INTERNATIONAL STANDARD

ISO
24365

First edition
2022-08

Radiators and convectors — Methods and rating for determining the heat output

Reference number
ISO 24365:2022(E)

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Contents

Page

Foreword

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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).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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

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.

Introduction

This document results from the recognition that the heating appliances falling into the field of application hereinafter stated are traded on the basis of their thermal output.

To evaluate and compare different appliances it is therefore necessary to refer to a single stipulated value, hereinafter called the standard rated thermal output.

In addition, for low temperature systems, a standard low temperature thermal output is given.

The standard thermal outputs (standard rated thermal output and standard low temperature thermal output) are a defined value taken from the characteristic equation.

The pre-requisites of the standard thermal outputs, as defined by this document, are the following:

— to be representative of the actual output of the appliance in different operating conditions;

— to be reproducible within the tolerances defined by this document, taking into account the state of measuring techniques;

— to be representative of the thermal outputs, obtainable under the same test conditions, of any identical sample taken out of the current production (within the tolerances defined by this document, taking into account the state of measuring techniques and methods of manufacture).

Radiators and convectors — Methods and rating for determining the heat output

1 Scope

This document defines procedures for determining the standard thermal outputs and other characteristics of radiators and convectors installed in a permanent manner in construction works, fed with water or steam at temperatures below 120 °C, supplied by a remote energy source.

This document specifies the laboratory arrangements and testing methods to be adopted, the admissible tolerances, the criteria for selecting the samples to be tested and for verifying the conformity of the current production with the samples tested at the initial test.

This document also defines the additional common data that the manufacturer shall provide with the product in order to ensure the correct application of the products.

This document does not apply to fan-assisted radiators, fan-assisted convectors and trench convectors or to independent heating appliances.

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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/

3.1.1
heating appliance
device having the purpose of transferring heat in order to provide specific temperature conditions inside buildings

3.1.2
independent heating appliance
self-contained *heating appliance* (3.1.1) which does not need to be connected to a remote energy source (e.g. a boiler) as it contains its own energy source (e.g. gas fired appliances, electric appliances, air to air heat pump appliances)

3.1.3
radiator
heating appliance (3.1.1) produced with different materials (e.g. steel, aluminium, cast-iron) and with different designs (e.g. plate type, column type, tube type, finned tube type), which emits heat by free convection and radiation

3.1.4
sectional heating appliances
heating appliance (3.1.1) manufactured in sections of identical design and traded in this form, which can be joined together into modular assemblies so that the desired output can be obtained

Note 1 to entry: Mainly applied to *radiators* (3.1.3).

3.1.5
convector
heating appliance (3.1.1) which emits heat almost entirely by free convection

Note 1 to entry: A convector comprising at least a heat emitter and a casing which provides an unheated convective chimney of defined height.

3.1.6
skirting convector
special *convector* (3.1.5) of limited height running along the base of an interior wall

3.1.7
dry heating surface
secondary heating surface
portion of the heat emitting surface which is in contact with air only (e.g. fins projecting from the wet surface)

3.1.8
family of heating appliances
group of *heating appliances* (3.1.1) of similar design and construction and of identical material, positions of primary fluid connections and other related variables that particularly affect the conditions of flow of the primary fluid within the *heating appliance* (3.1.1)

3.1.9
model
heating appliance (3.1.1) of defined height, length and depth within a type

3.1.10
range of heights
difference between the maximum and minimum height of the *models* (3.1.9) in a type

3.1.11
module
<heating appliance>
reference length of the useful portion of a *heating appliance* (3.1.1)

Note 1 to entry: The module coincides with:

— the section, in the case of *sectional heating appliances* (3.1.4);

— a length of 1 m, in the case of non-sectional *heating appliances* (3.1.1);

— a finned length of 1 m, in the case of finned tube *convectors* (3.1.5).

3.1.12
sample
representative *heating appliance* (3.1.1) used for the determination of one or more of the performance characteristics

3.1.13
inlet water temperature
bulk temperature of the water entering the *heating appliance* (3.1.1)

3.1.14
outlet water temperature
bulk temperature of the water leaving the *heating appliance* (3.1.1)

3.1.15
temperature drop
difference between *inlet* (3.1.13) and *outlet water temperature* (3.1.14)

3.1.16
mean water temperature
arithmetical mean of *inlet* (3.1.13) and *outlet water temperature* (3.1.14)

3.1.17
reference air temperature
air temperature measured on the vertical line at the centre of the test booth, 0,75 m above the floor level

3.1.18
excess temperature
difference between *mean water temperature* (3.1.16) and *reference air temperature* (3.1.17)

3.1.19
standard excess temperature
excess temperature (3.1.18) of 50 K as determined in the standard conditions

Note 1 to entry: *Inlet water temperature* (3.1.13) of 75 °C, *outlet water temperature* (3.1.14) of 65 °C and *reference air temperature* (3.1.17) of 20 °C.

3.1.20
air pressure
measured value at the test site

3.1.21
water flow rate
amount of water flowing through the *heating appliance* (3.1.1) per unit of time

3.1.22
standard water flow rate
water flow rate (3.1.21) relating to standard test conditions

3.1.23
standard rated thermal output
thermal output of a *heating appliance* (3.1.1) defined at 50 K *excess temperature* (3.1.18)

3.1.24
standard low temperature thermal output
thermal output of a *heating appliance* (3.1.1) defined at 30 K *excess temperature* (3.1.18)

3.1.25
characteristic equation
power function with a specific characteristic exponent that gives the thermal output as a function of the *excess temperature* (3.1.18) at constant *water flow rate* (3.1.21)

3.1.26
standard characteristic equation
characteristic equation (3.1.25) which is valid for *standard water flow rate* (3.1.22) and from which the standard thermal output can be found for the *standard excess temperature* (3.1.19) of 50 K

3.1.27
test installation
combination of:

— test booth and other related parts, and

— measuring instruments and related equipment

3.1.28
test system
combination of:

— *test installation* (3.1.27), and

— *master radiators* (3.1.34)

3.1.29
pressure drop
difference of pressure between water inlet and water outlet of the *heating appliance* (3.1.1)

3.1.30
supplementary test
test for the purpose of establishing the effect of minor technical modifications on the thermal output of *radiators* (3.1.3) that have already been tested

3.1.31
radiated heat output factor
Sk
assumed ratio between the radiation heat output and the overall heat output of the *radiator* (3.1.3), which is only valid for *air pressure* (3.1.20) correction purposes

3.1.32
exponent n_p
exponent for the *air pressure* (3.1.20) correction of the measured heat output of the *radiator* (3.1.3)

3.1.33
emissivity
ε
ratio of energy radiated by a particular material to energy radiated by a black body at the same temperature

3.1.34
master radiator
sample (3.1.12) used for the calibration of *test installations* (3.1.27)

Note 1 to entry: Master radiators are used to determine repeatability and reproducibility of the results of the *test installations* (3.1.27) (see 5.2.3).

3.2 Symbols and units of measurement

Table 1 — Symbols, quanties and units of measurement

Quantity	Symbol	Unit
Thermal output	Φ	W
Standard thermal output	Φ_S	W
Modular thermal output	Φ_L	W
Reference value of a master radiator	Φ_0	W
Reference value of a primary set of master radiators for interlaboratory comparisons	Φ_M	W
Electrical method heat losses	Φ_V	W

Table 1 *(continued)*

Quantity	Symbol	Unit
Electric power	P_{el}	W
Thermodynamic temperature	T	K
Temperature	T	°C
Inlet water temperature	T_1	°C
Outlet water temperature	T_2	°C
Temperature drop	T_1-T_2	K
Mean water temperature	T_m	°C
Reference room air temperature	T_r	°C
Excess temperature	ΔT	K
Specific heat capacity	c_p	J/kg·K
Specific enthalpy	h	J/kg
Inlet water enthalpy	h_1	J/kg
Outlet water enthalpy	h_2	J/kg
Water flow rate	q_m	kg/s
Standard water flow rate	q_{ms}	kg/s
Pressure	p	kPa
Maximum operating pressure/resistance to pressure	p_{max}	kPa
Pressure drop	Δp	kPa
Repeatability tolerance	S_0	-
Reproducibility tolerance	S_m	-
Overall height of the heating appliance	H	m
Range of heights	H_r	m
Overall length of the heating appliance	L	m
Length of a section	L_S	m
Number of sections	N_S	-
Thermal resistance	R	m²·K/W
Time interval	τ	s
Radiated heat output factor	Sk	-
Emissivity	ε	-

4 Selection of heating appliances to be tested

4.1 Classification

4.1.1 Heating appliances shall be grouped into families and types according to the definition in this document. A family can include different types.

4.1.2 For the purposes of determining catalogue outputs, a family shall be divided into a number of separate types (in a family of radiators there can, for example, be single or double panels, with or without convector surfaces, using the same basic components).

4.1.3 The output of each model shall not be greater than 3 500 W and the minimum thermal output of the selected model shall be not less than 200 W at standard excess temperature.

On request of the manufacturer, lower thermal output can be tested and the deviation from the previous requirements shall be registered in the test report.

4.2   Selection of models to be tested for determining the thermal outputs of a type

4.2.1   Selection of models to be tested when the variable characteristic dimension is the overall height and the cross-section of the variable part is constant

4.2.1.1   When a type includes only models of height 300 mm and greater, the models to be tested within that type shall be selected in accordance with 4.2.1.2, 4.2.1.3, 4.2.1.4 and 4.2.1.5.

If the type also includes heights below 300 mm, the minimum height below 300 mm shall be tested in addition to the above models.

For a type in which all heights are below 300 mm, only the minimum and the maximum height shall be tested.

4.2.1.2   The minimum number of models to be tested within a type is determined by the range of heights as shown in Table 2.

Table 2 — Minimum number of models to be tested

Range of heights (m) $H_r = H_{max} - H_{min}$	Number of models to be tested
≤ 1 m	3
> 1 m	4

4.2.1.3   The minimum length of finned coil of the models to be tested shall be 1 m or the closest to 1 m. For skirting convectors only, the finned coil length shall be the closest to 3 m. In the case of sectional radiators, having height $H \le 1$ m, the minimum number of sections shall be 10 or the minimum length 0,8 m. For sectional radiator having height greater than 1 m, the minimum length shall be 0,45 m.

For towel radiators see 4.2.2.

4.2.1.4   In the case of $H_r \le 1$ m, the models to be tested shall be three; the minimum and maximum height of the range and an intermediate height so that H_{int} is equal to or the closest value greater than:

$$H_{int} = H_{max} - \frac{1}{2} \times H_r$$

where H_{max} is the maximum height of the type.

4.2.1.5   In the case of 1 m < H_r ≤ 2,5 m, the models to be tested shall be four; the minimum and maximum height of the range and two intermediate heights so that H_{int1} and H_{int2} are the closest values respectively to:

$$H_{int1} = H_{max} - \frac{1}{3} \times H_r$$

and

$$H_{int\,2} = H_{max} - \frac{2}{3} \times H_r$$

4.2.2 Selection of models to be tested when the variable characteristic dimension for the type is other than the overall height

4.2.2.1 General principle

The minimum number of models to be tested is three, having the same overall height and respectively, the minimum, intermediate and maximum value of the relevant characteristic dimension (see 4.2.1.4).

The measured values shall be used to determine the characteristic equation of the type.

For the equation to be valid, all the measured thermal outputs shall fall within ±2 % of the prediction of the equation.

If any value falls outside this range, the type shall be divided and new equations derived for each subset of the results.

4.2.2.2 Selection of models to be tested when a type includes horizontal parallel flow models

This procedure applies to tubular radiators classified as "towel or bathroom radiators", according to Figure G.3.

If a type includes horizontal parallel flow models, with different heights and lengths, the thermal outputs of models having L_{min} and L_{max} respectively shall be tested. If there are more than three heights, the thermal output for all heating appliances having L_{min} and L_{max} respectively shall be established using the respective characteristic equation. For each height, the thermal output for models having length included between L_{min} and L_{max} shall be linearly interpolated. The adopted procedure shall be noted in the test report.

4.2.2.3 Straight or curved towel or bathroom radiator

For "towels and bathroom radiators" having similar external size (height, length, external diameter of the tubes) and different shape of horizontal tube (straight or curved):

If it is proved by at least two tests that the difference between the thermal outputs of the model having straight tubes and the model having curved tubes, is within ±4,0 %, then the catalogue data of the models having curved tubes can be assumed equal to the equivalent models having straight tubes.

If the difference exceeds ±4,0 % the models are classified as a different type and tested for any specific geometry.

4.2.2.4 Towel and bathroom radiator water circulation

For "towel and bathroom radiators" having the same external size (height, length, depth and external diameter of the tube), but different internal circulation of the hot water, if it is proved by at least two tests that the difference between the thermal outputs of the models having different internal circulation is within ±4,0 %, then the catalogue data of all the models can be assumed to be equal. If the difference exceeds ±4,0 % the models are classified as different type and so tested for any specific internal water circulation.

4.2.2.5 Different surface treatments (chromed, polished)

Models having the same external size (height, length, depth and external diameter of the tube), but different surface treatment (i.e. painted, chromed or mechanically polished), shall be tested as follows:

a) Models painted and chromed shall be tested according to 4.2;

b) For models having other surface treatments (e.g. satinated or polished) the minimum number of samples to be tested shall be defined as follows:

1) for each other type, two models, having the minimum and the maximum heat output as measured on painted model, shall be tested only to determine the less favourable reduction coefficient;

2) the thermal output of all the models shall be calculated using the reduction coefficient determined according to 1).

