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Paper

MEASUREMENT OF ULTRAVIOLET RADIATION EMITTED FROM WELDING ARCS

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Abstract—It is well known that exposure to UV radiation can result in short- and long-term injury to the eyes and skin. Exposure to UV radiation is generally associated with many production processes involving either the use of UV or the emission of unwanted UV as a by-product. Welding arc machines are widespread sources of intense UV, as well as visible and infrared radiation. To evaluate the hazard associated with UV exposure during welding processes, the spectral irradiance must be measured and weighted in terms of biological effectiveness. Standardization of routine field measurement procedures is difficult because the emission depends on time dependent parameters. This paper presents a procedure suitable for the spectral irradiance measurement of welding arcs in the 250–400 nm range as well as other unstable sources.

INTRODUCTION

IN RECENT decades, exposure of humans to ultraviolet (UV) radiation (200–400 nm) emitted by the sun and artificial sources has been increasing. In workplaces, exposure to UV radiation is related to the increased number of production processes involving either the use or the emission as a by-product of UV radiation.

In humans, chronic or acute UV exposure may induce short- and long-term skin (erythema and skin cancer) (Ev65; Sl80; Ep83; Va84) and eye damage (photokeratitis, photoconjunctivitis and possibly cataracts) (Ku77; Pi73; Sl80). Most developed countries have some concern regarding both the nature and the extent of hazards associated with exposure to UV radiation (WH79).

At present, research on health effects of UV radiation exposure on humans is concentrated on the effects of non-acute repeated doses, because these are by far the most frequent and may give rise to delayed effects. In industrial processes, the UV radiation represents a potential risk factor for the health of operators and, thus, exposure should be controlled and kept at a level as low as reasonably possible. Welding arc machines used in industrial processes are intense, widespread sources of UV, as well as of visible and infrared radiation, to which a great number of workers are directly or indirectly exposed. Welding arcs are open sources of UV radiation, where complete shielding is practically impossible. To evaluate hazards of UV exposure during welding, one can measure the effective irradiance or the spectral irradiance (Em76; Ma77; Ba81; In78; Be79). The permissible maximum exposure time can be calculated referring to the threshold limit values proposed by the International Radiation Protection Association (IRPA) (IR85) or the American Conference of Governmental Industrial Hygienists (ACGIH) (AC79) in the spectral ranges 200–315 nm (UV-C and UV-B) and 315–400 nm (UV-A). Field measurements of spectral irradiance still present some difficulties. In metal arc welding, the intensity of the emitted UV radiation is very unstable because of difficulties of maintaining the proper arc length, even for an experienced welder. Moreover, fumes and gases, in addition to the molten metal arc stream and small sputtered slag drops, randomly absorb part of the emitted radiation. The time fluctuations of irradiance caused by some of these factors have considerable influence on the measurements and their reproducibility. In this paper, we present a practical procedure for spectral irradiance measurements of welding arcs.

MATERIALS AND METHODS

Laboratory measurements were performed on a shielded welding arc used to join metals in manufacturing, maintenance and repair processes. This apparatus is an ac/dc tungsten-argon shielded metal arc welding (GTAW) power source.* In our measurements, stainless steel was

* Miller Sincrowave 300P, ASCI-Miller S.P.A., 20139 Milan, Italy.

used as the base metal. An actinic radiometer IL730A** and a spectroradiometer IL782A** were used to make irradiance measurements. The former has a spectral response that approximately overlaps the relative spectral effectiveness curve as defined by the IRPA and ACGIH (Fig. 1), and it is supplied with a UV-B/UV-C blocking filter to correct the measurements for the contribution of UV-A, visible and infrared radiation. Therefore, this instrument can be used to measure the effective irradiance (E_{eff}) from which a direct evaluation of hazard (in terms of maximum exposure time) can be easily obtained.

The IL 782A spectroradiometer measures the spectral irradiance E_λ of a source from which the effective irradiance can be calculated. It incorporates a grating monochromator (250–800 nm, 1-nm bandwidth), an automatic wavelength scanning system and a photomultiplier as a detector. Before measuring, the calibration curve of the spectroradiometer in the range 250–400 nm has tested by means of a standard deuterium arc source.† Both radiometers can give time-integrated measurements. Spectral irradiance measurements of the arc were made with the actinic radiometer used as a monitor, to take into account the total intensity variations during the UV spectrum evaluation. Using a ratiometer,‡ the ratio between the output of the spectroradiometer and that of the actinic radiometer was recorded, thus obtaining a normalized measurement of spectral irradiance. A double track recorder, synchronized with a wavelength scanning system, was used to record simultaneously the readings of IL782A and IL730A radiometers or their ratio (Fig. 2).

