

Limit values for protection of the skin from burns due to exposure to radiant heat

IFA recommendations

Initial situation

People exposed to severe radiant heat may suffer damage to the skin and eyes. The level of radiant exposure therefore has to be limited. EU Directive 2006/25/EC on “Artificial optical radiation” [1] defines limit values for protection from damage due to exposure to optical radiation at workplaces. These have been transposed into German law by the OSH Ordinance on Artificial Optical Radiation (OStrV) [2]. The limit values of EU Directive 2006/25/EC are based on recommendations of the International Commission on Non-Ionising Radiation Protection (ICNIRP) [3, 4, 5]. However, there are loopholes in these recommended limit values. For instance, the ICNIRP recommendation for protection of the skin from burns due to exposure to visible and infrared radiation [4] in the wavelength range of 380 to 3000 nm does not contain any limit values for exposure for longer than 10 s. Such limit values are therefore lacking in the EU Directive and hence in practical application of the ordinance at the workplace. ICNIRP justifies the lack of recommended limit values for exposure times greater than 10 s by arguing that because of involuntary evasive action on exposure to severe radiant heat, exposure for longer than 10 s does not occur. However, this is not the case in practice. An abundance of studies and measurements in industry, some of them by the Federal Institute for Occupational Safety and Health (BAuA) [6] and by the IFA [7], show that radiant heat exposure for longer than 10 s does indeed arise at workplaces. It is often impossible for employees to evade exposure. So that they are still protected from heat damage to the skin, limit values for exposure within the visible and infrared wavelength range are required for exposure periods of longer than 10 s as well.



Figure 1: Exposure to radiant heat at a metal smelting furnace

A new calculation model

To fill the loophole in the limit values, a new calculation model has been developed. It is based firstly on the EU limit values while also permitting the application of limit values for protection of the skin from burns beyond 10 s exposure as well. To this end, the EU limit values have been combined with guide values that can be found in the German standard DIN 33403-3 [8]. Figure 5 of DIN 33403-3 shows the irradiance values that cause pain after a certain exposure duration. In most cases, pain arises on exposure of the skin to radiant heat before burning occurs. If the pain threshold is not exceeded, it can therefore be assumed that no skin burns will occur. In this respect, the time-dependent values of pain sensation in DIN 33403-3 can be adopted as limit values for protection from burns to the skin. The IFA therefore combines the EU limit values and DIN 33403-3 in such a way that the IFA recommendations for 1 to 10 s follows the formula of the EU Directive

$$E_{\text{skin}} = 20,000 \cdot t^{-0.75} \text{ W/m}^2.$$

In this case, H has been replaced by E and the exponent for t converted accordingly (see note).

From 10 to 1,000 s, the recommendation follows the formula

$$E_{\text{skin}} = 7,700 \cdot t^{-0.34} \text{ W/m}^2.$$

This curve follows on from the curve of the EU Directive and at the same time approximates very closely to the values of DIN 33403-3 between 50 and 1,000 s. The IFA recommendations are presented in Figure 2 together with the EU limit values and values of DIN 33403-3.

Note: Because of the relationship $H_{\text{skin}} = E_{\text{skin}} \cdot t$, it is also possible to express the limit value formula (index o) of the EU Directive $H_{\text{skin}} = 20,000 \cdot t^{0.25} \text{ [J/m}^2\text{]}$ as $E_{\text{skin}} \cdot t = 20,000 \cdot t^{0.25} \text{ [J/m}^2\text{]}$.

If both sides of the equation are divided by t, the relationship remains unchanged and the following is obtained: $E_{\text{skin}} = 20,000 \cdot t^{-0.75} \text{ [W/m}^2\text{]}$. The limit value of the EU Directive is thus expressed as the time-dependent irradiance E_{skin} . This is more appropriate than the variable H_{skin} used in the EU Directive, as skin burns depend on the irradiance E_{skin} and not on the irradiation H_{skin} . H_{skin} is a time-integrated variable and says nothing about the momentary intensity of the skin's exposure to radiation.

