EXPERT OPINION NO. LE-G25/24

Scope: Assessment of infrared emitters regarding emitted optical radiation according to ÖNORM M 6219-2:2022 and comparison with the ICNIRP limits for the eyes for defined infrared emitter arrangements.

Ordered by: Harvia Finland Oy

Address: Teollisuustie 1-7
40951 Muurame
FINLAND

Test item: Infrared full-spectrum radiators

- Vitae dark (DIR-350-R, DIR-500-R, DIR-750-R, DIR-1300-R)
- Nextrema white (WIR-350-R, WIR-500-R, WIR-750-R, WIR-1300-R)
- ECO dark (ECO-350-G, ECO-500-G, ECO-350-R, ECO-500-R, ECO-750-R)
- VitaMy (HVIS-350M, HVIS-500M, HVIS-750M, HVIS-1300M, HVIS-350M+grill, HVIS-500M+grill, HVIS-350G, HVIS-500G)

Infrared heater panel IR-WP-510

Remark: Different irradiation scenarios and irradiation geometries were analysed when using the "worst-case" front emitter (DIR-750-R). The results for this radiator type can therefore not be exceeded by other radiator types with an electrical connected load ≤ 750 W. This Expert Opinion LE-G25/24 is the English translation of the German Expert Opinion LE-G24/24.

This expert opinion includes the pages 1 to 47

Authorised person :

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Expert:

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Date: 14.02.2025
Order no.: L-2886

Note:
The expert opinion relates exclusively to the test item.
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1 General information

Period of measurements
19.04. - 06.06.2023, 02.10. - 05.12.2024

Testing location
Test House for Laser, LED & Lamp Safety, Laboratory CH 1-9, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria

Scope of expert opinion
The present expert opinion LE-G25/24 is an extension of expert opinion LE-G07/24 (Seibersdorf Labor GmbH) regarding the full spectrum radiators of type VitaMy and regarding the infrared heater panel. Additionally, the expert opinion was updated regarding the company name. The present expert opinion comprises the determination of the effective irradiance levels for skin and eyes as well as regarding heat stress according to chapter 6.4 of ÖNORM M 6219-2:2022 for infrared full spectrum radiators of the company Harvia Finland Oy for further use in infrared cabins. In this sense, irradiances and radiances measured in front of the emitters are compared with international limits with regard to possible damage to the eyes and skin (ICNIRP 2013) and heat stress (OVE/ÖNORM EN 60335-2-53). Other potentially possible (i.e. cannot be ruled out) adverse effects on the organism cannot be assessed as no applicable limits exist.
The report also includes an estimate of the partial power (percentage) of each spectral range in the emitted spectrum incident upon the user.
The effect of infrared radiation in a medical-physiological or therapeutic sense is not assessed in this report.
With regard to compliance with the infrared limit of 100 W m^{-2} (photobiological hazard "infrared, eye", t > 1000 s) for the anterior ocular media in accordance with ICNIRP (2013), irradiation scenarios with one, two and three front emitters were considered in this report. With regard to compliance with the limit value for heat stress of 1000 W m^{-2} (averaged over the chest and back) in accordance with OVE/ÖNORM EN 60335-2-53, a "worst-case" irradiation scenario with three 750 W front emitters at a lateral distance of 60 cm each (measured from emitter centre to emitter centre) and in combination with 500 W or 350 W back emitters was examined as part of this expert opinion.

Test items and labelling
1) Harvia Vitae full spectrum radiator dark DIR-750-R (230 V, 750 W, see Figure 1)
2) Harvia Vitae full spectrum radiator dark DIR-500-R (230 V, 500 W, see Figure 2)
3) Harvia Vitae full spectrum radiator dark DIR-350-R (230 V, 350 W, see Figure 3)
4) Harvia Nextrema full spectrum radiator white WIR-750-R (230 V, 750 W, see Figure 4)
5) Harvia full spectrum radiator ECO dark ECO-750-R (230 V, 750 W, see Figure 5)
6) Harvia VitaMy full spectrum radiator black glass HVIS-1300M (230 V, 1300 W, see Figure 6)
7) Harvia VitaMy full spectrum radiator black glass HVIS-750M (230 V, 750 W, see Figure 7)
8) Harvia VitaMy full spectrum radiator black glass HVIS-500M (230 V, 500 W, see Figure 8)
9) Harvia VitaMy full spectrum radiator black glass HVIS-350M (230 V, 350 W, see Figure 9)

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10) Harvia VitaMy full spectrum radiator black HVIS-500M + grill (230 V, 500 W, see Figure 10)
11) Harvia VitaMy full spectrum radiator black HVIS-350M + grill (230 V, 350 W, see Figure 11)
12) Harvia VitaMy full spectrum radiator grill HVIS-500G (230 V, 500 W, see Figure 12)
13) Harvia VitaMy full spectrum radiator grill HVIS-350G (230 V, 350 W, see Figure 13)
14) Harvia infrared heater panel IR-WP-510 (230 V, 510 W, see Figure 14)

Note: Measurement results for other emitter types were taken from expert opinion LE-G31/18 (Seibersdorf Labor GmbH) in the following chapters.

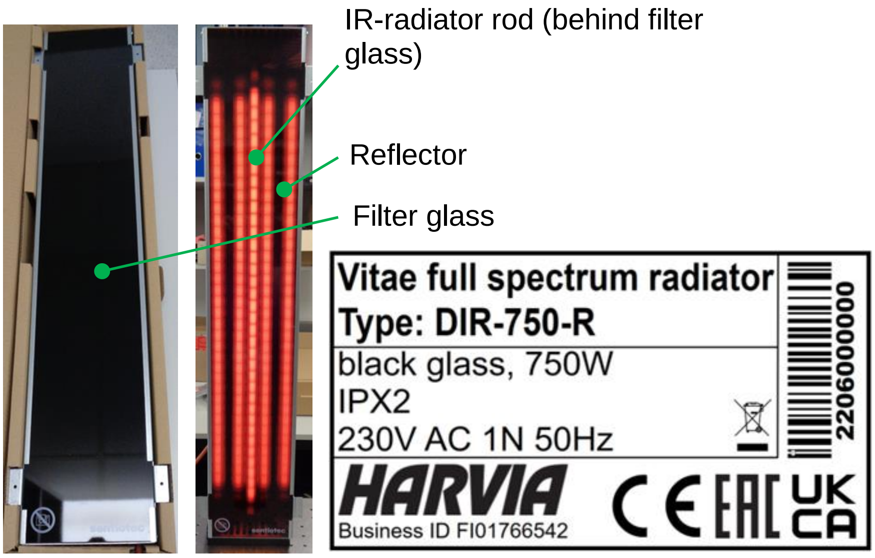

Figure 1: Harvia Vitae full spectrum emitter dark DIR-750-R in original packaging (left), when operated (centre) and label (right). The radiator dimensions are 818 mm x 150 mm x 63 mm (height x width x depth).

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Figure 2: Harvia Vitae full spectrum emitter dark DIR-500-R in original packaging (left), when operated (centre) and label (right). The radiator dimensions are 818 mm x 150 mm x 63 mm (height x width x depth).

Figure 3: Harvia Vitae full spectrum emitter dark DIR-350-R after unpacking (left), when operated (centre) and label (right). The radiator dimensions are 658 mm x 150 mm x 63 mm (height x width x depth).

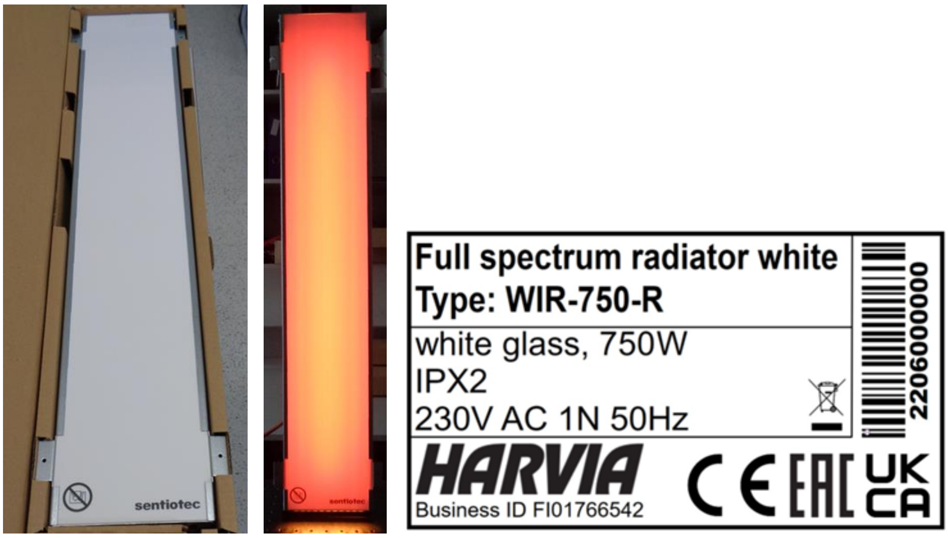

Figure 4: Harvia Nextrema full spectrum emitter white WIR-750-R in original packaging (left), when operated (centre) and label (right). The radiator dimensions are 818 mm x 150 mm x 63 mm (height x width x depth).

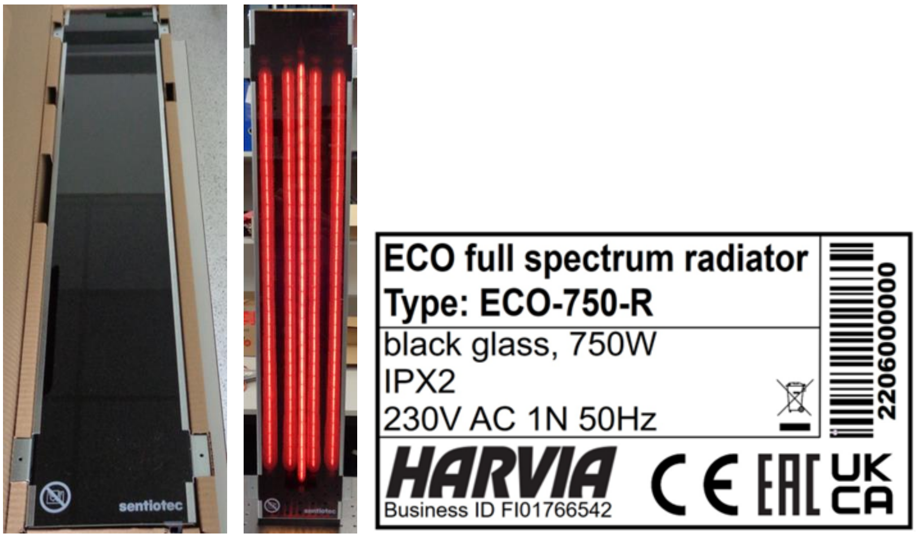

Figure 5: Harvia infrared heater ECO dark ECO-750-R in original packaging (left), when operated (centre) and label (right). The radiator dimensions are 818 mm x 150 mm x 63 mm (height x width x depth).

Figure 6: Harvia infrared heater VitaMy black glass HVIS-1300M (left), when operated (centre) and label (right). The radiator dimensions are 845 mm x 180 mm x 70 mm (height x width x depth).

Figure 7: Harvia infrared heater VitaMy black glass HVIS-750M (left), when operated (centre) and label (right). The radiator dimensions are 845 mm x 180 mm x 70 mm (height x width x depth).

Figure 8: Harvia infrared heater VitaMy black glass HVIS-500M (left), when operated (centre) and label (right). The radiator dimensions are 845 mm x 180 mm x 70 mm (height x width x depth).

Figure 9: Harvia infrared heater VitaMy black glass HVIS-350M (left), when operated (centre) and label (right). The radiator dimensions are 685 mm x 180 mm x 70 mm (height x width x depth).

Figure 10: Harvia infrared heater VitaMy black glass HVIS-500M + grill (left), when operated (centre) and label (right). The radiator dimensions are 845 mm x 180 mm x 70 mm (height x width x depth).

Figure 11: Harvia infrared heater VitaMy black glass HVIS-350M + grill (left), when operated (centre) and label (right). The radiator dimensions are 685 mm x 180 mm x 70 mm (height x width x depth).

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Figure 12: Harvia infrared heater VitaMy grill HVIS-500G (left), when operated (centre) and label (right). The radiator dimensions are 845 mm x 180 mm x 70 mm (height x width x depth).

Figure 13: Harvia infrared heater VitaMy grill HVIS-350G (left), when operated (centre) and label (right). The radiator dimensions are 685 mm x 180 mm x 70 mm (height x width x depth).

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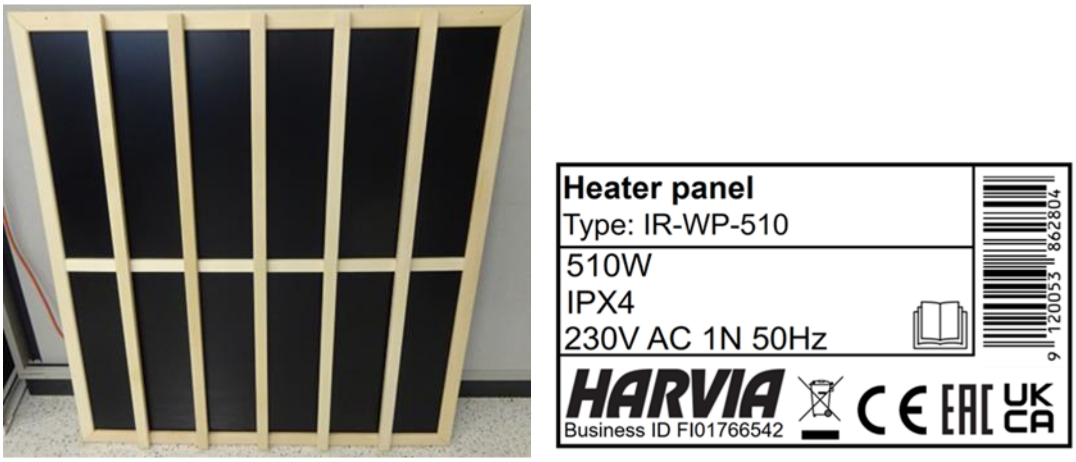

Figure 14: Harvia infrared heater panel IR-WP-510 (left) and label (right). The dimensions of the panel are 818 mm x 900 mm x 43 mm (height x width x depth).