4.2.2.6 Influence of water flow rate on thermal output

On request of manufacturers, the influence of water flow rate on thermal output shall be verified.

In this case, additional characteristics shall be tested, setting half and double standard mass flow.

4.3 Testing samples submission and identification

4.3.1 On initial application for the testing of a family of heating appliances, or of a type within a family, heating appliance samples and product drawings shall be submitted to the testing laboratory.

Product drawings shall be submitted by the manufacturer.

4.3.2 The product drawings shall:

— show all dimensions and features having an influence on the heat emission, including the detail of welds or other assembly methods used;

— state the type of material and the nominal material thicknesses of wet or dry surfaces, with the thickness tolerances, and type of paint;

— be identified by the drawing number and the date of revision.

4.3.3 Before proceeding with the thermal output testing, the laboratory shall identify the appliance against the drawing and shall note conformity of the sample with the drawing in respect of:

— dimensional tolerances given in Table 3;

— material thickness tolerances of convective surfaces, shown on the product drawings.

The laboratory shall also measure the mass and the water content of the sample models. The relevant values shall be reported in the test report.

The models for test shall be selected as specified in 4.2.

4.3.4 Samples of heating appliances already in production shall be taken from the production line or manufacturer's stock by the laboratory or its authorized representative.

Samples of prototype appliances shall be submitted by the manufacturer.

Table 3 — Dimensional tolerances

Dimensions in millimetres or %

Overall height[a] of heat exchanger	Panel radiators	Steel radiators — Tubular	Sectional	Lamellar	Cast iron (per section)	Extruded aluminium (per section)	Cast aluminium (per section)	Finned tube convectors
Overall height[a] of heat exchanger								**Height of casing (HC)**
H ≤ 250	+ 4 / – 2	+ 4 / – 2	±2	+ 4 / – 2	±3,0			+ 4 / – 2
250 < H ≤ 500	+ 4 / – 2	+ 4 / – 2	±2	+ 4 / – 2	±3,5	±2,5	±2,5	+ 4 / – 2
500 < H ≤ 600	+ 5 / – 2	+ 5 / – 2	±2	+ 5 / – 2	±4,0			+ 5 / – 2
600 < H ≤ 900	+ 5 / – 2	+ 5 / – 2	±2	+ 5 / – 2				+ 5 / – 2
900 < H	+ 6 / – 2	+ 6 / – 2	±2	+ 6 / – 2				+ 6 / – 2
Overall depth of heat exchanger								**Depth of casing (DC)**
All measures	+ 4 / – 3	±1,5	±2		±2	±0,65	+ 0 / – 1	+ 4 / – 3
D ≤ 100				±2				
100 < D				±3				
Curved models		±5	±5					
All measures		±1,5 %	±1,5 %	±1,5 %	±1,5 %	±0,65	±0,2	**Length of casing (LC)**
L ≤ 1 000	±5							±5
1 000 < L	±0,5 %							±0,5 %
Height of convector surfaces	+ 3 / – 1,5		+ 3 / – 1,5		+ 3 / – 1,5	+ 0,2 / – 0	+ 0,2 / – 0,8	Height of fins (HF): ±1
Depth of convector surfaces	±1,5		±2		±1,5	+ 0,2 / – 0	+ 0,2 / – 0,8	Depth of fins (DF): ±1,5
Distance between connection centre			±0,5		±0,5	+ 0 / – 1,2	+ 0,8 / – 1,2	±2
Material thickness of convectors	±0,06	±0,06						Material thickness of fins (TF): ±0,05
								Number of fins (NF): ±5 %
								Finned length: ±5 %
								Distance casing to fins (TA): ±5

a For tubular radiators, height refers to the dimension across header sections regardless of orientation of wall mountings.

Table 3 *(continued)*

Overall height[a] of heat exchanger	Steel radiators			Cast iron (per section)	Extruded aluminium (per section)	Cast aluminium (per section)	Finned tube convectors
	Panel radiators	Tubular	Sectional				
			Lamellar				Distance casing to fins (BA)
							±5

[a] For tubular radiators, height refers to the dimension across header sections regardless of orientation of wall mountings.

4.4 Supplementary test

Upon manufacturer's request, minor technical modifications can be investigated.

The testing laboratory investigates the effect of the change on heat output.

If the supplementary test reveals a deviation within ±4,0 % of the measured standard rated thermal output, the manufacturer can declare the old value of the standard thermal output.

If the difference exceeds ±4,0 % the models are classified as a different type in accordance with 4.2.

The findings of the supplementary test shall be demonstrated as follows:

— in the case of an assessment based on a visual check: by a written confirmation with the reference to the new drawing submitted by the manufacturer;

— in the case of measurements: by a complete test report.

5 Laboratory equipment and test methods

5.1 Principle

The aim of the test is to determine the standard thermal outputs of the heating appliance using its standard characteristic equation, which shall be obtained according to 5.4.5.

5.2 Apparatus

5.2.1 Test system

For the purposes of this document, a test system shall consist of:

a) a test installation;

b) a set of three master radiators built according to 5.2.3.

For the purposes of this document, test installations are classified as reference and approved.

5.2.2 Reference test installation

5.2.2.1 General

The reference test installation shall contain the following equipment:

a) a closed unventilated booth, comprising the test space within which the heating appliance under test shall be installed, equipped with water cooled surfaces to maintain specific thermal conditions independent of the external ambient, built according to 5.2.2.2;

b) apparatus for cooling the water circulating in the walls of the closed booth;

c) a primary heating circuit feeding the appliance under test, built in accordance with 5.4;

d) measuring and checking instruments in accordance with the requirements of 5.2.5 and 5.2.6.

5.2.2.2 Reference test booth

5.2.2.2.1 Test booth dimensions

The test booth shall have the following internal dimensions:

— length: (4 ± 0,02) m;

— width: (4 ± 0,02) m;

— height: (3 ± 0,02) m.

5.2.2.2.2 Test booth construction

The test booth shall be constructed with sandwich panels cooled by water (see Figure 1). The internal surface of the booth shall be smooth and made from flat sheets of steel. The sandwich panels (see Figure 1 and Figure 2) are made up of:

— a steel panel, water cooled;

— insulating foam injected between the steel panel and an external steel sheet, to form a single self-supporting body;

— an external steel sheet, 0,6 mm nominal thickness.

The steel water cooled panels (see Figure 3) are made up of two sheets welded together:

— one flat having 2 mm thickness;

— the other of 1 mm thickness having undulating shape to form waterways with a cross-section approximately 150 mm^2.

The thickness of the insulating foam layer shall be 80 mm. The minimum overall thermal resistance of each wall, floor and ceiling shall be 2,5 m^2 K/W. The wall behind the appliance under test is made by the same sandwich panels but it is disconnected from the cooling system (the steel panels are empty). The inside surfaces of the test booth shall be covered with a dull paint having an emissivity of at least 0,9. The panels are assembled so that the structure of the test booth is self-supporting, without thermal bridges (see Figure 4). The connections of the cooling panels to the circuit are made following a three-pipe circuit scheme (see Figure 5). The holes allowing water and electric connections with the outside of the test booth are provided with devices for air tightness.

5.2.2.2.3 Tightness of the test booth

The test booth construction shall be sufficiently tight to prevent uncontrolled air infiltration.

5.2.2.2.4 Cooling system

The water-cooling system shall be designed in such a manner that at the highest admissible output of the testing appliance, the temperature difference occurring on the cooled internal surfaces of the test booth will not be more than ±0,5 K compared with the average temperature of all cooled surfaces. In order to ensure this, each panel shall be supplied with a flow rate of at least 80 kg/h per m^2 of internal surface. This condition is a pre-requisite for operating the test booth.

During the tests the average temperature of the cooled internal surface shall be regulated so that the reference air temperature will be (20 ± 0,5) °C and will conform to steady-state conditions.

The surface average temperature is the mean of the inlet and outlet water temperatures of the relevant surface.

5.2.2.3 Measurements in the booth

5.2.2.3.1 Temperature measurements in the booth

Temperature measurements shall be made in the booth:

— to determine the reference room temperature;

— to monitor the thermal state of the test installation.

5.2.2.3.2 Air temperature measuring points

On the central vertical axis of the booth:

a) at the reference air temperature point 0,75 m from the floor,

b) at the following additional points:

    1) 0,05 m from the floor,

    2) 1,50 m from the floor,

    3) 0,05 m from the ceiling.

Dimensions in millimetres
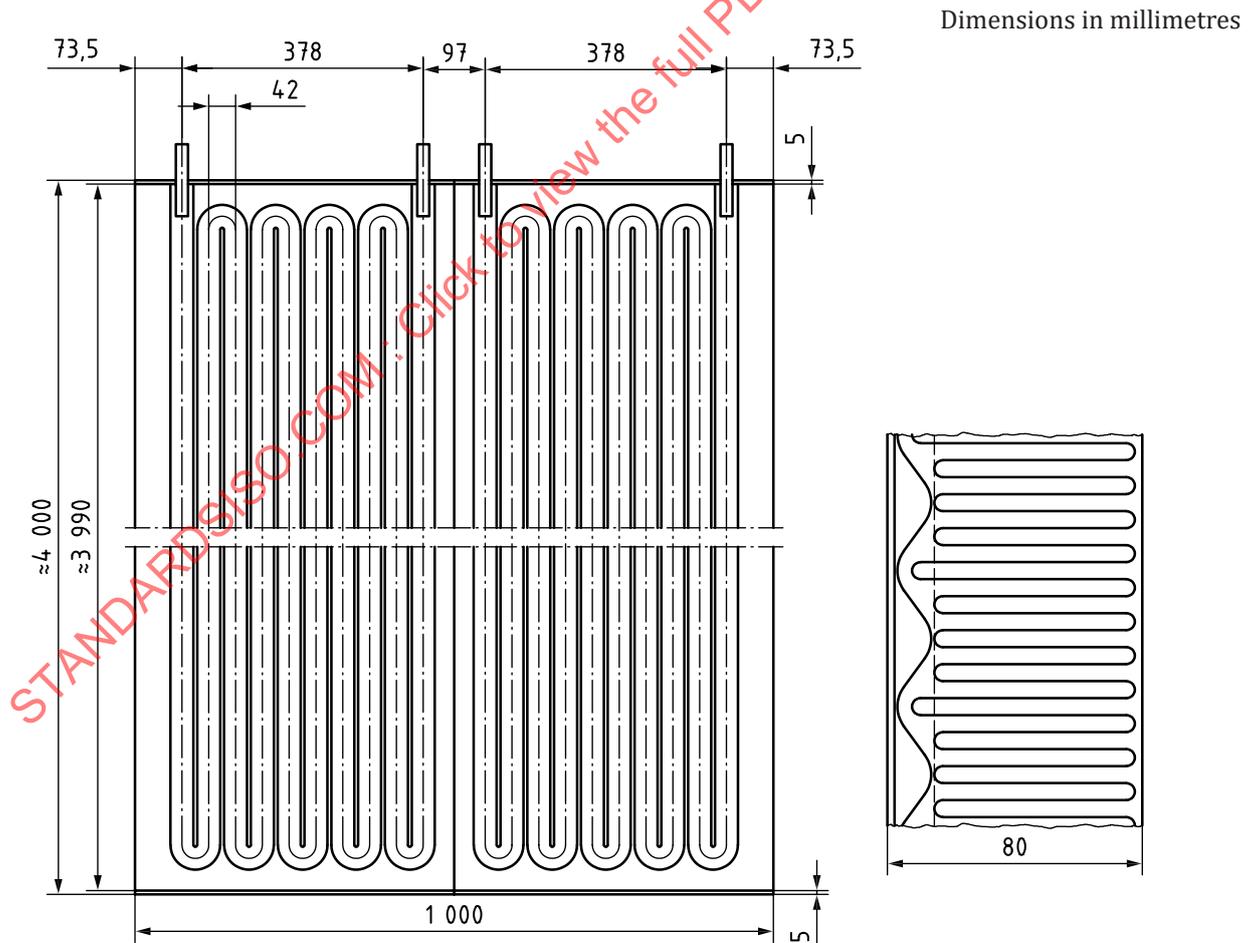
Figure 1 — Sandwich panel cooled by water

5.2.2.3.3   Temperatures of the internal surfaces

On the back beside wall apart from the central point, a point on the centre axis at 0,5 m from the floor.

The surface temperatures (excluding those of the wall behind the heating appliance) shall be maintained within a ±0,3 K spread.

5.2.2.3.4   Other measurements

Air pressure.

5.2.3   Master radiators

5.2.3.1   General

The purposes of the master radiators are the following:

a) to verify that the reproducibility of test values among test installations is within the limits set by this document;

b) to verify that reference and approved test installations give test results within the limits set by this document;

c) to establish a common basis for all test installations in verifying that the repeatability of test values in each laboratory is within the limits set by this document.

To verify the reproducibility among test installations built to the present document, a single set of master radiators constructed and verified according to this document will be circulated among reference test installations to determine the respective Φ_0 and Φ_M values (see 5.2.4.3.3).

This single set of master radiators is named "primary set". Each laboratory shall equip itself with a set of master radiators constructed and verified to this document. This set, named "secondary set", shall be used to verify the repeatability of the test installation. The secondary set of one reference test booth, shall be used to verify the reproducibility of approved test installations.