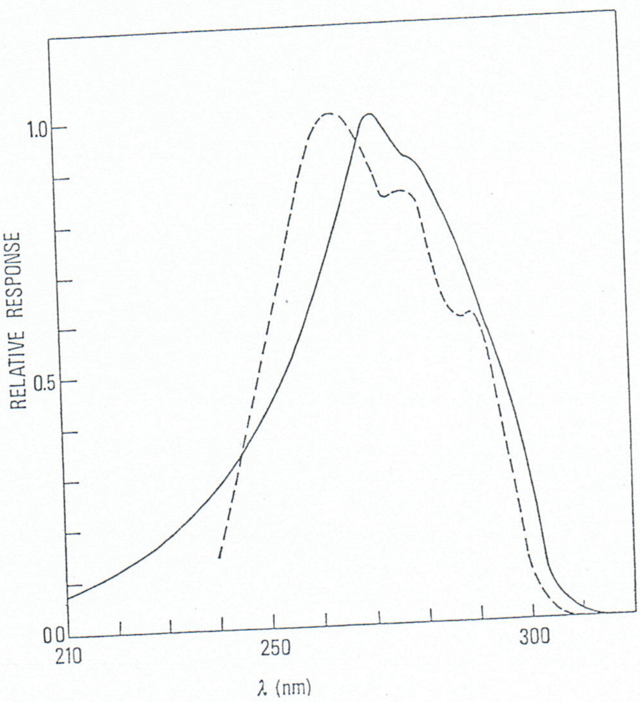

Fig. 1. Relative spectral effectiveness of UV radiation as defined by the American Conference of Governmental Industrial Hygienists (—) and the spectral response of the actinic radiometer (--).

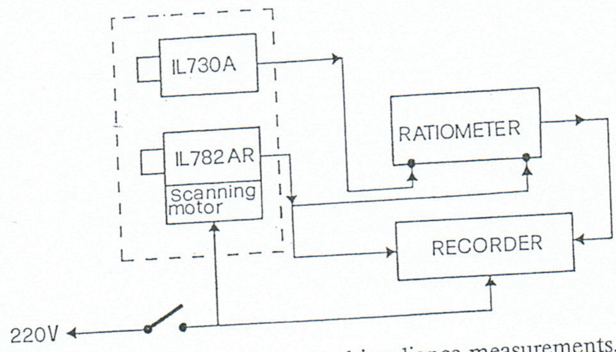

Fig. 2. Apparatus used for spectral irradiance measurements.

To improve reproducibility of the measurements, the following procedures were adopted: (a) the position of the electrode holder was mechanically blocked to reduce casual fluctuations deriving from the unstable length of arc in the GTWA source measurements, (b) a local ventilator exhausted fumes and ozone produced during welding, and (c) because of electromagnetic interference from the arcs, the instruments were operated using internal batteries. No signal was measured blinding the two radiometers.

EXPERIMENTAL RESULTS

Firstly, the spectral emission between 250 nm and 400 nm of the GTAW arc was measured carrying out readings of irradiance E_λ, at 1-nm wavelength intervals, integrated for 10 s. The detector was placed at the same level of the arc plane at a distance of 40 cm. All E measurements at single wavelengths were made simultaneously with E_{eff}. In this way, 151 readings of E_{eff} were obtained, with a mean value of

$$E_{eff} = (6.6 \pm 1.6)\ \mathrm{W\ m^{-2}},$$

the error being the standard deviation.

With this value, the maximum allowed exposure time (t_{max}), established by IRPA and ACGIH for unprotected eyes and skin in an 8-h period can be calculated as

$$t_{max} = \mathrm{MPE}_{270}/E_{eff} \simeq 4\mathrm{s},$$

where $\mathrm{MPE}_{270} = 30\ \mathrm{J\ m^{-2}}$ is the maximum permissible exposure value established at 270 nm. This wavelength is the maximum of the relative spectral effectiveness curve.

The E_λ values measured at single wavelengths were

** International Light Inc., Dexter Industrial Green, Newburyport, MA 01950.

† National Physical Laboratory, Teddington, Middlesex TW11 0LW, United Kingdom.

‡ PAR Model 188, Princeton Applied Research, P.O. Box 2565, Princeton, NJ 08540.