Note regarding selection of radiators:
First of all one DIR-750-R, WIR-750-R and ECO-750-R was tested regarding total irradiance, partial irradiance in the wavelength range ≤ 3000 nm for the hazard "infrared, eye" and for the "worst-case" irradiance distance for the eyes (the distance measured orthogonally to the plane of the filter glass of the respective emitter from which the effective irradiance for the photobiological hazard "infrared, eye" of 100 W m^{-2} is reached when looking directly into the centre of the emitter. The DIR-750-R and ECO-750-R radiators are very similar in terms of total irradiance and partial power in the relevant wavelength range for the hazard "infrared, eye". As a slightly longer worst-case irradiation distance was measured for the DIR-750-R emitter compared to the ECO-750-R emitter, the **DIR emitters (Vitae full spectrum dark emitters)** were **identified as worst-case infrared emitters** and all further measurements were carried out with emitters of type DIR. The radiators of type WIR have a significantly lower total irradiance and a smaller worst-case irradiation distance compared to the radiators of type DIR and ECO. **If the corresponding limits are not exceeded when using the Vitae DIR-XXX-R emitter type, it can be assumed that all other emitter types from Harvia with the same electrical connected load do not exceed the corresponding limit value either.**

No measurements were carried out on the DIR-1300-R or WIR-1300-R (230 V, 1300 W) and ECO-350-G and ECO-500-G (each with grill) full-spectrum radiators as part of this report; the corresponding measured values were taken from report LE-G18/13.

Measurement conditions
All measurements were carried out after a heating time of at least 10 minutes, in a thermally stable state of the radiators. When only one emitter was operated, it was connected directly to the local mains (230 V, 50 Hz). If two or three IR radiators were operated simultaneously, one radiator was connected directly to the mains, each additional radiator was connected to the "Infra-M" infrared control unit and operated at the highest possible power level (8) via the "ProD Infra black" control unit (see Figure 15). The infrared control unit was connected directly to the

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mains. External light sources were switched off during the measurements. All measurements were carried out with the radiators positioned vertically, as shown in Figure 1.
All measurements were carried out at a room temperature between 22 - 25°C.

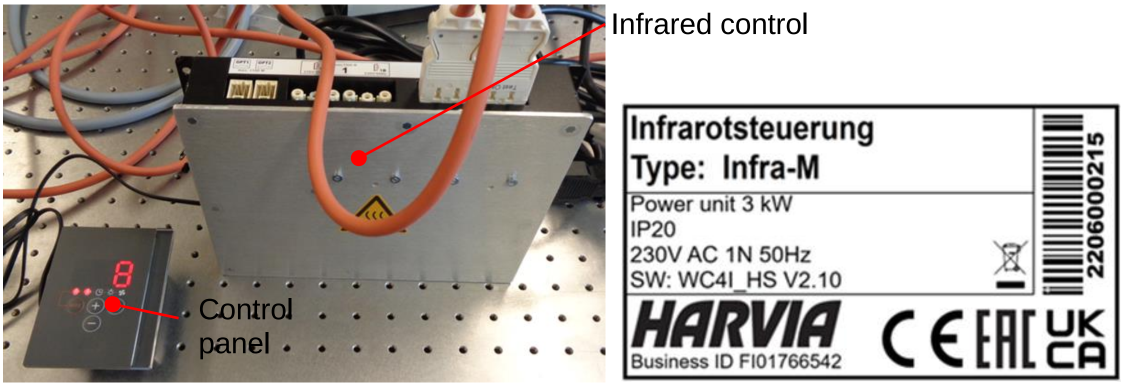

Figure 15: Infrared control unit Infra-M and control panel ProD Infra black (left) and labelling of the infrared control unit (right). The "8" on the control panel display indicates that the heaters are being operated at the highest possible power level.

Measurement devices used

- OPHIR thermopile detector L40 (MM-35/03) with USB interface (MM-35/07)
- Thermometer testo 174H (MM-40/02)
- Tape measure (MM-LE0469)
- Ocean Insight spectrometer Flame-S+XR1-ES (MM-LE0384)
- Ocean Optics spectrometer NIRQuest 512 (MM-39/03)
- Control Development Spectrometer NIR256 (MM-39/01)
- Ocean Optics spectrometer NIRQuest 512-2.5 (MM-LE0197)
- Infrared camera testo 885-2

Documents used

- ÖNORM M 6219-2 "*Requirements for public and commercial sauna installation, infrared cabins, steam and other warm chambers - Part 2: Infrared cabins*", 2022
- ICNIRP *"ICNIRP Guidelines on limits of exposure to incoherent visible and infrared radiation",* Health Physics, Volume 105(1), p.74-96, 2013
- ICNIRP "*ICNIRP Statement on far infrared radiation exposure*", Health Physics, 91(6), p. 630-645, 2006
- ÖVE/ÖNORM EN 60335-2-53:2012 *"Household and similar electrical appliances - Safety - Part 2-53: Particular requirements for sauna heating appliances and infrared cabins."*
- IEC 62471:2006 "*Photobiological safety of lamps and lamp systems*"
- Expert Opinion LE-G18/13 (Seibersdorf Labor GmbH)
- Expert Opinion LE-G07/24 (Seibersdorf Labor GmbH)

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2 Technical description

The Harvia IR emitter modules consist of a quartz halogen emitter element (rod) with a reflector behind it. The emitters are covered by a dark red filter glass (Schott Nextrema black or white, a different filter glass is used for the ECO- and VitaMy - emitters, see for example Figures 1, 4, 5 and 6). The quartz rod is heated electrically, causing the emitter module to emit visible light and infrared radiation. The emitters are intended for use in infrared cabins. The 1300 W emitters are usually used as ceiling emitters, the 750 W emitters are used as standard front emitters in an infrared cabin. The radiators with an electrical connected load of 500 W and 350 W are installed as standard back radiators in infrared cabins. During the measurements for this expert opinion, the heaters could either be connected directly to the local mains (230 V) or operated using the infrared control unit. When used in an IR cabin, the heaters are usually connected to an infrared control unit such as the "Infra-M" type and the power of the heaters is regulated via the "ProD Infra" control unit (see Figure 15). Eight different power levels can be selected on the control unit (level 8 = max. selectable emitter power). The infrared control unit is connected to the local mains (230 V). The "Infra-M" control unit used for the measurements is just one example; there are also other IR control units that can be used in combination with the IR radiator modules by Harvia. According to the manufacturer, the different IR controls work equally and should therefore not lead to more restrictive measurement results for the IR emitters analysed in comparison to the IR control used. When used in an IR cabin, the emitters are connected to a timer.
The tested infrared heaters can also be used in saunas (e.g. in the Alaska Corner Infra+ hybrid cabin). The hybrid cabin can be used either as a classic sauna or as an infrared cabin. According to clause 6.1 of ÖNORM M 6219-2:2022, the maximum cabin temperature of 45°C must be ensured when operating the sauna heater and the infrared heater at the same time. The temperature of 45°C must not be permanently exceeded in an IR cabin with commercial use. To ensure this, a temperature sensor with a switch-off at 45°C can be connected to the IR control unit.
The infrared heater panel of type IR-WP-510 is an electrically heated radiant panel heating for use in infrared- and sauna-cabins which emit optical radiation mainly in the infrared-C.

3 General information on relevant limits

In accordance with ÖNORM M 6219-2:2022, the limit values specified in the **ICNIRP guidelines** (ICNIRP-Guidelines on limits of exposure to incoherent visible and infrared radiation, Health Physics 105(1): 74-96, 2013) or in **ÖVE/ÖNORM EN 60335-2-53** apply in public and commercial infrared cabins for the irradiance of the eye and skin, which must not be exceeded in the intended seating positions. The ICNIRP limit values are designed for persons with normal pain sensation and do not apply to direct contact with the emitter.
The following chapters briefly list the distances for skin and eyes at which the corresponding limit values for prolonged exposure are reached for each type of emitter. I.e., for distances ≥ (greater than/equal to) the specified distance, the corresponding limit values for prolonged exposure are not exceeded.

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The following limits must be considered in accordance with ÖNORM M 6219-2:2022:

- Skin thermal: The limit for possible thermal damage to the skin (burns) for an exposure time of **10 s** is **3550 W m^{-2}** . No limit value is specified for longer exposure times. The provider of the limit argues for times > 10 s with the heat pain and that the user then automatically moves away from the radiation field. For the skin, the radiation of the entire half-space must be considered (measurement using open field-of-view). All wavelengths ≥ 380 nm must be considered.
- Infrared, eye: The limit for possible thermal damage to the anterior eye media (lens) for an irradiation duration ≥ **1000 s (16 min 40 s)** is **100 W m^{-2}**. Higher irradiances are permitted for shorter exposure durations. According to ICNIRP, only the radiation within an angle of 80° must be considered for the anterior ocular media (measurement with restricted field-of-view depending on the distance to the radiator). During the assessment of the defined cabin and irradiation geometries, there are sometimes even two or three radiators within a field-of-view (FOV) of 80°.
- Retinal thermal, eye: The radiance limit for **t ≥ 10 s** and source size α = 0.1 rad is **280000 W m^{-2} sr^{-1}**. To measure the photobiologically effective radiance, an angle of acceptance of 0.011 rad, the biological action spectrum $R(\lambda)$ and the wavelength range 380 nm - 1400 nm must be considered.
- Blue light, eye: For the photochemical retinal hazard, the radiance limit for **t ≥ 1000 s** is **100 W m^{-2} sr^{-1}**. To measure the photobiologically effective radiance, an angle of acceptance of 0.11 rad, the biological action spectrum $B(\lambda)$ and the wavelength range 300 nm - 700 nm must be considered.

From a photobiological point of view, only the limit values for the photobiological hazards "thermal skin" and "infrared, eye" are relevant for the tested Harvia IR emitter modules. An exceedance of the two limits for the retina is, as described in chapter 5.2.1 is not possible in case of the tested full spectrum radiators.

- Heat stress: The irradiance limit value is **1000 W m^{-2}** and the measurement must be carried out in accordance with ÖVE/ÖNORM EN 60335-2-53:2012, Annex BB, VII. The average irradiance at the chest and back area is determined over an area of 20 cm x 20 cm and at least 16 measuring points must be considered for the chest and the back. The mean value of the mean irradiance on the chest and the mean irradiance on the back must not exceed 1000 W m^{-2}.

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4 Partial power per spectral range

To determine the partial power per spectral range, the spectral irradiance of the full-spectrum emitters was measured at a distance of 30 cm from the filter glass or grill of the respective emitter (centred in front of the emitter, measuring arrangement see Figure 16) after a heating time of at least 10 min. The irradiance was measured using four spectrometers in the wavelength range 300 nm - 2500 nm. As the full spectrum emitter is a temperature emitter, the emitted spectrum can be extrapolated for wavelengths > 2500 nm using Planck's law for greybodies. The measured or extrapolated spectrum is shown in Figure 17 and Figure 18. An uncertainty in the Planck extrapolation results from the filter glass. The spectral transmittance of the filter glass was not considered in the extrapolation.

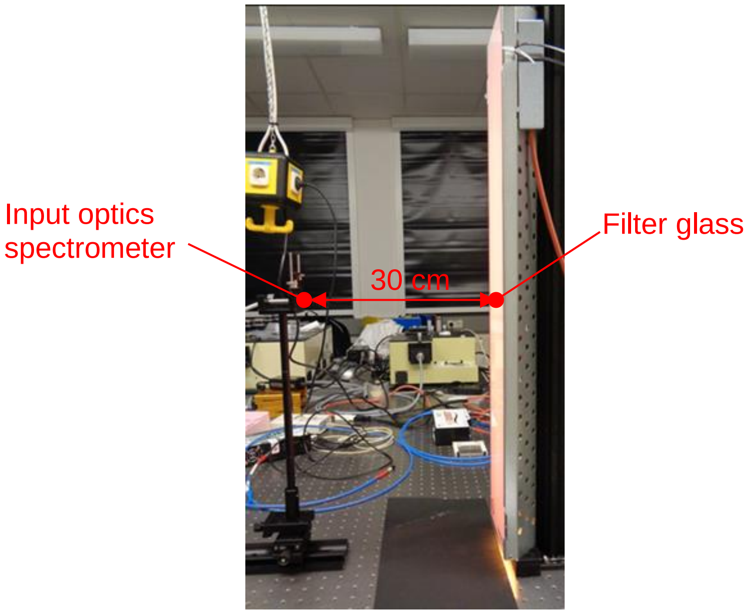

Figure 16: Measurement setup for measuring the spectral irradiance in the wavelength range 300 nm - 2500 nm 30 cm in front of the filter glass of the respective full spectrum emitter (in the picture: emitter type WIR-750-R). The measurement is carried out in the centre in front of the emitter after a heating time of at least 10 minutes at maximum power (emitter connected directly to the local mains).

Part of the radiation emitted by the radiator is absorbed by the components of the radiator module (e.g. filter glass, reflector). As a result, these parts heat up and radiate the heat in the infrared-C range. This additional radiation is recognised by the spectrum in Figure 17 and Figure 18 (wavelength range > 2500 nm) but can be measured using the thermopile detector. If the additional radiation detected by the thermopile detector is also considered, the distribution of the spectral irradiance shifts towards longer wavelengths. The estimated radiation distribution, considering the spectral measurements and the measurements with the thermopile detector, is shown in Table 1.

The surface temperature of the infrared heater panel was measured using an infrared camera (max. measured surface temperature = 86°C). By knowledge of the surface temperature the emitted spectrum was calculated using Planck's law for greybodies. The determined emitted spectrum of the heater panel is shown in Figure 19.

Table 2 shows the total irradiance measured with the thermopile detector 30 cm in front of the filter glass or grill of the respective radiator (at maximum power - radiator directly connected to the mains).