Dimensions in millimetres
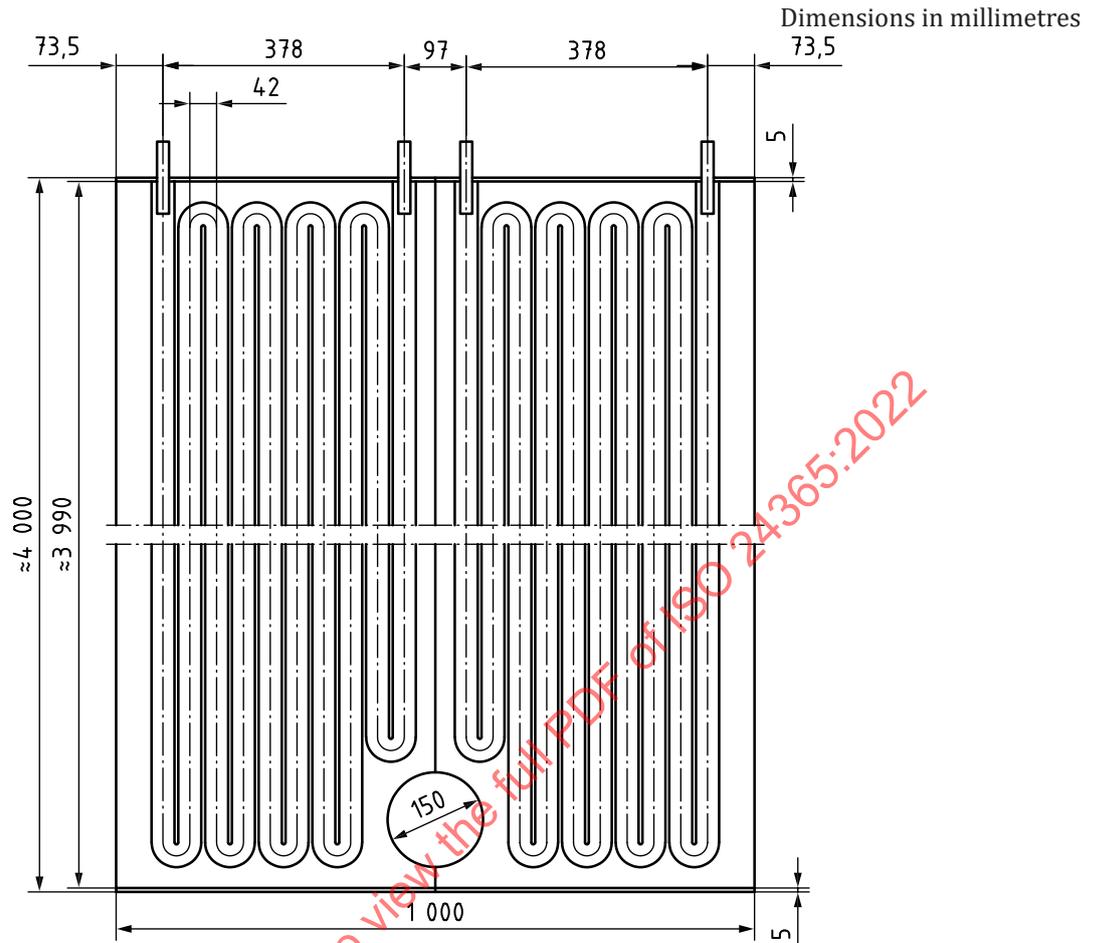
Figure 2 — Sandwich panel cooled by water with hole for external connections

Dimensions in millimetres
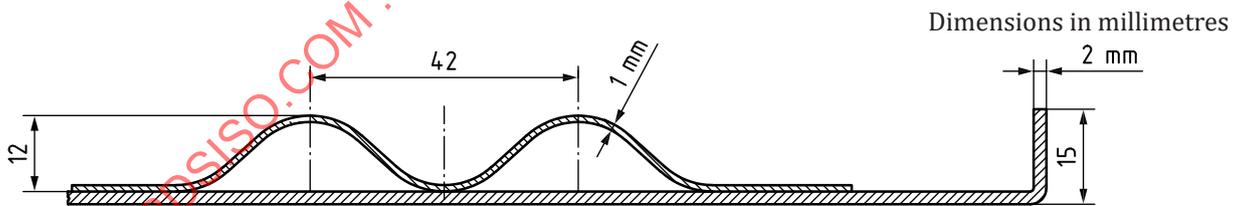
Figure 3 — Steel water cooled panel cross-section

15
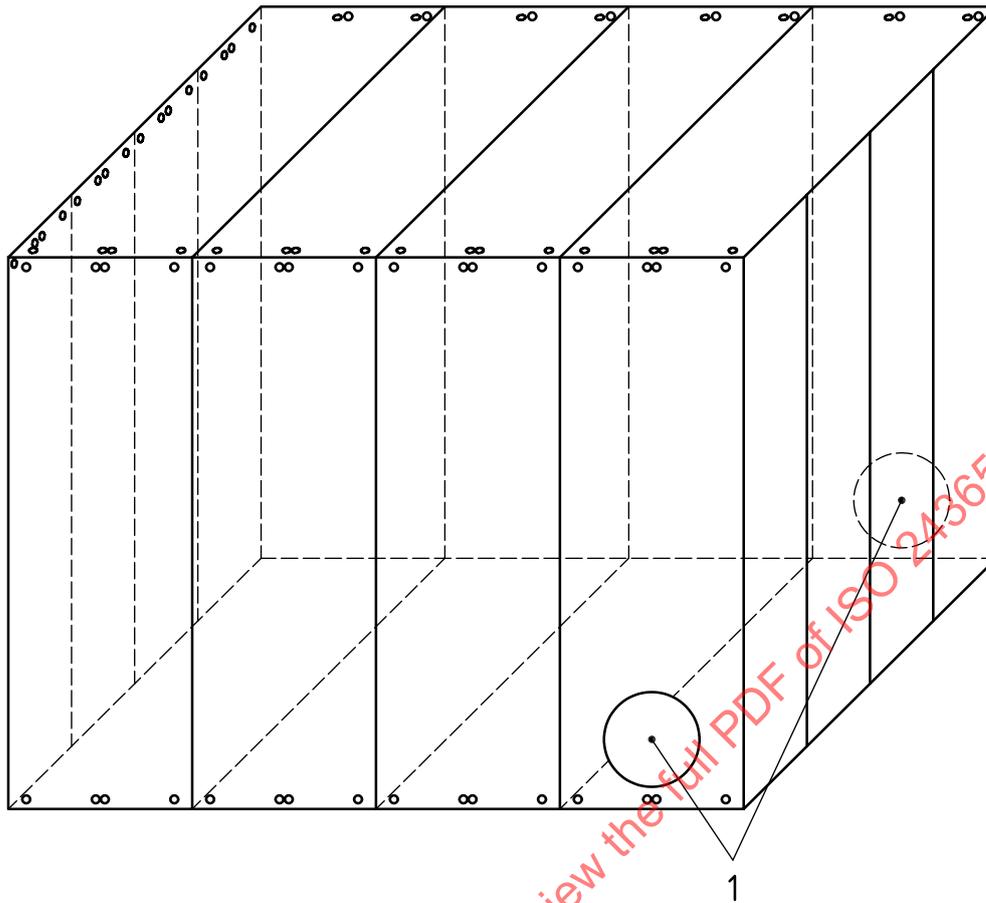
Key

1   air tight opening for electric and water connections

Figure 4 — Panel assembly
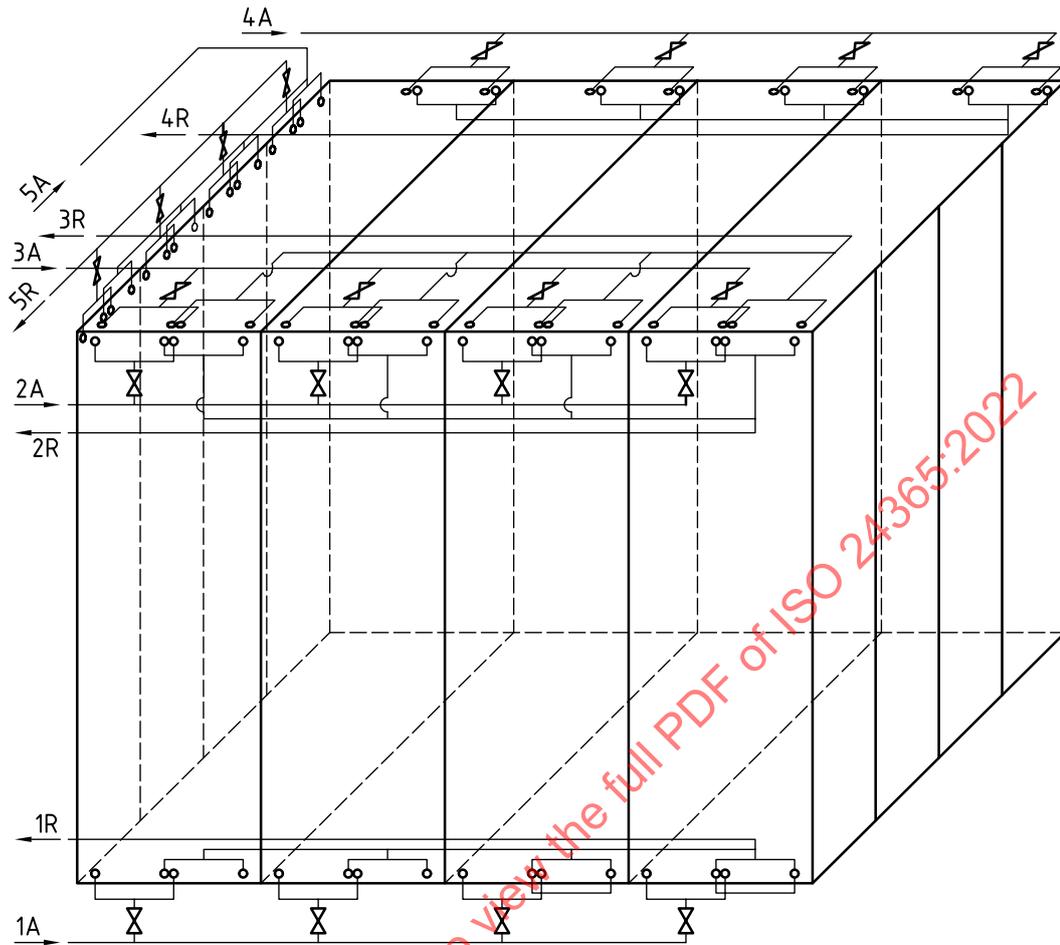
a) Water piping scheme
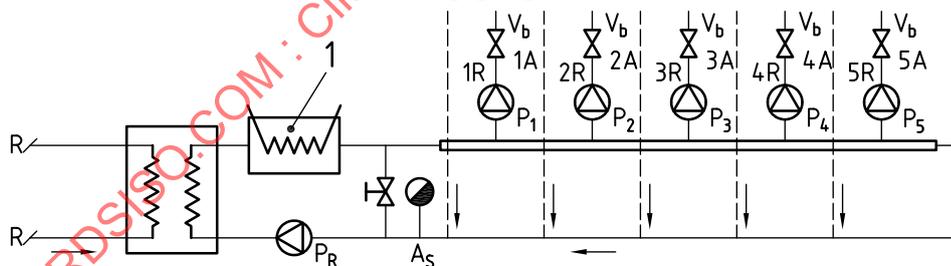
b) Main chilled water circuit (example)

Key

1   electric re-heater

R   refrigerant circuit connection

A_s air separator

Figure 5 — Cooling circuits

5.2.3.2   Determination of Φ_0 and Φ_M values of master radiators (primary set)

Each reference test installation shall state a single Φ_0 reference value for each master radiator. This Φ_0 reference value can be derived from the results of more than one test.

A mean value shall be calculated from the reference values stated by the reference test installations, having discarded aberrant values. This shall be taken as the reference value Φ_M of each master radiator.

The Φ_0 reference value, submitted by each reference test installation shall be within ±1 % (S_m tolerance), of the reference value Φ_M for each master radiator.

5.2.3.3 Dimensions

The main dimensions of the three master radiators are given in Figure 6, Figure 7 and Figure 8.

5.2.3.4 Material

The master radiators shall be constructed from X5CrNiMo 17-12-2 stainless steel.

5.2.3.5 Construction

Master radiators shall be constructed according to the relevant specifications contained in this document.

5.2.3.6 Dimensional verification

Master radiators shall be dimensionally verified according to the procedure contained in this document (see Annex A) and a complete report as requested by this document shall be prepared and kept available for any further check.

5.2.4 Verification of test installation repeatability and reproducibility

5.2.4.1 General principles

This subclause deals with the verification of test installations built in accordance with this document (reference test installations). It also describes the procedure for the subsequent approval of test installations built according to other designs (approved test installations).

All test installations shall be verified for:

— constructional conformity: any statement concerning thermal outputs shall be accompanied by a statement concerning the test conditions in which the stated outputs have been obtained;

— repeatability: within a tolerance S_0 accepted when testing one individual sample of the same master radiator in the same test installation at short- or long-time intervals;

— reproducibility: within a tolerance S_m accepted when testing one individual set of master radiators in different test installations.

