in the underfloor plenum

Note 1 to entry: Underfloor air diffusers are connected to ductwork, similar to conventional ceiling based air distribution systems.

3.12

stratification height

height of the virtual horizontal surface separating two zones with different air temperature profiles

3.13

occupied space

volume of the conditioned space vertically between the floor and the ceiling, which can be divided into the lower occupied zone and the upper mixed zone

3.14**lower occupied zone**

volume of the occupied space below the stratification height

3.15**upper mixed zone**

volume of the occupied space above the stratification height

3.16**interior zone**

volume of the occupied space usually farther than 5 m from the exterior envelope, whose thermal loads are not typically affected by the exterior conditions, such as outdoor air temperature and solar radiation

3.17**perimeter zone**

volume of the occupied space adjacent to the exterior envelope, usually within 5 m, whose thermal loads are highly affected by the exterior conditions (e.g. outdoor air temperature and solar radiation)

3.18**underfloor terminal unit**

unit installed under the raised floor at the end of an air distribution system intended to control air flow rate, pressure or temperature, or to mix air flows

4 Symbols and subscripts

Symbol	Quantity	Unit
A	area	m ²
B	buoyancy flux	m ⁴ /s ³
H	height	m
m	number of plumes	–
n	number of diffusers	–
Q	airflow	m ³ /s
T	temperature	°C
W	room convective heat extraction (also known as cooling load)	W
θ	discharge angle from vertical	°
Φ	dimensionless number representing the stratification in the occupied space ^[3]	–
Γ	dimensionless number representing the ratio of momentum to buoyancy forces ^[3]	–

Subscripts	Significance
DA	diffuser discharge air
diff	diffuser
eff	effective
os	occupied space
oz	lower occupied zone
RA	return air

5 Technical specifications and considerations

5.1 Technical specifications

5.1.1 Major approaches to designing underfloor plenums

UFAD systems can take advantage of the underfloor plenum by blowing conditioned air into the occupied space through the underfloor plenum, which allows UFAD systems to operate as the personal thermal comfort system. Typical plenum heights integrated with UFAD systems are 0,15 m to 0,45 m from the structure slab. According to the pressure condition of the underfloor plenum, four different approaches commonly used in designing underfloor plenum in UFAD systems are described in [Table 1](#):

- pressurized plenum;
- neutral plenum;
- a combined feature of pressurized and neutral plenums;
- ducted plenum.

Table 1 — Different design approaches for underfloor plenums

Approach	Description
Pressurized plenum	In the pressurized plenum approach, passive diffusers are placed in the occupied spaces and no local fans in the underfloor air diffusers are needed. Due to the maintained pressure difference between the underfloor plenum and the occupied space, conditioned air can be provided into the occupied space from the underfloor plenum without the operation of local fans in the underfloor air diffusers.
Neutral plenum	Local fans are embedded inside the underfloor air diffusers to provide enough of the conditioned air into the occupied space.
Combined (pressurized + neutral) plenum	This approach is the combined feature of pressurized and neutral plenum designs. The zone AHU or central AHU blows the conditioned air into the underfloor plenum to maintain positive pressure in the underfloor plenum relative to the occupied space. Passive diffusers serve in interior zones having a relatively stable thermal load profile, while under-floor air diffusers integrated with local fans are placed in the perimeter zones where thermal load fluctuates rapidly due to the building envelope.
Ducted plenum	The zone AHU or central AHU supplies the conditioned air into the underfloor plenum through ductwork, similar to conventional ceiling-based air distribution systems. Under-floor air diffusers on the raised floor are connected to the underfloor ductwork to provide the conditioned air from the underfloor plenum into the occupied space.

Details of different approaches in designing underfloor plenums are provided in [Annex A](#). Examples of the two commonly used UFAD system designs in practice are provided in [Annex D](#).

5.1.2 Major types of diffusers

Different types of underfloor air diffusers commonly used in UFAD systems are provided in [Table 2](#).

Table 2 — Major types of underfloor air diffusers

Type	Description
Passive swirl diffuser	The passive diffuser has small openings to supply the conditioned air into the occupied zone with a swirling conditioned air. It allows the zone air and the conditioned air to be mixed from the underfloor plenum. It is usually a round shape diffuser, but a square or rectangular diffuser can be applied with the shape of air openings. Generally, it is preferable to place it in the interior zone instead of perimeter zones.
Displacement ventilation diffuser	In the displacement ventilation diffuser, the air is supplied into the zone with its main velocity component parallel to the floor, which tends to create high stratification.
Variable-area variable air volume (VAV) diffuser	It has internal air regulators like an air damper in the diffuser to control the flow rate of the supply air with automatic or manual control. To control air flow rate or flow velocity of the supply air by motor drive, it commonly requires a motor drive and thermostats of the zone. It is a type of the passive diffuser which does not require fan but still controls supply air volume.
Linear bar grilles	Bar grilles have narrow and long openings which can supply the conditioned air with a targeted direction. When controlling the air flow direction, it is usually placed in the perimeter zones near the exterior windows and walls where the thermal load changes by time.
Fan powered VAV diffuser	The underfloor fan powered VAV diffuser is composed of an inlet, an outlet and control dampers, integrated with the fan operation. The operation of the control dampers and fan is governed by different modes, i.e. heating, cooling and recirculation.
Air permeable carpet tile integrated with perforated access floor	The air permeable carpet tile is laid over the perforated and fully accessible floor system. The system supplies fresh cool air or fresh heated air at a very low velocity up through the double floor, a space that also accommodates wiring and cabling. The rising air carries with it impurities and heat generated by people, appliances, and other sources, continuing upward all the way to air-release slots in the ceiling. This purifying process prevents the recirculation of airborne contaminants in the indoor environment.