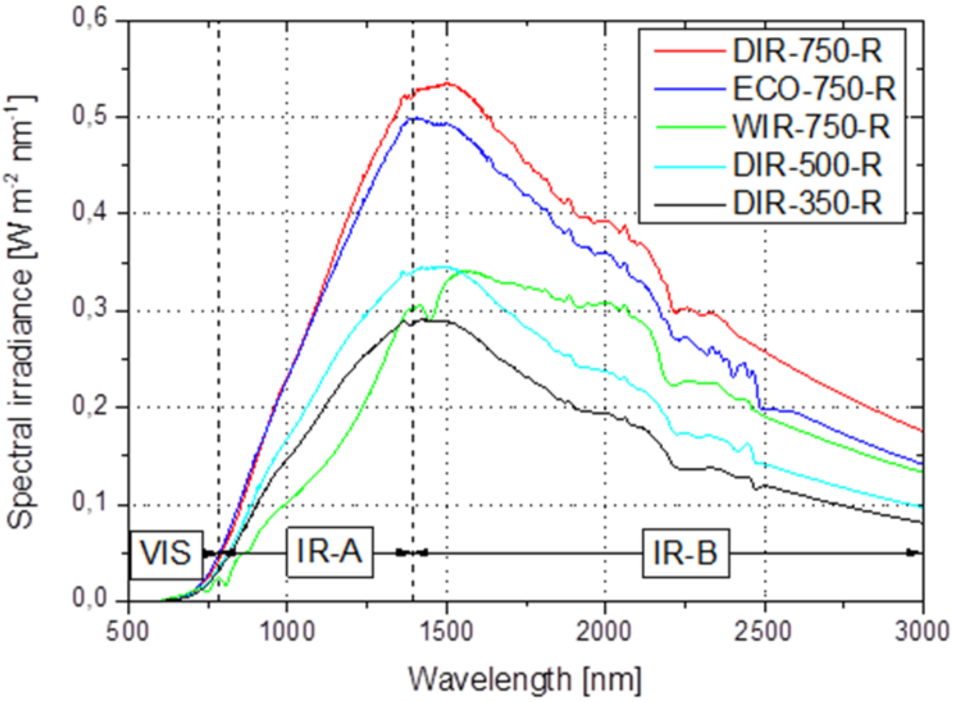

Figure 17: Spectral irradiance measured in the wavelength range 300 nm - 2500 nm 30 cm in front of the filter glass of the respective full spectrum emitter, as well as extrapolation for wavelengths > 2500 nm using Planck's radiation law. The transmission of the filter glass was not considered in the extrapolation. Due to the water in the air, some of the emitted radiation is absorbed before it reaches the body (concerns wavelength range > 2500 nm - extrapolation using Planck). In the sense of a worst-case estimation, this effect is not considered in the expert opinion.

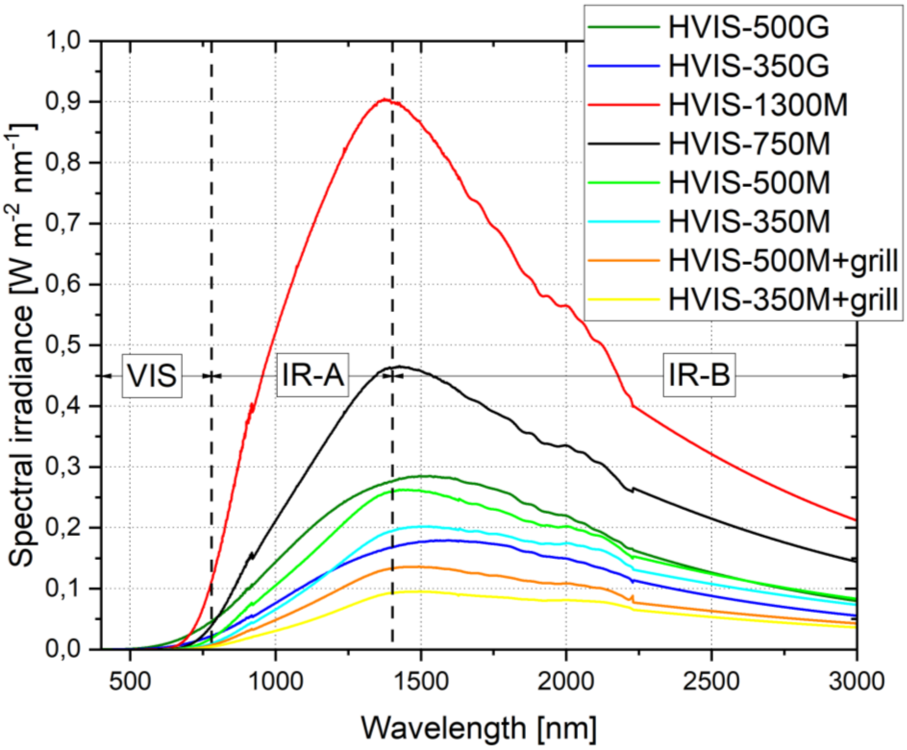

Figure 18: Spectral irradiance measured in the wavelength range 300 nm - 2500 nm 30 cm in front of the filter glass or grill of the respective full spectrum emitter, as well as extrapolation for wavelengths > 2500 nm using Planck's radiation law. The transmission of the filter glass was not considered in the extrapolation. Due to the water in the air, some of the emitted radiation is absorbed before it reaches the body (concerns wavelength range > 2500 nm - extrapolation using Planck). In the sense of a worst-case estimation, this effect is not considered in the expert opinion.

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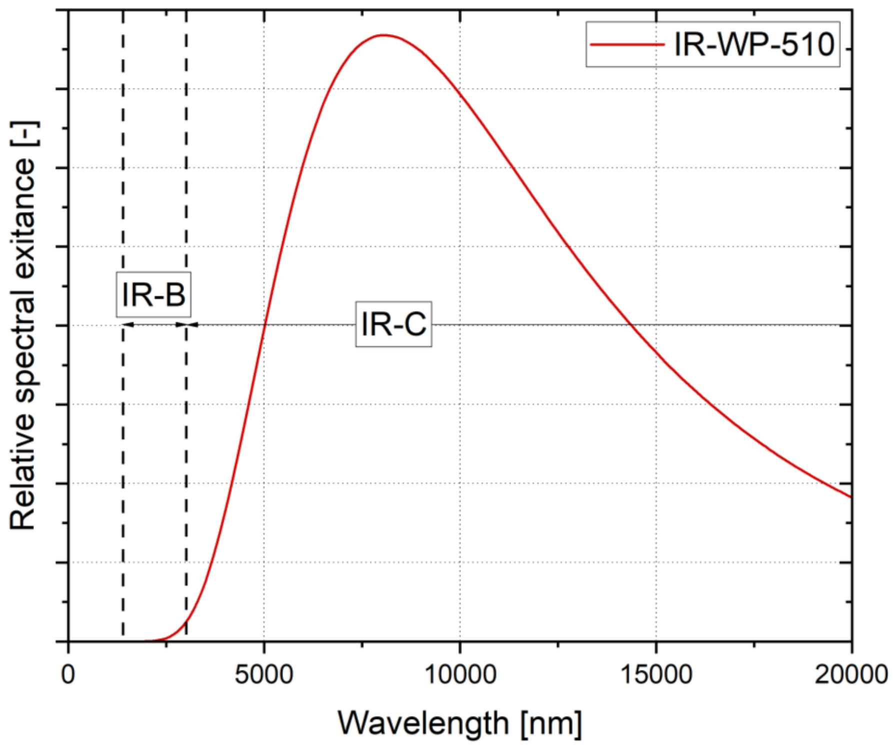

Figure 19: Relative spectral exitance of the heater panel. The spectrum shown above is based on Planck's radiation law for a greybody with a surface temperature of 86°C. The surface temperature of the heater panel was measured using an infrared camera.

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Table 1: Percentage of the measured spectral irradiance per spectral range (spectral measurement between 300 nm - 2500 nm, additional measurements with thermopile detector L40 with or without borofloat glass filter, measurements 30 cm in front of filter glass or grill, all measurements were carried out after a warm-up period of approx. 10 min of the respective emitter at max. emitter power - emitter directly connected to local mains). In case of the infrared heater panel of type IR-WP-510 the numbers indicated below are based on the spectral distribution as shown in Figure 19.

	Wavelength range			
Type IR emitter	VIS (500 nm-780 nm)	IR-A (780 nm-1400 nm)	IR-B (1400 nm-3000 nm)	IR-C (≥ 3000 nm)
DIR-750-R	0,2 %	18,1 %	55,6 %	26,1 %
ECO-750-R	0,2 %	17,7 %	52,3 %	29,7 %
WIR-750-R	0,2 %	11,1 %	54,2 %	34,5 %
DIR-500-R	0,3 %	20,5 %	55,9 %	23,4 %
DIR-350-R	0,3 %	21,6 %	56,4 %	21,7 %
HVIS-1300M	0,3 %	20,1 %	46,0 %	33,6 %
HVIS-750M	0,2 %	16,3 %	45,4 %	38,0 %
HVIS-500M	0,2 %	15,4 %	48,5 %	35,9 %
HVIS-350M	0,1 %	12,5 %	54,5 %	32,9 %
HVIS-500M+grill	0,07 %	9,5 %	38,6 %	51,8 %
HVIS-350M+grill	0,06 %	7,6 %	40,6 %	51,7 %
HVIS-500G	0,65 %	15,7 %	42,0 %	41,6 %
HVIS-350G	0,04 %	11,9 %	42,1 %	45,7 %
IR-WP-510	0,00 %	0,00 %	0,07 %	99,93 %

Table 2: Total irradiance measured with thermopile detector 30 cm in front of the filter glass or grill of the respective radiator (in case of heater panel IR-WP-510 30 cm in front of black surface of the panel), all measurements were carried out after a warm-up period of approx. 10 min of the respective radiator at maximum radiator output - radiator directly connected to the mains.

Type IR emitter	Total irradiance [$W m^{-2}$]
DIR-750-R	1039
ECO-750-R	1029
WIR-750-R	811
DIR-500-R	634
DIR-350-R	520
HVIS-1300M	1871
HVIS-750M	1039
HVIS-500M	582
HVIS-350M	489
HVIS-500M+grill	457
HVIS-350M+grill	374
HVIS-500G	696
HVIS-350G	520
IR-WP-510	176

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5 Relevant irradiances according to ÖNORM M 6219-2

5.1 Irradiance for the skin

In accordance with ÖNORM M 6219-2, a maximum total irradiance of 3550 W m^{-2} must be maintained for the skin. In the infrared cabins by Harvia, IR full spectrum radiators with an electrical connected load of 500 W are usually used as back radiators (alternatively, a 350 W radiator can also be used). The skin has the shortest distance to the back emitter when the infrared cabin is usually used in a foreseeable manner. As the highest total irradiance was measured at a distance of 30 cm in front of the filter glass of the respective emitter with the 750 W emitter of type DIR-750-R (see Table 2, except radiator HVIS-1300M for which a higher irradiance was measured) and for the DIR-750-R emitter also the greatest distance was determined from which the IR limit value of 100 W m^{-2} for the anterior ocular media is not exceeded (see Table 6), the DIR-XXX-R emitters were identified as "worst-case" emitters. The measurements regarding the irradiance for the skin were therefore carried out 4 cm in front of the filter glass of DIR-500-R and DIR-350-R emitters. The measured values are compared with the limit in Table 3.

Table 3: Total irradiance measured with thermopile detector 4 cm in front of the filter glass of the respective radiator, all measurements were carried out after a warm-up period of approx. 10 min of the respective radiator at maximum radiator output - radiator directly connected to the local mains.

Type IR emitter (back emitter)	Total irradiance [W m^{-2}]	Limit according to ÖNORM M 6219-2 [W m^{-2}]
DIR-500-R	2235	3550
DIR-350-R	2183	

At a distance of 4 cm from the filter glass of the DIR-500-R and DIR-350-R radiators, the irradiance limit of 3550 W m^{-2} for the skin in accordance with ÖNORM M 6219-2 is not exceeded. Based on the knowledge gained during the measurements of the parameters of the tested IR emitters, it can be assumed that the limit is not exceeded even 4 cm in front of the filter glass or grill of the WIR-500-R, WIR-350-R, ECO-500-R, ECO-350-R, HVIS-500M, HVIS-350M, HVIS-500G, HVIS-350G, HVIS-500M+grill and HVIS-350M+grill emitter types.

From expert opinion LE-G31/18 (issued by Seibersdorf Labor GmbH), the values listed in Table 4 were adopted for the skin, some of which had already been determined earlier. For the distances shown in Table 4 a total irradiance of 3550 W m^{-2} is given for the distances to the filter glass of the respective emitter. For the two currently measured IR emitters of type DIR-500-R and DIR-350-R, the hazard distance for the skin was determined in Table 4 as < 4 cm.

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Table 4: Distance to the filter glass or grill of the respective IR emitter with a total irradiance of 3550 W m^{-2}. In case of heater panel IR-WP-510 the distance was measured to the black surface of the panel.

Type IR emitter	Skin hazard distance (total irradiance = 3550 W m^{-2})
DIR-350-R	< 4 cm
DIR-500-R	< 4 cm
DIR-750-R	approx. 6 cm*
DIR-1300-R	approx. 16 cm*
WIR-350-R	< 4 cm*
WIR-500-R	approx. 2 cm*
WIR-750-R	approx. 4 cm*
WIR-1300-R	approx. 14 cm*
ECO-350-G	< 4 cm*
ECO-500-G	< 5 cm*
ECO-350-R	< 4 cm*
ECO-500-R	< 5 cm*
ECO-750-R	approx. 6 cm*
HVIS-1300M	approx. 16 cm
HVIS-750M	approx. 5 cm
HVIS-500M	< 4 cm
HVIS-350M	< 4 cm
HVIS-500M+grill	< 4 cm
HVIS-350M+grill	< 4 cm
HVIS-500G	< 4 cm
HVIS-350G	< 4 cm
IR-WP-510	< 3 cm

*Distances taken from expert opinion LE-G31/18

5.2 Irradiance for the eyes

5.2.1 Limits regarding retina

The following radiance limits for the photobiological hazards regarding the retina of the eye must not be exceeded in accordance with ÖNORM M 6219-2:

a) Retinal thermal (wavelength range 380 nm - 1400 nm): 280000 W m^{-2} sr^{-1} (for t > 10 s and source size $\alpha \geq 0.1$ rad when using a measurement FOV of 0.011 rad)
b) Blue light (wavelength range 300 nm - 700 nm): 100 W m^{-2} sr^{-1} (for t > 1000 s when using a measurement FOV of 0.11 rad)

With regard to the photobiological risks for the retina of the eye, only "worst-case" measurements were carried out using the front emitters DIR-750-R, WIR-750-R, ECO-750-R, HVIS-1300M (only for hazard retinal thermal) and HVIS-500G (only for hazard blue light). These radiators are usually located in the field of vision of the user of the IR cabin. The radiator of type HVIS-500G was chosen as this radiator does not include any filter glass and consequently the emission of this radiator is not filtered. At a measurement distance of 30 cm from the filter glass or grill (HVIS-500G), a field-stop (metal plate with a circular aperture with a diameter of 5 cm) was placed in the centre in front of the respective radiator and the rest of the radiator was completely covered (for measurement setup see Figure 20). This corresponds to a measurement FOV of 0.167 mrad. For the evaluation, it was assumed that the spectral irradiance measured in this way using a spectrometer in the wavelength range 300 nm - 1400 nm was measured with a measurement FOV of 0.11 rad (for the photobiological hazard "blue light") or 0.011 rad (for the photobiological hazard "thermal retina") (alternative method for radiance measurements in accordance with IEC 62471). The values given in Table 5 are therefore significantly higher compared to the effective radiances when using the correct, smaller measurement FOV per photobiological hazard.

