

COMMONWEALTH DEPARTMENT OF HEALTH



Australian Radiation Laboratory

**Spectral Irradiance Measurements and Hazard Evaluations
of Sunbeds and Sunlamps**

by

H. Peter Gies, Colin R. Roy and Graeme Elliott

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ABSTRACT

The proliferation of solaría, coupled with a growing awareness of the harmful effects of exposure to ultraviolet radiation (UVK) has prompted a study on solaría and the UVR sources used in them. The detrimental effects of UV-B radiation have been known for some time but recently there has been increasing concern over the effects of UV-A radiation, which had at first been thought of as relatively harmless.

Previous studies of solaría have made radiometric measurements of the UVR lamp outputs, but since the biological effectiveness of UVK is wavelength dependent, particularly in the UV-B region where it varies by several orders of magnitude, there is a need for spectroradiometric measurements. Such measurements have been made at fourteen solaría in the Melbourne metropolitan area. Laboratory measurements have also been made on individual UVK fluorescent lamps and sunlamps. Results have been compared with the requirements of Australian Standard 2635 (1983), "INSTALLATION, MAINTENANCE AND OPERATION OF SOLARIA FOR COSMETIC PURPOSES".

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1. INTRODUCTION

The adverse and beneficial effects of radiation have been the subject of many years of research. Investigations have been concerned primarily with ionising radiation but in recent years there has been a dramatic increase in the number of non-ionising radiation sources in the workplace and in the general community. These include coherent sources, that is, lasers which can radiate in the ultraviolet (UV), visible and infrared regions of the electromagnetic spectrum, and non-coherent sources which cover the region from the UV to radiofrequency radiation. The biological effects of non-ionising radiation are now the subject of intense study but there are still many unknowns, especially the effects of chronic exposure to low-level radiation.

This report presents the results of a study designed to investigate and make measurements on the various ultraviolet radiation (UVR) sources employed for artificial suntanning. The UV region of the spectrum covers the wavelength range from 100 to 400 nm, and is divided into three bands, the UV-C (100-280 nm), the UV-B (280-315 nm) and the UV-A (315-400 nm). The UVK tanning sources are of two main types, sunlamps, which are small, portable and inexpensive units for home use, and UVR fluorescent lamps which are usually incorporated into sunbeds or tanning booths (Figure 1). The sunbeds are available either as a single bed or with a movable upper portion so that a person can be simultaneously exposed on both sides.

The fluorescent lamps used in solaría are low pressure mercury discharge lamps which have a phosphor coating on the inside of the glass envelope. The 254 nm mercury emission line is absorbed by the phosphor and is re-emitted at longer wavelengths. The sunlamps consist of a lamp bulb containing a high pressure mercury quartz burner and a tungsten filament which acts as a ballast and a heat source. The inner surface is coated to reflect radiation through the front diffusing surface.

The introduction of solaría (commercial establishments specializing in the operation of sunbeds or tanning booths) has meant that members of the Australian population can increase their UVR exposures, for cosmetic purposes, at a time when informed advice is to minimize exposures during both working and leisure hours. The National Health and Medical Research Council is currently considering an Australian UVR occupational exposure standard to limit exposure in the workplace. Application of this standard by State Health Authorities will eventually control UVR exposures during working hours. However, only public education campaigns rather than legislation, can influence individuals to minimize their UVR exposures during leisure hours.

For this reason the Commonwealth Department of Health and State Anti-Cancer Councils have for many years promoted the use of sunscreens and protective clothing, including headwear, to minimize exposure to solar UVR during leisure time activities. This campaign has been reasonably successful. However, Australia still has one of the highest incidences of skin cancer in the world. The introduction of artificial sources of UVR to add to the already high natural levels is undesirable, but the use of artificial sources for cosmetic tanning appears to have gained significant public acceptance from about 1980, when the number of solariums operating in the Melbourne metropolitan area rapidly increased.

If damage to individuals using artificial UVR sources for tanning is to be minimized, the radiation emissions and conditions of use of the sources require careful control. The 1983 Australian Standard AS 2635 "The Installation, Maintenance and Operation of Solariums for Cosmetic Purposes" was developed for this purpose (Appendix A). In particular, the standard requires that the irradiance of a UV-A source, expressed as a percentage of the UV irradiance, shall not exceed:

0.01 % for the wavelength range 100 to 280 nm,

0.1 % for the wavelength range 280 to 300 nm and

1.0 % for the wavelength range 300 to 315 nm.

The maximum irradiance of a sunbed is limited to 200 W/m^2 .

The Standard requires that the initial exposure dose shall not exceed $50,000 \text{ J/m}^2$ and that the maximum repeated dose be $200,000 \text{ J/m}^2$, with a minimum time interval between exposures of 48 hours.

2. THE EFFECTS OF ULTRAVIOLET RADIATION

2.1 UVR and the Skin

The biological effects of UVR have been studied for over sixty years. These effects can be categorized into short term effects, where results become evident within minutes, hours or days, and long term effects where results may not become evident for many years.

(a) Short Term Effects

(i) Interaction of UVR with the Skin

The skin has three major tissue layers, the epidermis, the dermis and the subcutaneous layer. The epidermis, consisting of cells called keratinocytes, has a tough outer layer called the stratum corneum formed from dead epidermal cells. This stratum corneum provides a protective layer against abrasion and water loss, is chemically resistant and attenuates UVR. The basal layer of the epidermis contains the melanocytes, the producers of the UVR absorbing melanin (Figure 2). The dermis consists mostly of connective tissues as well as blood vessels, lymphatics and nerves.

UVR incident on the skin may undergo reflection, refraction, scattering, transmission and absorption or produce fluorescence (Figure 2). The absorption and scattering processes in the skin are influenced by many factors, such as pigmentation, location of area irradiated, thickness of stratum corneum, previous UVR exposures and the wavelength of the incident UVR. The transmission of optical radiation through the skin increases with increasing wavelength, that is, UV-B radiation is absorbed in the epidermis whereas the longer wavelength UV-A can penetrate to the dermis (Diffey, 1980). UVR is thought not to reach the subcutaneous layer. Absorption of UVR will result in photochemical reactions, such as DNA strand breaks or stimulation of melanocytes.

(ii) Erythema

The appearance of erythema (skin reddening) following the absorption of UVR is due to the dilation of small blood vessels in the dermis. This dilation is due to the production (initiated by the absorption of UVR) of substances which directly affect the vessel walls.

The severity of the erythema will depend upon many factors, such as intensity of the UVR source, duration of exposure, wavelength of the UVR, and the photosensitivity of the individual in question. The sensitivity of skin is generally classified into six main types (Table 1). People with type I skin cannot tan and are usually very sensitive to UVR so that a minimal dose will cause erythema. At the other extreme, people with type VI skin are very insensitive to UVR.

TABLE 1

Tanning and burning properties of different skin types on exposure to UVR.

Skin Type	Reaction
I	always burns, never tans
II	always burns, sometimes tans
III	sometimes burns, always tans
IV	never burns, always tans
V	moderately pigmented
VI	heavily pigmented

(iii) Erythematous Effectiveness of UVR

The amount of UVR which will produce a just perceptible erythema is called the minimum erythematous dose (MED). The MED varies significantly between individuals of different skin types, but is of the order of 1000 J/m^2 for unpigmented skin at wavelengths near 300 nm (Magnus, 1976). In the UV-A region the MED is much higher, approximately 100,000 to 500,000 J/m^2 (Parrish et al, 1974).

The erythematous response curve of Coblenz and Stair (1934), which was adopted by the International Commission on Illumination (CIE) as a standard curve in 1935, is shown in Figure 3. Recent work (Everett et al, 1969; Diffey, 1982) has revealed similar curves (Figure 3) but with differences below 290 nm. The American Conference of Governmental Industrial Hygienists adopted an occupational exposure standard (ACGIH, 1981) for wavelengths below 315 nm which is based on a curve similar to the response curve of Everett et al (1969) (Figure 3).

The degree of erythema produced by doses of UVR in excess of 1 MED will vary markedly with the wavelength of the incident radiation. For example, a dose of 30 MED of 254 nm radiation produces only a more pronounced erythema (Parrish, 1971), while a dose of 10 MED of 297 nm radiation produces an intense erythema with blistering and oedema. Further, erythema produced by 254 nm radiation takes 5-8 hours to develop, while erythema produced by 297 nm radiation requires up to double that time to develop.

(iv) Tanning

Tanning can result from either of two processes, the instantaneous darkening in the skin of existing melanin (immediate tanning) or the formation of new melanin in the melanocytes (melanogenesis). The darkening of existing melanin becomes apparent immediately after exposure to UVR, but usually fades after less than an hour, although occasionally it may persist for a few days. It is induced mainly by wavelengths in the 340 to 360 nm region (Hauser and Vahle, 1969). Melanogenesis results from the absorption of UV-B radiation followed by a series of chemical reactions. Pigmentation of the skin results when the melanin is transported to the stratum corneum after a latent period of approximately four to six days. This pigmentation is longer lived than that produced by immediate UV-A tanning, and reaches its peak after about twenty-one days (Groves, 1980).

If a tan is produced by UVR containing some UV-B then the ability of the skin to resist further exposure to UVR is enhanced. This is due to the increased amount of melanin and the thickening of the stratum corneum which usually accompanies UV-B, but not UV-A, tanning (Kaidbey and Kligman, 1978).

(b) Long Term Effects

(i) Skin Ageing

The link between permanent skin damage and cumulative UVR exposure appears beyond dispute. The cumulative absorption of UVR rather than the age of the person has been shown to cause the degeneration of the collagen component of the connective tissue which holds the skin in its normally firm position (Smith et al, 1965; Cockerell et al, 1961). However, for any individual, because UVR exposure accumulates with age, permanent skin damage increases as the individual grows older. The accumulation of damage will be more rapid for those people who regularly receive high UVR exposure than for those who take precautionary steps to prevent unnecessary exposure.

(ii) Skin Cancer

The connection between exposure to UVR and the incidence of basal and squamous cell carcinomas has been firmly established (Blum, 1959; Urbach et al, 1972; Emmett, 1973). Studies have shown that the global incidence of these skin cancers is highest where the levels of natural UVR are high, and

where there exists a fair skinned population not necessarily native to the area (Robertson, 1969). There is evidence to suggest that the UVR wavelengths effective in inducing skin cancer are similar to those for producing erythema (Robertson, 1972). In general, people who develop these skin cancers have a high susceptibility to erythema. It is generally considered that the damage to DNA caused by UVR eventually leads to formation of cancers due to the inability of the repair mechanisms to cope with cumulative damage sustained over a long period.

UVR has also been implicated in the etiology of malignant melanoma. However the relationship does not appear to be strong because the distribution of this carcinoma over the body is not restricted to habitually UVR exposed areas.

2.2 UVR and the Eye

Use of solarium can often result in inadvertant exposure of the eye to UVR. The absorption of UVR in ocular media is shown schematically in Figure 4. Values represent the percentage of various UVR wavelengths incident upon the corneal surface that are absorbed by the different ocular components (Boettner, 1962). UVR with wavelengths less than 310 nm is absorbed principally by the cornea and the lens. Conversely, the lens absorbs relatively more radiation with wavelengths greater than 330 nm. It should also be noted that for wavelengths greater than 310 nm the percentage of UVR reaching the retina increases with increasing wavelength (Pitts, 1981).

The two main responses of the eye to excessive amounts of UVR are photokeratoconjunctivitis and lenticular cataracts. Photokeratoconjunctivitis or "welder's flash" is an inflammation of the cornea and conjunctiva and usually lasts less than 48 hours. Lenticular cataracts are alterations of the lens or its capsule that result in apparent decreased transmission or increased scattering of visible light, but the term is usually applied only to cases where there is significant impairment to vision.

During recent years, considerable evidence has been produced implicating UVR as a significant factor in the "in vitro" generation of fluorescent compounds and in protein cross-linking associated with lens ageing and cataractogenesis in the mouse, rat and human lens. "In vivo" studies have also demonstrated that UVR is capable of generating cataracts in mouse, rat

and primate lenses (Zigman, 1974; Pitts, 1977). In humans, epidemiological studies (Hiller, 1977; Zigman, 1979) suggest that there is also a relationship between the incidence of cataract and exposure to sunlight, in particular, exposure to solar UVR. In a recent study (Hollows, 1981) the ophthalmic examination of over sixty thousand Aborigines in outback Australia revealed a positive correlation between the prevalence of senile cataract and levels of climatic UVR.

In a well-documented clinical study, Lerman (1980) reported an incident in which three patients developed lens opacities following exposure to UVR over an 18 month period. Measurements of the radiation emissions from the type of appliance involved (Peterson, 1975) indicated levels that did not appear to significantly exceed the recommended maximum permissible exposure levels (ACGIH, 1981). If correct, this would suggest that the margin of safety incorporated into these levels is not as wide as was thought.

An increase in the sensitivity of the skin to UV-A radiation can be induced by a variety of compounds. The most dramatic effect is seen with furocoumarins, or psoralens, and this is used to advantage in the treatment of psoriasis. However, it has been noted (Lerman, 1980, 1982) that these photosensitisers can be present in the eye for up to 24 hours following treatment. A number of other compounds used in pharmaceutical preparations, including phenothiazines, thiazides, sulphonylureas and oral contraceptives, are considered to be photosensitising. Individuals who are exposed to UVR while taking such compounds risk permanent eye damage.

