Solar UV Simulator Skin Testing

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Protection of the skin against damaging ultraviolet radiation (UVR) by sunscreens and cosmetics or testing pharmaceuticals and care products for photosensitization requires as a radiant testing source one which has a spectrum like the sun's. It is the sun's UV which wrinkles, burns, tans, photosensitizes and, in the extreme, causes skin cancer.

The testing source need emit only UVR (**Figure 1**). It is an advantage to delete other parts of the solar spectrum from the source's output since the intensity of the UVR can be increased. In sunlight UVR is about 6% of the total irradiance. Making UVR 90% or more of the output means that the source's total intensity can be equal to that of sunlight, with no more heating effect while the UV is 15 times more intense than for an overhead sun in a clear sky. The 80 milliwatts per square centimeter of solar maximum irradiance for small areas of skin is below the thermal discomfort limit so that UVR can be even more than 15 times the maximum in sunlight before the discomfort level is reached. In practice, UVR intensities of 20-25 times solar are used for testing with the 1 centimeter diameter output solar UV simulator. Photo effects in the skin are within wide limits reciprocal, that is the effect is only due to the total dose and not the intensity which produces the dose. Very low intensities which require hours to theoretically produce an effect may have that effect reduced or eliminated by the repair processes in the skin. Very high intensities which cause the skin to be excessively heated may produce a false heat erythema or actually burn the skin.

The heating effect from the simulator's output is due to the power absorbed by the skin. Fair skin absorbs less energy in the visible than does dark skin but in the ultraviolet region all skins absorb similarly.

The spectral shape of the test source (solar UV simulator) is critically important, particularly for the

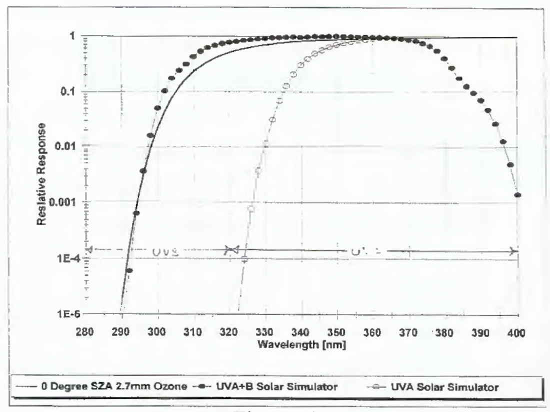

Figure 1.

UVB component (**Figure 1**). In sunlight the intensity of UVR begins falling at an accelerated rate for wavelengths shorter than 330nm. until there is negligible intensity by about 295nm. UVB which extends from 315nm. to 280nm. is strongly affected by ozone thickness in the atmosphere. Although the total power in the UVB is never more than a tenth of the total UVR, its biologic effects are much greater.

In order to simulate solar UVR the artificial source must have a continuous, fairly smooth spectrum. In addition, the UVB spectrum must have a rapid fall off like that of the ozone absorption of the sun's spectrum.

The sun's irradiance is similar to that of a black body radiator at about 5,600°K. This temperature is also that of the arc in the xenon lamp. Consequently, the spectral output of that lamp emits a continuum in the ultraviolet region like that of the extra-terrestrial sun (**Figure 2**). The strong absorbance of ozone for UVB wavelengths is simulated by the WG 320 filter manufactured by the Schott Co. In particular a filter thickness of approximately 1mm. simulates the absorption of about 2.5mm. of ozone. The absorptivity of each WG320 melt is measured to determine the exact WG320 filter thickness that best

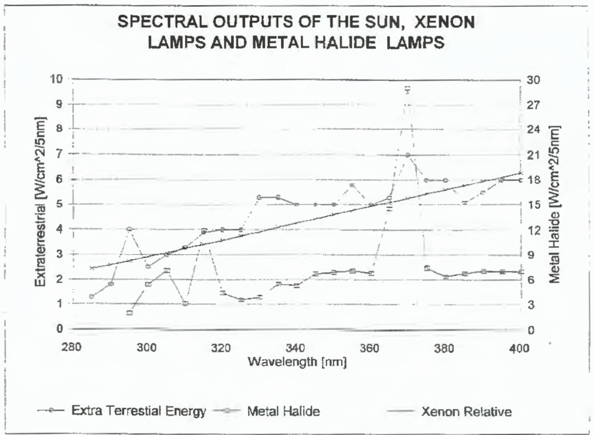

Figure 2.

simulates a 2.5mm ozone absorption. The resulting spectral output conforms to the COLIPA standard.

The unwanted visible and infrared wavelengths of the xenon lamp can be eliminated in 2 different ways; either by absorbing them in a black glass filter immersed in a water bath, or transmitting them through an interference filter which reflects UVR. This second method is preferred, although the first is possible.

The optical layout of the first Solar UVR Simulator, built in 1965, is shown in **Figure 3**. The basic schema is followed in all UVR simulators made today. Radiant energy from the lamp is collected and collimated, here by lenses and a mirror, in other configurations by only a mirror. The collimated beam reaches a 45° interference filter reflecting about 90% of the UVR and about 10% of the visible. The reflected UVR beam passes through a WG320 filter which has an ozone-like absorption. Following the WG320 is a black glass filter absorbing most of the remaining visible radiation. The beam then strikes a lens which images the collimating lens on the subject in a uniform 1 centimeter diameter spot.

