Safety Tips for Using Solar Simulators

What Are Solar Simulators?

A solar simulator (artificial sun) is a device that provides illumination approximating natural sunlight. The purpose of the solar simulator is to provide controllable laboratory conditions for the testing of solar cells, sunscreens, plastics, and other materials and devices. There are three main types of solar simulators: continuous, flashed, and pulsed.

The continuous simulator is most often used for low-intensity testing, with intensity ranging from less than 1 sun (irradiance of 100 milliwatts per square centimeter) to several suns. Continuous solar simulators may have several different lamp types combined (e.g., an arc source and one or more halogen lamps) to extend the spectrum far into the infrared.

The flashed simulator is qualitatively similar to flash photography and uses flash tubes. With typical durations of several milliseconds, very high intensities of up to several thousand suns are possible. This type of equipment is often used to prevent unnecessary heat buildup in the device under test.

The pulsed simulator uses a shutter to quickly block or unblock the light from a continuous source. Typically, the pulses range from 100 milliseconds (ms) to 800 ms (for special Xe Long Pulse Systems).

Examples of solar simulators

Solar simulators can vary with regard to spectra and irradiance distributions. Several types of lamps are used as the light sources within solar simulators; the type of lamp determines the spectral power distribution, although the spectrum may be modified by optical filters. The beam optics determine efficiency and irradiance geometry.

Solar simulators fall into one of three classes: A, B, or C, based on three characteristics: spectral match to sunlight, non-uniformity of the light beam and stability of the light beam over time. If a manufacturer does not clearly specify the class and tolerances for these characteristics, then more likely this is a xenon light source rather than a solar simulator.

Classification	Spectral Match to Sunlight (each interval)	Irradiance Spatial Non-Uniformity	Temporal Instability
Class A	0.75–1.25	2%	2%
Class B	0.6–1.4	5%	5%
Class C	0.4–2.0	10%	10%

Lamps Used in Solar Simulators

The *xenon arc lamp* is the most common type of lamp both for continuous and flashed solar simulators. These lamps offer high intensities and an unfiltered spectrum that matches reasonably well to sunlight.

The *metal halide arc lamp* was developed primarily for use in film and television lighting, wherein both a high temporal stability and daylight color match are required.

The *quartz tungsten halogen (QTH) lamp* offers spectra that very closely matches black body radiation, although typically with a color temperature lower than the sun's.

Light-emitting diodes (*LED)* have recently been used in research laboratories to construct solar simulators, and may offer promise in the future for energy-efficient production of spectrally tailored artificial sunlight.

Threshold Limit Values

The most restrictive applicable threshold limit value (TLV) for a solar simulator is the UV-C at 270 nanometers, which is set at 3 millijoules per square centimeter. This is the maximum safe level of exposure that one may receive in an 8-hour period. To compare the radiant exposure TLV to the irradiance of the unit, a conservative estimate of potential exposure time must be used. If one is potentially exposed for the entire 8 hours, the effective irradiance TLV is 0.1 microwatts per square centimeter.

Hazard and Risks from Solar Simulator UV Radiation

Solar simulators produce light radiation from ultraviolet through visible to infrared radiation. The biggest hazard comes from the UV radiation (UVR). UVR cannot be seen and is not felt immediately, but it is harmful to human tissue in the eyes and skin. The user may not realize the danger until after the exposure has caused damage. Symptoms can occur 4 to 24 hours after exposure.

The effects on skin are of two types: acute and chronic. Acute effects appear within a few hours of exposure, while chronic effects are long-lasting and cumulative and may not appear for years. An acute effect of UVR is redness of the skin called erythema (similar to sunburn). Chronic effects include accelerated skin aging and skin cancer.

UVR is absorbed in the outer layers of the eye – the cornea and conjunctiva. Acute overexposure leads to a painful temporary inflammation, mainly of the cornea, known as photokeratitis. Repeat overexposure to the UV is unlikely because of the pain involved. However, chronic exposure leads to an increased risk of certain types of ocular cataracts.

Working unprotected for even a few minutes can cause injury. It is possible to calculate acute threshold for acute effects and to set exposure limits. It is not possible, however, to calculate threshold for chronic effects; therefore, because no exposure level is safe, exposure should be reduced as much as possible.

Other Hazards Related to Use of Solar Simulators

Lamp explosion

Arc lamps used with solar simulators contain high-pressure gas and may explode if not handled properly. Avoid touching or scratching the glass section of the lamp. Fingerprints should be wiped off with isopropyl alcohol and a clean soft tissue; otherwise they will weaken the lamp envelope.

Install the lamp with the proper polarity of electrical wiring. Do not stress the glass parts when tightening electrical connections. Replace the lamp when it reaches its lifetime limit. An old lamp, with a darkened glass envelope, has a high likelihood of exploding and should be replaced.

Mercury (Hg)

Some of the solar simulators use mercury-based arc lamps (Hg or HgXe). Mercury contamination can occur if a lamp breaks or explodes. Consult with the industrial hygienist on proper handling of mercury contamination.

Ozone

Short-wavelength UV light converts oxygen into ozone. Ozone produced by lamps with high UV output can be a major irritant to the user. Even ozone-free lamps can produce enough ozone to be uncomfortable for an individual who is particularly sensitive. Proper ventilation should be considered before the system is in use.