Dimensions in millimetres
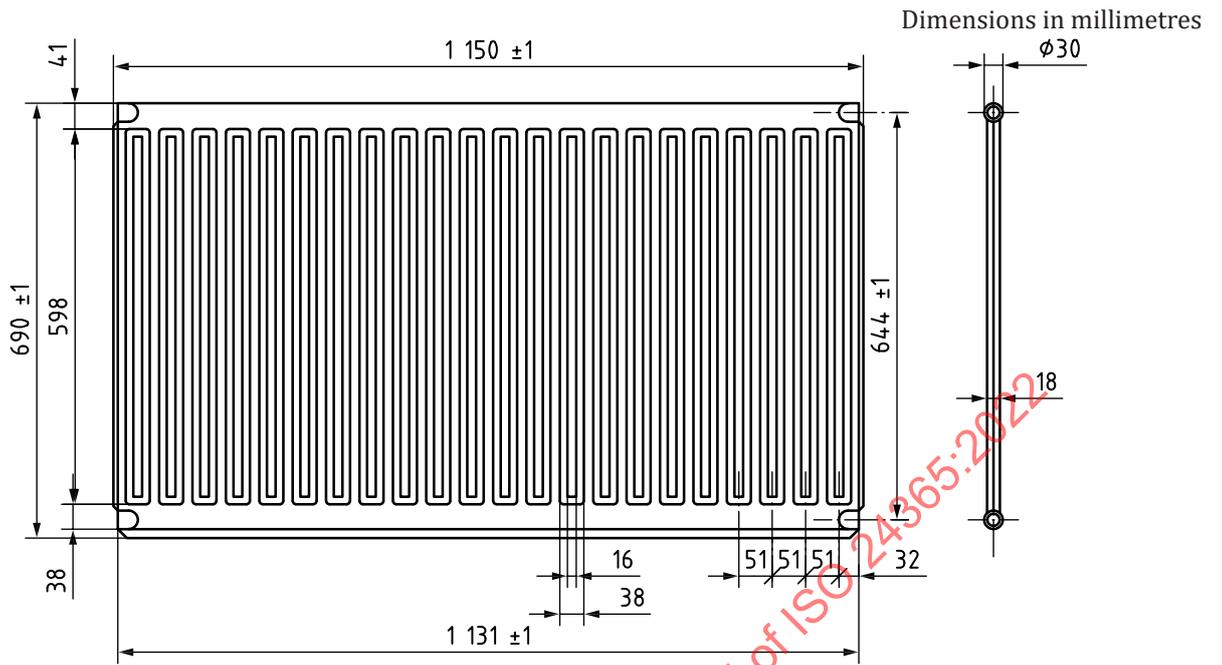
Figure 6 — Master radiator No. 1

Dimensions in millimetres

Key

X   detail of pipes welding
1   pipe thread ISO 7-1/1 Rp 1/4
2   pipe thread ISO 7-1/1 Rp 3/4
3   38 pipes

Figure 7 — Master radiator No. 2
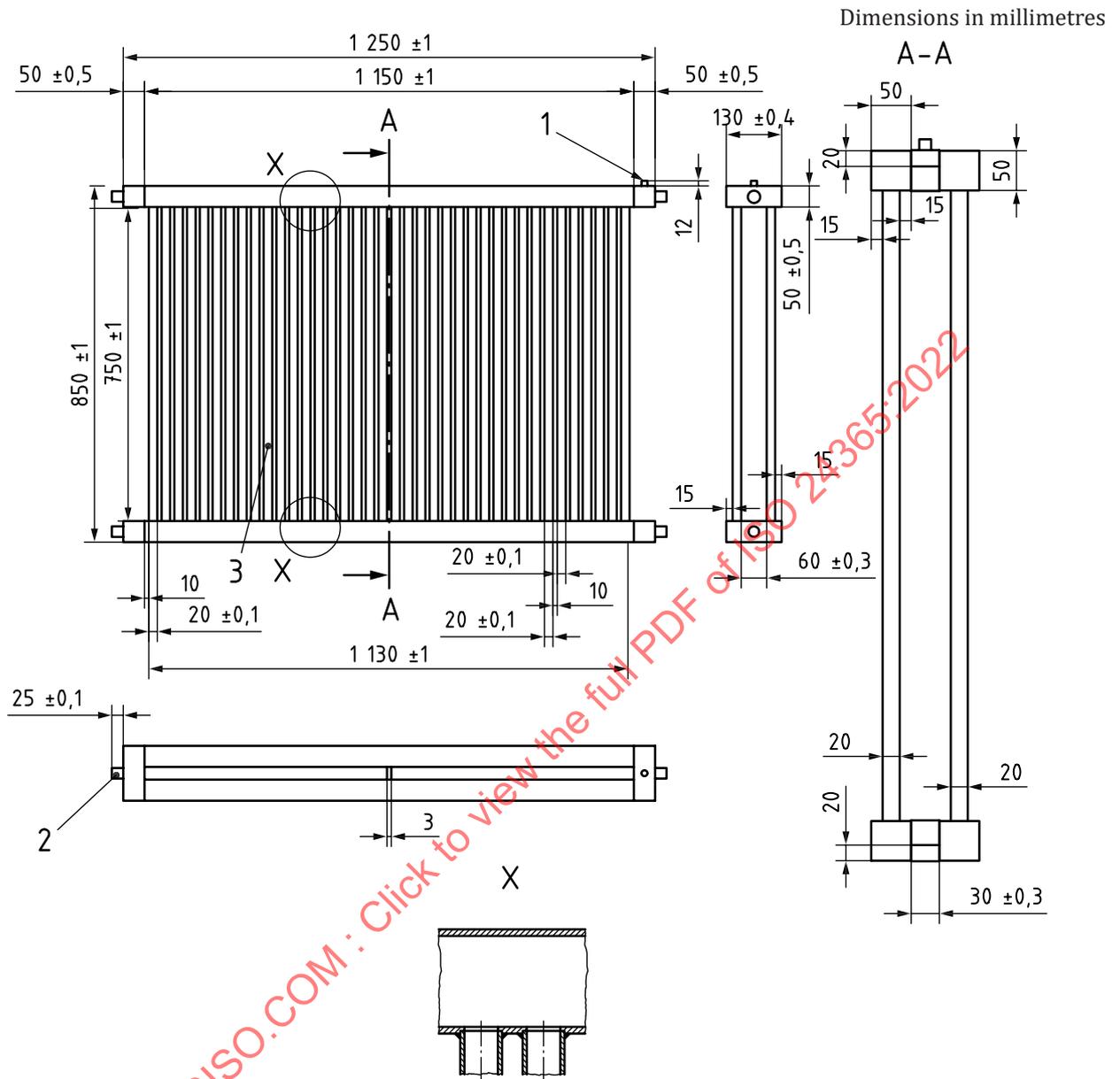
Key
X   detail of pipes welding
1   pipe thread ISO 7/1 Rp 1/4
2   pipe thread ISO 7/1 Rp 3/4
3   38 pipes

Figure 8 — Master radiator No. 3

Only test installations constructed in accordance with 5.2.2 can be nominated as reference test installations.

Only reference test installations shall be used to determine the reference value Φ_M of master radiators. Approved test installations can operate provided that their repeatability and reproducibility, as well as their constructional conformity, has been verified with a reference test installation.

The reference value Φ_M for each master radiator is recorded in Annex H and the list of reference test installations is indicated in Annex I.

5.2.4.2 Test installation verifications

5.2.4.2.1 Reference test installations

— **Constructional conformity:**

The laboratory shall state the conformity to this document.

— **Repeatability:**

The testing laboratory shall use its own set of master radiators (secondary set) to determine the repeatability tolerance S_0 of the test installation.

Using these master radiators, heat output tests shall be carried out in accordance with 5.3 and 5.4.

The results of 10 consecutive tests shall be comprised within a 1 % spread (tolerance S_0).

— **Reproducibility:**

The reproducibility shall be verified using the primary set of master radiators. The test results (carried out in accordance with 5.3 and 5.4) shall be within ±1 % (tolerance S_m) of the Φ_M value of each master radiator.

5.2.4.2.2 Approved test installation

The laboratory shall describe the complete specifications suitable for the identification of the test installation and the operating conditions (constructional conformity), stating that these specifications are those in which the repeatability and reproducibility verifications have met the tolerances set in this document.

The statement shall be undersigned by the reference laboratory with which the reproducibility verifications have been made at the same time as repeatability and reproducibility verification.

— **Repeatability:**

The procedure given in 5.2.4.2.1 shall be followed.

The laboratory shall use its own set of master radiators (secondary set).

— **Reproducibility:**

The reproducibility shall be verified using the secondary set of a reference test system. The verification statement shall be countersigned by the relevant reference test laboratory.

The test installation shall determine a single Φ_0 reference value for each master radiator. This Φ_0 reference value can be derived from the results of more than one test.

The Φ_0 reference value, submitted by the test installation, shall be within ±1 % (tolerance S_m) of the repeatability test value for each master radiator (see 5.2.3.2) obtained in the reference test installation with which the verification has been made.

Test installation, conforming with the repeatability tolerance S_0 and reproducibility tolerance S_m can operate as approved test installation.

5.2.4.3 Periodic verification of test installations

5.2.4.3.1 General

Verification tests shall be carried out periodically to ensure continuing conformity of test installations. The periodic verification of test installation shall be carried out according to Annex H.

5.2.4.3.2 Constructional conformity

The test installation shall be periodically checked for constructional conformity.

5.2.4.3.3 Repeatability

Using its own set of master radiators (secondary set), the laboratory shall carry out an output test at least every three months. The result shall fall within the 1 % spread (S_0 tolerance) obtained from the initial 10 consecutive tests.

5.2.4.3.4 Reproducibility

All test installations shall be periodically verified using the primary set of three master radiators of the reference test system with which the initial reproducibility verification was made, following the procedures described in 5.2.4.2.1 and 5.2.4.2.2.

5.2.5 Accuracy of measuring instruments and devices

5.2.5.1 General

In order to facilitate easy processing and a safe documentation of measurement data, all measurements can be recorded as electric values.

5.2.5.2 Mass

For the weighing method, a weighing machine with a maximum error of 2 g at 10 kg shall be used to measure the water collected in the measuring vessel.

5.2.5.3 Time

The time taken to collect the water shall be measured with a timer connected to a switching system and to the swivelled spout between the measuring vessel and to the collecting tank (max. error 0,015 s). The collection period shall be not less than 30 s.

5.2.5.4 Temperatures

The water temperatures shall be directly measured at the water connection points of the heating appliance under test.

The sensors can be mounted in a special device which shall be designed to ensure that the bulk temperature is recorded with sufficient accuracy.

The maximum uncertainty in determining the bulk temperature shall not be larger than 0,05 K and no more than 0,1 K for the temperature drop and the excess temperatures.

The air temperature measurement points shall be equipped with a radiation shield.

The total uncertainty shall be smaller than 0,1 K.

5.2.5.5 Electric output

The accuracy of measuring instruments shall be ±0,1 % of the measured value. The voltage shall be stabilized to ±0,1 %.

5.2.5.6 Air pressure

The accuracy in measuring the air pressure shall be ±0,2 kPa.

5.2.6 Calibration of measuring instruments

The calibration of the measuring instruments, for the primary test variables shall be traceable, in accordance with ISO/IEC 17025.

5.3 Preparation for thermal output test

5.3.1 The heating appliance shall be installed in the following reference conditions:

a) the heating appliance shall be placed parallel to, and symmetrically about the centreline of the rear wall;

b) the gap between the rear of the nearest heat emitting surface of the heating appliance and the rear wall shall be (0,050 ± 0,002) m;

c) the gap between the floor and the bottom of the heating appliance shall be (0,110 ± 0,005) m;

d) the heating appliance on test shall be connected with the flow connection at the top of one end and the return connection at the bottom of the same end.

e) it shall be ensured that no air locks occur in the connecting pipes on the primary fluid circuit. This can be realized, for example, using the arrangement described in Annex B.

5.3.2 If the manufacturer's technical literature or standard fittings require installation differing from any of the above reference conditions, the heating appliance shall be installed according to the manufacturer's specification using, where relevant, the components normally supplied by the manufacturer.

5.3.3 In addition to the thermal output tests in the reference installation conditions defined in 5.3.1, other tests can be performed as specified by the manufacturer.

5.3.4 The laboratory shall state in the test report the installation conditions and the manufacturer shall report the same specifications in the technical literature.

5.4 Test methods

5.4.1 General

The quantities to be measured for determining the thermal output differ according to the method chosen. The thermal output can be determined in two ways:

— Weighing method: by the measuring of the water flow rate (see 3.1.27) through the heating appliance and by determining the enthalpy differential between inlet and outlet.

— Electrical method: by measuring the energy input to the water circuit.

5.4.2 Weighing method

The thermal output of the heating appliance under test is determined by measuring the water flow rate (weighing method) through the heating appliance and its enthalpy differential between inlet and outlet.

Using a test set-up such as illustrated in Figure 9, part of the water flows through the circulating pump (1) to the overflow (5), while the larger part is constantly circulated through the electric boiler (3) and the mixing device (4). The water used during the test flows down the overflow (5) through the radiator under test (7) and into the measuring vessel (14).

The water flow rate can be measured by other devices provided that they are verifiable by the weighing method and that they have at least the same accuracy.

5.4.3 Electric method

Water is circulated through an electric boiler (1) to the radiator under test (4), as for instance shown in [Figure 10](#).

The thermal output of the radiator is determined from the electric power supplied to the electric boiler, after having deducted the heat loss Φ_V of the electric boiler and pipes, and taking into account the power of the pump (9).