Details of different types of underfloor air diffusers are provided in [Annex B](#).

5.1.3 Major types of underfloor terminal units

The thermal environment of perimeter zones is typically more dynamic than interior zones. These spaces have time-variant thermal loads and often require additional heating. Underfloor terminal units in the perimeter zones generally supply a larger volume of conditioned air to control the envelope load than those of the interior zone. Different types of underfloor terminal units commonly used in UFAD systems are provided in [Table 3](#).

Table 3 — Major types of underfloor terminal units

Type	Description
Variable-area VAV diffusers with constant speed heating fan coils	Variable-area VAV diffusers with constant speed heating fan coils are composed of a set of two diffusers and constant-speed fans which allows the underfloor plenum air to be supplied into the occupied space by the pressure difference between the upstream and downstream of the fan. During the cooling operation, the fan is switched off and the volume of the air is modulated by the internal damper depending on the cooling load. During the heating operation, the constant-speed fan is switched on so that return air can be pulled through one diffuser from the occupied space and can be supplied back into the occupied space after heated up by the internal heating coil as illustrated in Figure D.3 .
Variable speed fan coil unit (FCU)	A fan coil unit (FCU), or vertical fan-coil unit (VFCU), is a device that has either a heating or cooling coil, or both, and a fan to either heat or cool, or both, the occupied space without ductwork. Air moves over the coil and the coil heats or cools the air before returning it into the room. The supply air flow rate can adjust in the case of variable speed FCUs. A variable frequency driver (VFD) is a popular equipment to control the speed of the fan motor.
Fan powered VAV with reheat	A VAV unit can change the operational mode either between recirculating the space air or supplying plenum air to the space, or both. It has control dampers to switch the air flow. This allows the conditioned air to be re-heated if it is necessary. The flow rate can be adjustable depending on the space thermal environment.
Natural convection floor convector	Floor convectors are based on the principle of natural air convection. They are designed for secondary room heating.
Floor convector with fan (underfloor fan-coil unit)	Floor convectors use the fan for obtaining forced air convection, achieving higher capacities than natural convection floor convectors. They use secondary (e.g. room, recirculating) air and can also be used for cooling.
Underfloor induction unit	Underfloor induction units provide centrally conditioned primary air (fresh air) to the room. The secondary (room) air is induced, and passed across the heat exchanger used for either additional cooling or heating, or both. The mix of primary and secondary air is supplied to the room.
Decentralised ventilation unit	Decentralised ventilation units are supply and extract units with secondary (room) air addition used for room ventilation and either heating or cooling, or both, of the room.

Details of different types of perimeter terminal units in UFAD systems are described in [Annex C](#).

5.2 Technical performance consideration

5.2.1 Space air stratification

The rated space air stratification of diffusers in different operating conditions (characteristic curve) should be evaluated experimentally. Space air stratification is influenced by discharge angle and effective area of diffusers, supply airflow, number of plumes, number of diffusers and thermal load of the occupied space.

5.2.2 Thermal decay

The rated thermal decay of the underfloor plenum in different operating conditions (characteristic curve) should be evaluated experimentally. Thermal decay of the underfloor plenum is influenced by the supply airflow, insulation of slab and raised floor, airflow pattern within the underfloor plenum, thermal load of the occupied space and air leakage of the underfloor plenum.

5.2.3 Air leakage of underfloor plenum

The rated air leakage of the underfloor plenum in different operating conditions (characteristic curve) should be evaluated experimentally. Air leakage of the underfloor plenum is largely influenced by the construction of the raised floor, especially the locations where columns and diffusers are jointed with the raised floor.

5.2.4 Acoustic performance

Noise can occur when too much airflow is supplied inside the fan-powered diffusers or FCUs. Domestic acoustic regulations can be considered to limit the corresponding noise level.

5.3 Comfort consideration

Occupants are affected by velocity of the air, the vertical air temperature distribution caused by the space air stratification and the discharge temperature coming out of the diffusers. Although ISO 7730 and ASHRAE Standard 55 [1] prescribe 3 °C as the limit for the vertical air temperature difference between head and ankle levels, acceptable stratification can be up to 7 °C depending on the operative temperature of the occupied space.[2] Vertical temperature distribution for thermal comfort shall be considered. Discharge air temperature from the diffusers below 16 °C can cause a cold draft for the occupants and thus the discharge air temperature shall be maintained so that it does not go below 16 °C.

5.4 Maintenance of conformity

Operation and maintenance of the UFAD system shall be performed to meet conformity with conventional HVAC systems. The maintenance check for joints and insulation of a raised floor, space air stratification, thermal decay, air leakage of the underfloor plenum, space air temperature distribution and acoustic performance shall be conducted on a regular basis 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 any change is made to the manufacturing process having an influence on the thermal output.

Table 4 — Maintenance checklist

Category	Contents	Checklist
System specification and installation	— System specification	
	a) Raised floor panel	— Check the joints with column or diffusers
	b) Underfloor diffusers	— Measure thermal resistance of raised floor
	c) Dimensional tolerances	— Check the dust on the diffusers
Technical performance	— Space air stratification	— Measure dimensions of the underfloor plenum
	— Thermal decay	— Measure rated space air stratification
	— Air leakage of underfloor plenum	— Measure rated thermal decay
	— Acoustic performance	— Measure rated air leakage of underfloor plenum
		— Measure noise level