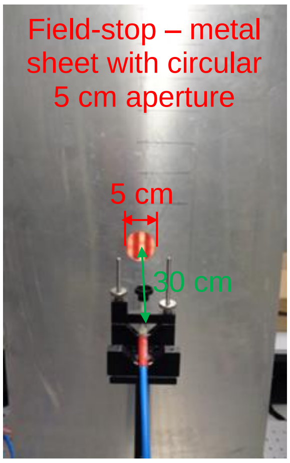

Figure 20: Measurement setup for the "worst-case" radiance measurements.

Table 5: Comparison of the worst-case measurement results for the three 750 W front radiators, the 1300 W radiator and the 500 W radiator without filter glass with the limit values for retinal hazards according to ÖNORM M 6219-2.

Photobiological hazard	Wavelength range [nm]	Radiator type	Measured effective radiance [W m^{-2} sr^{-1}]	Limit [W m^{-2} sr^{-1}]
Retinal thermal	380 - 1400	DIR-750-R	21962	280000
		ECO-750-R	22835	
		WIR-750-R	10327	
		HVIS-1300M	46089	
Blue light	300 - 700	DIR-750-R	$5{,}2\cdot10^{-3}$	100
		ECO-750-R	$4{,}8\cdot10^{-3}$	
		WIR-750-R	$7{,}4\cdot10^{-3}$	
		HVIS-500G	$7{,}0\cdot10^{-2}$	

The comparison of the measured effective radiances with the corresponding limits in Table 5 shows that it is not possible to exceed the limits for the photobiological hazards of the retina. Even in the case of worst-case analysis the limits are not exceeded. Based on the knowledge gained during the measurements regarding the properties of the tested IR emitters, it can be assumed that the retinal limit values are not exceeded by any other lamp type with an electrical connected load of 500 W and 350 W. Furthermore, it can be assumed that the limit values for

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the retina cannot be exceeded by emitters with an electrical connected load of 1300 W (DIR-1300-R and WIR- 1300-R) due to the IR emitter element and the filters used.

5.2.2 "Worst-case" hazard distance regarding IR limit of 100 W m^{-2} for the lens of the eye

Based on the determined partial irradiance in the wavelength range 780 nm - 3000 nm to the total irradiance, the displayed value for the thermopile detector was calculated, for which an IR irradiance of 100 W m^{-2} is measured. Measurements were carried out with the thermopile detector axially directly in the centre in front of an IR emitter of a defined type. The distance to the filter glass or grill of the respective emitter was determined from which an effective IR irradiance of 100 W m^{-2} (for t > 1000 s) is measured in the wavelength range of 780 nm – 3000 nm. The measurement setup for these measurements is shown in Figure 21.

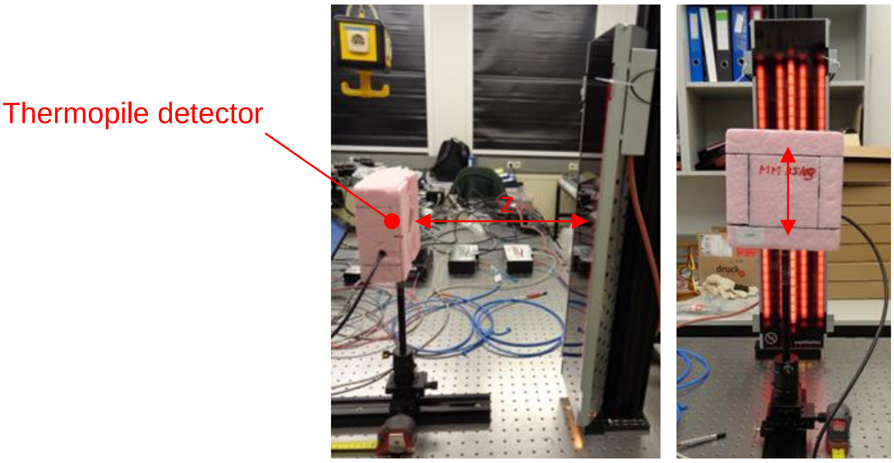

Figure 21: Measurement setup for determining the "worst-case" distance for the IR limit for the eye lens of 100 W m^{-2}. “z" denotes the normal distance between the filter glass and the thermopile detector. The measurement was carried out in the centre in front of the radiator, the thermopile detector was also shifted vertically to determine the maximum distance.

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Table 6: Distance ("worst-case") to the filter glass of the respective IR emitter with an irradiance of 100 W m^{-2} for the IR limit value regarding the eye lens.

Type IR emitter	Hazard distance eye lens (z) (IR irradiance = 100 W m^{-2} for wavelengths ≤ 3000 nm)
DIR-350-R	approx. 75 cm
DIR-500-R	approx. 88 cm
DIR-750-R	approx. 115 cm
DIR-1300-R	approx. 190 cm*
WIR-350-R	approx. 68 cm*
WIR-500-R	approx. 80 cm*
WIR-750-R	approx. 90 cm
WIR-1300-R	approx. 153 cm*
ECO-350-G	approx. 69 cm*
ECO-500-G	approx. 85 cm*
ECO-350-R	approx. 75 cm*
ECO-500-R	approx. 88 cm*
ECO-750-R	approx. 110 cm
HVIS-1300M	approx. 140 cm
HVIS-750M	approx. 94 cm
HVIS-500M	approx. 72 cm
HVIS-350M	approx. 64 cm
HVIS-500M+grill	approx. 47 cm
HVIS-350M+grill	approx. 41 cm
HVIS-500G	approx. 72 cm
HVIS-350G	approx. 56 cm
IR-WP-510	< 5 cm

*Distances taken from expert opinion LE-G31/18

The hazard distances for defined irradiation scenarios are listed in Section 6 of this report.

5.3 Heat stress according to ÖVE/ÖNORM EN 60335-2-53

The measurement setup for the heat stress measurements is shown in Figure 22 and Figure 23 are shown. A "worst-case" arrangement consisting of three DIR-750-R front radiators (at a lateral distance of 60 cm) in combination with one DIR-500-R and one DIR-350-R back radiator each was analysed. The measurement distance to the filter glass of the centre front radiator was 50 cm, the measurement distance to the filter glass of the back radiator was 4 cm. The overall measurement arrangement is shown in Figure 24.

Measurement of the irradiance at the chest area (see Figure 22):
Three DIR-750-R emitters are installed at a lateral distance of 60 cm (distance between the emitter centres). The thermopile detector is located 50 cm in front of the filter glass of the centre IR radiator and is shifted by 5 cm in the x and y directions in order to measure the total irradiance at 25 points within a grid of 20 cm x 20 cm at the chest area. The centre of the selected grid was located in the centre of the middle front radiator. Table 7 shows the

measured total irradiance per grid point as well as the average total irradiance for the entire grid of the chest area.

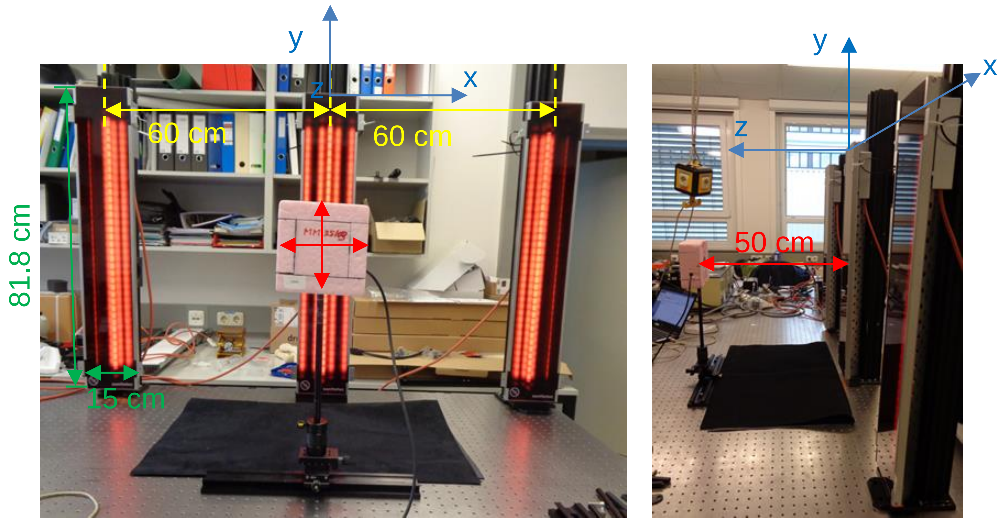

Figure 22: Measurement setup for the grid measurement of the average total irradiance at the chest area on three DIR-750-R front radiators at a measurement distance of 50 cm. The origin of the coordinate system is located in the centre of the upper edge of the middle radiator.

Table 7: Measured total irradiance in W m^{-2} per grid point for the chest area 50 cm (= z) in front of the filter glass of the centre DIR-750-R radiator and mean total irradiance for the chest area (mean value over all grid points)

	x-value grid point				
y-value grid point	-10 cm	-5 cm	0 cm	5 cm	10 cm
-32 cm	551	582	582	592	561
-37 cm	572	592	592	603	572
-42 cm	582	603	592	603	592
-47 cm	572	592	592	603	582
-52 cm	561	582	582	592	572
Average total irradiance for the chest area: 584 W m^{-2}					

Measurement of the irradiance at the back area (see Figure 23):
To measure the irradiance in the back area, measurements were carried out on one DIR-500-R and one DIR-350-R radiator. The thermopile detector was positioned 4 cm in front of the filter glass of the respective radiator and shifted by 5 cm in the x and y directions in order to measure the total irradiance at 25 points within a grid of 20 cm x 20 cm in the back area. The centre of the selected grid was located in the centre of the respective back radiator. Table 8 and Table 9 show the measured total irradiance per grid point and the average total irradiance for the entire grid of the back area.

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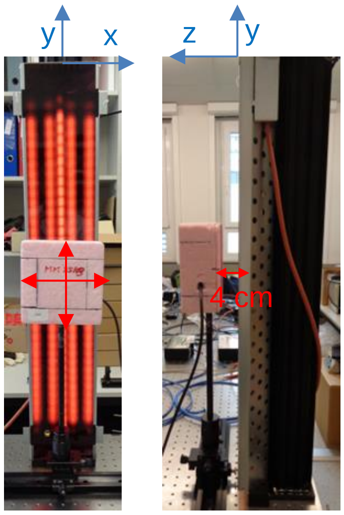

Figure 23: Measurement setup for the grid measurement of the average total irradiance at the back area on one DIR-500-R and one DIR-350-R back radiator at a measurement distance of 4 cm. The origin of the coordinate system is located in the centre of the upper edge of the radiator.

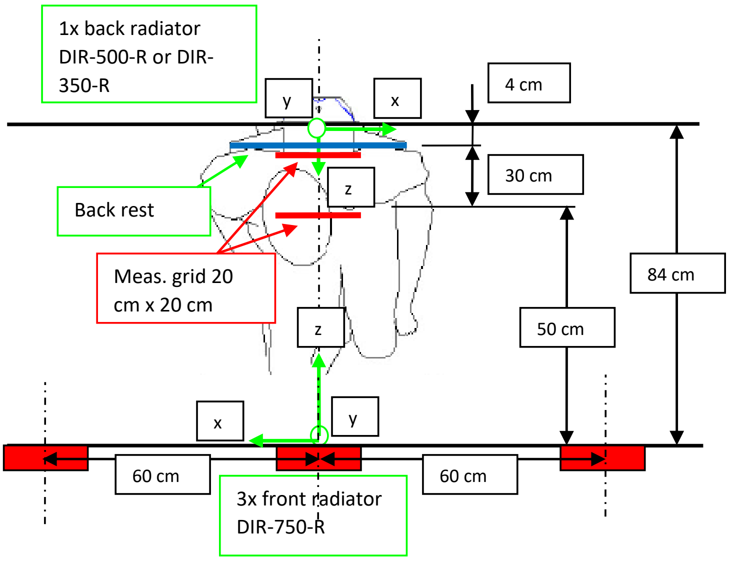

Figure 24: Overall measurement set-up for the heat stress measurements.

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Table 8: Measured total irradiance in W m^{-2} per grid point for the back area 4 cm (= z) in front of the filter glass of a DIR-500-R radiator and mean total irradiance for the back area (mean value over all grid points)

	x-value grid point				
y-value grid point	-10 cm	-5 cm	0 cm	5 cm	10 cm
-32 cm	395	1860	2235	2079	489
-37 cm	385	1819	2224	2016	478
-42 cm	385	1798	2203	2027	457
-47 cm	385	1798	2131	2006	437
-52 cm	364	1819	2152	1996	447
Average total irradiance for the back area: 1375 W m^{-2}					

Table 9: Measured total irradiance in W m^{-2} per grid point for the back area 4 cm (= z) in front of the filter glass of a DIR-350-R radiator and mean total irradiance for the back area (mean value over all grid points)

	x-value grid point				
y-value grid point	-10 cm	-5 cm	0 cm	5 cm	10 cm
-23 cm	385	1767	2079	1860	468
-28 cm	395	1819	2183	1954	561
-33 cm	374	1788	2079	1892	457
-38 cm	364	1736	2037	1798	426
-43 cm	353	1715	2006	1715	395
Average total irradiance for the back area: 1304 W m^{-2}					

<u>Mean total irradiance averaged over the back and chest:</u>
In Table 10 the average total irradiance values for the two considered irradiation scenarios are compared with the limit value of 1000 W m^{-2}.

Table 10: Measured total irradiance in W m^{-2} per grid point for the back area 4 cm (= z) in front of the filter glass of a DIR-350-R radiator and average total irradiance in the back area (average over all grid points)

Irradiation Scenario	Average chest [W m^{-2}]	Average back [W m^{-2}]	Average over chest and back [W m^{-2}]	Limit [W m^{-2}]
<u>Front emitters:</u> 3 pcs. DIR-750-R at a lateral distance of 60 cm, measuring distance 50 cm <u>Back emitter:</u> 1 piece DIR-500-R, measuring distance 4 cm	584	1375	980	1000
<u>Front emitters:</u> 3 pcs. DIR-750-R at a lateral distance of 60 cm, measuring distance 50 cm <u>Back emitter:</u> 1 piece DIR-350-R, measuring distance 4 cm	584	1304	944	

In the analysed "worst-case" irradiation scenario, the limit for heat stress of 1000 W m^{-2} is not exceeded.