The heat loss within the range of temperature differentials, to be observed, is determined using a short circuit test (a heat-insulated pipe with a known heat loss is mounted in place of the radiator).

It is recommended that the temperature measurement points (5) be located directly at the inlet and outlet connections of the electric boiler, in order to counter check the heat loss at the electric boiler.

5.4.4 Measurements and calculations

5.4.4.1 General

To establish the standard characteristic equation of a heating appliance it is necessary to determine the related values of thermal output and excess temperatures.

Neither of these quantities can be measured directly, but shall be calculated using the values of other quantities which can be measured, either directly or with additional information (calibration test, material properties table), and using mathematical relationships.

5.4.4.2 Weighing method

The thermal output Φ_{me} is calculated using the water flow rate q_m and the measured temperatures t_1 and t_2.

These temperatures are used to calculate the specific enthalpies as determined by the international steam tables at a reference water pressure of 120 kPa.

$$\Phi_{me} = q_m \, (h_1 - h_2)$$

The water flow rate is calculated using the mass of the water m collected in the measuring vessel and the relevant time interval τ.

$$q_m = \frac{m}{\tau}$$
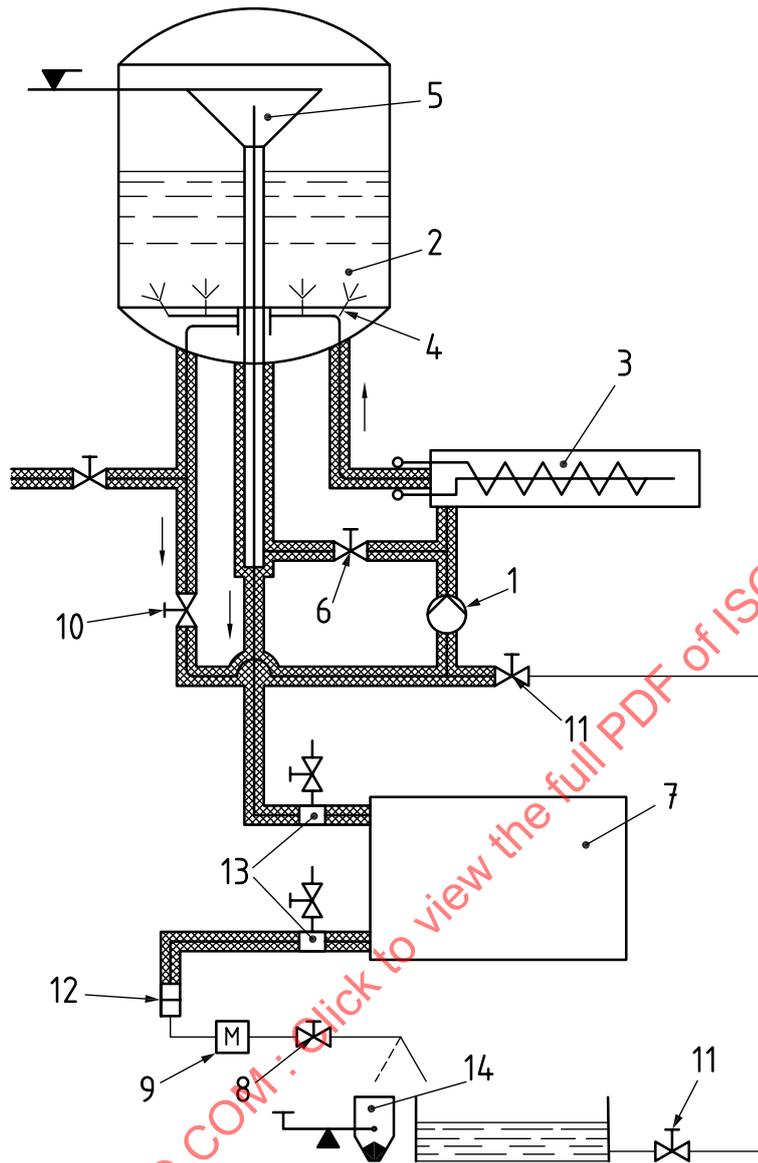
Key

1	circuit pump	8	valve
2	constant level supply tank	9	heat exchanger
3	electric boiler	10	valve
4	mixing device	11	valve
5	overflow	12	filter
6	valve	13	water temperature measuring device
7	radiator	14	measuring vessel

Figure 9 — Weighing method: Test set-up
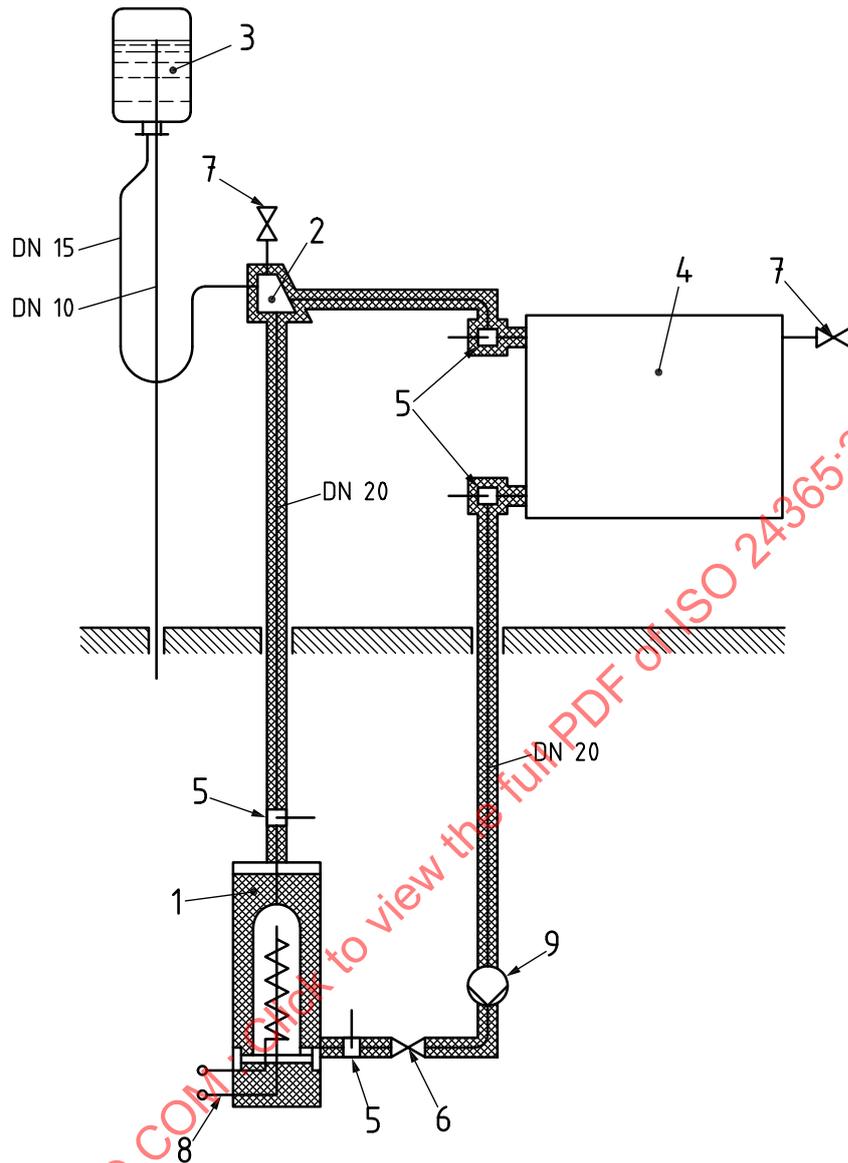
Key

1	electric boiler	6	valve
2	air purging bottle	7	air purging valve
3	expansion tank	8	connection to the constant voltage supply
4	radiator under test	9	pump
5	water temperature measuring point		

Figure 10 — Electric method: Test set-up

5.4.4.3 Electric method

The thermal output Φ_{me} is the difference between the electric power P_{el} to the heater, minus the heat losses Φ_V of the heater and the pipes:

$$\Phi_{me} = P_{el} - \Phi_V$$

The power of the pump is taken into consideration.

The water flow rate is calculated using the thermal output and the difference between the specific enthalpies.

$$q_{\mathrm{m}} = \frac{\Phi_{\mathrm{me}}}{(h_1 - h_2)}$$

5.4.4.4 Correction due to the air pressure

In consideration of atmospheric pressure deviating from p_0 = 101,325 kPa, the thermal output calculated by the relevant measured values Φ_{me} shall be corrected as follows:

$$\Phi = \Phi_{\mathrm{me}} \left[S_{\mathrm{k}} + (1 - S_{\mathrm{k}}) f_{\mathrm{p}} \right]$$

The correction factor f_{p} shall be calculated with the following formula:

$$f_{\mathrm{p}} = \left(\frac{p_0}{p} \right)^{n_{\mathrm{p}}}$$

in which p is the barometric pressure measured during the test, and the exponent n_{p} as well as the value of S_{k} are to be taken from Table 4.

NOTE   Examples are given in Annex G.

5.4.5 Determination of the characteristic equation

5.4.5.1 The characteristic equation shall be determined on the basis of at least three points at constant water flow rate and at the following excess temperature:

ΔT = (30 ± 2,5) K

ΔT = (50 ± 2,5) K

ΔT = (60 ± 2,5) K

During the determination of the characteristic equation, the reference air temperature shall not change more than 1 K from one measurement to the next (in addition to the conditions for steady-state given in 5.4.5.2).

The water flow rate shall not fluctuate or differ more than 1 % from the adjusted value during the whole test.

To determine the standard characteristic equation, the water flow rate shall be adjusted to the standard water flow rate (q_{ms} ±5 %).

Energy Calculation parameters:

If the manufacturer decides to use product-specific characteristics for the energy efficiency calculations in the system standardization (ISO 52031), additional measurements shall be carried out for water-flow of q / q_{ms} = 30 % and at the following excess temperature:

ΔT = (30 ± 2,5) K

ΔT = (50 ± 2,5) K

ΔT = (60 ± 2,5) K

The results shall be added to the test report.

5.4.5.2 Steady-state conditions

Steady-state conditions shall be maintained throughout the duration of the test, so far as both the primary fluid circuit and the ambient conditions in the test installation are concerned. Parameters shall be monitored at regular intervals by an automatic system. Steady-state conditions are deemed to exist when the standard deviations of all the readings (not less than 12 sets) taken at least in 30 min, are less than one half of the ranges specified below.

— water and air temperature (see 3.1.19, 3.1.20, 3.1.23) ±0,1 K;

— water flow rate   ±1 %

5.5 Presentation of results

5.5.1 Standard thermal output of a model

5.5.1.1   For heating appliances classified as radiators, the standard characteristic equation (Annex C) obtained from the test of a model is:

$$\Phi = K_m \cdot \Delta T^n$$

where

K_m is the constant of the model;

n   is the exponent of the characteristic equation.

The coefficient "K_m" of each model is determined by the following relationship $K_m = \Phi_{50} / 50^n$.

Then the heat output at any ΔT is equal to:

$$\Phi = \Phi_{50} (\Delta T/50)^n$$

$$\Phi_{30} = \Phi_{50} (30/50)^n$$

5.5.1.2   For heating appliances classified as radiators and comprised in a type, according to 4.2.1.4 and 4.2.1.5, the thermal output is almost linear with length (i.e. exponent is close to unity) (see Annex D).

Thus $\Phi = \Phi_L \cdot L$ and for heaters constructed from a number of identical vertical sections, $L = N_S \cdot L_S$.

The characteristic regression equation becomes:

$$\Phi_L = K_T \cdot H^b \cdot \Delta T^{(c_0 + c_1 \cdot H)}$$

where

K_T is the constant for the type;

b   is the exponent of the characteristic dimension.

5.5.1.3 For heating appliances classified as radiators and comprised in a type according to 4.2, catalogue outputs for not tested models in the type shall be calculated from the characteristic regression equation of the type.

The exponent n for tested models is the value determined from the measurements.

For not tested models belonging to type:

— exponent "n" is determined by linear interpolation between two nearby values.

— water content and dry mass is determined by linear interpolation between two nearby values.

5.5.2 Determination of the catalogue outputs of a type made at variable water flow rate

The characteristic equation becomes:

$$\Phi_L = K_T \cdot H^b \cdot q_m{}^c \cdot \Delta T^{(c_0 + c_1 \cdot H)}$$

where q_m is the water flow rate.

6 Test report

The laboratory shall prepare a test report based on the procedures and calculations contained in this document. The specimen of the test report is given in Annex E.

The following data shall be stated in the test report:

a) the standard characteristic equation of each tested model;

b) the standard thermal outputs (Φ_{30}, Φ_{50}) of each model;

c) any non-standard installation conditions which apply;

d) the pressure drop equation (i.e. pressure drop versus water flow rate), if requested by the manufacturer.

The thermal output of the module shall be indicated with one decimal digit if its value is below 100 and rounded mathematically, while it is rounded mathematically to the whole number in the other cases.

The exponent of the function shall be indicated with four decimal digits.

The temperature shall be indicated with one decimal digit.