3. EXPERIMENTAL METHOD

Spectral irradiance measurements were made using an Optronics model 740A spectroradiometer. This instrument consists of a small, single grating monochromator (blazed at 300 nm) and a radiometer. The wavelength scan drive of the monochromator controls an automatic filter wheel which positions optical filters in the radiation beam to reduce unwanted orders and stray radiation. These are significant problems in the UV region with single grating monochromators. The input optics of the monochromator incorporates a quartz diffuser disc with a cosine response. A schematic of the experimental arrangement is shown in Figure 5.

Measurements of UVR were made using a solar blind photomultiplier detector mounted on the exit port of the monochromator. The monochromator bandwidth was set at 2 nm. The wavelength response of the spectroradiometric system must be known in order to determine spectral irradiances of sources under examination. This was achieved by calibrating the system over the wavelength range 250 to 410 nm against a quartz halogen standard lamp traceable either to the US National Bureau of Standards or the CSIRO National Measurement Laboratory. A microcomputer was programmed to drive the monochromator over the wavelength range 250 to 410 nm at 2 nm intervals and to sample the detector current at each wavelength until the standard deviation of the sample was less than 1 percent. The minimum detection level for the photomultiplier was $2 \times 10^{-7} \text{ W/m}^2$ at 350 nm.

Measurements were also made using a calibrated silicon photodiode detector. The range covered was from 250 to 450 nm with a bandwidth of 10 nm. The minimum detection level was $7 \times 10^{-6} \text{ W/m}^2$ at 450 nm. These results were used as a check of the performance of the measurement system. The visible spectrum (400 to 750 nm) was not studied.

The spectroradiometer system was calibrated immediately before and after any field measurement. Measurements were routinely taken with both detectors. In solaria it was not always possible to eliminate all extraneous sources of radiation, so these background levels were subtracted from all spectral scans.

The arrangement of input optics and monochromator mounting limited the minimum distance between the diffuser disc and the UV source to 60 mm. The variation of the irradiance of a sunbed with distance from the surface was measured with an International Light model 700A radiometer incorporating the same input optics as the spectroradiometer. This radiometer has separate detection heads for measuring UV-A and UV-B irradiances plus the facility to change the calibration factor in order to make the instrument direct reading. At the surface of the sunbed the irradiance was approximately 15 percent higher than at 60 mm and this correction was applied to all measurements.

Previous solaria surveys (Chan, 1982; Bowker, 1984) used radiometric methods for determining both the spectral content and the irradiances of the lamps used. If the radiometer is calibrated against a source of similar

spectral content to the one under investigation then the measurements will be reasonably accurate, as will the determination of the relative amounts of UV-A and UV-B. Interpretation of these measurements require some understanding of the fundamentals of the radiometer as well as knowledge of the filter transmission and detector response.

Towards the end of the measurement programme a questionnaire was sent to eighty-one solarium and health or beauty centres throughout the Melbourne metropolitan area requesting information on the types of UVR lamps in use, to ensure that all types had been included in this study.

4. RESULTS AND DISCUSSION

4.1 Spectral Distribution of UVR Tanning Lamps

The UVR lamps investigated in this study fall into three main categories according to the characteristics of their emission spectra (Figure 6). The UV-A fluorescent lamp has most of its emission in the range 315 to 400 nm, with a peak at 350 nm, while the UV-B fluorescent lamp has most of its emission in the range 280 to 350 nm, with a peak at approximately 310 nm. Some of the mercury emission lines are present in the spectra. Most of the lamps used in solarium are of the UV-A type. Table 2 lists the various brands of UVR lamps that were measured either in the laboratory or in solarium. There is some variation in the amount of UV-B emission measured for each lamp (Table 2), due to variations in lamp design such as the composition of the lamp phosphor, the transmission of the glass envelope and the transmission of the perspex top of the sunbed. UV-B lamps are commonly used in stand-up tanning booths, where the lamps are mounted in the corners, or spaced along the walls. The third type of lamp is the sunlamp, which has a spectrum consisting solely of mercury emission lines covering the UV (from 250 nm) and visible regions. Small portable sunlamps for domestic use are generally of this type, although a unit containing four such lamps was seen in one solarium.

Most of the lamps have low levels of UV-B emission and thus comply with the requirements of AS 2635 (Table 2). However some of the earlier types of

TABLE 2

Measurements of the radiation emissions for all lamps examined expressed as a percentage of the total UVR. The requirements of AS 2635 are listed at the bottom of the table.

LAMPS	UV-C		UV-B
	250-280 nm °/° of UVR	280-300 nm °/° of UVR	300-315 nm °/° of UVR
<u>UV-A LAMPS</u>			
BELLARIUM SA1-10-100W	<0.001	0.014	1.13
BELLARIUM S SA1-12-100W	<0.001	0.020	1.40
DR. KERN SONNENSPEZIALIST	<0.001	0.008	0.532
PHILIPS TL65-80W/09	<0.001	0.009	0.45
PHILIPS TL85-100W/09 N	<0.001	0.008	0.49
PHILIPS TL85-100W/09 A	<0.002	0.005	0.038
RELARIUM RA1-100W	<0.001	0.009	0.57
SOLARIUM A1-11-100W	<0.001	0.008	0.43
SOLARLUX A1	<0.001	0.007	0.54
SONNE DA-1	<0.001	0.011	0.63
SONTEGRA SL1a	<0.001	0.140	0.70
SYLVANIA FL40SBL	<0.016	0.51	1.62
<u>UV-B LAMPS</u>			
OLIPHANT FL-20SE	0.524	18.5	33.5
TOSHIBA FL20 SE/E	0.358	17.3	34.8
<u>Hg LINE LAMPS</u>			
BREVILLE WOTAN RZ1 ULTRA-VITALUX	0.143	4.0	23.0
PHILIPS 57265F/28 300w	0.114	2.88	19.14
AS 2635 REQUIREMENT	<0.01	<0.1	<1.0

UV-A lamps (for example Bellarium) emitted levels of UV-B which were slightly greater than 1 percent of the total UVR and thus may not comply with the Standard. Few of the lamps had any detectable emission at wavelengths less than 280 nm. Laboratory measurements of the emission spectra of the UVK lamps using a Spex model 1404, 0.8 m double grating monochromator with an operational wavelength range down to 200 nm found negligible emission below 280 nm, apart from the mercury emission line at 254 nm.

The UV-A lamps have very similar emission spectra, with the exception of the Sontegra SL1a. The spectrum of the Sontegra SL1a is compared to that of the Relarium RA1 UVR lamp (the most commonly encountered type) in Figure 7. It can be seen that the main emission peak is considerably narrower for the Sontegra SL1a, lying predominately between 350 and 390 nm compared with 320 to 400 nm for the Relarium lamp. Emission in the UV-B is also significantly different in that while the percentage of UV-B in the region 300-315 nm is below the level required by AS 2635, emission in the region 280-300 nm is 0.14 percent, above the required level of 0.1 percent. The Sontegra SL1a is thus the only lamp to meet the requirements of AS 2635 for the region 300 to 315 nm, but not meet the requirements for the region 280 to 300 nm.

The spectral distribution measurements of sunbeds with the same lamp types but made at different establishments were usually in good agreement, the exception being one sunbed with Philips TL85 lamps (denoted in the Tables as Philips TL85 A). This sunbed had relatively very low levels of UV-B (Figure 8) and the irradiance was also lower than other similar sunbeds. One possible explanation is the use on this sunbed of perspex with different transmission characteristics.

4.2 Measured UV Irradiances of Solaria

The maximum irradiance for a solarium or sunbed permitted by AS 2635 is 200 W/m^2 and at this intensity the recommended initial dose of $50,000 \text{ J/m}^2$ and the maximum dose of $200,000 \text{ J/m}^2$ would be achieved in approximately 4 minutes and 16 minutes respectively. The measured sunbed irradiances varied considerably, from 5.7 to 22 W/m^2 (Table 3). These levels are significantly below the maximum permitted irradiance of 200 W/m^2 . Allowable exposure times for these sunbeds can be calculated by dividing the $200,000 \text{ J/m}^2$ maximum dose by the measured irradiance to give the time in seconds.

Doses received in solarium will, of course, be larger than any recommended by occupational exposure limits, which seek to limit exposures to levels that will not cause biological damage. However, comparison with occupational exposure limits allows a better perspective of the UVR levels required by AS 2635. The most generally accepted occupational UVR exposure limits are those of the ACGIH (ACGIH, 1981), which for the wavelength range 200 to 315 nm combine the action spectra for skin erythema and eye photokeratoconjunctivitis. The ACGIH limits are applicable to environmental or occupational exposures to artificial sources of UVR during an eight hour working day. It defines a maximum exposure of 30 J/m^2 for monochromatic radiation at 270 nm. All other wavelengths in the 200 to 315 nm band are given a spectral effectiveness relative to that at 270 nm. For a broadband source, such as solarium UVR lamps, the maximum allowable exposure time is calculated by firstly weighting the spectral irradiance of the source with the relative spectral effectiveness of the radiation at each particular wavelength. The summation of these weighted spectral irradiances from 200 to 315 nm is called the effective hazardous irradiance, E_{eff} . The maximum allowable exposure time T_{max} , in seconds, is then calculated from

$$T_{\text{max}} = \frac{30}{E_{\text{eff}}} \frac{\text{J/m}^2}{\text{W/m}^2}$$

These times, which are shown in Table 3 for all UVR sources evaluated, are dependent on both the intensity and the UV-B content of the sunbed emission.

The ACGIH recommended limit for UV-A radiation assumes that all wavelengths in the UV-A contribute equally to erythema and therefore sets the limit for the entire UV-A as being equal to the limit at 315 nm. In this study the spectral effectiveness estimates of van der Leun (1965) for the wavelengths in the UV-A region have been used to modify the ACGIH limits. Maximum allowable exposure times calculated using these modified limits are considerably longer (Table 3). AS 2635 permits exposure times of 2.5 to 20 hours depending upon the lamp type. Practical considerations would normally restrict exposures to approximately 30 minutes which is close to the times calculated using the ACGIH (modified) erythema response curve. It should be noted that the method used to calculate E_{eff} assumes that there are no interactive effects between different wavelengths. However this effect, called photoaugmentation, does occur (Kaidbey and Kligman, 1975) but the assumption should not result in a large error.

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TABLE 3

UV irradiances and calculated maximum permissible exposure times for each source examined. Exposure times are calculated using limits from AS 2635, ACGIH and a modified combination of ACGIH for the UV-B and the results of Van der Leun (1965) for the UV-A. Solar flux measurements are listed for purposes of comparison.

LAMPS	UV IRRADIANCE (w/m ²)	MAXIMUM TIME ALLOWABLE (mins)		
		SAA	ACGIH (modified)	ACGIH
DR. KERN SONNENSPEZIALIST	9.6	347	28.2	16.6
RELARIUM RA1 - 100W	7.3	457	40.0	21.5
RELARIUM RA1 - 100W	8.0	417	35.6	20.0
RELARIUM RA1 - 100W	10.0	333	28.7	16.0
RELARIUM RA1 - 100W	14.6	228	17.1	10.7
RELARIUM RA1 - 100W	16.0	208	15.2	9.6
RELARIUM RA1 - 100W	22.0	151	12.7	7.2
PHILIPS TL65-80W/09	7.9	422	37.0	20.4
PHILIPS TL85-100W/09	9.7	344	28.8	18.2
PHILIPS TL65-80W/09	16.2	206	18.3	9.9
PHILIPS TL85-100W/09	5.7	585	62.7	28.7
SYLVANIA FL40SBL	2.7	1235	35.6	29.4
SOLARLUX A1	6.5	513	41.0	24.5
BELLARIUM SA1-10-100W	7.5	444	35.2	21.2
SONTEGRA SL1A	8.2	406	33.4	17.2
SOLARIUM A1-11	16.0	208	18.9	10.2
OLIPHANT FL-20SE	2.6	*	1.47	1.53
TOSHIBA FL20 SE/E	2.8	*	1.52	1.57
SOLAR FLUX (SUMMER)♠	70.7	47	2.12	1.52
SOLAR FLUX (WINTER)♠	26.4	126	11.5	5.8

* Not applicable to UV-B lamps

♠ Measured at noon in Melbourne

4.3 Measurement Errors and Precision

Calculations of the spectral irradiance of UVR lamps are subject to errors in the measurement of wavelength and intensity. The spectra of all lamps examined had prominent mercury emission lines, which served as a wavelength calibration of the monochromator so that wavelength errors were never greater than 1 nm. The absolute values of spectral irradiance will have an error of approximately 20 percent comprised mainly of the uncertainty in the calibration of the standard lamp and in the transfer of this calibration to the spectroradiometric system. The irradiance which is obtained by integration of the spectral irradiances over the relevant wavelength range will have a similar error.

The relative spectral content of various UVK lamps was determined on several occasions and the results are given in Table 5. The precision of these values for the UV-A lamps is approximately 2 percent for the 300 to 315 nm range and approximately 10 percent for the 280 to 300 nm range due to the much lower emission in this region.

TABLE 4

Results of tests to determine the uncertainty in the relative spectral content of various UVK lamps.

LAMPS	SPECTRAL TYPE	280-300 nm % of UVR	300-315 nm % of UVR
DR KERN SONNENSPEZIALIST	UV-A	0.010	0.62
		0.011	0.62
		0.010	0.61
SONNE DA1	UV-A	0.013	0.61
		0.011	0.63
		0.012	0.62
		0.012	0.63
BREVILLE WOTAN SUNLAMP	Hg Line	3.90	20.8
		4.08	26.0
OLIPHANT FL20 SE	UV-B	19.1	33.7
		18.8	33.5
		18.6	33.1
		18.1	33.6

4.4 Erythematous Effectiveness of UV-B Radiation

The Australian Standard requires that less than 1.1 percent of the UVR be in the UV-B region. Radiation in this region is very efficient in producing erythema. The UV-B spectral irradiances have been weighted with the modified ACGIH and CIE erythematous response values for the UV-B region. Results are given in Table 5. The weighted UV-B emissions of each lamp are very different as a result of the dissimilarities in the two erythematous response curves evident in Figure 3. Maximum allowable exposure times have been calculated for a normalized irradiance of 10 W/m^2 using the ACGIH modified erythematous response. These times decrease rapidly as the unweighted UV-B content increases (Figure 9). The difference between lamp types is very marked, with maximum allowable exposure times of 1 to 2 minutes for the UV-B lamps and 20 to 30 minutes for most of the UV-A lamps.

