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UV RADIATION EMITTED BY SELECTED SOURCES AT WORK STANDS

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Abstract. The paper presents the results of UV effective irradiance measurements at work stands for sources such as: welding arcs, gas blowpipes, exposure processes, printing machines and insecticide lamps. The irradiance measurements were performed using broad-band instruments with detector heads corrected to the Polish action spectra (erythematous and conjunctivitis). The obtained values of effective irradiance for the above sources ranged from 0.2 to 8000 mW/m2. Safe exposure time corresponding to irradiance was calculated for the Polish threshold limit values. For welding processes the spectra of selected welding arcs are presented additionally. These spectra were measured using a fiber-optic spectrometer.

Key words:
UV radiation sources, UV measurements and exposure, Effective irradiance

INTRODUCTION

In their lifetime people may be exposed to excessive natural ultraviolet radiation, as part of solar radiation, as well as to UV radiation coming from artificial sources. Among electric sources of non-laser UV radiation there are low, middle and high pressure mercury lamps, metal halide lamps, deuterium lamps, xenon lamps and others. These sources are in widespread use. Low and high-pressure mercury lamps and metal halide lamps are used in disinfecting (in medicine, pharmaceutical and food industry, hairdressing salons, etc.), phototherapy, (e.g. treatment of psoriasis), printing industry (copying, ink and varnish drying), electronic industry (EPROM memory cleaners), beauty parlours (sun lamps), etc. Low-pressure mercury lamps are also installed in many devices, for example, in banknotes testers, or insecticide lamps. Xenon lamps are used among others in printing equipment, projectors and spectrophotometers.

UV radiation also accompanies various technological processes. In such cases, radiation can be emitted, for instance, by a processed material or due to the interaction between machinery and a processed material. There are processes, during which UV radiation is emitted following arc and gas welding [1,2,3], cutting with a plasma arc, oxygen-thermal cutting, thermal spraying, spark machining and others. In Poland, thousands of people work with these processes, which shows the importance of ensuring safe working conditions.

In this paper the results obtained during UV measurements for selected sources such as welding arcs, gas blowpipes, exposure processes, printing machines and insecticide lamps are presented.

METHODS

The UV effective irradiance measurements were performed using a broad-band instrument (type UV-1, Sonopan) with detector heads corrected to erythematous

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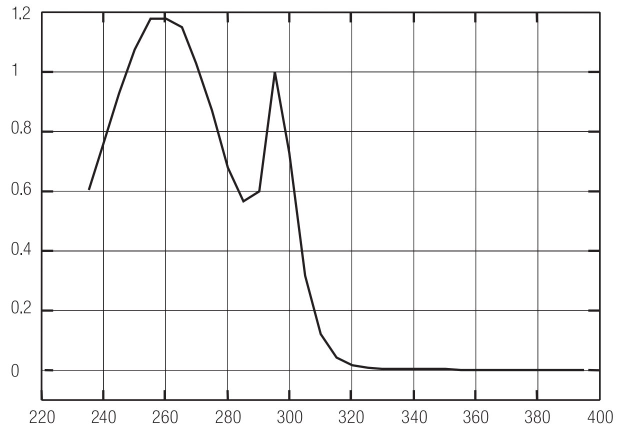

Fig. 1. Erythematous action spectrum $s_{er}(\lambda)$ recommended by the Polish standard [5]: first maximum for 257 nm, second maximum for 296 nm.

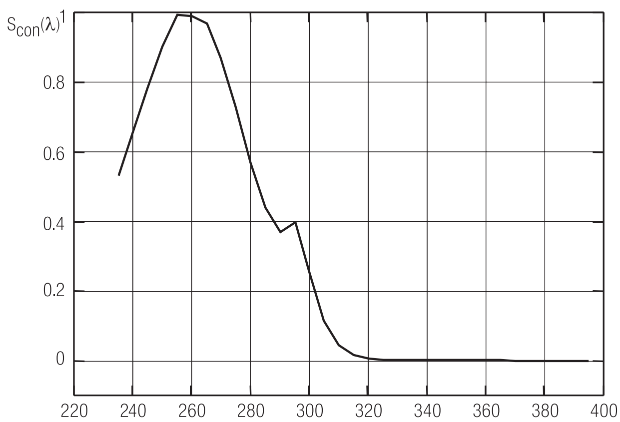

Fig. 2. Conjunctivitis action spectrum $s_{con}(\lambda)$ recommended by the Polish standard [5]: maximum for 257 nm.