Table 4 — Radiated heat output factor "*Sk*" and exponent "*n*$_p$"

Radiator type	Radiated heat output factor	Exponent n_p	
		Height of radiator	
	S_k	*H* < 400 mm	*H* ≥ 400 mm
Sectional vertical radiators (see Figure G.1)			
Depth b ≤ 110 mm	0,30	0,40	0,50
Depth b > 110 mm	0,25	0,45	0,65
Horizontal water flow radiators / towel radiators (see Figure G.3)			
Depth b ≤ 30 mm	0,27	0,36	0,40
Depth b > 30 mm	0,25	0,40	0,45
Sectional vertical radiators, front closed (see Figure G.2)	0,25	0,55	0,65
Multi column radiators (see Figure G.9)			
Depth b ≤ 110 mm	0,30	0,40	0,50
Depth b > 110 mm	0,25	0,45	0,65
Pleated steel radiator (see Figure G.4)	0,25	0,55	0,70
Pipe grill radiators (see Figure G.5)	0,20	0,65	0,75
Single panel radiators without convectors	0,50	0,40	0,50
Single panel radiators with 1 convector			
Pitch of the fins ≤ 25 mm	0,35	0,60	0,70
Pitch of the fins > 25 mm	0,35	0,55	0,60
Single panel radiators with 2 convectors			
Pitch of the fins ≤ 25 mm	0,25	0,65	0,75
Pitch of the fins > 25 mm	0,25	0,60	0,65
Double panel radiators without convectors	0,35	0,40	0,55
Double panel radiators with 1 or 2 convectors between the panels (see Figure G.6)			
Pitch of the fins ≤ 25 mm	0,20	0,60	0,75
Pitch of the fins > 25 mm	0,20	0,55	0,70
Double panel radiators with 3 convectors or 2 convectors behind each panel			
Pitch of the fins ≤ 25 mm	0,15	0,60	0,75
Pitch of the fins > 25 mm	0,15	0,55	0,70
Triple panel and multi-panel radiators without convectors	0,20	0,40	0,55
Triple panel and multi-panel radiators with 1 convector			

NOTE 1 For radiators with chromed and polished final finish S_k = 0 and n_p is the same of the corresponding painted radiators. For other surface treatments the factor S_k is calculated as:

$$\frac{\varepsilon}{0,92} \cdot S_{k,p}$$

where

$S_{k,p}$ is the Sk factor for the corresponding painted radiator;

ε is the emissivity of the surface.

NOTE 2 The exponent n_p is almost independent from the excess temperature *ΔT*.

NOTE 3 In the above table, the values are based on a *ΔT* = 50 K and they can be used for any *ΔT*.

Table 4 *(continued)*

Radiator type		Radiated heat output factor	Exponent n_p	
			Height of radiator	
		S_k	$H < 400$ mm	$H \geq 400$ mm
	Pitch of the fins ≤ 25 mm	0,15	0,55	0,70
	Pitch of the fins > 25 mm	0,15	0,50	0,65
Triple panel and multi-panel radiators with more than 1 convector (see [Figure G.7](#))				
	Pitch of the fins ≤ 25 mm	0,10	0,65	0,90
	Pitch of the fins > 25 mm	0,10	0,60	0,80
Convectors without case 2,5 < Pitch of the fins ≤ 4 mm		0,05	1,0	
	Pitch of the fins > 4 mm	0,05	0,8	
Convectors with case height < 400 mm				
	2,5 < Pitch of the fins ≤ 4 mm	0,00	0,90	
	Pitch of the fins > 4 mm	0,00	0,75	
Convectors with case height ≥ 400 mm				
	2,5 < Pitch of the fins ≤ 4 mm	0,00	0,60	
	Pitch of the fins > 4 mm	0,00	0,55	

NOTE 1 For radiators with chromed and polished final finish $S_k = 0$ and n_p is the same of the corresponding painted radiators. For other surface treatments the factor S_k is calculated as:

$$\frac{\varepsilon}{0,92} \cdot S_{k,p}$$

where

$S_{k,p}$ is the Sk factor for the corresponding painted radiator;

ε is the emissivity of the surface.

NOTE 2 The exponent n_p is almost independent from the excess temperature ΔT.

NOTE 3 In the above table, the values are based on a $\Delta T = 50$ K and they can be used for any ΔT.

Annex A
(normative)

Master radiators dimensional verification

After having been painted, master radiators shall be dimensionally verified using the relevant form of this annex (see Figure A.1, Figure A.2 and Figure A.3).

The arithmetical mean value of each dimension shall be within the limits indicated in the form.

The measured weight and water content shall be reported in the form.

The filled-in form shall be made available by the laboratory for any further check.

Dimensions in millimetres
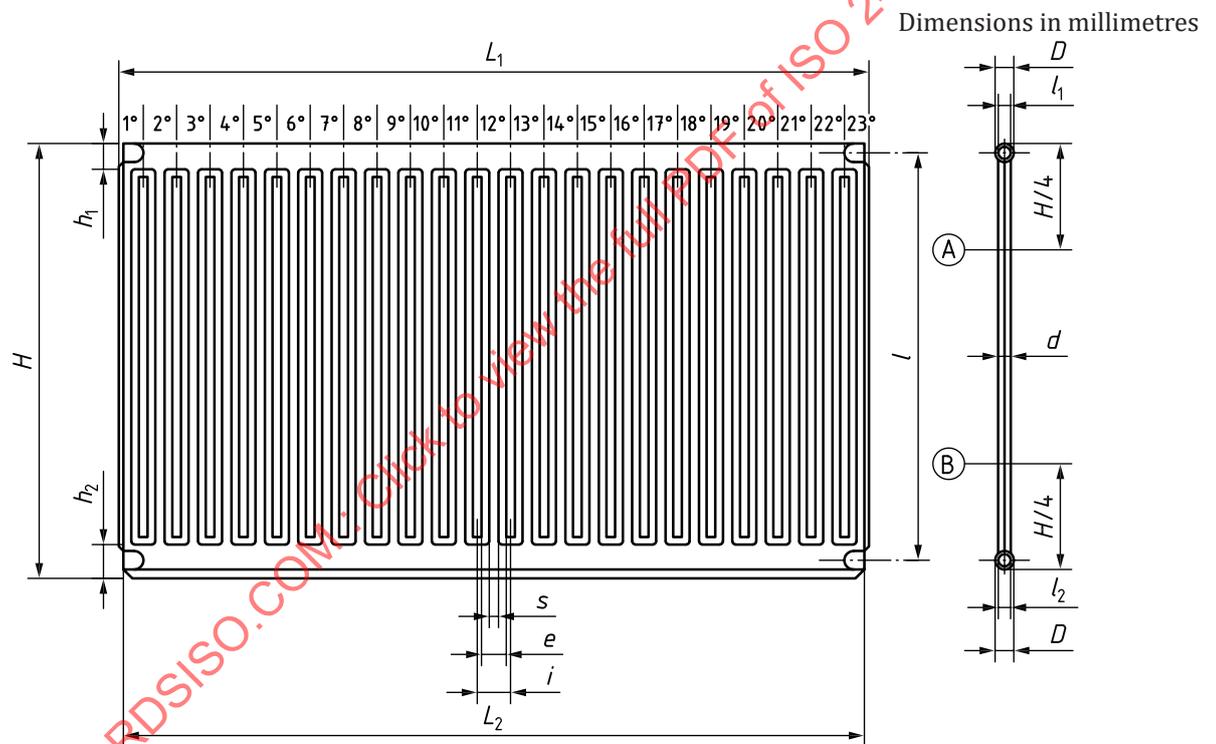
N_s	H	s		e		i	
		sA	sB	eA	eB	iA	iB
1							
2							
3							
4							
5							
6							
7							
8							
9							

Other data
(maximum and minimum accepted value of the relevant measure)

Length L_1 (1 149 mm to 1 151 mm)
L_2 (1 130 mm to 1 132 mm)

Distance between axes
l (643 mm to 645 mm)

Junction external diameter
D (29,7 mm to 30,3 mm)

10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
Mean values	H	s		e		i			

Maximum and minimum accepted values of the relevant dimensions

H	$l_1 = l_2$	s	e	i	d	h_1	h_2
689	Rp 1/2	12,9	34,9	50,9	17,9	40,7	50,7
691		13,1	35,1	51,1	18,1	41,3	51,3

Figure A.1 — Master radiator No. 1 dimensional verification — Measurements to be taken

Dimensions in millimetres

N_s	H	D		External column diameter		Other data
		D_1	D_2	dA	dB	

	H	D	d		
1					Length L_1 (1 249 mm to 1 251 mm)
2					L_2 (1 149 mm to 1 151 mm)
3					
4					Distance between axes
5					l (799 mm to 801 mm)
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
Mean values	H	D		d	

Maximum and minimum accepted values of the relevant dimensions

H	D	d	h
849	49,5	19,9	49,5
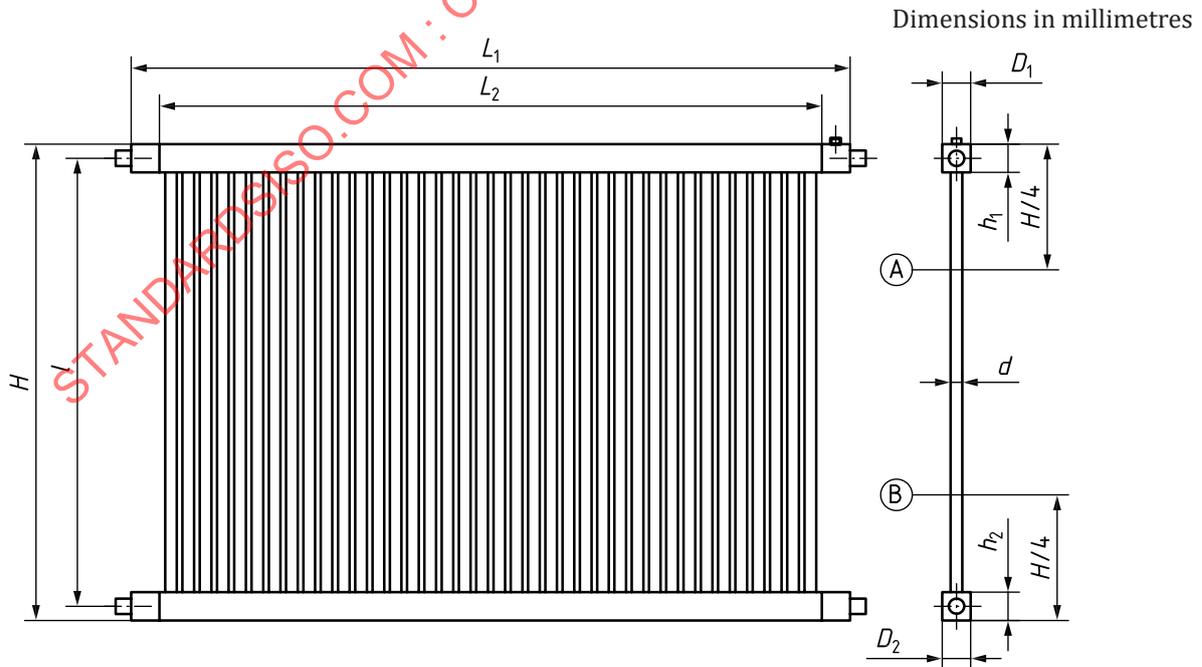
851	50,5	20,1	50,5

Figure A.2 — Master radiator No. 2 dimensional verification — Measurements to be taken

Dimensions in millimetres
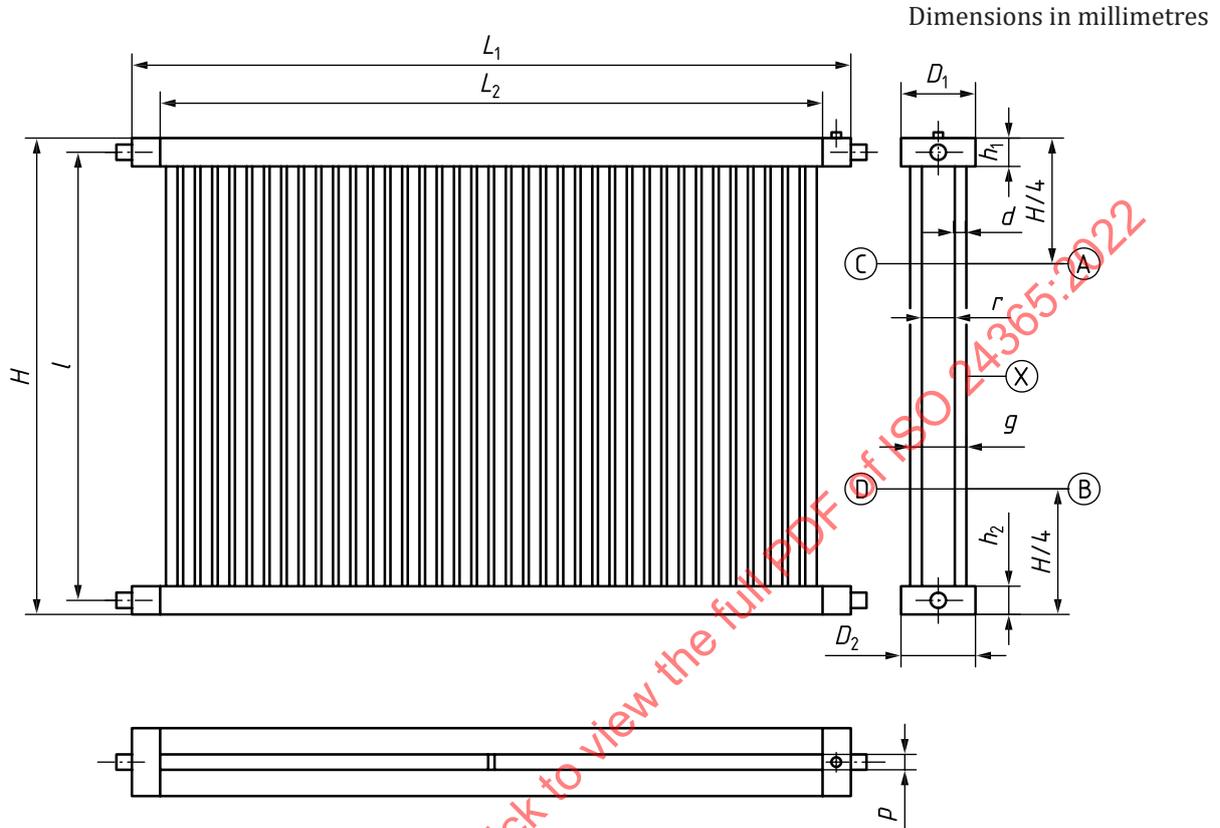
N_s	H	D		External column diameter d				g			r			Other data
		D_1	D_2	dA	dB	dC	dD	gA	gX	gB	rA	rX	rB	
1														Length L_1 (1 249 mm to 1 251 mm)
2														L_2 (1 149 mm to 1 151 mm)
3														
4														Distance between axes
5														l (799 mm to 801 mm)
6														
7														
8														
9														
10														
11														
12														
13														
14														