4.5 Lamp Ageing

Previous results on the variation of irradiance of UVk fluorescent lamps with time (Nachtwey and Rundel, 1981) indicated that the UVk intensity fell to 70 percent of its initial value within 10 hours. Thereafter the output changed very slowly, decreasing at the rate of 0.14 percent per hour. Numerous tests on UV-B lamps in this laboratory showed that the UV-B irradiance decreased to 86 percent of its initial value after 10 hours, while that of the UV-A for the same lamp fell to 94 percent during the same period. The UV-B irradiance continued to decrease more rapidly (0.1 percent per hour) than did the UV-A output (0.04 percent per hour), although both rates were much slower than the average rate during the initial 10 hour period. It was observed that older UV-A lamps measured in solarium had relatively less UV-B emission than did newer lamps of the same type. It would appear that for both UV-A and UV-B lamps, the UV-B irradiance decreases at a faster rate than the total UV irradiance.

TABLE 5

Measured UV-B emissions and maximum allowable exposure times calculated for a normalized irradiance of 10 W/m^2 using the ACGIH modified erythema response curve. The UV-B emissions weighted by the modified ACGIH and CIE erythema response curves are also given.

LAMPS	UV-B as a % of the UVR	weighted UV-B as a % of the UVR ACGIH (mod)	CIE (mod)	Maximum Allowable Exposure Time (mins)
<u>UV-A LAMPS</u>				
PHILIPS TL85-100w/09 A	0.043	3.0	4.8	36
SOLARIUM A1-11-100w	0.44	6.5	15.8	29
PHILIPS TL65-80w/09	0.45	6.6	16.2	30
PHILIPS TL85-100w/09 N	0.49	6.9	18.7	28
SOLARLUX A1	0.55	7.2	21.1	27
RELARIUM RA1 - 100w	0.58	8.7	23.4	29
DR. KERN SONNENSPEZIALIST	0.62	8.4	22.0	28
SONNE DA-1	0.64	8.9	23.2	28
SONTEGRA SL1a	0.84	46.8	70.5	29
BELLARIUM SA1-10-100w	1.14	13.3	36.0	25
BELLARIUM S SA1-12-100w	1.42	17.6	43.7	24
SYLVANIA FL40SBL	2.1	65.3	68.3	10
<u>Hg LINE LAMPS</u>				
PHILLIPS 57265F/28 300w	22.0	91.1	97.3	1.98
BREVILLE WOTAN R21	30.1	91.5	98.2	1.35
<u>UV-B LAMPS</u>				
OLIPHANT FL-20SE	51.7	95.1	98.9	0.38
TOSHIBA FL20 SE/E	52.1	95.6	90.8	0.42
SOLAR FLUX (summer)*	3.8	54.2	82.3	16.2
SOLAR FLUX (winter)*	1.2	18.3	49.1	33.3

* Measured at noon in Melbourne

4.6 Numbers of Solaria

The number of solaria and other establishments listed as using UVR sources for cosmetic tanning in Melbourne since 1977 is shown on a yearly basis in Table 6. The total number of establishments where tanning is not the primary function but is offered as an option has increased steadily since the late seventies as a result of the introduction of the UVR fluorescent lamp in the mid seventies and its increasing availability at a relatively low cost since then. The number of solaria (which offer tanning services exclusively) peaked in 1982, but has since steadily decreased. This decrease in solaria numbers could be ascribed either to the success of campaigns to inform the public of the possible hazards of exposure to UVR from solaria which were initiated at about that time or to the seasonal nature of the industry affecting economic viability.

TABLE 6

The numbers of solaria and other centres in the Melbourne metropolitan area which advertised the use of UVR lamps for tanning for each year since 1977.

	YEAR						
	77	78	79 - 80	81	82	83	84
SOLARIA	*	*	*	24	59	38	20
OTHER CENTRES	11	19	21	38	53	64	69
TOTAL	11	19	21	62	112	102	89

* None listed

4.7 Protective Eyewear

The Australian Standard requires that protective goggles be provided in solarium. Section 3.2 states that for protective goggles the transmission in the wavelength ranges 180 to 315 nm and 315 to 360 nm should be less than 0.1 and 1 percent respectively, while maintaining sufficient visible transmittance to enable the client to locate the manual safety switch on the sunbed. The spectral transmissions of black, dark green and red of protective goggles were determined (Figure 10). All goggles met the requirements of the Standard, despite the fact that the red goggles had significant transmission in the UV-A region.

4.8 Other Requirements of AS 2635

As well as the technical requirements discussed above, AS 2635 makes a number of recommendations on the physical arrangements and procedures to be adopted by solarium (Appendix A). Fourteen solarium were visited during this study. Some note of the operating procedures was taken whilst making the spectral measurements and conclusions drawn from these observations should be applicable to the majority of establishments.

Sections 2.2.1 and 2.2.2 of AS 2635 requires that each sunbed must have a manual safety switch, for all sources of UVR, located within reach of the user. Each sunbed must also have an automatic timer controlling the UVR lamps. Most of the solarium visited complied with these requirements but a few did not have the manual safety switch.

Sections 2.3.1 and 2.3.2 require mechanical screening to prevent user contact with the UVR lamps and screening of the sunbed to prevent unintentional exposures to any person other than the user. All sunbeds provided mechanical screening of the UVR lamps. This consisted of a perspex sheet upon which the user lies. However, some solarium which had sunbeds with movable upper portions did not have mechanical screening on the upper portion thus providing no protection in the event of lamp breakage. All solarium visited had sunbeds in separate cubicles so that UVR screening was adequate, although many of these cubicles did not extend to the ceiling thus permitting the exposure of non-users to reflected UVR.

Section 2.4 deals with the provision of handrails in tanning booths where the user is in a standing position while undergoing UVR exposure. Only one of the solarium visited had this type of tanning booth and no handrail was provided.

Section 2.6 requires measurement of the irradiance at least every six months or whenever lamps are replaced. In general such irradiance measurements were not taken.

Section 3.1.2 includes the requirement that there be a minimum of 48 hours between exposures. This is to allow sufficient time for the development of any adverse skin reaction. Many of the solarium operators were not aware of this requirement and placed no restrictions on bookings by clients.

Section 3.2 requires that solarium operators ensure that clients wear protective eyewear. Four of the fourteen solaria visited provided goggles or protective eyewear, however, their use was not actively encouraged as only two had notices warning of the possibility of eye damage. The exposure of the eyes to UVR should be minimized and operators and users should be made aware of the possible dangers and of the fact that UVR can penetrate the eyelid. In some instances, solaria had small units meant purely for facial tanning where users underwent exposures at very close range. Protective eyewear was not used with these units as this would have interfered with the evenness of the tan.

Section 3.3 requires the sunbed to be disinfected after each user. This requirement was not strictly adhered to although most establishments kept their sunbeds in a clean condition.

Section 3.4 deals with solarium supervision and warning notices as well as a form of advice to clients which lists some of the dangers associated with UVR exposures. Only three of the solaria visited had warning notices displayed in a prominent position. Solarium supervisors should be familiar with the requirements of the standard and have some knowledge of UVR and its effects. Most of the solarium operators were not aware of the existence of the standard and knew very little about the effects of UVR or any of the associated hazards.

5. CONCLUSIONS

The results of the spectral irradiance measurements made in solaria on sunbeds and tanning booths and in the laboratory on UVR lamps show that most of the UV-A fluorescent lamps meet the requirements of AS 2635. These UV-A lamps should cause the least biological damage (to skin and eyes) of all UVR lamps measured. The UV-B lamps and portable sunlamps are much more hazardous since they emit large amounts of UV-B radiation. Also, as maximum allowable exposure times are considerably shorter for the UV-B lamp, the possibility of users achieving doses in excess of 1 MED and thus sustaining erythema or eye damage is increased.

The wearing of protective eyewear is advisable regardless of the type of UVR source but essential with sources emitting significant UV-B radiation. This point requires much more emphasis, both in solaria, by way of warning signs and advice to users from operators and in the written instructions provided with sunlamps.

Education of the public, and in particular the operators and supervisors of solaria on the hazards of UVK exposures is needed. Closer supervision of both users and scheduling of their exposures is necessary.

It should be emphasized that excessive exposure to UVK causes short and long term damage to the skin and eyes. Although solar radiation is the principal source of UVR, the use of sunbeds and sunlamps will add to the cumulative effect and hence their prolonged use should be discouraged by regular public education campaigns.

ACKNOWLEDGEMENTS

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REFERENCES

Australian Standard 2635-1983 The Installation, Maintenance and Operation of Solaria for Cosmetic Purposes, Standards Association of Australia, Sydney.

American Conference of Governmental and Industrial Hygienists (ACGIH), (1981) Threshold Limit Values for Physical Agents Adopted by the ACGIH for 1981, Cincinnati.

Blum, H.F. (1959) Carcinogenesis by Ultraviolet Light, Princeton University Press, Princeton.

Boettner, E.A., and Wolter, J.R. (1962) Transmission of the Ocular Media, Invest. Ophthalmol., 1:776.

Bowker, K.W. (1984) Ultraviolet Hazards from the use of Artificial Tanning Equipment, Inter. Rad. Prot. Assoc. 6th International Congress Compacts, III, 303.

Chan., R. (1982) Solariums Survey, Aust. Phys. and Eng. Sci. in Med., 5:23.

Coblentz, W.W., and Stair, R., (1934) Data on the Spectral Erythemic Reaction of the Untanned Human Skin to Ultraviolet Radiation, Bur. Stand. J. Res., 12:13.

Cockerell, E.G., Freeman, K.G., and Knox, J.M. (1961) Changes After Prolonged Exposure to Sunlight, Arch. Dermatol., 84:467.

Diffey, B.L. (1980) Ultraviolet Radiation Physics and the Skin, Phys. Med. Biol., 25:405.

Diffey, B.L. (1982) The Consistency of Studies of Ultraviolet Erythema in Normal Human Skin, Phys. Med. Biol., 27:715.

Emmett, E.A. (1973) Ultraviolet Radiation as a Cause of Skin Tumors, CRC Crit. Rev. Toxicol., 2:211.

Everett, M.A., Olsen, R.L. and Sayre, R.M. (1965) Ultraviolet Erythema, Arch. Dermatol., 92:713.

- Everett, M.A., Sayre, R.M., and Olsen, R.L. (1969) Physiologic Response of Human Skin to Ultraviolet Light, in Urbach, F. The Biologic Effects of Ultraviolet Radiation with Emphasis on the Skin, Pergamon Press, Oxford, p181.
- Groves, G.A. (1980) Sunburn and its Prevention, *Aust. J. Dermatol.*, 21:115.
- Hausser, K.W., and Vahle, W. (1969) Sunburn and Suntanning, in Urbach, F., The Biologic Effects of Ultraviolet Radiation with Emphasis on the Skin, Pergamon Press, Oxford, p3.
- Hiller, R., Giacometti, L., and Yuen, K. (1977) Sunlight and Cataract: An Epidemiological Investigation, *Am. J. Epidemiol.*, 105:450.
- Hollows, F., and Moran, D. (1981) Cataract - The Ultraviolet Risk Factor, *The Lancet*, Dec. 5, 1249.
- Kaidbey, K.H. and Kligman, A.M. (1975) Further Studies on Photoaugmentation in Humans: Phototoxic Reactions, *J. Invest. Dermatol.*, 65:472.
- Kaidbey, K.H. and Kligman, A.M. (1978) Sunburn Protection by Longwave Ultraviolet Radiation-Induced Pigmentation, *Arch. Dermatol.*, 114:46.
- Lerman, S., Megan, J., and Willis, I. (1980) Potential Ocular Complications from PUVA Therapy and their Prevention, *J. Invest. Dermatol.*, 74:197.
- Lerman, S. (1982) Ocular Phototoxicity and Psoralen Plus Ultraviolet Radiation (320-400nm) Therapy: An Experimental and Clinical Evaluation, *J Natl. Cancer Inst.*, 6:287.
- Magnus, I.A. (1976) Dermatological Photobiology, Blackwell, Oxford.
- Nachtwey, D.S., and Rundel, R.D. (1981) A Photobiological Evaluation of Tanning Booths, *Science*, 211:405.
- Parrish, J.A. (1971) Expanding the Clinical Spectrum of Sunscreen Testing, *Cutis*, Vol. 8:498.
- Parrish, J.A., Anderson, R.R., Urbach, F. and Pitts, D. (1978) UV-A Biological Effects of Ultraviolet Radiation with Emphasis on Human Responses to Longwave Ultraviolet, Plenum Press, New York.

Peterson, R.W., Brostrom, R.G., Coakley, J.M., and Ellingson, O.L. (1975) Measurements of the Radiation Emissions from the NUVA-Lite Dental Appliance, DHEW (FDA) Publ. No. 75-8031.

Pitts, D.G. (1981) Threats of Ultraviolet Radiation to the Eye - How to Protect against it, J. Amer. Optom. Assoc., 52:949.