The intensity of the spot permits a 15-30 second irradiation to elicit sunburn in an average, unacclimated Caucasian.

Testing with UVA, 320-400 nm., (**Figure 1**) is important in the evaluation of newer sunscreens, for pharmaceutical and cosmetic firms concerned with the photosensitization potential of their products, and medically for testing subjects with suspected photosensitivities. The UVA testing mode is readily obtained from the Simulator by merely absorbing the UVB part of the output. A sharp cut-off filter in the Schott WG series, the WG345 at 2mm. thickness, absorbs the UVB. The remaining UVA has an intensity of about 65-75 milliwatts per square centimeter. With such an intensity skin responses requiring 30 joules per square centimeter of UVA can be elicited in less than 8 minutes. In sunlight this dose would require about 2½ hours on a cloudless day if repair mechanisms in the skin weren't reducing the dose's effectiveness.

The described simulator (**Figure 4**) allows both UVB and UVA testing to be carried out with a similarity to effects obtained in sunlight. If the simulator's UVB didn't have an ozone-like attenuation, simulator results could be different from sunlight's. Filters having a less steep attenuation than ozone could permit wavelengths below 290 nm. to irradiate the skin which, depending on the spectral absorption of the sunscreen, could give an incorrect protection factor.

The xenon arc lamp requires a special power supply. The lamp has a maximum life of 1,000 hours. These expenses and the relatively small area that can be irradiated has encouraged the use of alternate lamps which are less expensive and irradiate a larger area. Metal halide and fluorescent type lamps have been used for solar simulation. However, these lamps cannot properly simulate the UVB because of mercury spectral lines in their outputs. Also, the large irradiated area is not uniform in intensity or in spectrum and obtaining accurate readings for an irradiated site can be difficult. Offsetting the cost for

Optical schematic of the solar simulator

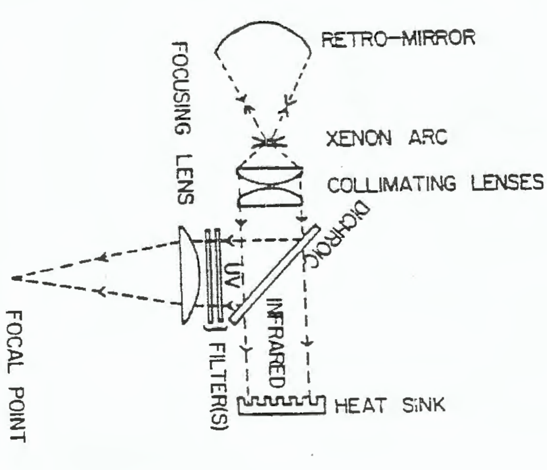

Figure 3.

Figure 4.

Figure 5

xenon arc simulators are their outstanding characteristics; the output for the xenon lamp is spectrally close to sunlight in both the UV-B and A, the intensity is high, the uniformity is good and reproducible, accurate measurements of intensity and dose are easily made, and the 1 cm. diameter spot per irradiation is adequate without using an excess skin area.

Measuring the simulator output is essential and should be taken before and after irradiations. The UVB measurement is best taken with a detector which has the erythema action spectrum as the detector response. This allows the subject to be measured in respect to the reference sensitivity of fair skinned, untanned Caucasians. Contrariwise, using a spectrally unweighted UVB detector allows least biologically effective UVB wavelengths to have the major effect on the meter reading, masking the effect of low power but more biologically effective wavelengths at the short end of the UVB.

The UVA detector should have a flat spectral response, in distinction to the UVB detector.

The Solar UV Simulator should be the least demanding aspect of skin testing. Uniform and reproducible application of the sunscreen or putative sensitizer, reading of the minimal erythema dose and selecting an adequate number of similar subject for SPF tests are where the main concerns in phototesting are directed.

For photosensitivity testing it is usual to first determine that the subject has a normal response to the full UVR spectrum. The subject is then challenged with a patch test using the potentially photosensitizing material and only UVA radiation. Doses below 20 joules per cm^2 should not normally cause erythema. Covering small areas of test material with an opaque patch avoids sensitization from ambient light. Most photosensitizing materials are phototoxic but certain materials in particular individuals may cause a photoallergic reaction. To properly handle this possibility, it is recommended that a dermatologist trained in photo responses be involved with photosensitivity testing.

• The Simulator has made possible routine medical testing of suspected photosensitivities and the differential diagnoses of various diseases.

• It has allowed numerous new products entering the consumer market to be tested for possible photosensitization.

• Perhaps, most importantly, it has allowed the development and validation of sunscreens which prevent skincancers and sunburn, reduce the development of wrinkles and allow normal as well as photosensitive people to safely spend more time outdoors.

Daniel Berger

Biography

Inventor of the Solar UV Simulator, a development that made possible the clinical testing of biologically effective UV radiation, as well as the determination of sunscreen efficacy or Sun Protection Factor (SPF) ratings. Founded Solar Light Company (Phila, Pa. USA). With more than 30 years of research experience in the fields of photobiology and electrical engineering, Berger is the leading expert in the development and refinement of UV sources and meters for the study of biologically effective UV radiation.