Along with the lack of values for longer exposures, the wavelength range of 380 to 3000 nm covered by the EU Directive is in many cases insufficient. Radiant heat sources such as molten metal or glass can have temperatures as high as about 1500°C. In the processing of quartz glass, temperatures may even exceed 2000°C. This means that these sources emit radiant heat comprising wavelengths over 3000 nm. The radiant share among wavelengths over 3000 nm can be so high that they make a major contribution to burns if the skin is exposed to it. To protect the skin from burns on exposure to such radiant heat sources, account has to be taken of wavelengths up to 10000 nm (10 µm) and in isolated cases even up to 20000 nm (20 µm). With the aid of Planck's law, it can be shown that, with a radiant source temperature of 1500°C, a sizable 33% of the IR irradiance lies within the wavelength range of 3 to 20 µm. Given a source temperature of 1000°C, as much as 55% of the irradiance lies within the range of 3 to 20 µm, and this is not covered by the EU Directive. In accordance with the ICNIRP statement on exposure to far infrared radiation [5], the share of wavelengths over 3000 nm (UV-C) in these cases can be included in the calculation of the level of exposure and in the comparison with the limit value for protection from skin burns [4]. For exposure to radiant heat sources, the IFA therefore recommends the inclusion of all radiant shares up to a wavelength of 20 µm so that exposure is not underestimated in the assessment of these sources. Radiation with wavelengths smaller than 380 nm, on the other hand, can be disregarded, as their share of emitted radiation is negligible.

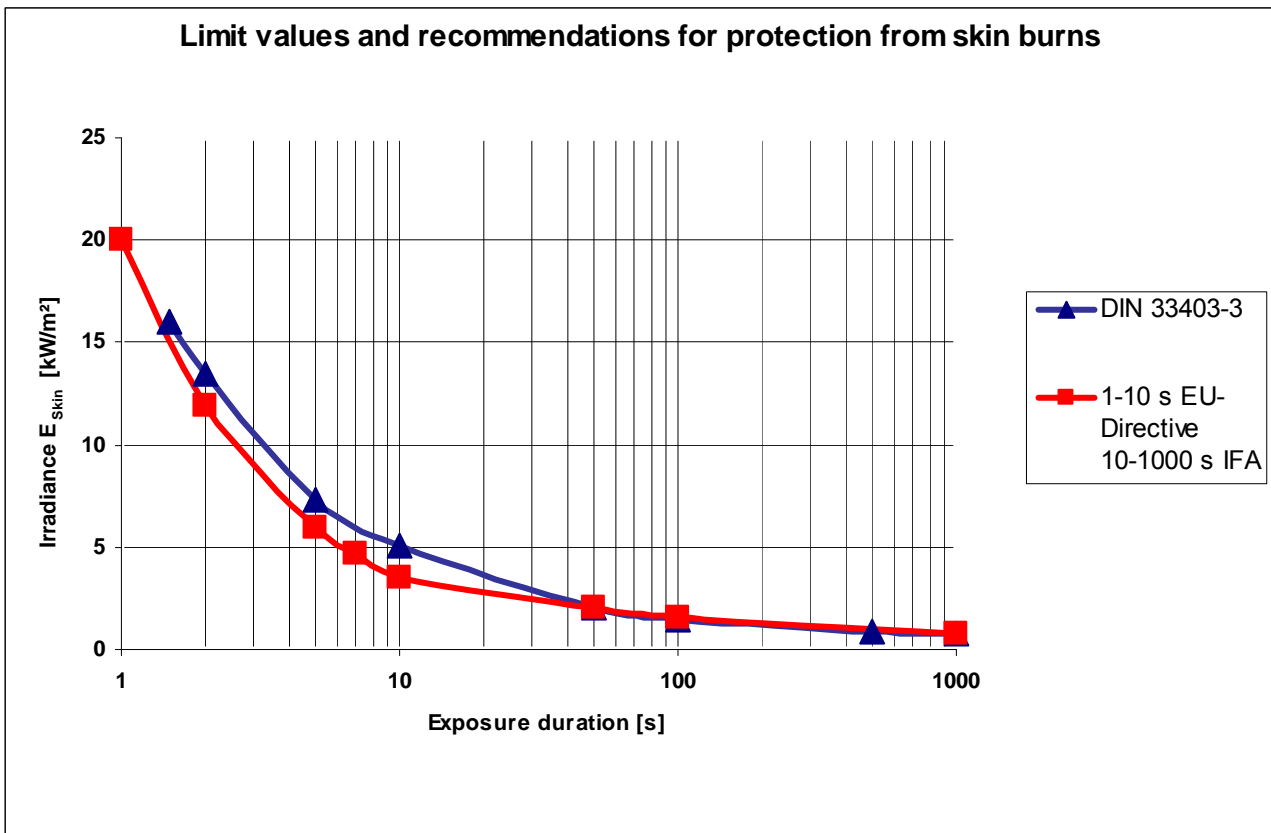


Figure 2: The curves show the time-dependent exposure limit value of EU Directive 2006/25/EC (lower red curve between 1 and 10 s, value points expressed as squares), the IFA recommendation (lower red curve between 10 and 1000 s, value points expressed as squares) and the pain sensation curve given in DIN 33403-3, Figure 5 (upper blue curve between 1,5 and 1000 s, value points expressed as triangles).