Pitts, D.G., Hacker, P.D., and Parr, W.H. (1977) Ocular Ultraviolet Effects from 295nm to 400nm in the Rabbit Eye, DHEW (NIOSH) Publ. No. 77-175.

Robertson, D.F. (1969) Long-term Field Measurements of Erythemally Effective Natural Ultraviolet Radiation in Urbach, F. The Biologic Effects of Ultraviolet Radiation with Emphasis on the Skin, Oxford; Pergamon Press, p433.

Robertson, D.F. (1972) The Prophylaxis of Ultraviolet Radiation Damage - A Physicist's Approach, in McCarthy, W.H., ed., Melanoma and Skin Cancer, N.S.W. Government Printer, p273.

Smith, J.G. and Finlayson, G.R. (1965) Dermal Connective Tissue Alterations with Age and Chronic Sun Damage, J. Soc. Cosmet. Chem., 16:527.

Urbach, F., Rose, D.B. and bonnem, M. (1972) Genetic and Environmental Interactions in Skin Carcinogenesis, in Environment and Cancer, Williams and Wilkins, Baltimore.

Van der Leun, J.C. (1965) Theory of Ultraviolet erythema, Photochem. Photobiol., 4:453.

Wilkinson, F.J. (1983) Recommended UV Exposure Limits for Tanning Equipment, and Spectral Irradiances of Solarium Lamps, Sunlamps and Daylight, Aust. Phys. and Eng. Sci. in Med., 6:26.

Zigman, S., Schultz, J. and Yulo, T. (1974) Cataract Induction in Mice Exposed to Near UV Light, Ophthalmic Res., 6:259.

Zigman, S., Datilies, M., and Torczynski, E. (1979) Sunlight and Human Cataracts, Invest. Ophthalmol. Visual Sci., 18:462.

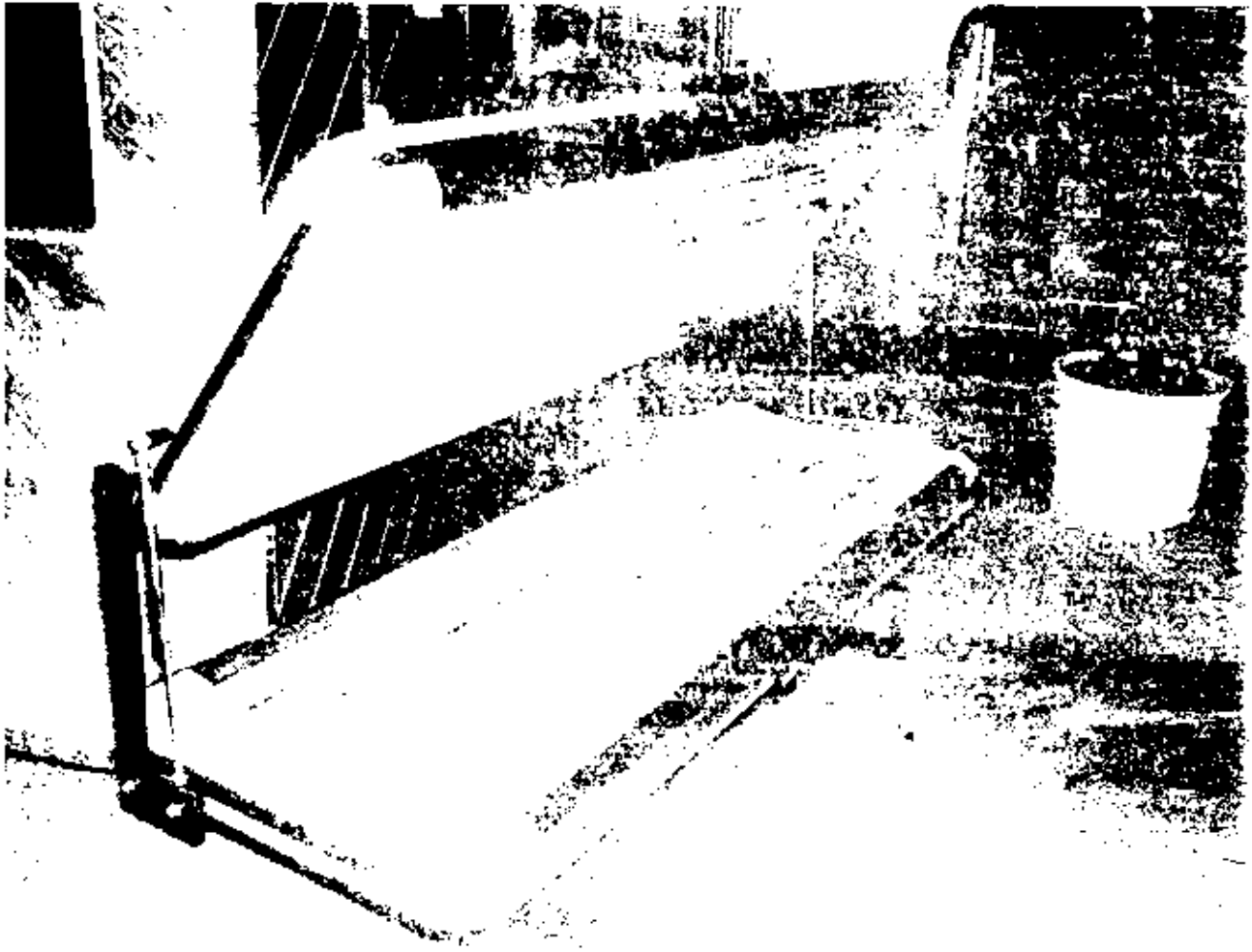


Figure 1: A typical garden bed, with a movable upper section

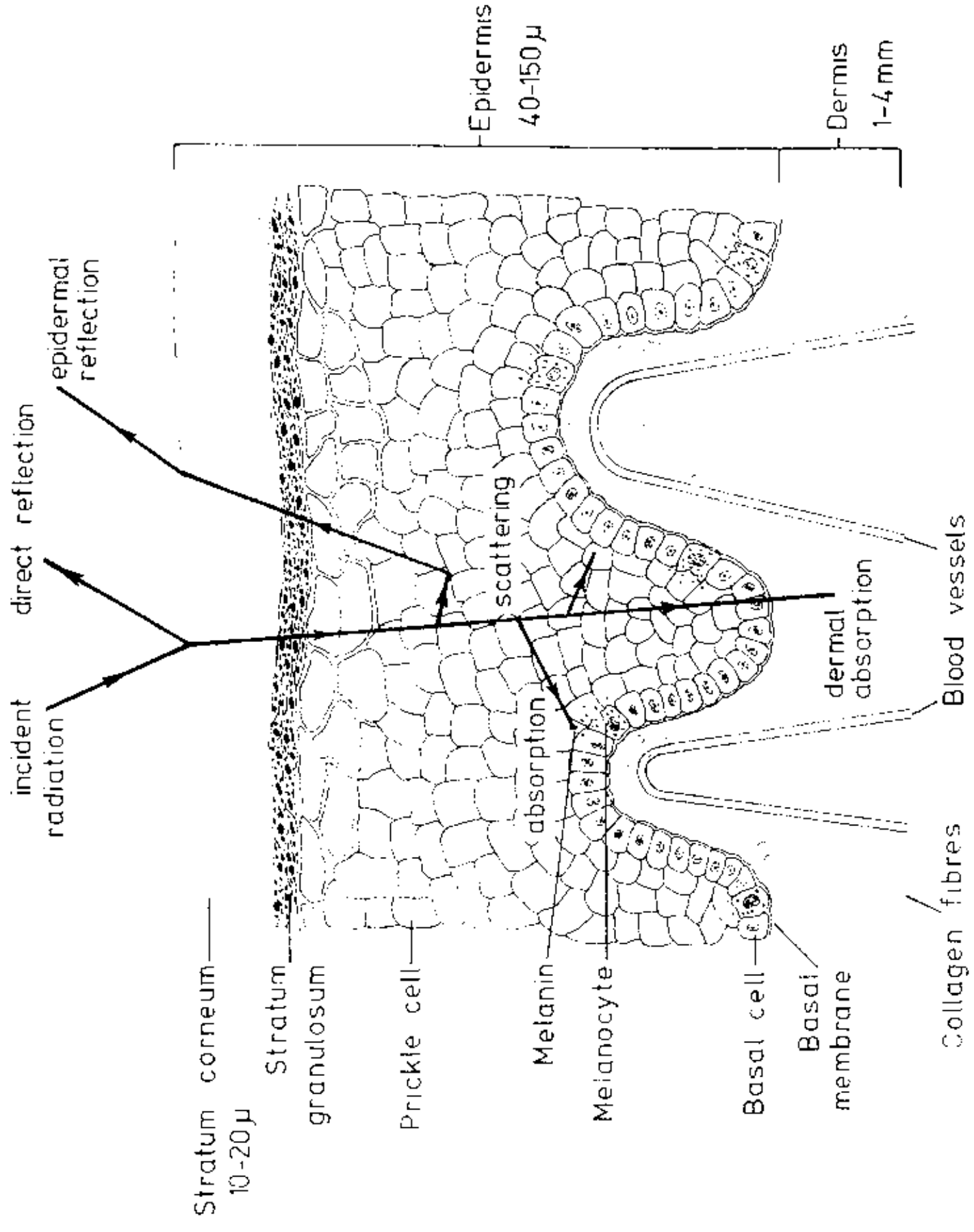


Figure 2: A schematic cross-section of human skin. Possible pathways for incident radiation are also shown.

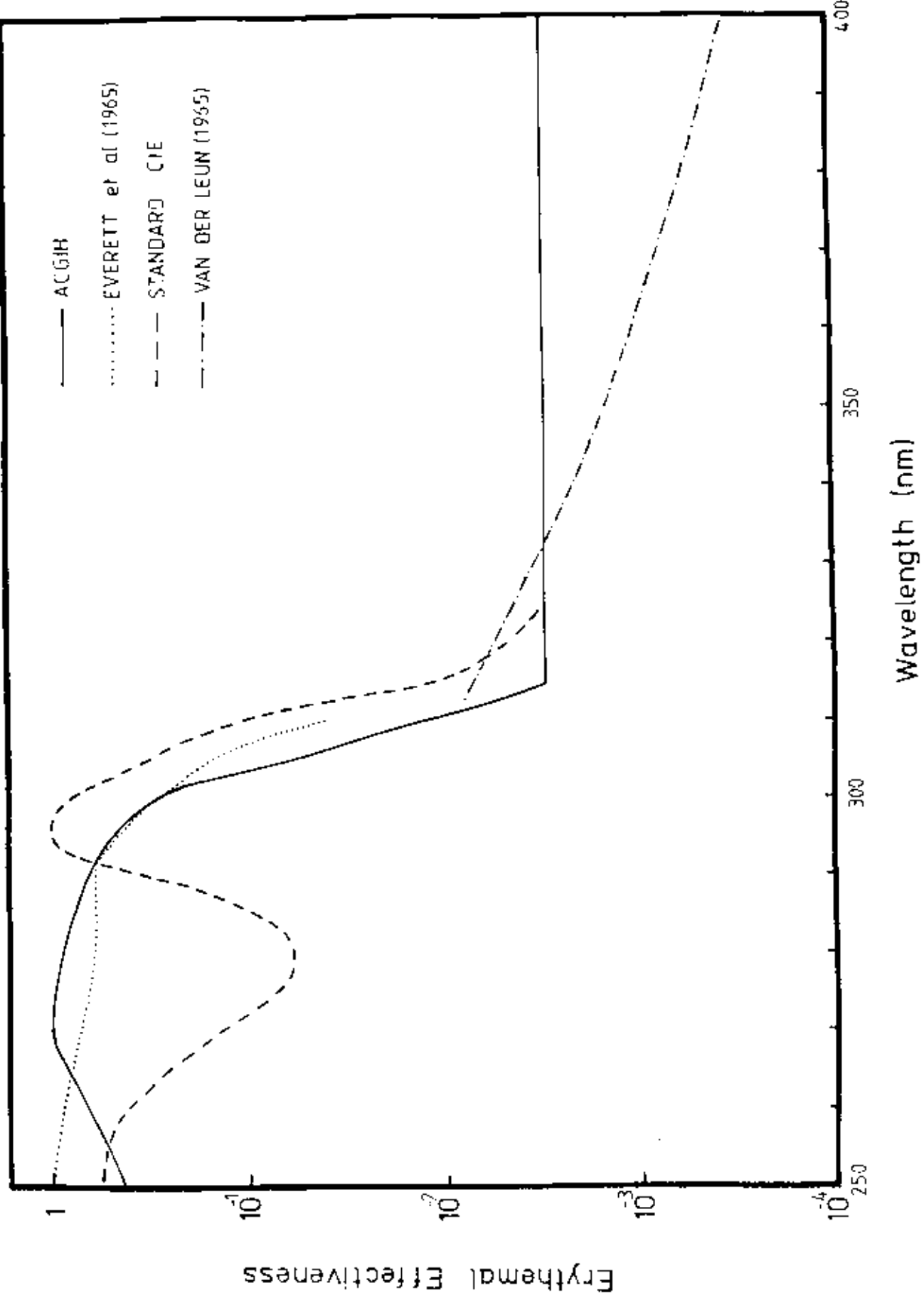


Figure 3: The erythema effectiveness curves of Coblenz and Stair (1934) normalized to unity at 297 nm, Everett et al (1965) normalized to unity at 250 nm, and the ACGIH (1981) curve normalized to unity at 270 nm. The values of Van der Leun (1965) for wavelengths between 315 nm and 400 nm have been used for hazard evaluations in this work.