	H	D	d			gA	gX	gB	rA	rX	rB
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
Mean values	H	D	d			gA	gX	gB	rA	rX	rB

Maximum and minimum accepted values of the relevant dimensions

H	D	d	e	g	r	h	p
849	129,6	19,9	29,7	99,7	59,7	49,5	29,7
851	130,4	20,1	30,3	100,3	60,3	50,5	30,3

Figure A.3 — Master radiator No. 3 dimensional verification — Measurements to be taken

Annex B
(informative)

Determination of pressure drop

B.1   General

Radiators are not very influenced by the water flow rate and pressure drops in them are negligible. Even in convectors, the pressure drop is usually less than 1 000 Pa and for some families of appliances less than 200 Pa. Consequently, the appliance pressure drop is not a major contributor to pressure losses in heating systems.

Nevertheless, in convectors and other appliances, the thermal output of which is influenced by the water flow rate, it is necessary to supply each appliance of the heating system with the correct water flow rate in order to obtain the rated thermal output.

It is therefore recommended that such appliances, which will have been tested at more than one water flow rate, be subjected to pressure drop tests and the coefficients of the pressure drop equation be quoted in the catalogue.

The pressure drop through an appliance is related only to the design of the heat emitter (not the casing) and is dependent on:

a)   the water flow rate;

b)   the water temperature in so far as it affects the fluid density and viscosity;

c)   the cross-sectional area of the waterways (governed by the number of parallel paths and their cross-sections);

d)   the length of the waterways (that is, the length of each path);

e)   the number of local losses (such as bends) in each path;

f)   the water distribution between the parallel paths.

If the same samples are used for both heat output tests and pressure drop tests, the effect of length cannot be determined and the pressure drop equation can be quoted only for the tested models. If pressure drop characteristics are required for a type or family, the effect of length is significant and can only be determined by testing additional samples of other lengths. In this case the models chosen should span the range of lengths of the type.

It is preferable that pressure drop tests be carried out at the standard excess temperature. However, the effect of temperature is generally low/minor and tests must be carried out at 20 °C ± 10 °C provided that this is stated in the catalogue.

If they are taken to be the same as those required for heat output tests, there is the possibility of carrying out pressure drop tests simultaneously with the heat output tests. At least three water flow rates should be chosen to be representative of the manufacturer's recommended installation practice.

B.2 Pressure drop equation of a type

B.2.1 General

The pressure drop equation of a type is of the form:

$$\Delta p = K \times L^g \times A^a \times q_m{}^d$$

where A is the cross-sectional area of the waterways. For most existing convector types, the heat emitters differ only in length, so A is not a variable.

Where the types within a type have a simple geometric relationship, one with another, the equation must be applied to the whole family.

Coefficients of the pressure drop equation shall be determined by multiple regression as described in Annex D.

For the equation to be valid, all the measured pressure drops shall fall within ±10 % of the prediction of the equation. If any fall outside this range, the type should be divided and new equations derived for each subset of the results.

B.2.2 Pressure drop characteristic equation of a model

The pressure drop characteristic equation of a model is:

$$\Delta p = K \times q_m{}^d$$

where the index d is usually close to 2.

The pressure drop test shall be made on the same model taken for the thermal output test.

The pressure drop shall be determined at not less than three water flow rates, corresponding to 50 %, 100 % and 200 % of the standard water flow rate.

The test data shall be correlated with the regression method to determine the parameters of the characteristic equation.

B.3 Test method

B.3.1 Test circuit

An example of a suitable test set-up for determining the pressure drop is shown in Figure B.1.

The heating appliance shall be installed in a test circuit made up of two lines of tubing with the nominal diameter of the respective heater connection. Each line of tubing shall have a length of no less than 20 times its internal diameter Its inner surface shall be clean and smooth.

B.3.2 Pressure tappings

The lines of tubing shall be provided with one measuring head each with several holes or ring opening. The design of a measuring head with hole distribution is shown in Figure B.3. The distance between the measuring heads and the heating appliance to be tested shall be as follows:

— 5 times the internal diameter for the measuring head fitted in flow direction before the heating appliance;

and

— 10 times the internal diameter for the measuring head fitted in flow direction behind the heating appliance.

B.4 Test procedure — Setting up

B.4.1 Connect the lines of tubing to heating appliance and supply line and connect the instrument for measuring the pressure drop to the measuring heads.

B.4.2 Set a water flow rate higher than the standard water flow rate and carefully bleed the water system of air. Before the tests are made, the measuring heads shall be de-aired. Air locks can easily be determined by using transparent plastic pipes.

B.5 Measurements of differential pressures using an inverted U tube manometer

B.5.1 Techniques of measurement

The values of the differential pressure obtained in these tests are small and consequently, minor faults in technique of measurement lead to errors that are disproportionately large.

Greater confidence in measurement is ensured by eliminating the common sources of error described in the following subclauses.

B.5.2 Surface tension effect

The stability of the meniscus is improved by:

— the use of manometer tubes with internal bore > 10 mm;

— adding two or three drops of wetting agent to the inverted U tube manometer and the piezometer ring (see Figure B.3).

B.5.3 Leakage

Piping should be inspected for cracks, particularly where there are bends. Care should be taken to ensure that tubing is connected securely to adapter tailpieces or nipples, but at the same time, not cut.

Leakage can also occur through an imperfect equalizing valve. If a leak is suspected, the inverted U tube manometer assembly should be tested hydraulically at a static pressure of > 5 kPa.

B.5.4 Air pockets in connecting piping

Errors can be caused by the lack of homogeneity of the inverted U tube manometer fluid. There is a risk that air will collect at any point in the rim of connecting piping between piezometer ring and inverted U tube manometer and also within the piezometer ring itself. It is therefore important to run connecting piping from the bottom of the piezometer ring to the inverted U tube manometer free from kinks by a continuous upward gradient. Before the tests are made, the piezometer ring should be vented. The use of transparent/translucent plastic tubing enables air pockets to be detected more easily.

B.5.5 Blocked pressure holes

Pressure holes should be checked before and after a series of tests to ensure that they are not blocked.

The plugs of the piezometer ring provide access through which the blockage may be cleared by means of a thin probe.

B.5.6 Level of inlet and outlet connections

The inlet and outlet connections should preferably be on the same horizontal centreline.

B.5.7 Damping (throttling) of excessive movement (oscillation) of inverted U tube manometer liquid

Damping can be affected by use of plug or pinch cocks, by a capillary (viscous) restriction or by porous plugs in the connecting piping. Excessive damping causes error and it is essential that damping is equal on each side of the inverted U tube manometer (see Figure B.2).
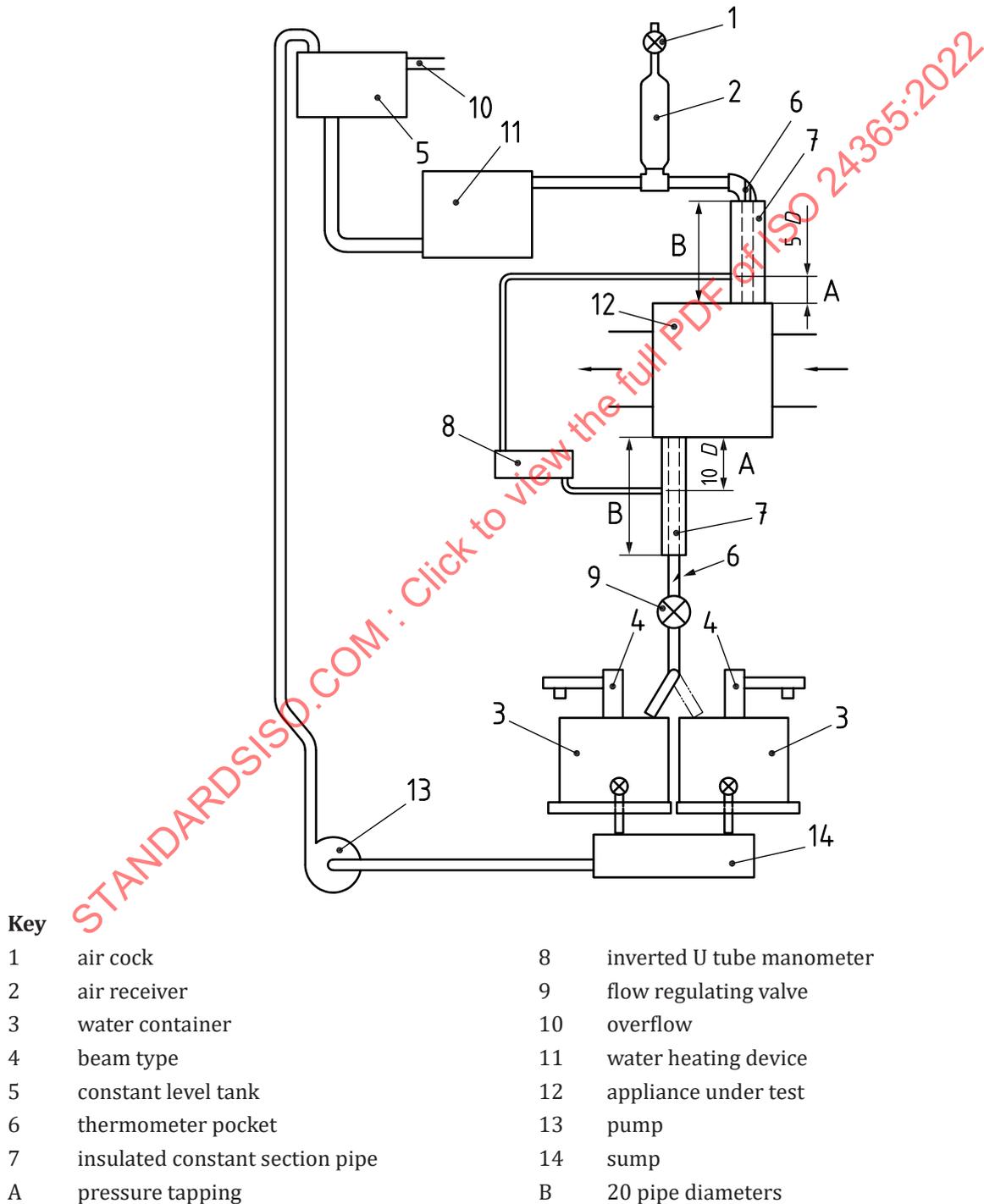
Key

1	air cock	8	inverted U tube manometer
2	air receiver	9	flow regulating valve
3	water container	10	overflow
4	beam type	11	water heating device
5	constant level tank	12	appliance under test
6	thermometer pocket	13	pump
7	insulated constant section pipe	14	sump
A	pressure tapping	B	20 pipe diameters

Figure B.1 — Pressure drop measuring set-up (open-circuit water system)

Key
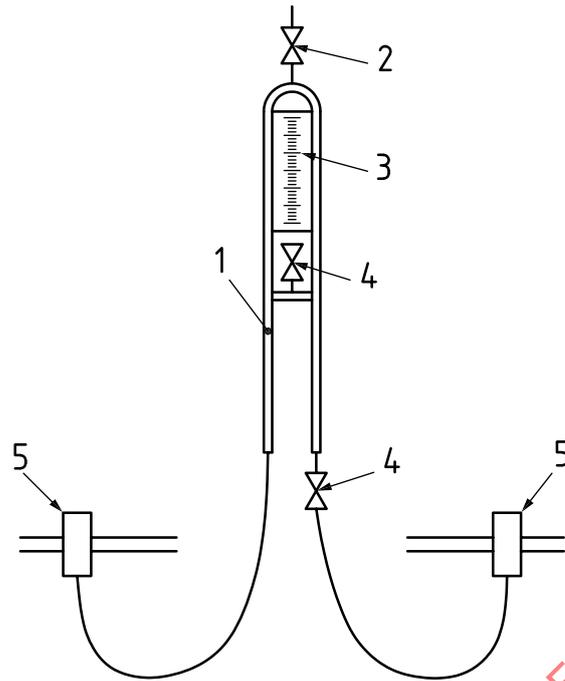
1	tubing φ 10 mm	4	valve
2	valve	5	piezometer ring
3	scale with magnifier		