(Fig. 1) and conjunctivitis (Fig. 2) action spectra. For the majority of sources. irradiance was measured at the level of the worker's face and hands. Only for insecticide lamps irradiance was measured near the enclosure of the lamp. The uncertainty of erythematous E_{er} and conjunctivitis E_{con} irradiance measurements was about 30%. The safe exposure time t_s was calculated for the Polish threshold limit values [4]: 30 J/m2 for an 8-hour period for skin (erythematous) and 30 J/m2 or 18 J/m2 for an 8-hour period for eyes (conjunctivitis). The safe distance from insecticide lamps d_s was also determined in accordance with the above criteria.

Spectrum measurements of UV radiation emitted by welding arcs were performed using a fibre-optic spectrometer (type S 2000, Ocean Optics Inc.). This instrument has an input fibre-optic probe (NA = 0.4), a grating monochromator (600 g/mm) and a CCD detector (2048 pixel linear array). The spectrometer was calibrated using standard mercury and halogen lamps. Measurements of radiation were made for the 200–850 nm spectral range. The real spectral range is wider, but for wavelengths below 200 nm and above 850 nm, the measurements were not precise enough. The end of the fibre-optic probe was situated about 0.75 m from the welding arcs. The welding current was in the range from 40 A to 60 A. The percentage of ultraviolet contribution (W_{uv}) in the whole radiation emitted by welding arcs was calculated in accordance with equation:

Table 1. UV irradiance and safe exposure time during selected welding processes

Electric welding

Electrode type	Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (s)	Conjunctivitis irradiance E_{con} (mW/m^2)	Safe exposure time t_s (s) everyday exposure	Safe exposure time t_s (s) non-everyday exposure
Acid-resisting E518-8NbR ϕ 4	4000	7.5	4000	4.5	7.5
Low-hydrogen EB 146 ϕ 4	3500	8.6	2500	7.2	12
Rutile ER 346 ϕ 4	8000	3.8	8000	2.3	3.8

Argon arc welding

Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (s)	Cnjunctivitis iradiance E_{con} (mW/m^2)	Safe exposure time t_s (s) everyday exposure	Safe exposure time t_s (s) non-everyday exposure
3000	10	6000	3	5

Gas welding

Blowpipe	Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (h)	Conjunctivitis irradiance E_{con} (mW/m^2)	Safe exposure time t_s (h) everyday exposure	Safe exposure time t_s (h) non-everyday exposure
Perun	3	2.78	2	2.5	4.2

Gas cutting

Blowpipe	Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (h)	Conjunctivitis irradiance E_{con} (mW/m^2)	Safe exposure time t_s (h) everyday exposure	Safe exposure time t_s (h) non-everyday exposure
PU212A1	6.5	1.28	3.5	1.43	2.38

$$W_{UV} = \frac{\int_{200}^{400} I_{rel}(\lambda)\,d\lambda}{\int_{200}^{850} I_{rel}(\lambda)\,d\lambda} \cdot 100\,(\%)$$

where $I_{rel}(\lambda)$ is relative spectral radiant intensity.

The percentage of UV-A, UV-B and UV-C contribution in the ultraviolet part of welding arcs spectra was also calculated (Table 2a).

RESULTS

Welding work stands (Tables 1–2a and Figs. 3 and 4).
Exposure process (Table 3).
Printing process (Table 4).
Insecticide lamps (Table5).

Table 2. Percentage of ultraviolet contribution in the spectra of welding arcs

Electrode type	W_{UV} (%)
Rutile ER 246 ϕ 5	24
Acid-resisting ϕ 3.55	21.3
Low-hydrogen heavy coated electrodeEB 146 ϕ 6.26	24.2
For cast iron welding	23.2

Table 2a. Percentage of UV-A, UV-B and UV-C contribution in the ultraviolet part of welding arcs spectra.

	Electrode type: Rutile ER 246 ϕ 5	Acid-resisting ϕ 3.55	Low-hydrogen heavy coated electrode EB 146 ϕ 6.26	For cast iron welding
UV-A	71	69	66.3	68.3
UV-B	11.5	12.3	11.9	10.7
UV-C	17.5	18.7	21.8	21