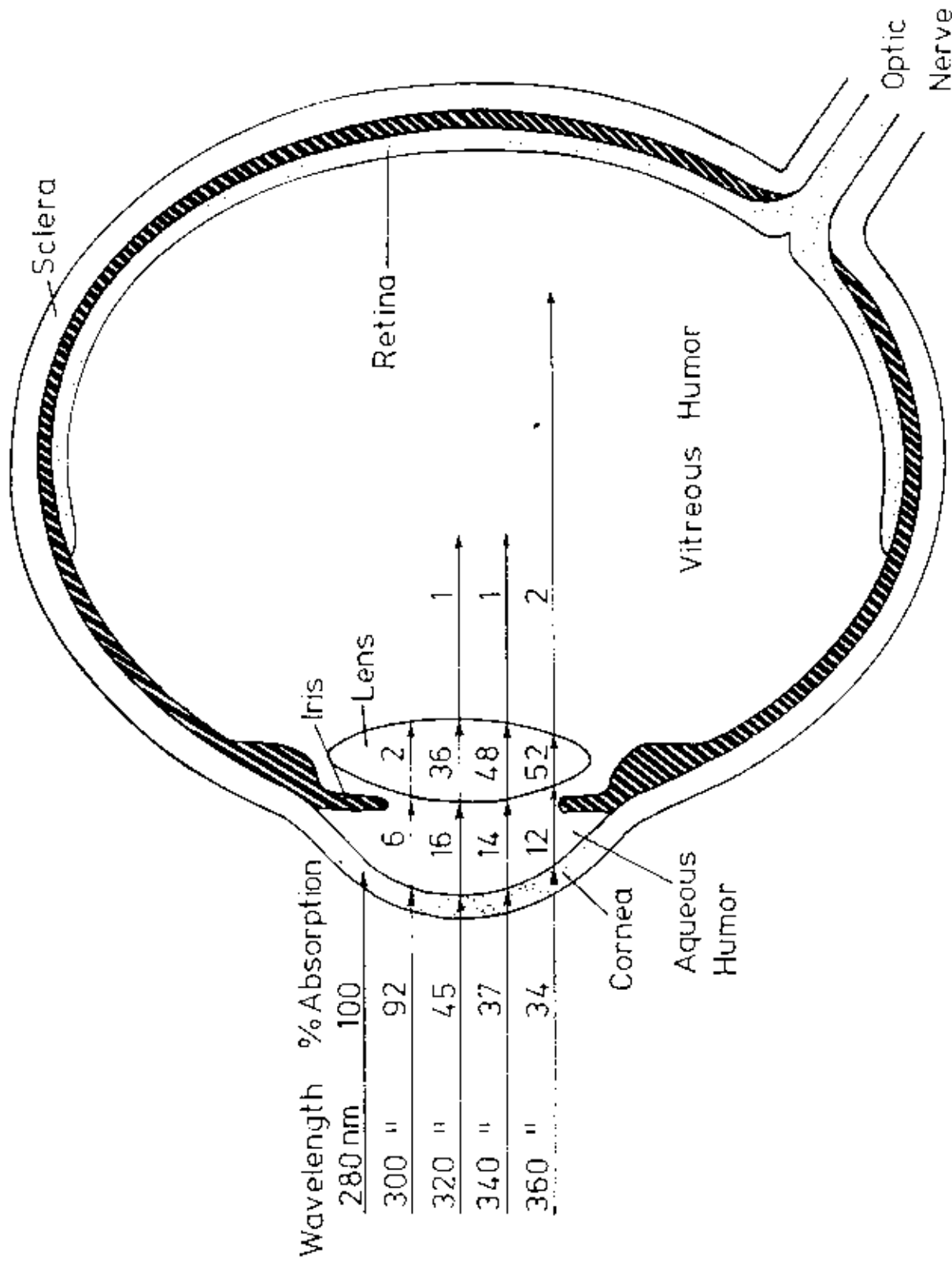


Figure 4: UVR absorption in the eye. The values given are the percentages of the incident radiation absorbed in each layer of the eye. Based on data by Boettner and Wolter (1962).

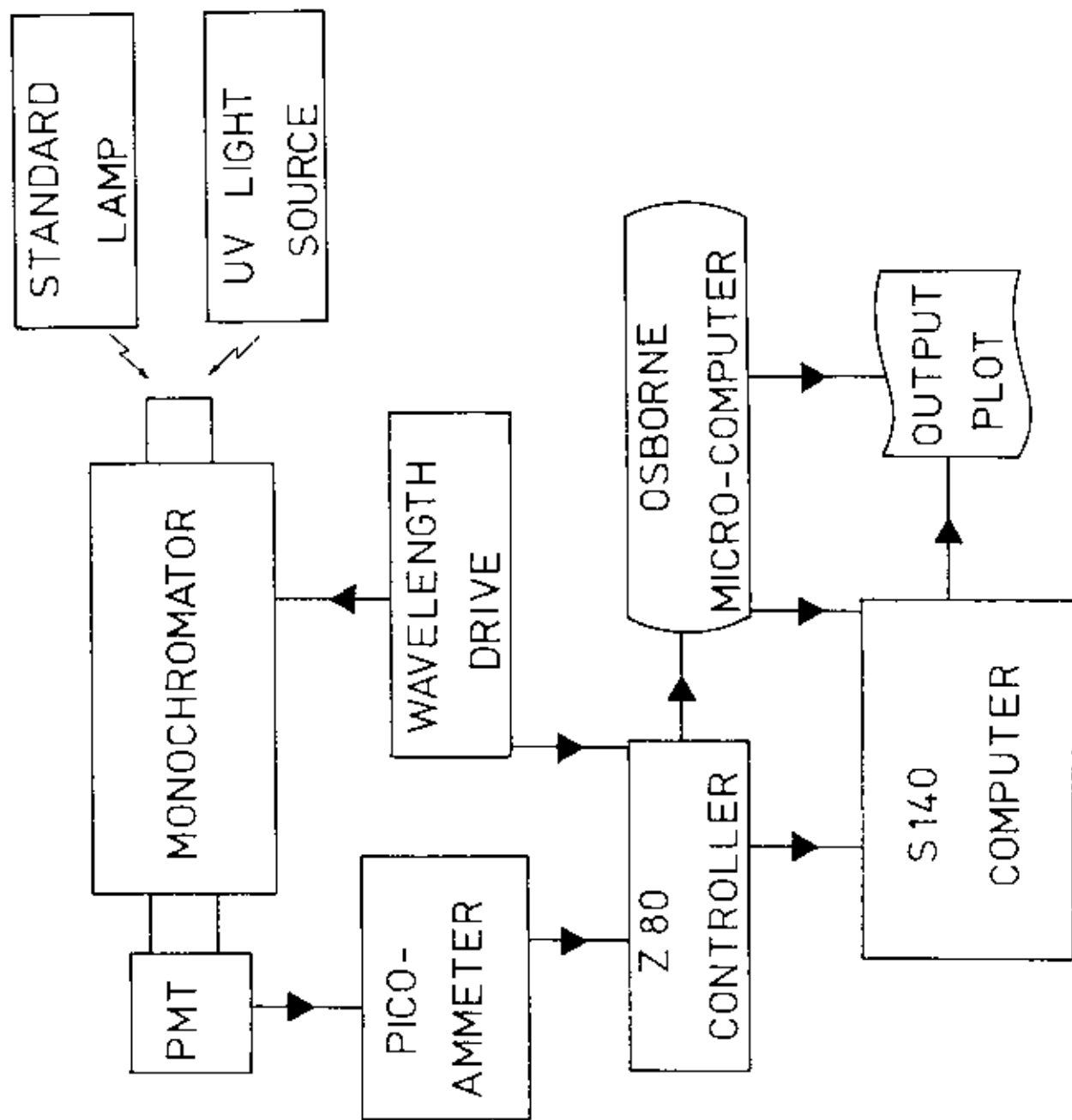


Figure 5: A schematic of the experimental arrangement. The photomultiplier (PMT) can be replaced by a photodiode if required, to allow measurements to be extended into the visible.

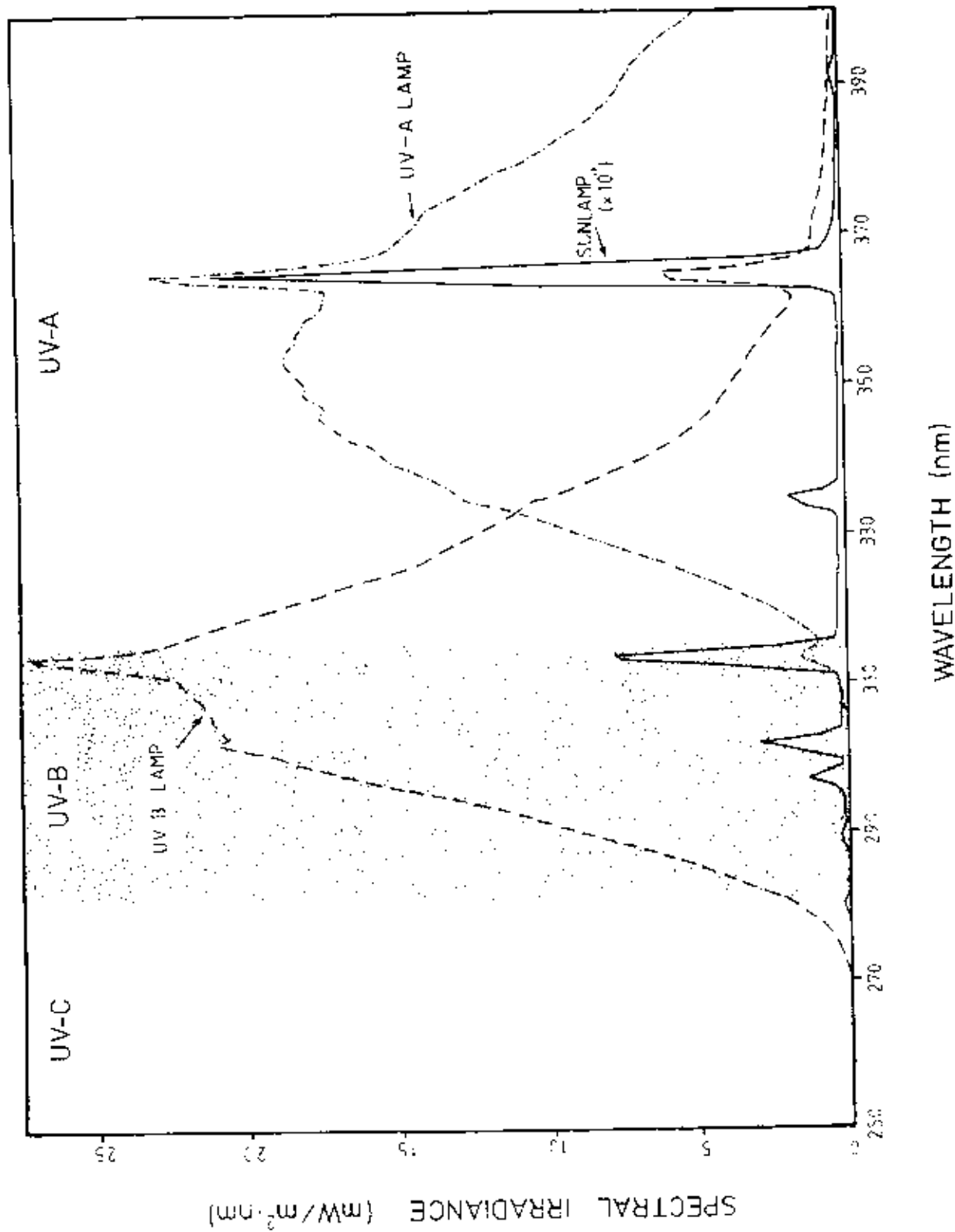


Figure 6: Emission spectra of UVR fluorescent lamps, showing continua and prominent mercury emission lines. Also shown is the spectrum of a sunlamp, consisting solely of mercury emission lines. The sunlamp spectral irradiances have been divided by 10 for ease of comparison.