Figure B.2 — Inverted U tube manometer
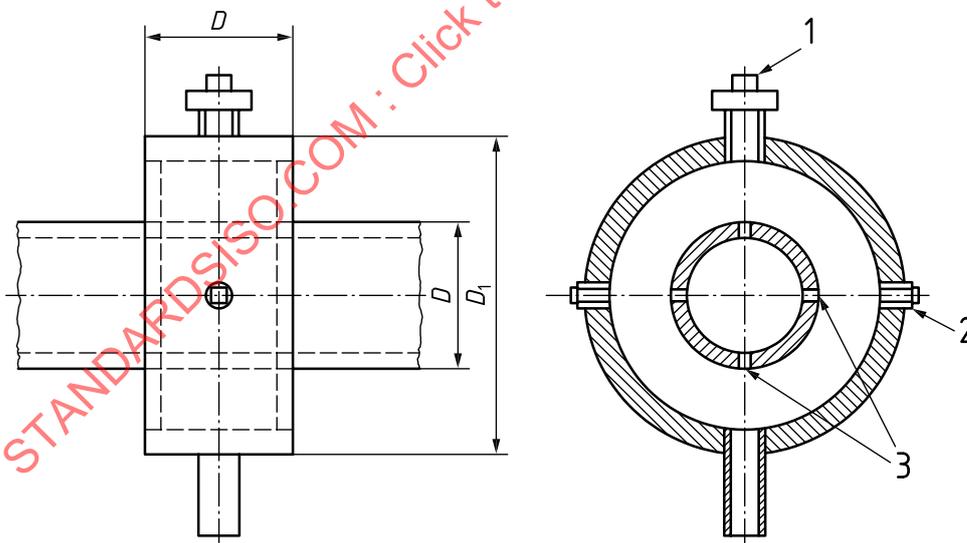
BPS pipe nipple to the inverter U tube manometer

Key

1   air vent

2   pipe plug

3   1 mm drill (remove burrs)

$D_1 = D + 10$ mm $+ 2$ mm x pipe wall thickness

Figure B.3 — Piezometer ring detail

Annex C
(normative)

Least squares regression for a model

The characteristic equation:

$$\Phi = K_M \cdot \Delta T^n$$

becomes, in logarithmic coordinates:

$$\log \Phi = \log K_M + n \cdot \log \Delta T$$

Applying the least squares method, the $\log K_m$ and $_n$ values are obtained as follows:

$$\log K_M = \frac{\sum(\log\Phi)\cdot\sum\left[(\log\Delta T)^2\right] - \sum(\log\Delta T \cdot \log\Phi)\cdot\sum(\log\Delta T)}{N\cdot\sum\left[(\log\Delta T)^2\right] - (\sum(\log\Delta T))^2}$$

$$n = \frac{N\cdot\sum\left[(\log\Delta T \cdot \log\Phi)\right] - \sum(\log\Delta T)\cdot\sum(\log\Phi)}{N\cdot\sum\left[(\log\Delta T)^2\right] - \left(\sum(\log\Delta T)\right)^2}$$

where n is the number of measured points.

Annex D
(normative)

Analysis of test results by the method of least squares multiple regression

The general formula which describes the heat output of a type is:

$$\Phi = K_{\mathrm{T}} \times L^a \times H^b \times \Delta T^{(c_o + c_1 H)} \times (q_{\mathrm{m}})^c \tag{D.1}$$

Any invariant parameters of a series of tests are omitted from the equation. The formula can be expressed in logarithmic form as:

$$\log \Phi = \log K_{\mathrm{T}} + \alpha \log L + b \log H + c_0 \log \Delta T + c_1 H \log \Delta T + c \log q_{\mathrm{m}} \tag{D.2}$$

For simplicity of notation this can be rewritten as:

$$\Phi = K' + aL' + bH' + c_0 \Delta T' + c_1 H \Delta T' + cq' \tag{D.3}$$

This formula has six unknowns, so a further five formulae are required to permit a solution. These are obtained by multiplying [Formula (D.3)](#) by each of five of the variables in turn. If the test results comprise N sets of measurements of the test variables, each equation can be expressed as the summation of N identical equations in each of which one set of measurements has been substituted. The six equations then become:

$$\sum \Phi' = K' N + a \sum L' + b \sum H' + c_0 \sum T' + c_1 \sum HT' + c \sum q' \tag{D.3}$$

$$\sum \Phi' L' = K' \sum L' + a \sum \left(L'\right)^2 + b \sum H' L' + c_0 \sum T' L' + c_1 \sum HT' L' + c \sum q' L' \tag{D.4}$$

$$\sum \Phi' H' = K' \sum H' + a \sum L' H' + b \sum \left(H'\right)^2 + c_0 \sum T' H' + c_1 \sum HT' H' + c \sum q' H' \tag{D.5}$$

$$\sum \Phi' T' = K' \sum T' + a \sum L' T' + b \sum H' T' + c_0 \sum \left(T'\right)^2 + c_1 \sum HT' T' + c \sum q' T' \tag{D.6}$$

$$\sum \Phi' HT' = K' \sum H'T' + a \sum L' HT' + b \sum H' HT' + c_0 \sum T' HT' + c_1 \sum \left(HT'\right)^2 + c \sum q' HT' \tag{D.7}$$

$$\sum \Phi' q' = K' \sum q' + a \sum L' q' + b \sum H' q' + c_0 \sum T' q' + c_1 \sum HT' q' + c \sum \left(q'\right)^2 \tag{D.8}$$

These formulae must be solved simultaneously to give the least squares best fit estimates of the six unknowns K, a, b, c_0, c_1, c. in most cases, one or more of the parameters will be invariant, and all terms containing that variable will be omitted.

The formulae can be conveniently written in matrix form:

$$\sum \Phi' \qquad = N \qquad \sum L \qquad \sum H' \qquad \sum T' \qquad \sum H'T' \qquad \sum q' \qquad K'$$

$$\sum \Phi' L' = \sum L' \quad \sum (L')^2 \quad \sum L'H' \quad \sum L'T' \quad \sum HT'L' \quad \sum q'L' \quad a$$

$$\sum \Phi' H' = \sum H' \quad \sum L'H' \quad \sum (H')^2 \quad \sum T'H' \quad \sum HT'H' \quad \sum q'H' \quad b$$

$$\sum \Phi' T' = \sum T' \quad \sum L'T' \quad \sum H'T' \quad \sum (T')^2 \quad \sum HT'T' \quad \sum q'T' \quad c_0$$

$$\sum \Phi' HT' = \sum HT' \quad \sum L'HT' \quad \sum H'HT' \quad \sum T'HT' \quad \sum (HT')^2 \quad \sum q'HT' \quad c_1$$

$$\sum \Phi' q' = \sum q' \quad \sum L'q' \quad \sum H'q' \quad \sum T'q' \quad \sum HT'q' \quad \sum (q')^2 \quad c$$

in which variables must be omitted by leaving out the appropriate rows and columns.

The matrices can be written as:

$$\{Y\}=[X]\{A\}$$

This can be rearranged to give an explicit formula for the regression coefficient vector **{A}**:

$$\{A\}=[X]^{-1}\{Y\}$$

The matrix **[X]** has maximum size 6 × 6, and is easily inverted by the many standard techniques available.

For the formula to be valid, all the measured thermal outputs shall fall within **±2 %** of the prediction of the formula.

If any fall outside this range, the type shall be divided and new formulae derived for each subset of the results.

Annex E
(normative)

Specimen of the test report

INSTITUTE...

ASSESSMENT REPORT No...

ISSUED BY ....   DATE...............................

A brief description of the test booth is attached.

This report consists of ....pages and it can be reproduced only in its integral form

TEST REPORT No..   DATE...................................

APPLICANT ....

APPLICANT ADDRESS ....

TEST ACCORDING TO ISO STANDARD ISO 24365...

BRIEF DESCRIPTION OF THE APPLIANCE (material, construction)

....
....
....

DRAWINGS (indicate the identification data, of the drawings on the basis of which the dimensional ver-ifications have been carried out)

....
....
....

TYPE...

MANUFACTURERS TRADEMARK................. ....

IDENTIFICATION SYMBOL OF THE TYPE..

THE TYPE COMPRISES THE FOLLOWING MODELS (in case of a single model indicate the model only):

Model	Drawing no.	Tested (Y/N)

....

Characteristic equation of the type

Characteristic variable dimension (see drawing N ....):

1. OVERALL HEIGHT ....   2. OTHER ....

Characteristic equation...

<div style="text-align:center">

Operator   Laboratory manager   Institute director
</div>

....

DESCRIPTION OF THE TEST INSTALLATION AND PROCEDURE

....
....
....
....
....
....
....
....

STANDARD THERMAL OUTPUT OF THE TESTED MODELS

Model	Length mm	Height mm	Depth mm	Mass kg	Water content l	Thermal output 50 K W/m W/section W/(m finned length)	Thermal output 30 K W/m W/section W/(m finned length)	n

Characteristic regression equation of the type:

$$\Phi_{\mathrm{L}} = K_{\mathrm{T}} \times H^b \times q_m{}^c \times \Delta T^{(c_0 + c_1 \ H)}$$

where:

K_T = ...

b = ...

c_0 = ...

c_1 = ...

c = ... (= 0 if radiator)

Characteristic equation of the tested models:

MODEL ....

$$\Phi = K_M \times \Delta T^n$$

where:

K_M = ...

n = ...

Difference between tested value and the value calculated by the regression equation of the type:

Difference = ...%

Non-tested models (calculated values):

MODEL ....

Φ_{50} = ... n = ...

Φ_{30} = ... n = ...

Average measured values and results (one sheet for each tested model)	Symbol	Unit	Measuring point		
			1	2	3
Air pressure	p	kPa			
Air ref. temperature	t_r	°C			
Water inlet temperature	t_1	°C			
Water outlet temperature	t_2	°C			
Temperature difference	t_1-t_2	K			
Inlet water enthalpy	h_1	J/kg			
Outlet water enthalpy	h_2	J/kg			
Enthalpy difference	Δh	J/kg			
Mean water temperature	t_m	°C			
Excess temperature	ΔT	K			
Weighing method Water flow rate	q_m	kg/s			
Thermal output measured	Φ_{me}	W			
Electric method Electric power input	P_{el}	W			
Circuit heat losses	Φ_V	W			
Thermal output corrected for barometric pressure influence	Φ	W			

Annex F
(informative)

Apparatus and method for checking the bulk temperature measuring devices

Figure F.1 shows the apparatus to check the bulk temperature measuring device. Temperature differences of approximately 10 K can be stabilized in the inlet to the measuring device. The temperature recorded in the test device is compared with the temperature in a second device (or the special blender) mounted behind the test device. Both measuring devices are extremely well insulated. The temperature recorded in the test device shall not differ by more than 0,1 K at 10 K temperature difference from the temperature recorded in the second device. On the assumption that there is a temperature difference of 2 K within the water flow at the inlet of the measuring device during the test, an uncertainty in determining the bulk temperature of 0,01 K can be extrapolated.
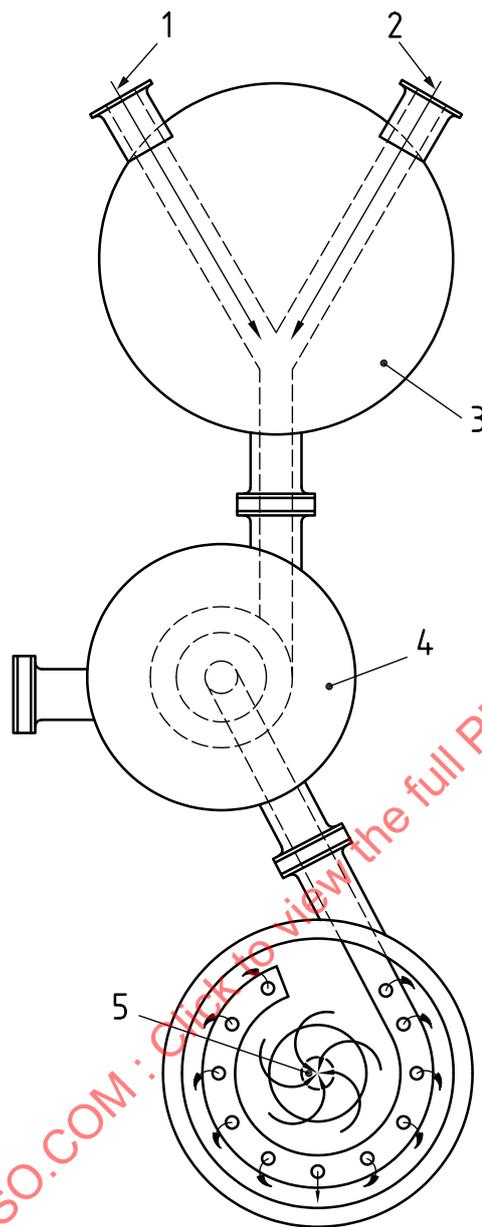
Key

1   cold
2   hot
3   layer device
4   measuring device
5   blender measuring of real bulk temperature (or a second measuring device)

Figure F.1 — Apparatus for checking the bulk temperature measuring devices

Annex G
(informative)

Examples of typical appliances according to Table 4

Figure G.1, Figure G.2, Figure G.3, Figure G.4, Figure G.5, Figure G.6, Figure G.7, Figure G.8 and Figure G.9 are different examples of typical radiator designs indicated in Table 4.