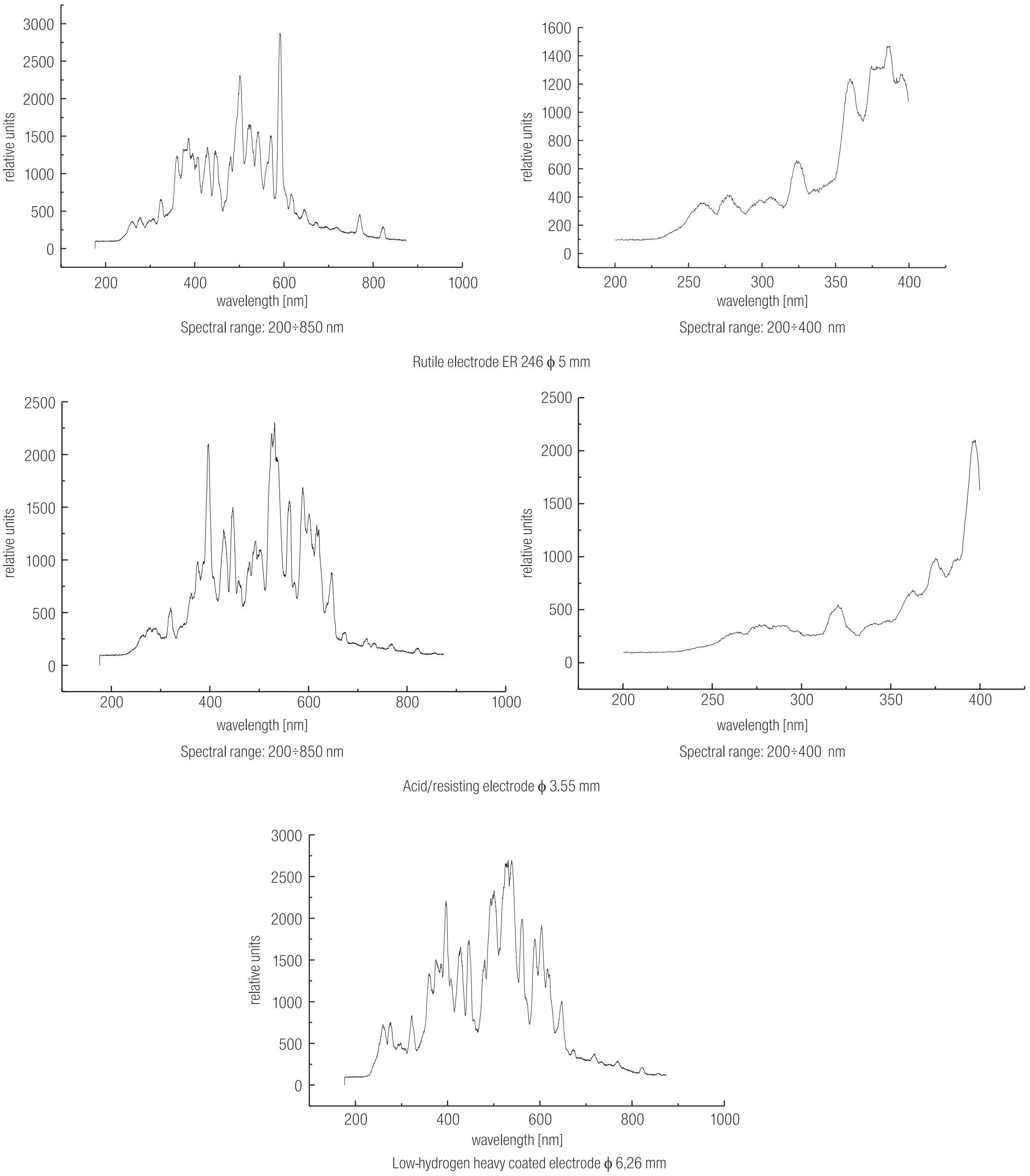

Fig. 3. Measured welding arcs spectra (steel welding).

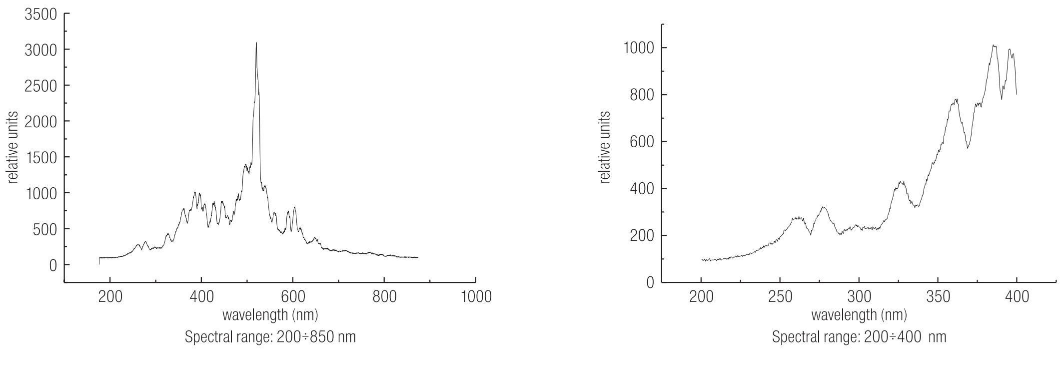

Fig. 4. Measured arc spectrum during cast iron welding.