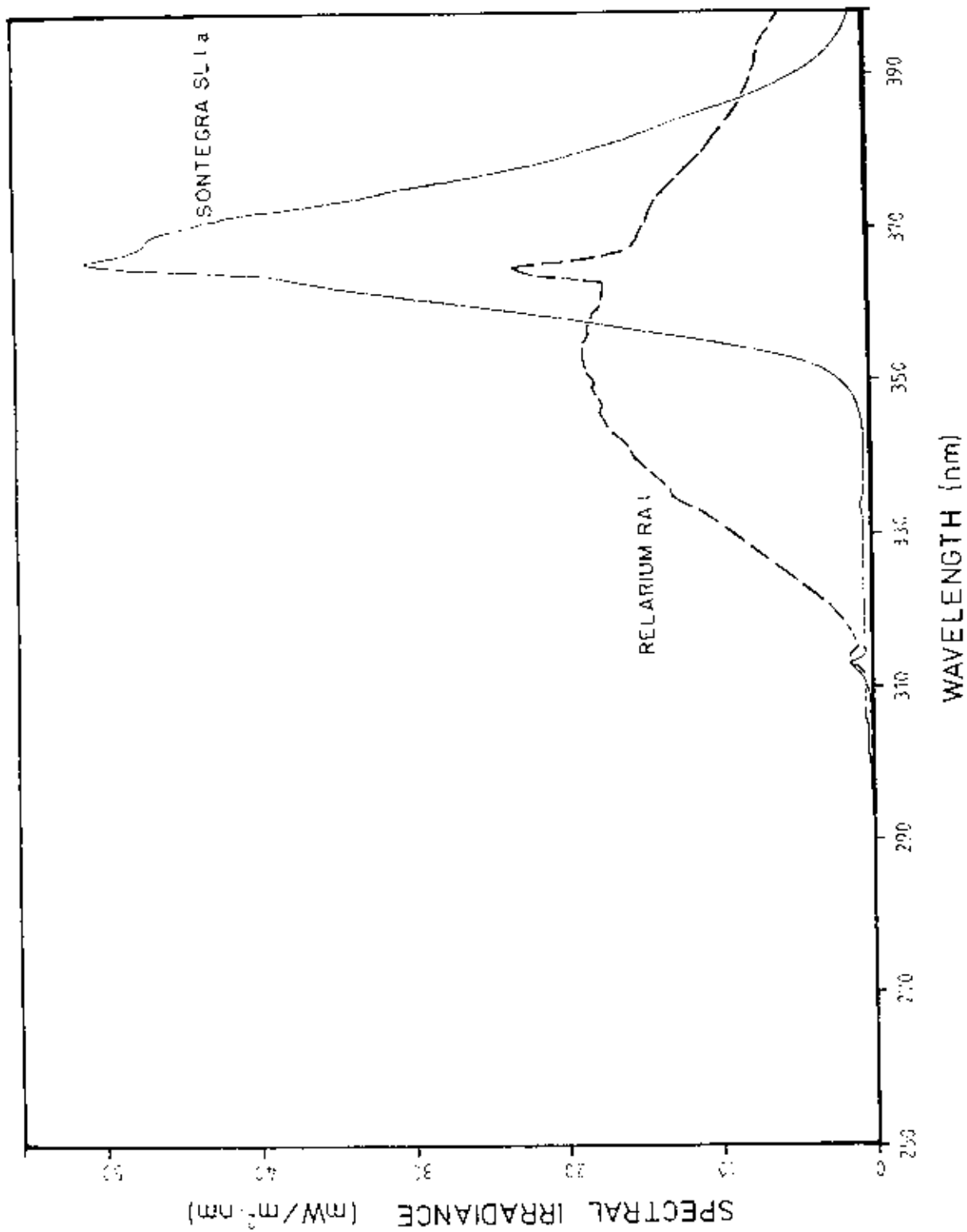


Figure 7: A comparison of the spectra of a typical UV-A lamp (Relarium RA-1) and the Sontegra S11a. The irradiances of both lamps have been normalized to 10 W/m².

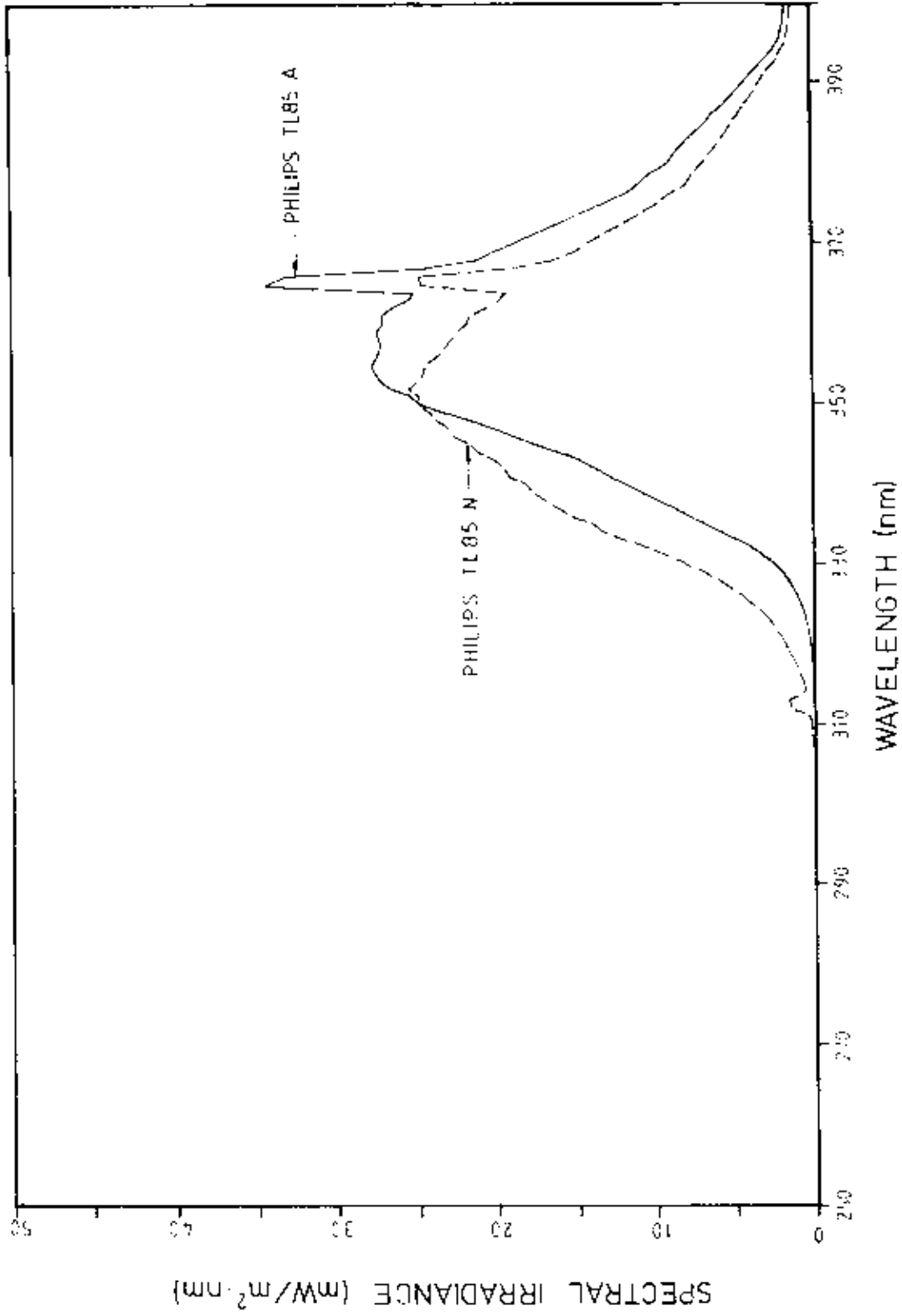


Figure 8: A comparison of the spectra of the Philips TL85 lamps, showing the 'normal spectrum' (N), which closely follows that of other UV-A lamps and the 'anomalous spectrum' (A) with its low levels of UV-B.

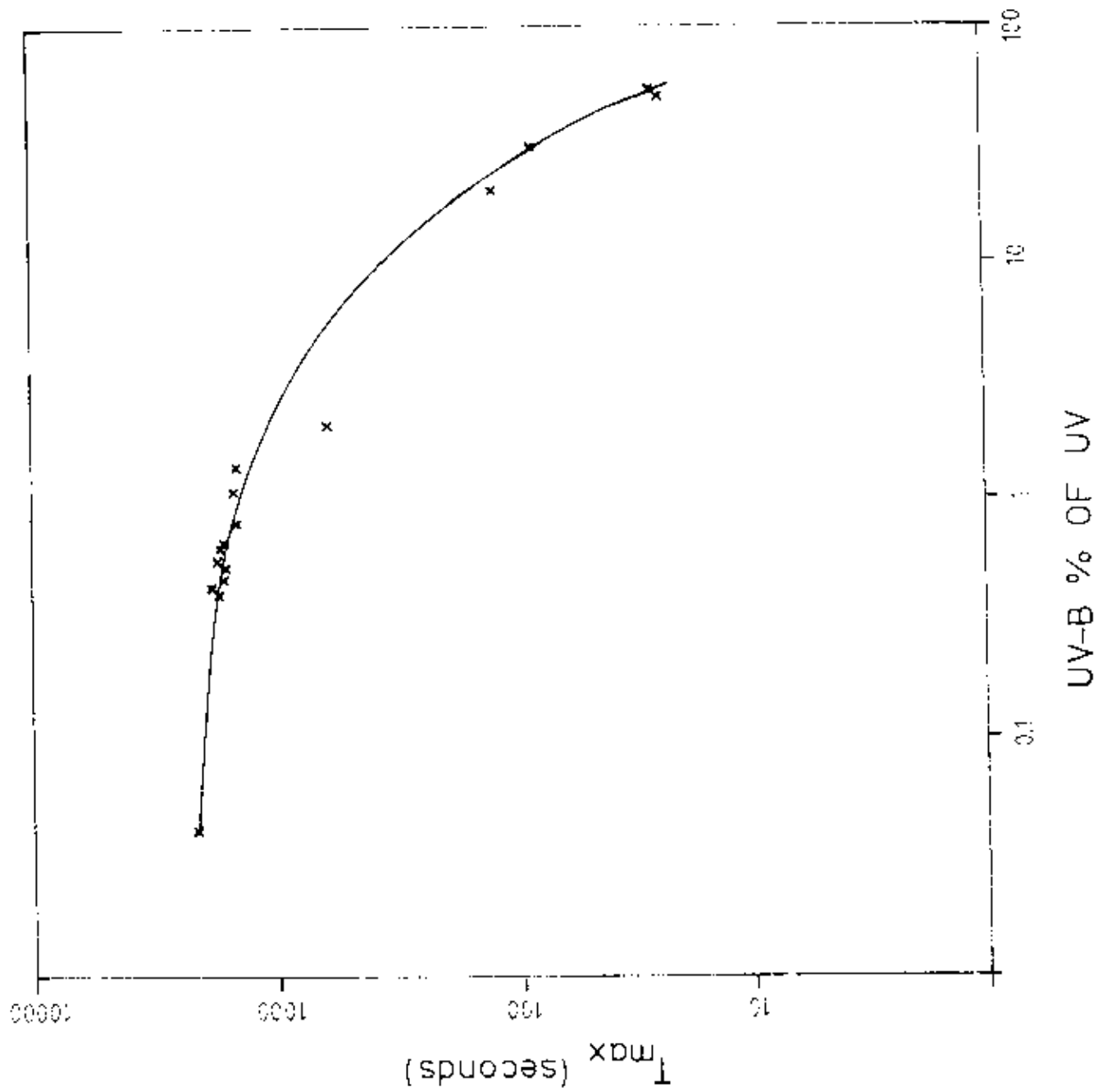


Figure 9: A plot of the results of Table 4, showing the maximum permissible exposure time versus the percentage of UVR which is UV-B for each lamp.

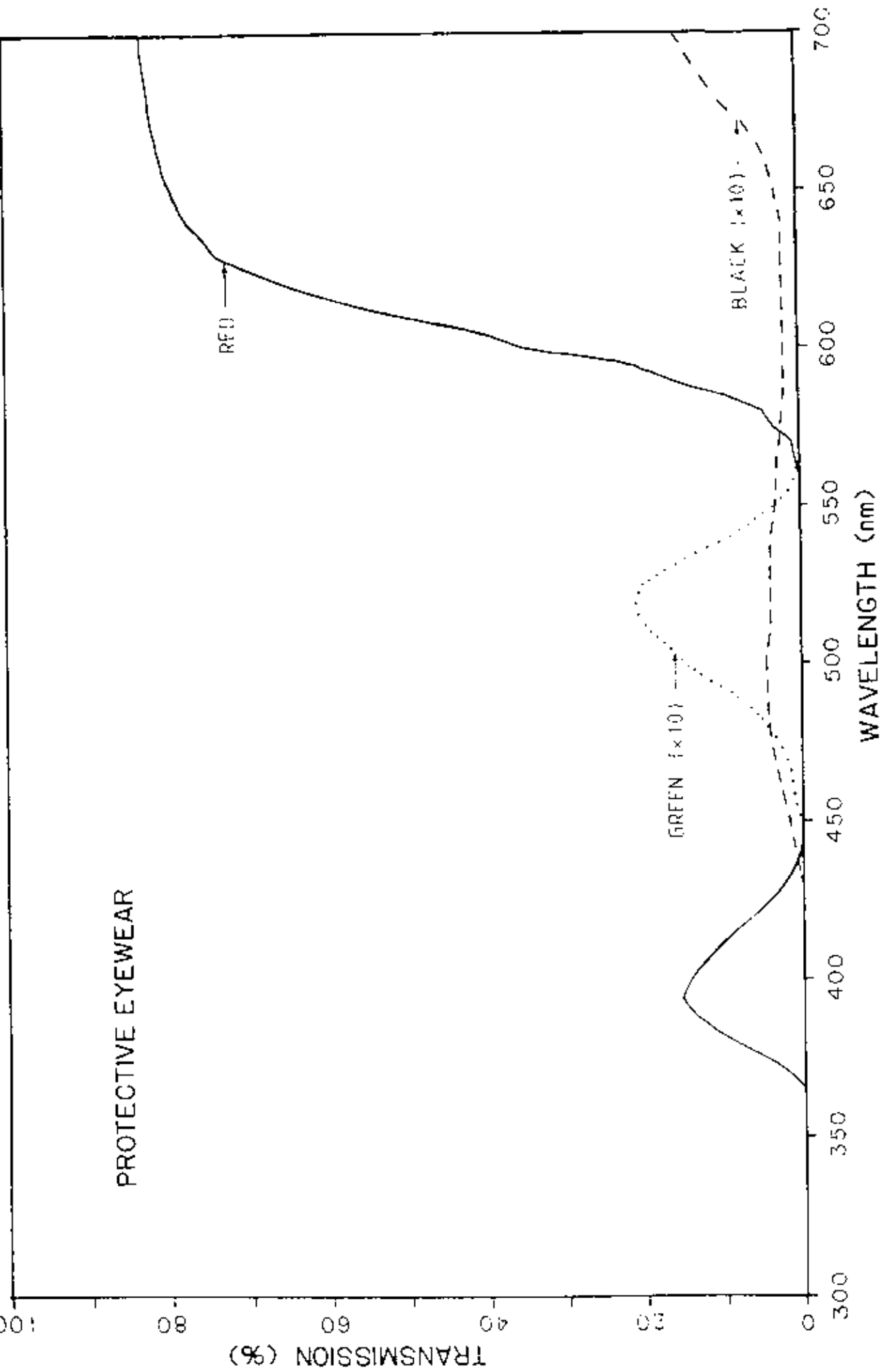


Figure 10: Spectral transmissions of safety goggles over the wavelength range 300-700 nm. The transmissions of the black and green goggles have been multiplied by 10 for purposes of comparison with the red goggles.