IFA limit value recommendation

In addition to the limit value specified in the EU Directive [1] under index o for protection of the skin from burns for exposure times up to 10 s, the IFA recommends the application of a limit value for exposure times between 10 and 1000 s. Furthermore, for comparison with the limit values, all the radiation shares in the wavelength range from 380 to 20000 nm should be covered. This yields the exposure limit values and recommended limit values listed in Table 1.

Table 1: EU exposure limit values and IFA recommendations for protection of the skin from burns due to radiant heat

Wavelength [nm]	Exposure limit value	Units	Part of body/hazard	Source
380 to 20000 (visible and IR)	$E_{\text{skin}} = 20,000 \cdot t^{-0.75}$ for $t < 10$ s	E: [W/m ²] t: [s]	Skin/burn	Table 1.1, index o of EU Directive 2006/25/EC [1], converted into E_{skin} , extended to 20000 nm wavelength
380 to 20000 (visible and IR)	$E_{\text{skin}} = 7,700 \cdot t^{-0.34}$ for $10 \text{ s} \leq t < 1000 \text{ s}$	E: [W/m ²] t: [s]	Skin/burn	IFA recommendation

This means that there are now continuous limit values and recommended limit values through to an exposure duration of 1000 s. The applicable exposure limit value can be calculated according to Table 1 on the basis of the duration of radiant heat exposure. In the event of several successive radiant heat exposures, a sufficiently long cool-off break has to be taken between the individual exposures. The cool-off break should last at least 5 minutes if the exposure exceeds 25% of the limit value. If the cool-off break is insufficient, successive radiant heat exposures are to be treated as a single long exposure and the limit value is then to be calculated for the duration of this long exposure.

Limit values for exposures up to 1000 s are usually sufficient in practice for the assessment of the risk from skin burns on exposure to severe radiant heat. For exposure durations above 1000 s, skin burns are no longer a decisive factor, as other hazards then predominate. In the event of prolonged exposure to radiant heat, the entire body is thermally stressed, and this places a strain on the cardiovascular system. The climatic factors of air temperature and humidity also contribute along with radiant heat. To prevent damage in the event of such exposure, reference can be made to limit and guide values from the field of climate assessment (see [9], for example).

List of sources

- [1] Directive 2006/25/EG of the European Parliament and of the Council of 5th April 2006 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) OJ EU, L 114/38 of 27.4.2006
- [2] Ordinance for the transposition of Directive 2006/25/EC for the protection of employees from hazards due to artificial optical radiation and for amendment of occupational safety & health ordinances of 19th July 2010. Federal Law Gazette I (2010) No. 38 of 26th July 2010

- [3] ICNIRP: Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation). Health Physics Vol 87 (2004), No. 2, pp. 171-186
- [4] ICNIRP: Guidelines on limits of exposure to broad-band incoherent optical radiation (0,38 µm to 3 µm). Health Physics Vol. 73 (1997), No. 3, pp. 539-554
- [5] ICNIRP Statement on far infrared radiation exposure. Health Physics Vol. 91 (2006), No. 6, pp. 630-645
- [6] See, for example, Neuschulz, H.: Thermophysiologische Beanspruchung des menschlichen Organismus durch anisotrope Infrarotstrahlung. BAuA publication series, special issue S79. Ed.: Federal Institute for Occupational Health and Safety (BAuA), Dortmund/Berlin/Dresden, 2003
- [7] See, for example, annual reports of the IFA 2009, pp. 36, and BGIA 2008, pp. 36, and 2007, pp. 35: www.dguv.de/ifa, Webcode [d92887](#)
- [8] DIN 33403-3: Climate at the workplace and its environments - Part 3: Assessment of the climate in the warm and hot working areas based on selected climate indices. Beuth, Berlin, 2011
- [9] BGIA-Report 6/2008: Grenzwerteliste 2008 – Sicherheit und Gesundheitsschutz bei der Arbeit. Ed.: German Social Accident Insurance (DGUV), Berlin, 2008
www.dguv.de/ifa, Webcode [d34078](#)

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