Table 3. UV irradiance and safe exposure time for operator of device for steel sheet exposure (during kinescope manufacturing)

Operator of device for steel sheet exposure											
Type of work	Measurement point	Erythematous irradiance E_{er} (mW/m^2)		Safe exposure time t_s		Conjunctivitis irradiance E_{con} (mW/m^2)		Safe exposure time t_s			
								everyday exposure		non-everyday exposure	
		without protection	with protection	without protection	with protection	without protection	with protection	without protection	with protection	without protection	with protection
Control illuminance measurement	hands	5500 – 6000	–	5–5.5 s	–	–	–	–	–	–	–
	face	15–50	–	10–33.3 min	–	8–16	less than 0.6	18.8 – 37.2 min	8 h	31.3 – 62.5 min	8 h
Exposure process supervising	face	30–40	1–8	12. –16.7 min	1–8 h	13–17	0.6–4	17.6 –23 min	1.25 –8 h	29.4 – 38.5 min	2.1 - 8 h

Table 4. UV irradiance and safe exposure time at selected work stands

Printing projector operator					
Measurement point	Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (h)	Conjunctivitis irradiance E_{con} (mW/m^2)	Safe exposure time t_s (h)	
				everyday exposure	non-everyday exposure
face	5	1.67	4.5	1.11	1.85
hands	90	0.09	–	–	–
Printing plate machine operator					
Measurement point	Erythematous irradiance E_{er} (mW/m^2)	Safe exposure time t_s (h)	Conjunctivitis irradiance E_{con} (mW/m^2)	Safe exposure time t_s (h)	
				everyday exposure	non-everyday exposure
face	0.5	8	0.2	8	8
hands	15	0.56	–	–	–

Screen process and UV drying machine operator											
Type of work	Measurement point	Erythematous irradiance E_{er} (mW/m^2)		Safe exposure time t_s (h)		Conjunctivitis irradiance E_{con} (mW/m^2)		Safe exposure time t_s (h)			
								everyday exposure		non-everyday exposure	
		without protection	with protection	without protection	with protection	without protection	with protection	without protection	with protection	without protection	with protection
Machine operating	hands	3.5–36	1.2–1.9	0.23–2.38	4.39–6.9	–	–	–	–	–	–
	face	0.2	<0.2	8	8	0.2	<0.2	8	8	8	8
Magazine emptying	hands	67–500	3.5–12	0.017–0.12	0.7–2.38	–	–	–	–	–	–

DISCUSSION

The results obtained during UV measurements confirmed that the values of irradiance at welding work stands depended on the type of the welding process. As expected, during electric welding the irradiance was very high – from 3000 to 8000 mW/m^2 for erythematous irradiance E_{er} and from 2500 to 8000 mW/m^2 for conjunctivitis irradiance E_{con} (Table 1.). The ultraviolet contribution in the welding arcs spectra and related UV exposure at work stand was determined by various parameters of welding such as the type of welding material, type and thickness of electrode and welding current. Most of ultraviolet radiation emitted by welding arcs was within the UV-A spectral range (Table 2a). During gas welding and cutting the level of irradiance was far lower than during electric welding, which was connected with the lower temperature of gas flame (compared with an electric arc). The safety exposure times t_s (for unprotected skin or eyes) ranged from seconds for electric welding to few hours for gas welding and cutting (Table 1).

The operators of devices for steel sheet exposure were also irradiated by ultraviolet (Table 3). For example, during control illuminance measurements, erythematous irradiance E_{er} achieved maximum values of several thousands mW/m^2 (for skin of the hands) and conjunctivitis irradiance E_{con} oscillated from 8 to 16 mW/m^2. After the mounting protection equipment at work stand the level of radiation was considerably reduced.

At printing work stands (Table 4) UV exposure depended on the kind of the process. There was no UV hazard for a printing plate machine operators. The biggest irradiance (erythematous E_{er} – for skin of the hands) was obtained during magazine emptying at screen process and UV drying work stand. Like in the case of steel sheet exposure the protection equipment (polycarbonate screens) reduced the level of radiation.

Insecticide lamps are commonly used in food processing plants, meat and food shops, restaurant kitchens, etc. In these cases, UV radiation emission ranges from several mW/m^2 to several hundred mW/m^2 (Table 5, see also [6]). The staff often spend their whole work day in rooms where there are insecticide lamps. Therefore, it is very important to define the safe distance from an insecticide lamp d_s; for the lamps d_s under study, the distance ranged from 0.8 to 2.35 m (Table 5 see, also [6]).

CONCLUSION

UV radiation emitted by most of the sources presented may be dangerous for workers. The investigations confirmed that welding arcs are one of the most intensive UV sources in the work environment. Devices used during industry exposure processes, printing equipment and insecticide lamps can also emit high intensity UV radiation. Bearing in mind the growing number of UV sources in the work environment with the advancement of technological developments, testing of radiation emitted by these sources should continue. Especially in the case of new sources, the measurements should employ spectroradiometric technique, because biological effectiveness (and hazard) of ultraviolet depends to a great extent on the wavelength.

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