APPENDIX A

Sections 2 and 3 of AS 2635

"The Installation, Maintenance and Operation of
Solaria for Cosmetic Purposes"

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SECTION 2. INSTALLATION AND MAINTENANCE

2.1 ULTRAVIOLET IRRADIANCE.

2.1.1 Effective Irradiance. For the purpose of this standard, the effective ultraviolet irradiance of a solarium is the maximum value of irradiance within the total region likely to be occupied by a user of the solarium.

When measured in accordance with Appendix B, the effective ultraviolet irradiance of a solarium shall not exceed 200 W/m^2 .

2.1.2 Lamp Emission Characteristics. For each ultraviolet lamp used in a solarium, the irradiance for each of the following wavelength ranges, expressed as a percentage of the overall ultraviolet irradiance of the lamp, shall not exceed the following corresponding value:

- (a) For the wavelength range 100 nm to 280 nm 0.01 percent.
- (b) For the wavelength range 280 nm to 300 nm 0.1 percent.
- (c) For the wavelength range 300 nm to 315 nm 1 percent.

2.2 SAFETY SWITCHES.

2.2.1 Manual Safety Switch. A manual safety switch shall be located within easy reach from the region of a solarium normally occupied by a user of the solarium, and shall be operable to disconnect power to all sources of ultraviolet radiation in the solarium. In a commercial establishment, provision shall be made to prevent re-activation of the switch by any person other than a solarium supervisor (see Clause 3.4.1).

2.2.2 Automatic Safety Switch. An automatic safety switch shall be operable to disconnect power to all sources of ultraviolet radiation in a solarium at the expiry of a period equal to the maximum initial or repeated exposure time specified in Clause 3.1 (as appropriate), or 30 min, whichever is the shorter. The accuracy of the timing function on the automatic safety switch shall be within ± 10 percent for all settings. In a commercial establishment, provision shall be made to prevent operation of the automatic safety switch by any person other than a solarium supervisor (see Clause 3.4.1).

2.3 PROTECTIVE SCREENING.

2.3.1 Mechanical Screening. All lamps used in a solarium shall be mechanically screened from the possibility of user contact, and such screening shall be of sufficient mechanical strength to withstand accidental impact.

2.3.2 Ultraviolet Screening. Sufficient ultraviolet screening shall be provided to ensure that all ultraviolet radiation emitted by a solarium is contained within the region normally occupied by a user of the solarium, thereby minimizing the possibility of unintentional exposure of any person other than the solarium user.

2.4 HANDRAILS. For a solarium where a user may undergo ultraviolet exposure in a standing position, at least one handrail shall be installed for the purpose of providing user support.

2.5 GENERAL REQUIREMENTS. Subject to the appropriate requirements of this standard, all artificial tanning equipment in a solarium shall otherwise comply with the requirements of AS XXXX. All electrical equipment shall comply with the requirements of AS YYYY.

2.6 MEASUREMENTS. Compliance with Clause 2.1.1 and Clause 3.1, as determined in accordance with Appendix B, shall be verified at intervals not exceeding 6 months, or immediately subsequent to any one of the following occurrences, whichever transpires first:

- (a) Any item of artificial tanning equipment is commissioned or replaced.
- (b) One or more solarium lamps are added or replaced.
- (c) There is any change to an item of solarium equipment which might possibly affect compliance with Clause 2.1.1 or Clause 3.1, e.g. a change relating to ultraviolet lamp configuration or location, any change affecting a filter or a reflector, a change relating to a solarium power supply, etc.

SECTION 3. OPERATION

3.1 MAXIMUM EXPOSURE TIMES.

3.1.1 Maximum Initial Exposure. When determined in accordance with Paragraph B5 of Appendix B, the time for an initial solarium exposure shall not exceed the time required to administer a dose of 50 000 J/m² of ultraviolet radiation. (See Clause 1.4.2.)

3.1.2 Maximum Repeated Exposure. When determined in accordance with Paragraph B5 of Appendix B, the time for each repeated solarium exposure shall not exceed the time required to administer a dose of 200 000 J/m² of ultraviolet radiation, and such repeated exposure shall be administered no sooner than 48 h after the previous exposure (including the initial exposure). (See Clause 1.4.4.)

3.2 EYE PROTECTION. In a commercial establishment, the solarium operator (see Clause 1.4.6) shall ensure that protective goggles are worn by every user of a solarium during any period for which the solarium is operative (see Note). The protective goggles shall comply with the following requirements:

- (a) The spectral transmittance of the goggles shall not exceed—
 - (i) for the wavelength range 180 nm to 315 nm
..... 0.1 percent;
 - (ii) for the wavelength range 315 nm to 360 nm
..... 1 percent.
- (b) For wavelengths longer than 400 nm, the spectral transmittance of the goggles shall be sufficient to enable a solarium user wearing the goggles to visually locate the manual safety switch specified in Clause 2.2.1.
- (c) The goggles shall be eyecup goggles which form a light-tight seal against the skin surrounding the eyes such that the transmission of light to the eyes from all directions is filtered by the goggles.
- (d) The goggles shall include a headband which enables their secure attachment over the eyes.

NOTE: It is strongly recommended that protective goggles be worn by a solarium supervisor (see Clause 3.4.1), or any other person, when in the vicinity of an operative solarium.

3.3 HYGIENE. In a commercial establishment, any part or surface of a solarium which may be subject to body contact with a user of the solarium shall be either thoroughly disinfected or, if disposable, completely replaced after the solarium has been used by any person. For the purposes of this clause, suitable disinfecting substances include the following:

- (a) Ethanol (ethyl alcohol) BP, in a dilution containing 70 percent (V/V).
- (b) Propan-2-ol (isopropyl alcohol) BPC, in a dilution containing 50 percent (V/V).

- (c) Any quarternary ammonium compound which, in a solution containing 1 part in 500 of water (m/V), has a sterilizing effect at least equal to the substance specified in (a) above.
- (d) Any non-irritant disinfecting solution which can be shown to have a disinfecting action at least equal to any of the substances specified in (a), (b) or (c) above.

3.4 SUPERVISION AND INFORMATION

3.4.1 Solarium Supervision. In a commercial establishment, all solarium use by any client of the establishment shall be subject to supervision at all times. A solarium supervisor, whether the solarium operator (see Clause 1.4.6) or an appointee of the solarium operator, shall be a person who is thoroughly familiar with the requirements of this standard and properly instructed as to their practical implementation.

3.4.2 Warning Notices. In a commercial establishment, one or more notices presenting the following information shall be placed so as to be within the immediate view of every client entering the establishment or awaiting solarium exposure:

- (a) A request that every client reads and signs a form of advice to clients before commencing a course of solarium exposure. (See Clause 3.4.3.)
- (b) Advice that clients should not undergo solarium exposure within 48 h of any previous solarium exposure and should avoid intentional exposure to sunlight within 48 h both before and after any solarium exposure.
- (c) Advice that protective goggles must be worn by every client while undergoing solarium exposure.
- (d) A request that clients do not smoke, eat or drink while undergoing solarium exposure.

3.4.3 Form of Advice to Clients. Prior to the commencement by a client of a commercial establishment of a course of one or more solarium exposure sessions, the solarium operator (see Clause 1.4.6) shall ensure that a form of advice to clients, as set out in Appendix A, is handed to the client.

The solarium operator shall further ensure the following:

- (a) That the client signs and dates the form.
- (b) That the client returns the signed and dated form, and that—
 - (i) the original signed and dated form is filed in the records of the establishment for a period of not less than 2 years; and
 - (ii) a copy of the signed and dated form is handed to the client.

APPENDIX B

Irradiance and Normalized Spectral Irradiance Measurements.

Tables B1 to B6: Sunbeds.

Tables B7 to B8: UV-A Lamps.

Table B9: Sunlamps.

Table B10: Tanning Booth.

Table B11: Noontime Solar Fluxes.

TABLE B1: Spectral irradiance as a percentage of the UV irradiance for sunbeds with Relarium KAl-100w lamps.

WAVELENGTH (nm)	A	B	C
302	.00	.00	.01
304	.00	.01	.01
306	.01	.01	.01
308	.01	.08	.02
310	.03	.13	.03
312	.12	.09	.14
314	.09	.14	.12
316	.13	.21	.14
318	.20	.29	.21
320	.28	.37	.29
322	.38	.48	.38
324	.47	.60	.48
326	.60	.79	.60
328	.76	.95	.79
330	.94	1.31	.93
332	1.18	1.43	1.13
334	1.38	1.55	1.32
336	1.51	1.67	1.45
338	1.62	1.76	1.56
340	1.66	1.76	1.59
342	1.69	1.77	1.62
344	1.69	1.78	1.65
346	1.74	1.79	1.73
348	1.77	1.80	1.70
350	1.81	1.82	1.80
352	1.81	1.80	1.80
354	1.81	1.89	1.82
356	1.80	1.74	1.83
358	1.75	1.78	1.81
360	1.69	1.76	1.79
362	1.68	2.09	1.78
364	1.83	2.08	1.76
366	2.36	1.61	2.36
368	1.71	1.48	1.73
370	1.48	1.37	1.54
372	1.42	1.27	1.43
374	1.33	1.21	1.35
376	1.25	1.12	1.26
378	1.14	1.03	1.14
380	1.09	.96	1.05
382	.98	.85	.96
384	.90	.77	.91
386	.84	.64	.85
388	.74	.57	.73
390	.62	.45	.61
392	.54	.36	.54
394	.44	.29	.43
396	.36	.24	.37
398	.33	.21	.28
400	.32	.24	.27
UV Irradiance (W/m ²)	8.0	14.6	22.0

TABLE B2: Spectral irradiance as a percentage of the UV irradiance for sunbeds with Relarium RA1-100w lamps.

WAVELENGTH (nm)	D	E	F
302	.01	.00	.01
304	.01	.00	.01
306	.02	.01	.01
308	.02	.01	.02
310	.04	.02	.03
312	.09	.09	.05
314	.22	.09	.18
316	.13	.12	.17
318	.21	.18	.17
320	.30	.26	.26
322	.42	.36	.35
324	.53	.46	.46
326	.65	.58	.58
328	.80	.73	.68
330	.90	.93	.80
332	1.05	1.18	.94
334	1.11	1.41	1.06
336	1.28	1.51	1.22
338	1.41	1.62	1.32
340	1.53	1.67	1.45
342	1.53	1.68	1.52
344	1.63	1.72	1.58
346	1.72	1.73	1.64
348	1.69	1.71	1.73
350	1.80	1.83	1.73
352	1.82	1.84	1.80
354	1.84	1.78	1.85
356	1.99	1.77	1.81
358	1.77	1.73	1.77
360	1.77	1.77	1.78
362	1.61	1.74	1.64
364	2.03	1.83	1.81
366	1.94	2.39	2.45
368	1.54	1.61	1.88
370	1.53	1.46	1.53
372	1.42	1.40	1.50
374	1.38	1.35	1.39
376	1.24	1.24	1.34
378	1.16	1.13	1.22
380	1.06	1.06	1.11
382	.98	.97	.98
384	.90	.91	.93
386	.86	.86	.86
388	.77	.80	.84
390	.78	.69	.77
392	.68	.56	.75
394	.64	.46	.69
396	.56	.36	.62
398	.55	.31	.57
400	.47	.29	.52

UV Irradiance (w/m²) 16.0 10.0 7.3

TABLE B3: Spectral irradiance as a percentage of the UV irradiance for sunbeds with Philips TL65-80w/09 lamps.

WAVELENGTH (nm)	A	B
306	.01	.01
308	.01	.01
310	.01	.02
312	.02	.07
314	.16	.19
316	.07	.07
318	.11	.13
320	.17	.19
322	.24	.28
324	.35	.37
326	.44	.46
328	.53	.60
330	.68	.76
332	.80	.91
334	.98	1.13
336	1.18	1.31
338	1.37	1.52
340	1.58	1.77
342	1.83	1.93
344	1.98	2.10
346	2.06	2.21
348	2.24	2.34
350	2.36	2.45
352	2.47	2.56
354	2.53	2.58
356	2.55	2.43
358	2.43	2.26
360	2.31	2.20
362	2.13	1.94
364	2.05	2.24
366	2.27	1.96
368	1.76	1.55
370	1.54	1.49
372	1.41	1.32
374	1.30	1.16
376	1.11	1.00
378	.93	.80
380	.75	.65
382	.59	.53
384	.52	.45
386	.44	.40
388	.39	.34
390	.35	.33
392	.31	.28
394	.25	.23
396	.20	.19
398	.15	.15
400	.13	.12
UV Irradiance (W/m ²)	16.2	7.9

TABLE B4: Spectral irradiance as a percentage of the UV irradiance for sunbeds with Philips TL85-100W/09 lamps.