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To avoid exceeding the limit in an IR cabin, it is recommended that

- A minimum distance of 50 cm is maintained between the chest area and the front radiator in an IR cabin when more than one front radiator is used.
- The front emitters must be installed in an IR cabin with a minimum lateral distance of 60 cm from each other (distance from emitter centre to emitter centre)
- The minimum distance between the back radiator and the back is 4 cm
- The electrical connected load of the front radiator does not exceed 750 W
- The electrical connected load of the back radiator does not exceed 500 W

6 Measurement results for defined cabin or irradiation geometries for limit value "infrared, eye" (100 W m^{-2})

6.1 General information

6.1.1 Selected coordinate system

For all irradiation geometries considered, the coordinate system shown in Figure 25 was used.

By knowledge of the

- Normal (orthogonal) distance of the eyes to the plane of the filter glass (z-value)
- Height of the eyes compared to the upper edge of the radiator module (y-value)

it is relatively easy to assess whether the ICNIRP limit of 100 W m^{-2} (IR limit for the lens of the eye for t > 1000 s) is exceeded or not in the most realistic possible irradiation scenario using the graphs shown below for each cabin geometry or connected load of the front emitters analysed.
The height of the eyes compared to the upper edge of the filter glass of the front emitter (y-value) depends on the installation height of the front emitter, the height of the seat in the IR cabin and the height of the eyes of the person in the cabin above the seat. In accordance with ÖNORM M 6219-2:2022, an **eye height of 68.5 cm above the seat** is assumed.

In order to apply the graphical assessment aids proceed as follows.

1. Selection of the correct graphic with regard to
   - Connected load (e.g. 350 W, 500 W, 750 W, 1300 W) of the front emitters used
   - Number of front emitters that are within a field of view of 80° at the distance z to be viewed. For this purpose, the following information in section 6.1.2 must be considered.
2. Insert the dimensions (y-value: height of the eyes above the upper edge of the filter glass of the front radiator, z-value: normal (orthogonal) distance eyes - filter glass) in the appropriate graphic.
3. If the intersection point is above the curve in the area highlighted in green, the limit value of 100 W m^{-2} cannot be exceeded.
4. If the intersection point is below the curve in the area highlighted in white, the limit value of 100 W m^{-2} is exceeded.

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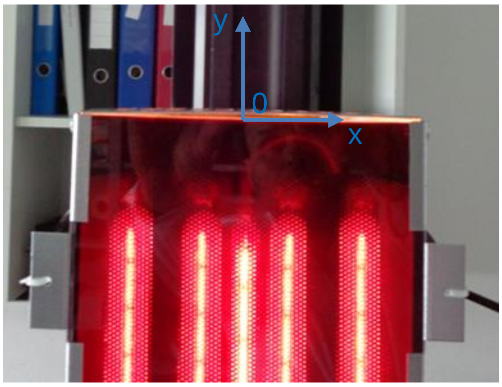

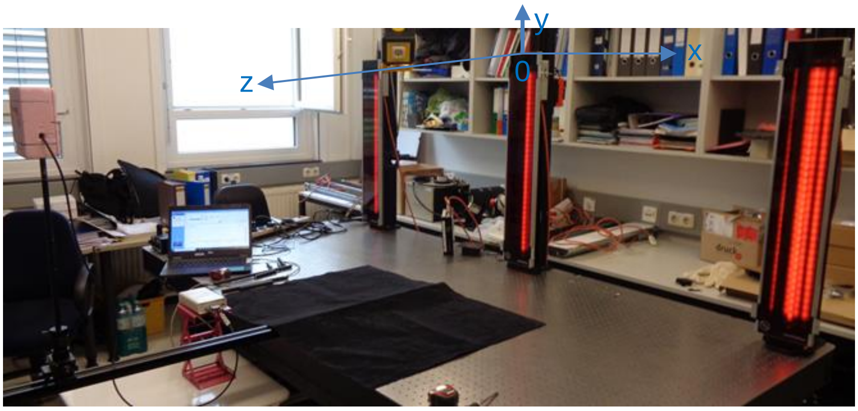

Figure 25: Hereinafter the normal distance between the measuring head (= eye position) and the plane of the filter glass is always specified as the hazard distance - even if the measuring position is above the upper edge of the front radiator, for example. For subsequent measurements, the origin of the coordinate system is placed on the upper edge of a front radiator. Negative (-) y values mean that the specified position is below the upper edge of the front radiators.

6.1.2 Use of multiple front radiators

When using several front emitters in an infrared cabin, it must be considered that according to ÖNORM M 6219-2 or ICNIRP guidelines, a measurement acceptance angle of 80° must be considered for the hazards relating to the anterior eye media (due to the physiology of the eye). If the front emitters in an IR cabin are installed at a corresponding distance from each other, it is possible that only one front emitter needs to be considered for the measurement regarding the hazard "infrared, eye", depending on the distance of the user to the front emitters. Figure 26 shows an exposure scenario with three front emitters. The user is seated at a distance z (distance from eyes to centre front radiator) in front of the centre front radiator, with a further front radiator installed at a certain distance x to the left and right. Table 11 shows the lateral distances x of the emitters as a function of the distance z between the user's eyes and the centre front emitter, from which there is an exact measurement acceptance angle of 80°. If the two lateral front emitters at a given distance z are installed further away from the centre front emitter than the specified distance x, only the centre front emitter needs to be considered for the hazard "infrared, eye". If, in the cabin geometries or distances z considered, only part of a

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lateral front radiator is within the viewing angle of 80°, this radiator was nevertheless fully taken into account in the measurement in the following irradiation geometries analysed with more than one front radiator.

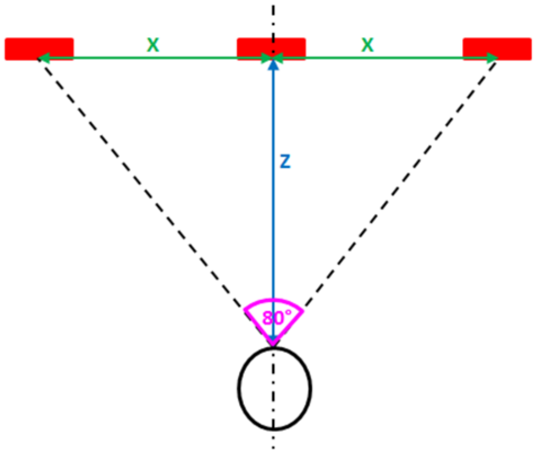

Figure 26: The user's eyes are located at a distance z in front of the filter glass of the centre front radiator. At a distance x, there is another front radiator to the left and right of the centre front radiator. Table 11 shows the numerical values x for this irradiation scenario, for which the measurement acceptance angle is exactly 80° at the given distance z.

Table 11: If the side front emitters are installed at a distance > x from the centre front emitter for a given distance z between the eyes and the centre front emitter, only the centre front emitter needs to be considered for the hazard "eye, infrared".

Distance **z** eyes - filter glass centre front radiator [cm]	50	55	60	65	70	75	80	85	90	95	100	105	110
Distance **x** between front radiators [cm]	42,0	46,2	50,3	54,5	58,7	62,9	67,1	71,3	75,5	79,7	83,9	88,1	92,3

Distance **z** eyes - filter glass centre front radiator [cm]	115	120	125	130	135	140	145	150	160	170	180	190
Distance **x** between front radiators [cm]	96,5	100,7	104,9	109,1	113,3	117,5	121,7	125,9	134,3	142,6	151,0	159,4

6.2 Single-seat cabin

The graphical solutions for compliance with the limit of 100 W m^{-2} regarding the hazard "infrared, eye" for a single-seat cabin are shown below, as exemplified in Figure27 (front and back radiators are arranged directly opposite each other).

It is important for all the irradiation scenarios analysed below that the lower edge of the front radiator is 5 cm above the cabin floor at the usual installation height. This is relevant for the height of the bench above the cabin floor, so that the limit of 100 W m^{-2} is not exceeded for small people whose eyes are only 68.5 cm above the bench surface. The height of the seat above the cabin floor is usually 40 cm - 50 cm.

The results given below for the DIR-XXX-R emitter types can also be used for the WIR-XXX-R and ECO-XXX-R emitter types with the same electrical connected load. In the case of the single-seat cabin, the ECO-750-R emitter and HVIS-13000M emitter (as ceiling emitter with reclining area below the emitter) were also measured. Very similar results were obtained for the DIR-750-R and ECO-750-R radiators.

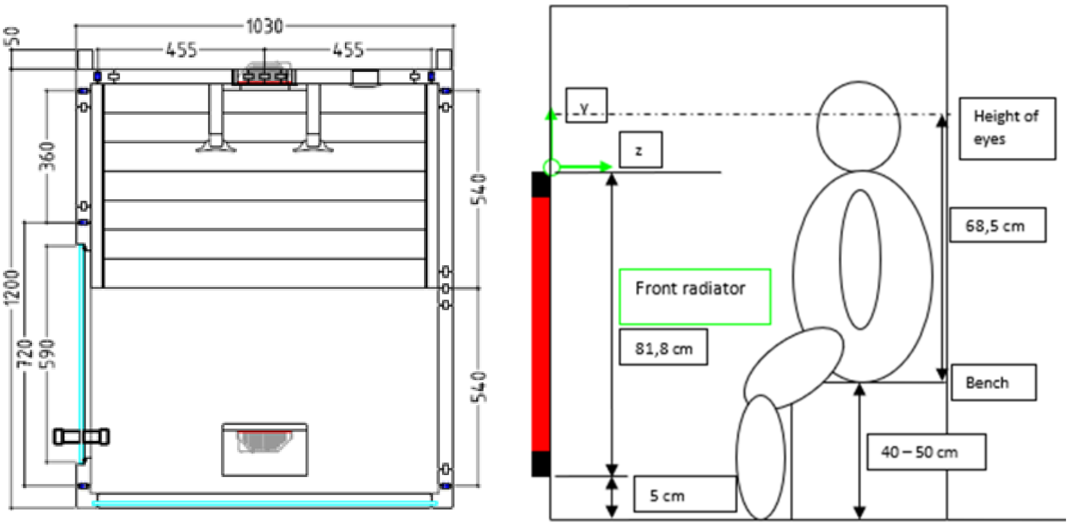

Figure27: Example of a single-seat cabin with one front and back radiator (left plan view, right cross-section with usual distances). In the cross-section on the right, the back radiator has been omitted as it is not relevant for compliance with the IR limit value for the eyes.

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6.2.1 Front radiator DIR-750-R (1 piece)

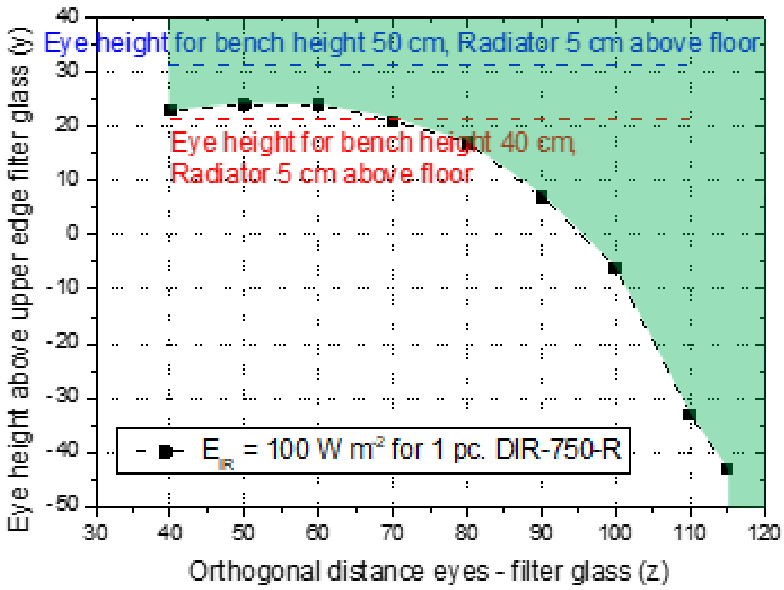

Figure 28: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a single-seat cabin when using a DIR-750-R front emitter. The shown eye height refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

When using one DIR-750-R front emitter in a single-seat cabin, it is recommended that the minimum height of the bench above the cabin floor is 43 cm. From this bench height, the limit value of 100 W m^{-2} cannot be exceeded even by a small person whose eyes are only 68.5 cm above the bench, given the usual installation height of the front emitter (lower edge of the front emitter 5 cm above the cabin floor).

If the height of the seat bench is only 40 cm, the eye distance to the front emitter in the intended seating position should be 70 cm in case of the usual installation height of the front radiator (lower edge of the radiator 5 cm above the cabin floor) so that the limit cannot be exceeded.

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6.2.2 Front radiator DIR-500-R (1 piece)

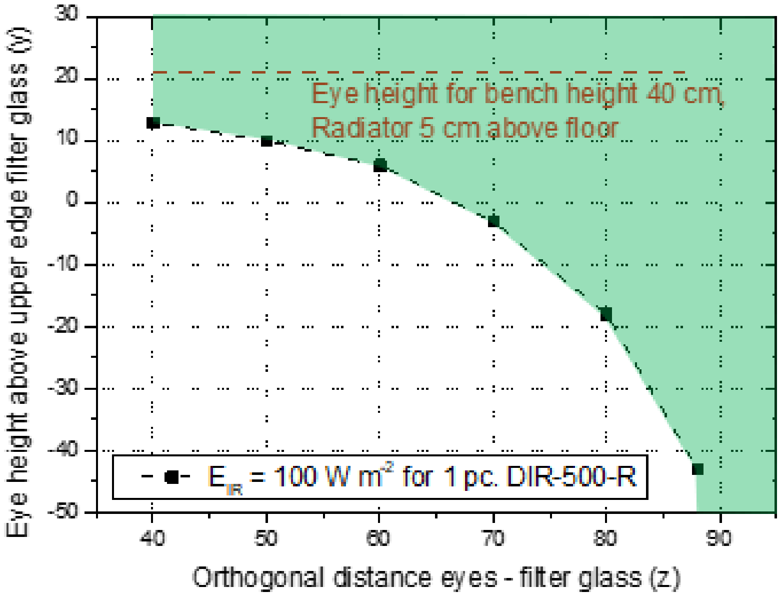

Figure 29: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a single-seat cabin when using a DIR-500-R front emitter. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y value in the diagram above).