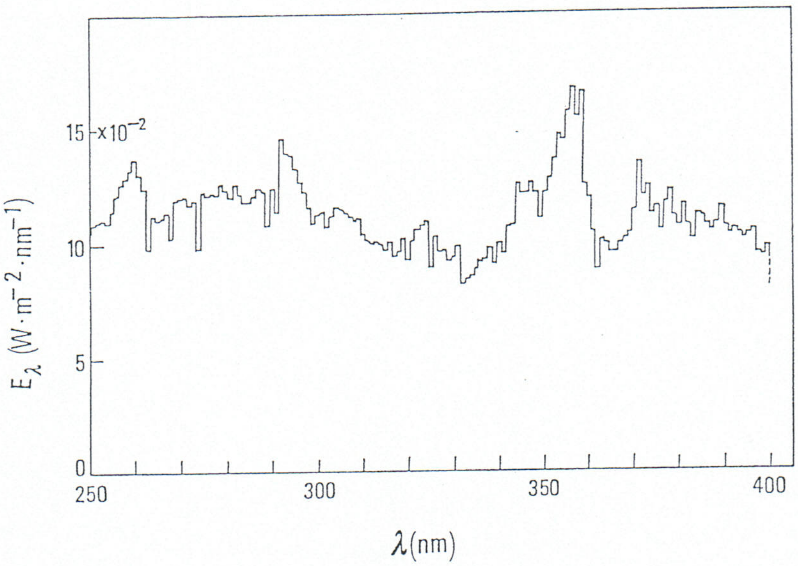

Fig. 3. Spectral irradiance E_λ of GTAW arc measured by time integrated (10-s) readings at single wavelengths and at a distance of 40 cm.

normalized to the mean value E_{eff}. The results are shown in Fig. 3.

This measurement required about 2 h, a period too long for routine measurements. The automatic scanning of wavelengths seemed more practical so that the irradiance spectrum (250–400 nm), recorded simultaneously with time fluctuations of effective irradiance, was obtained in about 3 min. Firstly, the measurements, which were repeated to check their reproducibility, were made without local ventilation. Marked fluctuations were revealed, but the position of the peaks was quite reproducible. In Fig. 4, the spectrum obtained with this procedure is shown.

To minimize these fluctuations in the following measurements, the procedures (a), (b) and (c) reported in the Materials and Methods were used and a ratiometer as previously described was employed.

Figure 5 shows the emission spectrum of the arc derived from normalizing the irradiance scale of ratio between the reading of spectroradiometer and the reading of actinic radiometer with the maximum value measured by the spectroradiometer. After repeating the scan four times, the reproducibility was better than ±10%.

In Fig. 5, some peaks that also were in the first measured spectra (Fig. 4) are recognizable, particularly around 350–360 nm, but the overall line structure is much less

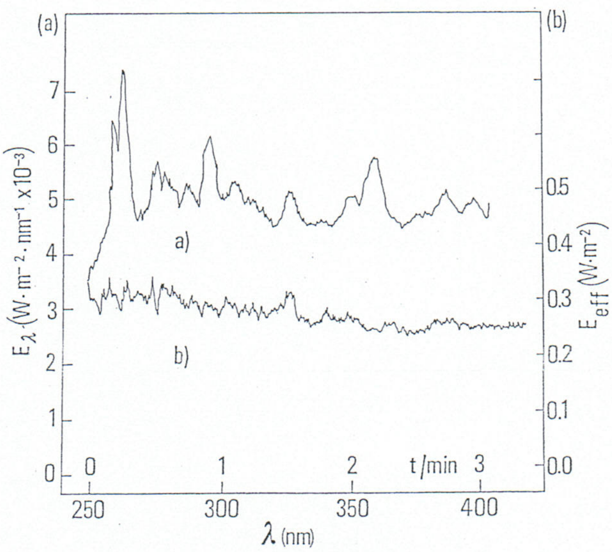

Fig. 4. Spectral irradiance E_λ of GTAW arc measured by automatic scanning (a) simultaneously with time fluctuations of effective irradiance E_{eff} (b).

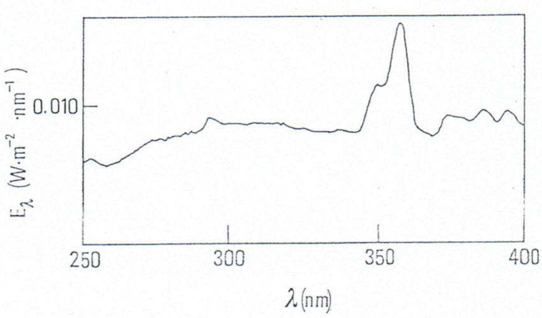

Fig. 5. Spectral irradiance E_λ of GTAW arc (measured with automatic scanning, internal batteries and a local ventilator) obtained normalizing the irradiance scale of the ratio between the reading of spectroradiometer and the reading of the actinic radiometer with the maximum value measured by the spectroradiometer.

marked. This shows that the results possibly can be misinterpreted due to random fluctuations.