WAVELENGTH (nm)	A	N
302	.00	.01
304	.00	.00
306	.00	.00
308	.00	.01
310	.00	.02
312	.01	.15
314	.00	.05
316	.01	.09
318	.01	.14
320	.02	.19
322	.04	.25
324	.05	.33
326	.08	.44
328	.15	.59
330	.23	.79
332	.36	1.01
334	.57	1.31
336	.77	1.52
338	.97	1.68
340	1.17	1.79
342	1.37	1.94
344	1.58	2.10
346	1.88	2.25
348	2.17	2.36
350	2.46	2.47
352	2.65	2.53
354	2.74	2.43
356	2.73	2.34
358	2.71	2.26
360	2.69	2.16
362	2.63	2.04
364	2.48	1.91
366	3.30	2.46
368	2.10	1.60
370	1.88	1.40
372	1.64	1.21
374	1.39	1.03
376	1.17	.87
378	1.03	.74
380	.88	.65
382	.80	.57
384	.70	.50
386	.60	.43
388	.49	.36
390	.40	.29
392	.31	.23
394	.23	.17
396	.18	.14
398	.16	.12
400	.15	.12

UV Irradiance (W/m ²)	5.7	9.7
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TABLE B5: Spectral irradiance as a percentage of the UV irradiance for sunbeds with the designated lamps.

WAVELENGTH (nm)	SOLARIUM A1-11	SONTEGRA SL1a	SOLARLUX A1
294	.00	.01	.00
296	.00	.02	.00
298	.00	.01	.00
300	.00	.02	.00
302	.00	.03	.00
304	.00	.03	.00
306	.00	.03	.01
308	.01	.04	.01
310	.01	.04	.02
312	.02	.11	.17
314	.13	.05	.07
316	.06	.05	.11
318	.09	.05	.16
320	.15	.05	.22
322	.22	.05	.28
324	.32	.05	.38
326	.41	.05	.52
328	.52	.05	.69
330	.65	.05	.89
332	.78	.05	1.19
334	1.01	.06	1.42
336	1.21	.05	1.61
338	1.43	.05	1.79
340	1.68	.05	1.91
342	1.92	.05	2.03
344	2.09	.05	2.18
346	2.24	.07	2.29
348	2.35	.11	2.43
350	2.46	.19	2.45
352	2.53	.36	2.45
354	2.56	.71	2.38
356	2.50	1.30	2.26
358	2.41	1.86	2.23
360	2.18	2.57	2.11
362	2.11	3.38	1.98
364	2.10	3.91	2.60
366	2.21	5.09	1.84
368	1.69	4.71	1.47
370	1.49	4.54	1.32
372	1.43	4.10	1.11
374	1.24	3.32	.95
376	1.09	2.77	.81
378	.91	2.29	.70
380	.71	1.86	.62
382	.58	1.53	.54
384	.47	1.25	.46
386	.41	.93	.39
388	.36	.67	.31
390	.32	.46	.24
392	.29	.32	.18
394	.25	.20	.13
396	.21	.13	.10
398	.16	.10	.09
400	.13	.09	.08

UV Irradiance (W/m²) 16.0 8.2 6.6

TABLE 86: Spectral irradiance as a percentage of the UV irradiance for sunbeds with Dr. Kern Sonnenspezialist and Bellarium SA1-11-100w lamps.

WAVELENGTH (nm)	DR. KERN SONNENSPZ.	BELLARIUM SA1-10-100w
302	.00	.01
304	.00	.01
306	.00	.01
308	.01	.03
310	.02	.04
312	.24	.21
314	.06	.13
316	.09	.20
318	.15	.29
320	.20	.37
322	.26	.46
324	.35	.56
326	.47	.71
328	.60	.89
330	.78	1.07
332	.99	1.28
334	1.27	1.45
336	1.52	1.57
338	1.77	1.64
340	1.87	1.67
342	1.97	1.73
344	2.07	1.77
346	2.18	1.84
348	2.29	1.89
350	2.39	1.93
352	2.41	1.95
354	2.44	1.89
356	2.34	1.83
358	2.18	1.77
360	2.23	1.76
362	2.05	1.70
364	1.93	1.65
366	2.41	2.08
368	1.61	1.49
370	1.46	1.38
372	1.23	1.28
374	1.03	1.14
376	.88	1.03
378	.75	.95
380	.66	.88
382	.59	.82
384	.49	.78
386	.42	.71
388	.32	.62
390	.27	.55
392	.20	.47
394	.15	.39
396	.10	.33
398	.08	.30
400	.07	.30

UV Irradiance (W/m ²)	9.6	7.5
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TABLE B7: Spectral irradiance as a percentage of the UV irradiance for single lamps.

WAVELENGTH (nm)	BELLARIUM SA1-10-100W	BELLARIUM S SA1-12-100W	SOLARIUM A1-11-100W
302	.01	.02	.00
304	.01	.02	.00
306	.02	.04	.01
308	.04	.05	.01
310	.06	.08	.02
312	.15	.11	.03
314	.28	.53	.22
316	.19	.23	.07
318	.28	.33	.11
320	.39	.45	.17
322	.52	.59	.25
324	.67	.73	.36
326	.80	.88	.48
328	.94	1.00	.59
330	1.07	1.13	.71
332	1.19	1.24	.85
334	1.37	1.39	1.04
336	1.46	1.49	1.24
338	1.57	1.59	1.45
340	1.66	1.66	1.61
342	1.72	1.67	1.80
344	1.77	1.76	1.98
346	1.82	1.76	2.11
348	1.79	1.79	2.22
350	1.81	1.78	2.32
352	1.81	1.82	2.39
354	1.85	1.78	2.41
356	1.80	1.75	2.39
358	1.76	1.72	2.29
360	1.66	1.64	2.15
362	1.60	1.56	2.02
364	2.41	1.54	1.91
366	1.78	1.90	2.27
368	1.44	1.37	1.64
370	1.38	1.30	1.49
372	1.32	1.29	1.39
374	1.23	1.22	1.24
376	1.12	1.11	1.09
378	1.02	.99	.93
380	.89	.90	.77
382	.81	.82	.67
384	.74	.74	.56
386	.66	.66	.48
388	.61	.62	.43
390	.57	.57	.38
392	.53	.54	.34
394	.48	.49	.29
396	.43	.44	.25
398	.38	.42	.22
400	.33	.37	.18
UV Irradiance (W/m ²)	1.4*	1.6*	1.8*

* Laboratory measurements at a distance of 0.6 metres.

TABLE B8: Spectral irradiance as a percentage of the UV irradiance for single lamps.

WAVELENGTH (nm)	DR. KERN SONNENSPZ.	RELARIUM RA1-100w	SONNE DA-1
302	.01	.00	.01
304	.00	.01	.00
306	.01	.01	.01
308	.01	.02	.01
310	.02	.03	.02
312	.08	.07	.08
314	.18	.15	.19
316	.08	.10	.09
318	.13	.16	.13
320	.19	.25	.20
322	.29	.37	.30
324	.40	.49	.41
326	.52	.61	.53
328	.65	.76	.66
330	.79	.89	.80
332	.93	1.02	.94
334	1.15	1.21	1.16
336	1.33	1.30	1.34
338	1.55	1.41	1.48
340	1.70	1.53	1.68
342	1.87	1.58	1.87
344	2.03	1.69	2.02
346	2.16	1.75	2.16
348	2.25	1.77	2.27
350	2.34	1.78	2.34
352	2.37	1.84	2.38
354	2.45	1.86	2.47
356	2.36	1.82	2.41
358	2.28	1.80	2.31
360	2.12	1.74	2.11
362	1.98	1.72	2.01
364	2.46	2.16	2.41
366	1.98	1.86	1.94
368	1.53	1.52	1.54
370	1.40	1.47	1.40
372	1.34	1.42	1.29
374	1.20	1.37	1.20
376	1.03	1.27	1.03
378	.87	1.17	.88
380	.72	1.05	.72
382	.61	.98	.61
384	.51	.91	.50
386	.43	.82	.43
388	.38	.77	.37
390	.34	.74	.33
392	.30	.71	.29
394	.26	.66	.24
396	.21	.61	.21
398	.17	.54	.17
400	.14	.46	.13

UV Irradiance (W/m²) 1.4* 1.4* 1.65*

* Laboratory measurements at a distance of 0.6 metres.

TABLE B9: Sunlamp spectral irradiance as a percentage of the UV irradiance.

WAVELENGTH (nm)	PHILIPS 57265F/28 300W	BREVILLE WOTAN RZ1 ULTRA-VITALUX
264	.00	.01
266	.01	.00
268	.00	.00
270	.00	.01
272	.00	.00
274	.00	.00
276	.01	.02
278	.01	.01
280	.04	.12
282	.04	.03
284	.01	.02
286	.02	.03
288	.03	.13
290	.19	.21
292	.04	.08
294	.10	.10
296	.05	.50
298	1.01	.70
300	.10	.20
302	1.87	3.00
304	.40	.19
306	.11	.15
308	.11	.16
310	.12	.19
312	.36	2.41
314	7.37	7.90
316	.98	.40
318	.21	.26
320	.19	.23
322	.19	.23
324	.18	.23
326	.19	.23
328	.19	.23
330	.20	.24
332	.21	.25
334	.42	1.31
336	1.47	.70
338	.20	.24
340	.23	.23
342	.18	.20
344	.18	.19
346	.16	.18
348	.16	.17
350	.15	.16
352	.14	.15
354	.14	.17
356	.19	.17
358	.15	.14
360	.15	.15
362	.18	.23
364	4.43	14.00
366	21.90	10.50

368	2.37	.67
370	.41	.32
372	.28	.22
374	.16	.13
376	.13	.12
378	.11	.11
380	.17	.11
382	.12	.10
384	.08	.07
386	.11	.09
388	.09	.08
390	.16	.20
392	.36	.25
394	.13	.07
396	.08	.07
398	.08	.08
400	.09	.07

UV Irradiance (W/m²) 1.7* 1.5*

* Laboratory measurements at a distance of 1.6 metres.

TABLE B10: Spectral irradiance as a percentage of the UV irradiance for single lamps measured in a tanning booth.

WAVELENGTH (nm)	OLIPHANT FL-20SE	TOSHIBA FL 20-SE/E	SYLVANIA FL40SBL
272	.01	.01	.00
274	.02	.01	.00
276	.04	.03	.00
278	.09	.07	.00
280	.17	.13	.00
282	.26	.21	.01
284	.37	.31	.01
286	.52	.44	.01
288	.67	.59	.02
290	.88	.78	.02
292	1.03	.95	.03
294	1.27	1.18	.03
296	1.53	1.43	.04
298	1.78	1.70	.05
300	1.97	1.89	.05
302	2.25	2.13	.07
304	2.19	2.17	.06
306	2.29	2.29	.07
308	2.29	2.32	.07
310	2.28	2.28	.08
312	2.30	2.31	.10
314	3.25	3.10	.43
316	2.10	2.13	.15
318	1.94	1.94	.20
320	1.77	1.78	.27
322	1.62	1.63	.36
324	1.46	1.50	.46
326	1.36	1.41	.58
328	1.29	1.35	.71
330	1.19	1.24	.84
332	1.09	1.12	.99
334	1.02	1.04	1.20
336	.87	.91	1.34
338	.75	.79	1.60
340	.65	.67	1.76
342	.57	.60	1.96
344	.50	.53	2.05
346	.45	.49	2.15
348	.42	.45	2.30
350	.39	.42	2.36
352	.34	.38	2.43
354	.30	.34	2.42
356	.29	.30	2.28
358	.22	.26	2.25
360	.18	.22	2.07
362	.16	.19	1.90
364	.68	.42	2.00
366	.30	.34	1.76
368	.11	.13	1.46

370	.10	.12	1.33
372	.09	.11	1.21
374	.08	.10	1.08
376	.07	.09	.94
378	.06	.07	.77
380	.05	.06	.64
382	.05	.05	.54
384	.04	.05	.45
386	.04	.04	.39
388	.03	.04	.35
390	.03	.04	.30
392	.03	.04	.27
394	.03	.03	.23
396	.03	.03	.20
398	.02	.03	.15
400	.02	.02	.10

UV Irradiance (W/m²) 2.6* 2.7* 2.8*

* Measured at a distance of 0.3 metres.

TABLE B11: Solar flux measured at noon in Melbourne.
Wavelength versus spectral irradiance as
a percentage of the UV irradiance.

WAVELENGTH (nm)	SOLAR FLUX SUMMER	SOLAR FLUX WINTER
300	.1	.0
302	.1	.0
304	.1	.0
306	.2	.0
308	.2	.1
310	.3	.1
312	.4	.2
314	.4	.2
316	.5	.3
318	.6	.3
320	.5	.4
322	.7	.4
324	.9	.6
326	.9	.7
328	1.0	.7
330	.9	.8
332	.9	.8
334	.9	.8
336	.9	.7
338	1.0	.9
340	1.0	.9
342	.9	.8
344	1.0	.9
346	1.0	.9
348	1.0	1.0
350	1.1	1.1
352	1.2	1.1
354	1.2	1.2
356	.9	1.0
358	1.1	1.1
360	1.1	1.1
362	1.2	1.2
364	1.5	1.4
366	1.4	1.5
368	1.5	1.5
370	1.4	1.5
372	1.2	1.4
374	1.3	1.3
376	1.6	1.6
378	1.4	1.6
380	1.0	1.5
382	1.1	1.2
384	1.2	1.5
386	1.3	1.5
388	1.5	1.7
390	1.6	1.9
392	1.0	1.5
394	1.5	1.6
396	1.4	1.5
398	2.1	2.6
400	2.2	3.0

UV Irradiance (W/m ²)	70.7	26.4
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