When using one DIR-500-R front emitter in a single-seat cabin, the limit cannot be exceeded in the intended seating position, even for a small person whose eyes are only 68.5 cm above the seat bench, even if the seat bench height is only 40 cm.

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6.2.3 Front floodlight DIR-350-R (1 piece)

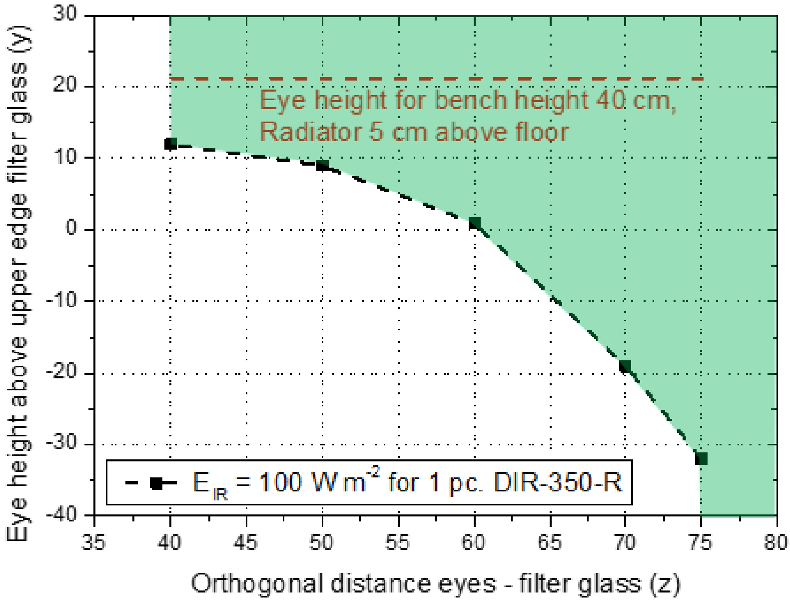

Figure 30: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a single-seat cabin when using a DIR-350-R front emitter. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, this person's eyes are 21.5 cm above the upper edge of the front emitter (y value in the diagram above). As the DIR-350-R emitter module is shorter compared to the emitter modules with a higher electrical connected load, it was assumed that the installation height for the DIR-350-R module is higher. It was assumed that the installation height of the upper edge of the DIR-350-R emitter is identical to the installation height of the upper edges of the other, longer IR emitters.

When using a DIR-350-R front emitter in a single-seat cabin, the limit cannot be exceeded in the intended seating position, even for a small person whose eyes are only 68.5 cm above the seat bench, even if the seat bench height is only 40 cm.

6.2.4 ECO-750-R front floodlight (1 piece)

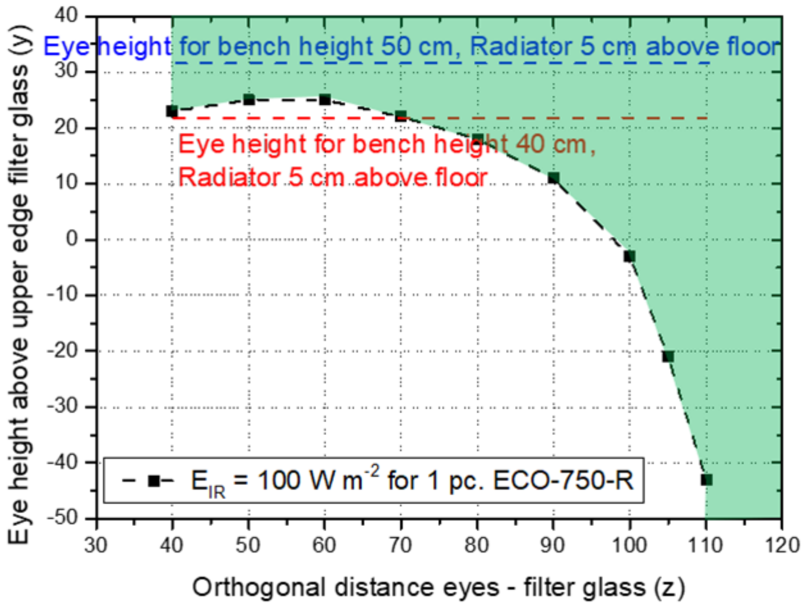

Figure 31: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a single-seat cabin when using an ECO-750-R front emitter. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. At a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front emitter (y value in the diagram above), at a bench height of 50 cm the eyes are 31.5 cm above the upper edge of the front emitter.

When using an ECO-750-R front emitter in a single-seat cabin, it is recommended that the minimum height of the bench above the cabin floor is 43 cm. From this bench height, the limit of 100 W m^{-2} cannot be exceeded even by a small person whose eyes are only 68.5 cm above the bench, given the usual installation height of the front radiators (lower edge of front radiator 5 cm above the cabin floor).

If the height of the seat bench is only 40 cm, the eye distance to the front emitter in the intended seating position should be 70 cm with the usual installation height of the front emitter (lower edge of the emitter module 5 cm above the cabin floor) so that the limit cannot be exceeded.

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6.3 2-seat cabin

An example of a 2 seat cabin in which the front and rear emitter modules are arranged directly opposite each other is shown in Figure32. Two variants of the cabin type with two seats were analysed as part of this report:

- Distance between the two DIR-750-R front radiators 60 cm
- Distance between the two DIR-750-R front radiators 75 cm

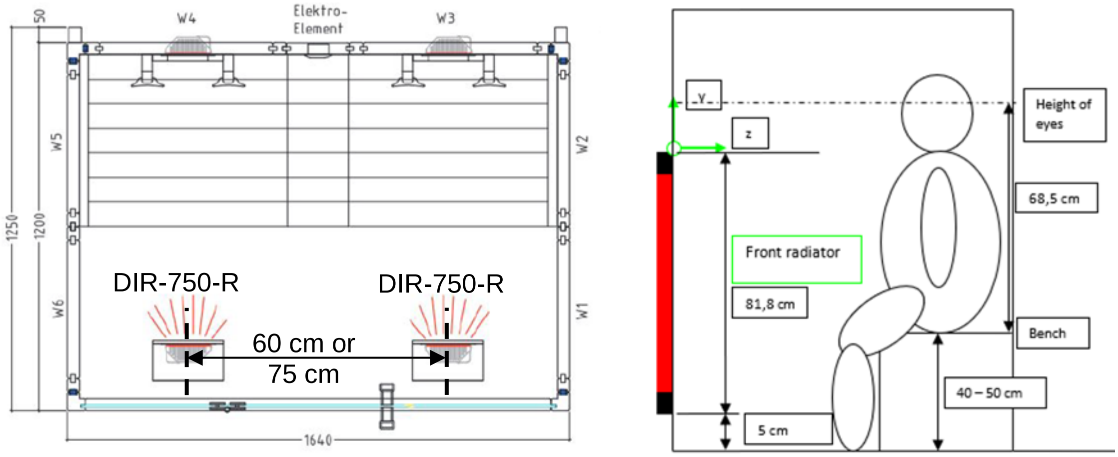

Figure32: Example of a two-seat cabin with two front and two back radiators (left plan view, right cross-section with usual distances). In the cross-section on the right, the back radiators are not shown as they are not relevant for compliance with the IR limit for the eyes.

6.3.1 2 pcs. DIR-750-R front radiators at a lateral distance of 60 cm

When using two front radiators at a lateral distance of 60 cm, both front radiators are within a field of view of 80° for distances ≥ 65 cm to the plane of the filter glass of the front radiators. For distances ≥ 65 cm, the graphical solution is as shown in Figure 33 is relevant. For distances < 65 cm, there is only one front radiator within a field of view of 80°. Therefore, for distances < 65 cm, the graphical solution according to Figure 28 should be used.

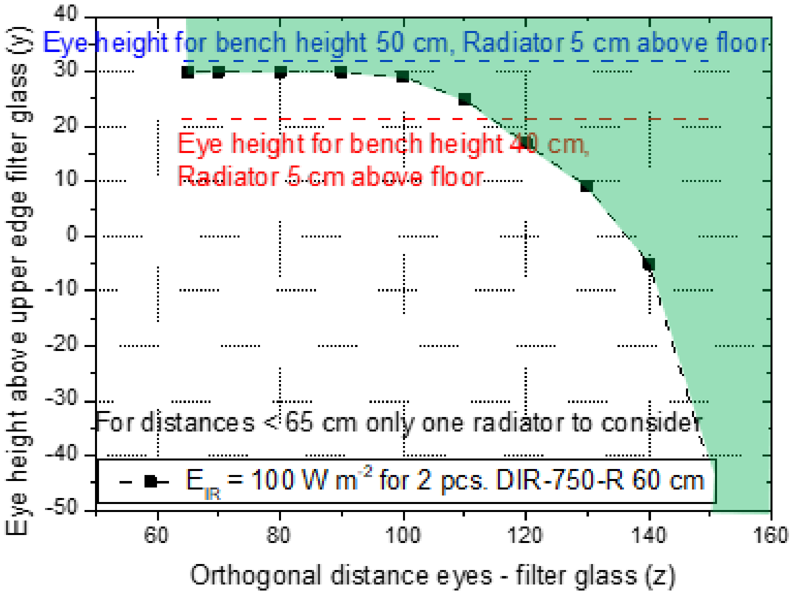

Figure 33: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a two-seat cabin with 2 pcs. DIR-750-R front emitters at a lateral distance of 60 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

In a two-seat cabin with two DIR-750-R front radiators at a lateral distance of 60 cm and a normal distance z between the eyes and the plane of the filter glass between 65 cm and 100 cm, the height of the bench above the cabin floor should be 49 cm. For this bench height, the limit of 100 W m^{-2} cannot be exceeded even by a small person whose eyes are only 68.5 cm above the bench, given the usual installation height of the front emitters (lower edge of front emitter 5 cm above the cabin floor). For distances < 65 cm to the front emitter, there is only one front emitter within the field of view of 80° and a seat bench height of 43 cm is sufficient to ensure that the limit value is not exceeded at the usual installation height of the front emitters (see Figure 28).

6.3.2 2 pcs. DIR-750-R front radiators at a lateral distance of 75 cm

When using two front radiators at a lateral distance of 75 cm, both front radiators are within a field of view of 80° for distances ≥ 80 cm to the plane of the filter glass of the front radiators. For distances ≥ 80 cm, the graphical solution shown in Figure 34 is relevant. For distances < 80 cm, there is only one front radiator within a field of view of 80°. Therefore, for distances < 80 cm, the graphical solution according to Figure 28 should be used.

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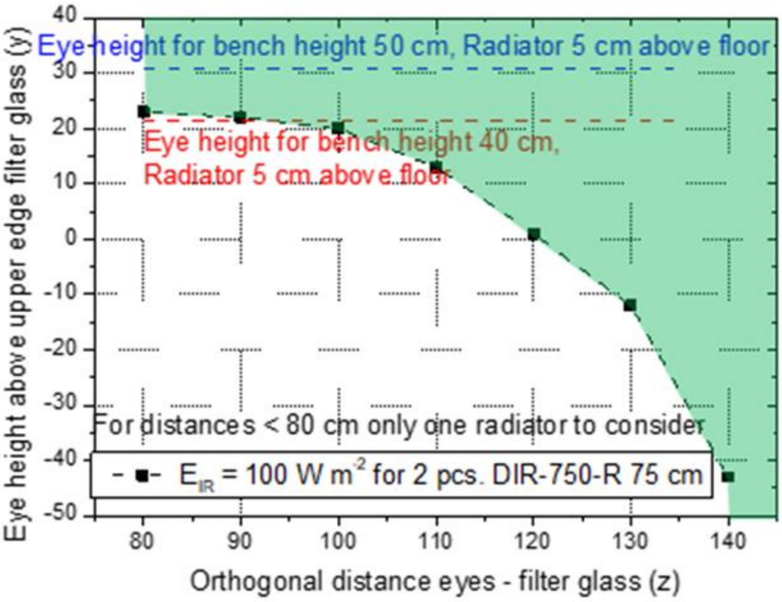

Figure 34: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a two-seat cabin with 2 pcs. DIR-750-R front emitters at a lateral distance of 75 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

In a two-seat cabin with two DIR-750-R front emitters at a lateral distance of 75 cm, the limit cannot be exceeded even for a small person whose eyes are only 68.5 cm above the seat bench in an upright sitting position, if the seat bench height is 43 cm above the cabin floor and the front emitters are installed at the usual installation height (lower edge of front emitter 5 cm above the cabin floor). With a seat height of 43 cm, the orthogonal distance of the eyes to the plane of the filter glass of the front radiators is irrelevant, as according to Figure 34 and Figure 28 the limit of 100 W m^{-2} is not exceeded for this bench height.

6.4 3-seat cabin

An example of a 3-seat cabin in which the front and back radiators are arranged directly opposite each other is shown in Figure 35. Four variants of the cabin type with three seats were analysed as part of this report:

- Lateral distance between the DIR-750-R front radiators 30 cm: It is not advisable to use this geometry in practice, as this case has not been investigated with regard to heat stress and it is very likely that the limits will be exceeded with regard to both limits heat stress and "infrared, eye".
- Lateral distance between DIR-750-R front radiators 60 cm
- Lateral distance between DIR-750-R front radiators 80 cm
- Lateral distance between DIR-750-R front radiators 100 cm

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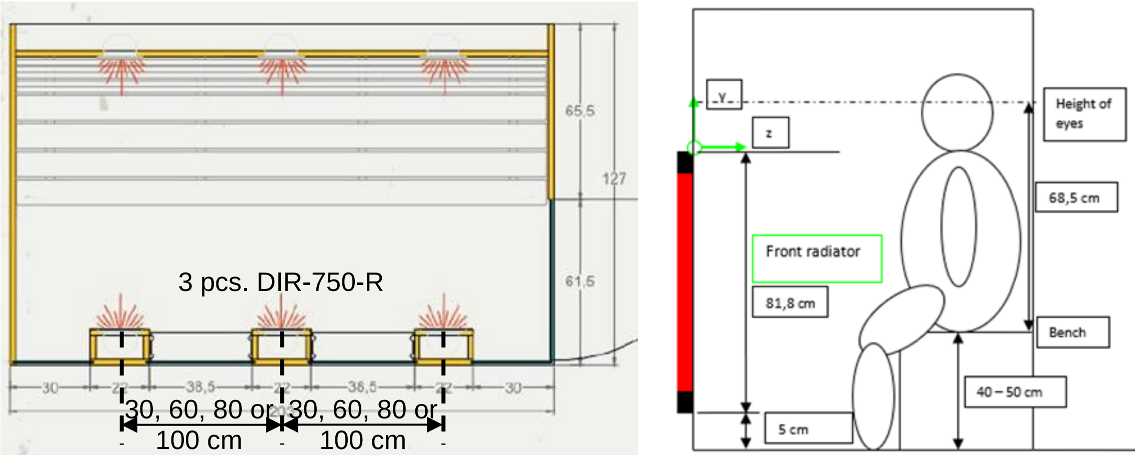

Figure 35: Example of a three-seat cabin with three front and three back radiators (left plan view, right cross-section with usual distances). In the cross-section on the right, the back radiators are not shown as they are not relevant for compliance with the IR limit for the eyes.