DISCUSSION

From measurements on the welding arc previously described, the maximum exposure time (without protective equipments) was on the order of seconds. In various workplaces, we observed that operators start the welding process without protecting their eyes to see the exact position of the electrode with respect to the work piece. For this reason, the maximum exposure time may be exceeded during an 8-h period. This result suggests the need for personal monitoring devices, if available, to evaluate doses due to repeated exposures for long-term studies of biological effects.

The spectral irradiance measurements show that it is very difficult to achieve stable conditions appropriate for standardizing the methods. Indeed, different experimental conditions, which are likely to occur in the workplace, can cause variations of a few orders of magnitude in the measured irradiance. Furthermore, as shown above, the presence of fumes gives unstable shielding of the radiation. Local ventilation is necessary to exhaust toxic fumes and ozone (Fo81) produced by short wavelength UV ($\lambda < 250$ nm), but it enhances the UV exposure.

Our method of making automatic spectral irradiance measurements has some limitations. By using the actinic radiometer as a monitor to account for time fluctuations of arc intensity, only a first approximation correction is obtained. In fact, we assume that any factor causing a time discontinuity of the emission alters the complete spectral irradiance by the same ratio. But it is presumed that the presence of fumes and ozone will alter the spectral composition of the revealed radiation. This alteration also depends on the base metal composition. Furthermore, during the scanning time, the arc geometry and temperature distribution between the electrodes can change.

Measurements with the equipment and the procedures described here have been performed in several workplaces, where a great number of different conditions exist. Even under these conditions, the methodology described here is useful for obtaining careful evaluation of exposure during welding arc processes.

REFERENCES

AC79 American Conference of Governmental Industrial Hygienists, 1979, *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for* 1978 (Cincinnati, OH: American Conference of Governmental Industrial Hygienists).

Ba81 Bartley D. L., Mc Kinnery W. N. Jr. and Wiegand K. R., 1981, "Ultraviolet emission from the arc-welding of aluminum magnesium alloys," Am. Ind. Hyg. Assoc. J. **42**,

Be79 Bennet A. P., Fannery C. and Harlen F., 1979, *Safety Aspects of Ultraviolet Emission from Welding Arcs*, Central Electricity Generating Board, Marchwood Engineering Laboratories, Southampton, United Kingdom, CEGB-R/M/N 1063.

Em76 Emmett E. A. and Horstman S. W., 1976, "Factors influencing the output of ultraviolet radiation during welding," J. Occupat. Med. **18,** 41.

Ep83 Epstein J. H., 1983, "Photocarcinogenesis, skin cancer and aging," J. Am. Acad. Dermatol. **9,** 487.

Ev65 Everett M. A., Olson R. L. and Sayre R. M., 1985, "Ultraviolet erithema," Arch. Dermatol. **92,** 713.

Fo81 Folinsbee L. J., 1981, "Effects of ozone exposure on lung function in man: a review," Rev. Environm. Health **3,** 211.

In78 Ingram J. W. and Horstman S. W., 1978, "A field study of near ultraviolet welding irradiance," Am. Ind. Hyg. Assoc. J. **38,** 456.

IR85 International Radiation Protection Association, 1985, "Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation)," Health Phys. **49,** 331.

Ku77 Kurzel R. B., Wolbarsht M. L. and Yamanashi B. S., 1977, "Ultraviolet radiation effects on the human eye," p. 133, in: *Photochemistry and Photobiology Review*, Vol. II (edited by K. C. Smith) (New York: Plenum Press).

Ma77 Marshall W. H., Sliney D. H., Lyon T. L., Krial N. A. and Del Valle P. F., 1977, *Evaluation of Potential Retinal Hazards from Optical Radiation Generated from Electric Welding and Cutting Arc*, Report no. 4-031-77 (Aberdeen Proving Ground, MD: U.S. Army Environmental Hygiene Agency).

Pi73 Pitts D. G., 1973, "The ocular UV action spectrum and protection criteria," Health Phys. **25,** 559.

Sl80 Sliney D. and Wolbarsht M., 1980, *Safety with Lasers and Other Optical Sources* (New York: Plenum Press).

Va84 Van der Leun, J. C., 1984, "UV-Carcinogenesis," Photochem. Photobiol. **39,** 861.

WH79 World Health Organization, 1979, *Ultraviolet Radiation*, Environmental Health Criteria 14 (Geneva: WHO).