Electrical shock

During normal operation, the user is protected from contact with any energized electrical connections. However, electrical shock danger will occur if interlocks are defeated or the power supply section is opened without the unit being unplugged. Unplug the unit before replacing the lamp or servicing the power supply section.

Heat

An arc lamp envelope reaches very high temperatures during normal operation and can cause severe burns if touched. Let the lamp cool at least 15 minutes before opening the lamp compartment door.

Limiting UV Exposure

Control measures must be in place to limit exposure to eyes and skin and to prevent cumulative exposure. The precautions needed depend on the risk assessment. Control measures designed to eliminate the risk of exposure to UV at its source, such as engineering and administrative controls and personal protective equipment (PPE), must be implemented wherever possible. A key element in achieving the goal of reduced UVR exposure is worker training and awareness.

Engineering Controls

Location

Having equipment located in a separate room, alcove, or low-traffic area of a lab is ideal. To avoid exposure to other personnel, avoid placing equipment in the direct vicinity of desk areas or other equipment.

Enclosure

The use of light-tight cabinets and enclosures is the preferred means of preventing UV exposure. Where it is not practicable to fully enclose the UV source, use screens, shields, and barriers.

Examples of different types of solar simulator enclosures

Interlocks

Solar simulator enclosures come with interlocks or can be fitted later with them. Interlocks prevent the UV source from operating when the enclosure is open. Interlocks should not be tampered with. Repair or replace them when defective.

Administrative Controls

Typical administrative controls include limiting access, ensuring that people are aware of the potential hazards, and providing training and safe working instructions for users.

Training

Personnel should be trained in using the UV equipment safely. The manufacturer's manuals provide specific safety-related information (type of eye/skin protection needed, ventilation requirements, etc.) that must be completely understood before using the equipment. If any

uncertainty or concern exists regarding the safe use of UV-generating equipment, contact the manufacturer for clarification.

Personnel should carefully study the manufacturer's manuals for the UV-generating equipment and be familiar with its use. It is important never to deviate from the instructions for safe operation without first contacting the manufacturer.

At a minimum, lab personnel should be familiar with the following when working with or around UV light:

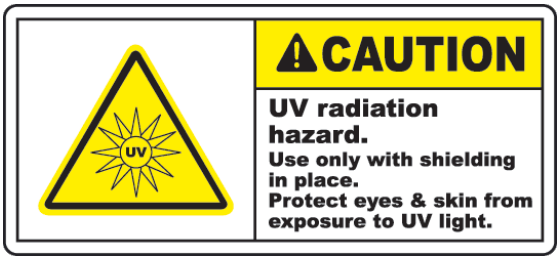
- UV light–producing equipment
- Warning signs
- Protective equipment
- Symptoms of UV exposure

Minimizing exposure

- Never view the UV lamp directly. Although the inverse square law applies to non-laser-beam UV radiation, it is not advisable to look directly at any UV source (e.g., an arc lamp) – at any distance.
- Keep exposure time to a minimum, and where the source is not enclosed or shielded, keep as far away from it as practicable.
- Restrict access to those personnel who are directly concerned with the operation of the UV source.

Hazard warning signs

Warning signs are necessary to inform about the risk of exposure during use and maintenance. Warning signs should be used where applicable to indicate the presence of potential UVR hazards, the requirement to restrict access, and the need for personal protective equipment (PPE).



Personal Protective Equipment

Appropriate PPE includes eyewear, face shields, gloves, and lab coats.

Eyewear

Use eyewear that is appropriate for the work. Special safety glasses are available for the different UV ranges. For best UV protection, the eyewear should be compliant with ANSI Z87.1 and should have a UV filter marking, *U*, followed by a number on a scale from 2 to 6.

UV-Protective Eyewear

Face shield

UV-absorbing full face shields should be worn in addition to safety glasses or goggles (goggles may not provide sufficient face protection). Severe skin burns can happen in a very short time, especially under the chin (which is often left exposed).

UV-Protective Face Shields

Gloves

Nitrile, latex, or tightly woven fabric gloves should be worn to protect against the significant amounts of UV-A and UV-B that may pass through to the skin; these types of gloves have a low transmission of UV compared to vinyl gloves. Gloves should protect personnel from UV light, as well as from the hazard of the activity being performed.

UV-Protective Gloves

Lab coat

Personnel should wear lab coats that fasten securely at the wrists and up the neck so that no skin is exposed. Note that burns to uncovered wrists and the neck are not uncommon.

UV Neck UV Face Mask

PPE must be either readily available and cleaned between users or personally allocated to each user. Eye and face protection must be inspected either regularly or before each use for damage or defects such as cracks, crazing, or bleaching, and replaced when necessary. Note that PPE may need to serve multiple purposes, such as protecting against both from chemical splashes and UV exposure.

Take-Away Safety Tips

- ALWAYS use appropriate PPE for the hazard: UV face shield, goggles, gloves, buttoned-up lab coat.
- Enclose the solar simulator light to the extent possible.
- NEVER temper or bypass the enclosure interlocks.
- Avoid touching or scratching the glass section of the lamp. Fingerprints weaken the lamp envelope, and this may lead to lamp explosion.
- Do not touch the lamp while working, Let the lamp cool at least 15 minutes before opening the lamp compartment door. The arc lamp envelope reaches very high temperatures during normal operation and can cause severe burns if touched.
- Use proper ventilation with lamps that are not ozone free.

The Environment, Health & Safety Division can provide assistance in measuring UV emissions and selecting the appropriate PPE to wear.

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