The measurements were carried out for the centre seat, where only the centre front radiator is within a field of view of 80° in the case of small distances (z). For larger distances (z), however, all three front radiators are within a field of view of 80°.

6.4.1 3 pcs. DIR-750-R front radiators at a lateral distance of 30 cm

It is not recommended to use this radiator arrangement in an IR cabin. According to Figure 36 the normal (orthogonal) distance between the eyes and the filter glass of the centre front radiator must be at least 178 cm (see Figure 36), so that the IR limit of 100 W m^{-2} is not exceeded at a bench height of 50 cm when considering the usual installation height of the front emitters. For distances (z) ≤ 50 cm, it can be assumed that the limit value for heat stress will be exceeded in case of this radiator arrangement.

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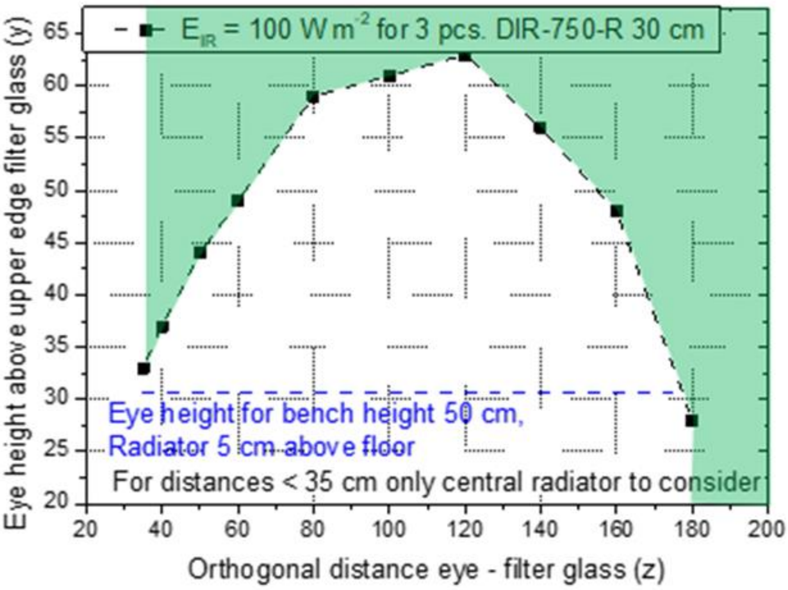

Figure 36: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a three-seat cabin with 3 pcs. DIR-750-R front emitters at a lateral distance of 30 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

6.4.2 3 pcs. DIR-750-R front radiators at a lateral distance of 60 cm

Figure 37 shows that in case of this particular arrangement of radiators, the normal distance z from the eyes to the plane of the filter glass must be > 165 cm in order not to exceed the limit when a bench height of 50 cm is used. For orthogonal distances z < 65 cm, there is only one radiator within the field of view of 80° and Figure 28 must therefore be used to assess if the limit has been exceeded. Figure 28 shows that with a seat bench height of 43 cm and the usual installation height of the front radiators, the limit is not exceeded for a small person in an upright sitting position.
Consequently, it can be deduced that with this radiator arrangement at normal distances z between 50 cm and 60 cm, the limit of 100 W m^{-2} should not be exceeded if the bench height is at least 43 cm and the usual installation heights (lower edge of front radiator 5 cm above the cabin floor) are observed.

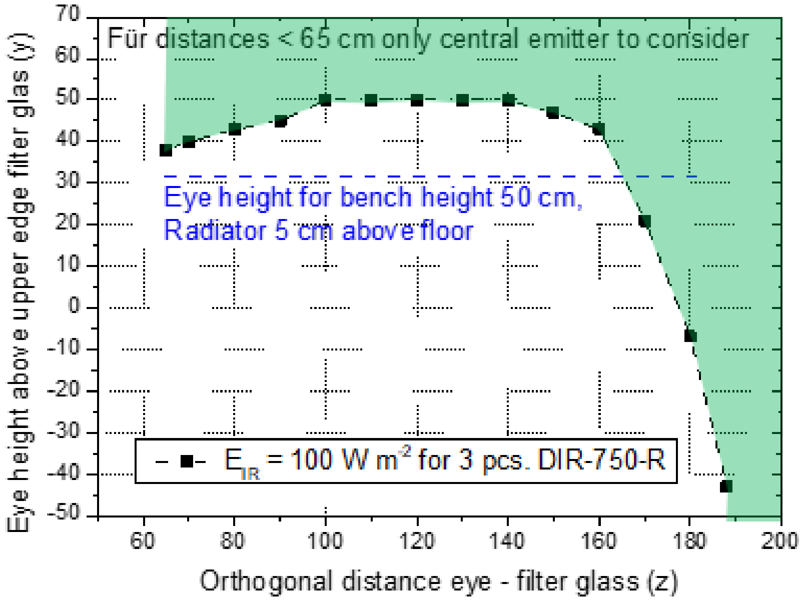

Figure 37: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a three-seat cabin with 3 pcs. DIR-750-R front emitters at a lateral distance of 60 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, 31.5 cm above the upper edge of the front radiator.

6.4.3 3 pcs. DIR-750-R front radiators at a lateral distance of 80 cm

When using 3 pcs. front radiators at a lateral distance of 80 cm, all three front radiators are within a field of view of 80° for the user sitting in front of the central back radiator for distances ≥ 90 cm to the plane of the filter glass of the front radiators. For distances ≥ 90 cm, the graphical solution shown in Figure 38 is relevant. For distances < 90 cm, there is only one front radiator within a field of view of 80°. Therefore, for distances < 90 cm, the graphical solution according to Figure 28 should be used.

If the orthogonal distance z of the eyes to the plane of the filter glass is between 90 cm and 130 cm, the bench height must be at least 52 cm in order not to exceed the limit when a small person is sitting upright in the cabin and the front emitters are installed at their usual height (lower edge of front emitters 5 cm above the cabin floor) (see Figure 38). For orthogonal distances z of the eyes between 50 cm and 85 cm, according to Figure 28 a minimum height of the seat bench of 43 cm above the cabin floor is sufficient in order not to exceed the limit when a small person is sitting upright in the cabin and the front emitters are installed at their usual height (lower edge of the front emitters 5 cm above the cabin floor).

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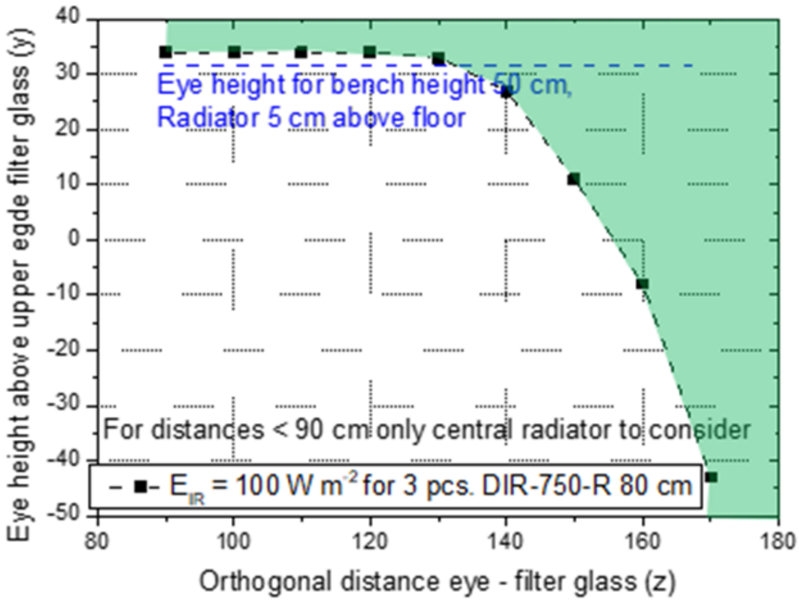

Figure 38: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a three-seat cabin with 3 pcs. DIR-750-R front emitters at a lateral distance of 80 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

6.4.4 3 pcs. DIR-750-R front radiators at a lateral distance of 100 cm

When using 3 pcs. front radiators at a lateral distance of 100 cm, all three front radiators are within a field of view of 80° for distances ≥ 110 cm to the plane of the filter glass of the front radiators in the centre seating position. For distances ≥ 110 cm, the graphical solution as shown in Figure 39 is relevant. For distances < 110 cm, there is only one front radiator within a field of view of 80°. Therefore, for distances < 110 cm, the graphical solution according to Figure 28 should be used.

In case of this specific arrangement of radiators, the conclusion is relatively simple: Regardless of the normal (orthogonal) distance (z) of the eyes to the plane of the filter glass, the limit of 100 W m^{-2} is not exceeded for a small person sitting upright at the centre seating position and the front radiators are installed as usual above the cabin floor (lower edge of front radiator 5 cm above the cabin floor) if the bench is installed at a height of at least 43 cm above the cabin floor.

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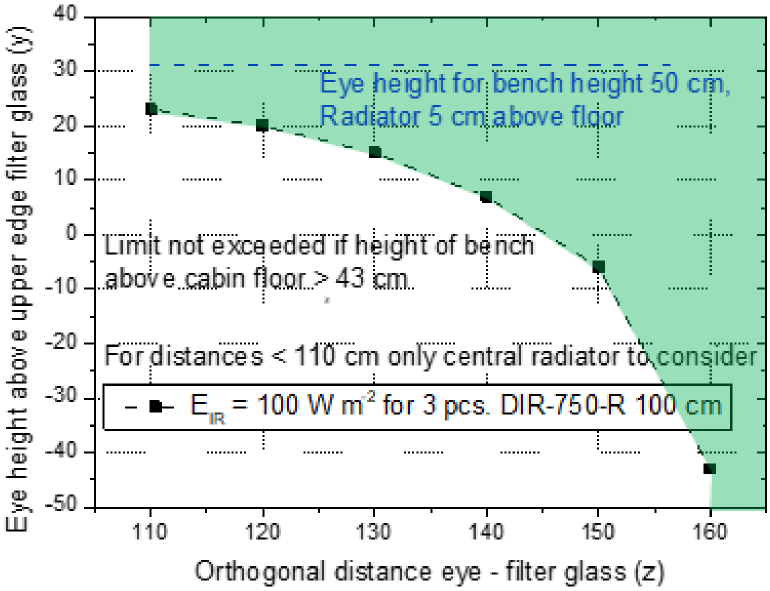

Figure 39: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for a three-seat cabin with 3 pcs. DIR-750-R front emitters at a lateral distance of 100 cm. The eye height shown refers to a person whose eyes are 68.5 cm above the bench. With a bench height of 40 cm, the eyes of this person are 21.5 cm above the upper edge of the front radiator (y-value in the diagram above), with a bench height of 50 cm, the eyes are 31.5 cm above the upper edge of the front radiator.

6.5 Hybrid sauna "Alaska Corner Infra+"

In the hybrid sauna “Alaska Corner Infra+”, two DIR-350-R or DIR-500-R full spectrum IR radiators are combined with a classic sauna heater in one cabin. The radiation scenario is shown in Figure 40. The hybrid cabin can be used either as a classic sauna or as an infrared cabin. According to clause 6.1 of ÖNORM M 6219-2:2022, simultaneous operation of the sauna heater and the infrared radiators is not permitted if the cabin temperature of 45°C is exceeded during commercial use. By installing seat sensors, the IR emitters can only be operated when a user is sitting directly in front of the respective IR emitter. This is to prevent a user from lying in front of an IR heater and looking directly into the heater from a short distance. The functionality of the seat sensors was not tested as part of this expert opinion.

In the case of the Figure 40 two IR emitters (each with an electrical connected load of either 350 W or 500 W) are used. One emitter - emitter 1 - is located as shown in Figure 40 on the cabin wall on the right. The second emitter - emitter 2 - is located as shown in Figure 40 on the lower cabin wall and can be used either in position 2a or 2b.

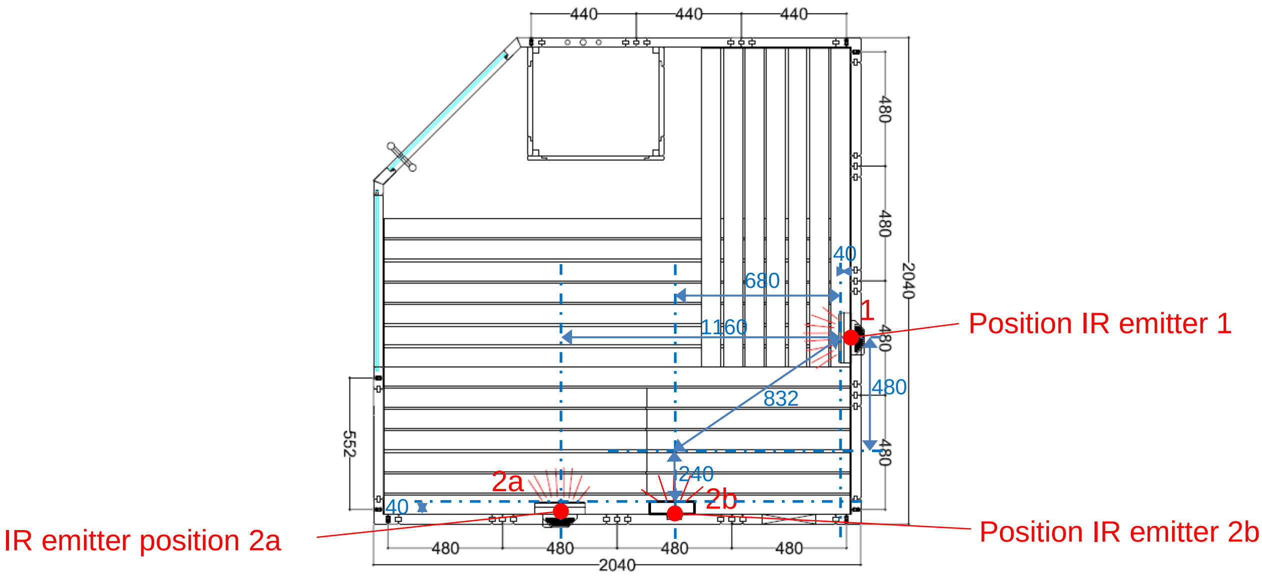

Figure 40: Irradiation scenario "Alaska Corner Infra+". Two IR heaters (either with 350 W or 500 W electrical connected load) are installed in a cabin in combination with a sauna heater. The IR radiator on the right (1) is installed in a fixed position. Two different positions were considered for the radiator at the bottom (position 2a or 2b).

The following can be derived from the measured values for the irradiation scenario in the hybrid cabin:

1) Use of two IR emitters (1 in combination with 2a or 2b) with an electrical connected load of **350 W** (DIR-350-R, WIR-350-R, ECO-350-R)

- If there is an IR emitter in position 2a (IR emitter in position 2b does not exist) and the user would slide all the way forwards on the wooden bench in front of this emitter so that you can virtually look straight into the other 350 W IR emitter installed in position 1, the irradiation distance is 116 cm. From a distance > 75 cm to the DIR-350-R, it is not possible to exceed the limit of 100 W m^{-2}, even when looking directly into the centre of the IR radiator (see Table 6).
- If the IR radiator is in position 2b (IR radiator in position 2a does not exist) and the user is sitting directly in front of it, the distance of the eyes to the side of the other IR radiator installed in position 1 is 83 cm. This distance is greater than the "worst-case" distance of 75 cm and therefore the limit value cannot be exceeded. If the user moves to the front of the wooden bench directly in front of the radiator in position 2b and looks from there directly into the other 350 W radiator in position 1, the distance is only 68 cm. Assuming that the eyes are 68.5 cm above the seat, the limit value will not be exceeded in this position as long as the lower edge of the 350 W radiator is not installed higher than 17 cm above the seat in the cabin. This can be derived from the following Figure 41 (based on Figure 30 for the DIR-350-R radiator):

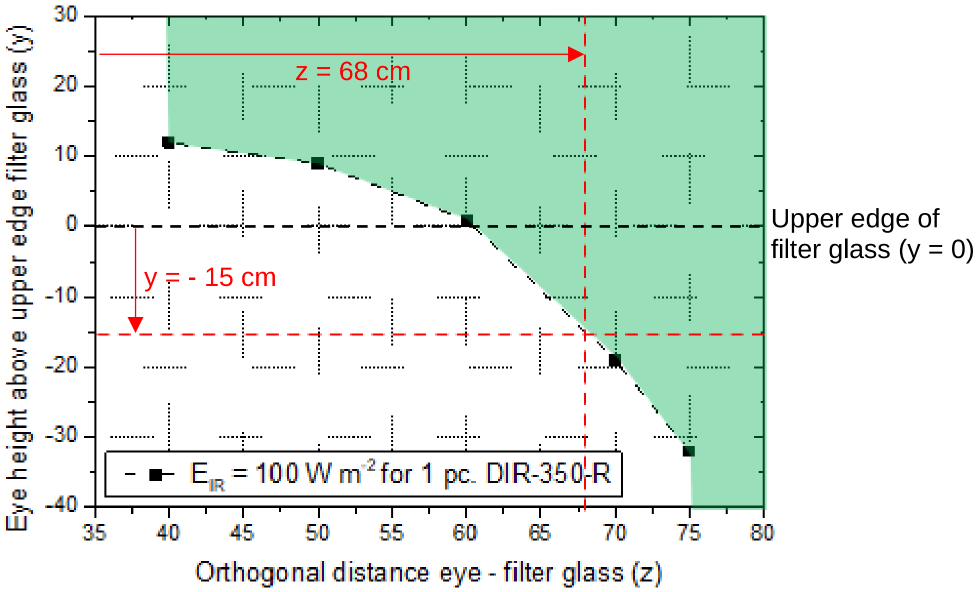

Figure 41: Graphical solution for the irradiation scenario in the "Alaska Corner Infra+" cabin when the IR emitter is at the bottom in position 2b and the user is sitting at the very front on the wooden bench and looking directly into the other 350 W IR emitter in position 1.

The length of the 350 W radiator is 66 cm. According to the diagram above, the limit of 100 W m^{-2} is reached when the eyes are 68 cm (z) away from the filter glass of the radiator and 15 cm (y) below the upper edge of the radiator. As the eyes of the considered small person are 68.5 cm above the bench, the limit is reached when the 350 W radiator is installed 17.5 cm above the seat.

2) Use of two IR emitters (1 in combination with 2a or 2b) with an electrical connected load of **500 W** (DIR-500-R, WIR-500-R, ECO-500-R)

- If the IR emitter is in position 2a (IR emitter in position 2b does not exist) and the user would slide all the way forwards on the wooden bench in front of the emitter so that it is possible to look straight into the other 500 W IR emitter installed in position 1, the irradiation distance is 116 cm. From a distance > 88 cm to the DIR-500-R, it is not possible to exceed the limit of 100 W m^{-2}, even when looking directly into the centre of the IR radiator (see Table 6).
- If the 500 W IR radiator is in position 2b (there is no IR radiator in position 2a) and assuming that the user is sitting directly in front of the radiator, the distance of the eye to the side of the other radiator installed in position 1 is 83 cm. The limit cannot be exceeded as long as the lower edge of the 500 W radiator is not installed higher than 15 cm above the bench (see Figure 42, length of 500 W radiator 82 cm, eye height above seat 68.5 cm, at a distance of 83 cm the eye may be 29 cm below the upper edge of the filter glass). However, if the user slides forwards and the distance is only 68 cm, the lower edge of the 500 W radiator would have to be installed well below the bench (13 cm below the bench) in order not to exceed the limit (see Figure 42). However, it does not seem practical to install the 500 W radiator at such a low position.

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This data was also taken from the corresponding graphic for the DIR-500-R radiator (Figure 29) and the sauna plan (Figure 40).

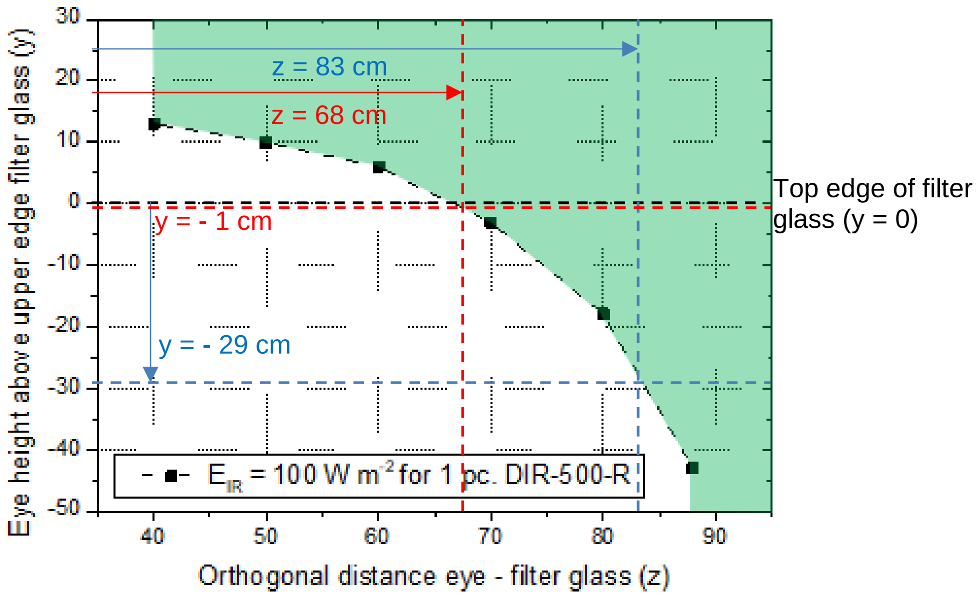

Figure 42: Graphical solution for the irradiation scenario in the "Alaska Corner Infra+" cabin when the IR emitter is at the bottom in position 2b and the user is sitting at the very front on the wooden bench and looking directly into the other 500 W IR emitter in position 1.

6.6 IR cabin with one 1300 W ceiling radiator with reclining area

For the IR cabin model shown in Figure 43 with a 1300 W radiator at the ceiling, the following can be derived from expert opinion LE-G31/18:

- In the case shown in Figure 43 the 1300 W radiator can be considered as a front radiator. If the minimum distances above the upper edge of the radiator specified below are considered (60 cm for DIR-1300-R and 40 cm for WIR-1300-R, 41 cm for HVIS-1300M), the user's body is below the upper edge of the radiator from the abdominal area downwards. In order not to exceed the limit for heat stress (averaged over the chest and back area) of 1000 W m^{-2}, the maximum irradiance in the chest area must be < 2000 W m^{-2} (as there is no irradiation of the back and the irradiance on the back is therefore assumed to be 0 W m^{-2}). If the minimum distances of the eyes above the upper edge of the IR radiator are considered, an irradiance in the chest area ≥ 2000 W m^{-2} seems very unlikely. The limit regarding heat stress is therefore very unlikely to be exceeded if the eye distances above the upper edge of the 1300 W emitter as indicated in Figure 43 are considered. According to Table 4 of this expert opinion, the hazard distance for the skin is approx. 14 cm for the WIR-1300-R emitter and approx. 16 cm for the DIR-1300-R and HVIS-1300M emitter (irradiance limit = 3550 W m^{-2}). Assuming the linear distance law, the WIR-1300-R has an irradiance < 2000 W m^{-2} for distances ≥ 25 cm and the DIR-1300-R and HVIS-1300M emitter for distances ≥ 29 cm.

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- When using the DIR-1300-R radiator at the ceiling of the cabin, the eye must be 60 cm above the upper edge of the radiator to ensure that the limit of 100 W m^{-2} is not exceeded (regardless of the distance to the radiator, see Figure 43). If the user is looking at the centre of the DIR-1300-R, the user would have to be approx. 190 cm away from the emitter to ensure that the limit is not exceeded.
- When using the WIR-1300-R radiator at the ceiling of the cabin, the eye must be 40 cm above the upper edge of the emitter so that the limit of 100 W m^{-2} is not exceeded (regardless of the distance to the emitter). If the user looks directly at the centre of the WIR-1300-R, the user will have to be approx. 153 cm away from the emitter to ensure that the limit is not exceeded.
- When using the HVIS-1300M radiator at the ceiling of the cabin, the eye must be 41 cm above the upper edge of the emitter so that the limit of 100 W m^{-2} is not exceeded (regardless of the distance to the emitter). If the user looks directly at the centre of the WIR-1300-R, the user will have to be approx. 140 cm away from the emitter to ensure that the limit is not exceeded. The graphical assessment aid for the HVIS-1300M radiator for compliance with the IR-limit for the eye lens of 100 W m^{-2} is shown in Figure 44.

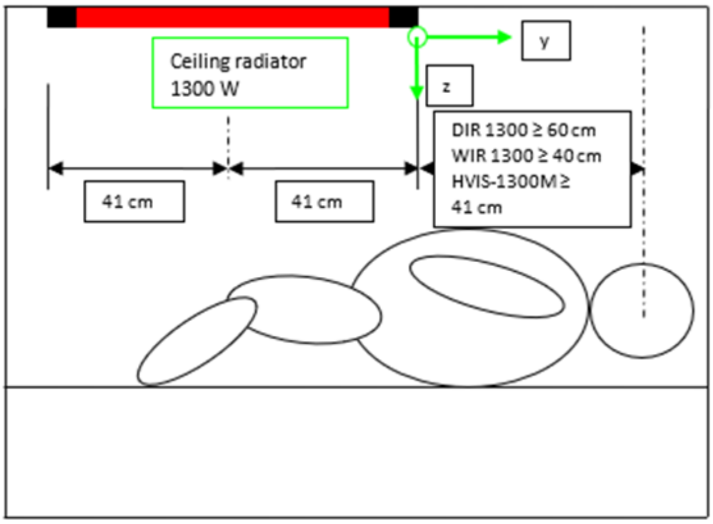

Figure 43: Irradiation scenario when using a 1300 W radiator on the ceiling of the cabin with reclining area below the radiator.

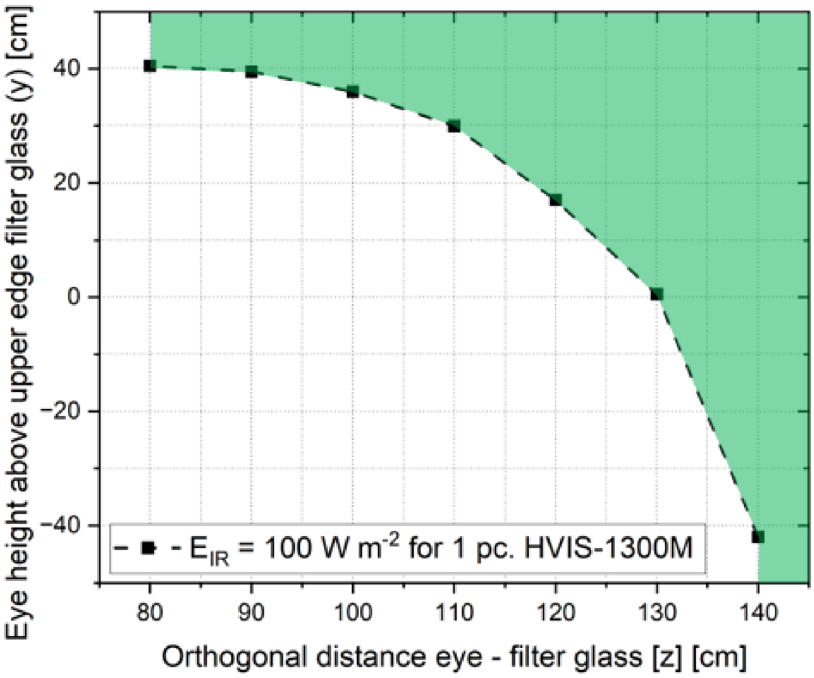

Figure 44: Graphical solution for compliance with the IR limit for the eyes of 100 W m^{-2} for an infrared cabin equipped with one HVIS-1300M ceiling emitter and a reclining area below the emitter.

End of expert opinion LE-G25/24

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