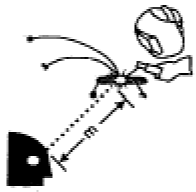

Arc Viewing Distance

PREFACE

This Fact Sheet is the AWS Labeling and Safe Practices Subcommittee's response to requests for information on hazard distances from the arc for skin and corneal exposures. Our committee decided to present the work of Mr. Terry Lyon, a physicist with the U.S. Army Laser/Optical Radiation Program, U.S. Army Center for Health Promotion and Preventive Medicine.

These hazard distances are for actinic ultraviolet radiation exposure to the skin and cornea. These are not safe viewing distances for viewing a bright light source.

Brief viewing of an arc, limited by natural aversion or the blink response, do not exceed personnel exposure limits for the retina. Staring at the arc should never be permitted without appropriate eye protection.

Mr. Lyon published his work in an article in the AWS *Welding Journal* (December 2002). With Mr. Lyon's permission, we decided to include his entire article as the substance of this Fact Sheet. His complete article appears on the following pages.

KNOWING THE DANGERS of Actinic Ultraviolet Emissions

Those who work around electric arc welding and cutting operations should be aware of the potential health hazards caused by these electromagnetic waves

BY TERRY L. LYON

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While open arc welding operations are common worldwide, the general population is largely unaware of the potential hazards. Before the mid 1970s, measures of optical radiation hazards and protection were largely empirically determined, even for welders and their helpers.

Today, we know serious potential hazards can exist wherever there are lines of sight to open arcs created by invisible emissions called "actinic ultraviolet radiation (UVR)." These UVR emissions are simply electromagnetic waves, like light, that travel in straight lines at the speed of light. A summary of the actinic UVR hazards to persons working around electric arc welding and cutting operations is contained in Table 1.

Table 1 — Distances(a) to Common Electric Arc Welding or Cutting Processes(b) at which the Actinic Ultraviolet Radiation (UVR)(c) Is Below the U.S. Daily Threshold Limit Value (TLV)(d) for Various Exposure Times(e).

Arc Welding/Cutting Process	Base Metal	Shielding Gas	Arc Current in Amperes	Distance in m for 1 min	Distance in m for 10 min	Distance in m for 8 h
Shielded Metal Arc (Stick)	Mild steel	None	100–200	3.2	10	71
GMAW	Mild steel	CO_2	90	0.95	3.0	21
			200	2.2	7.0	48
			350	4.0	13	87
	Mild steel	CO_2	175	1.1	3.6	25
			350	2.3	7.3	51
		95% Ar + 5% O_2	150	2.9	9.3	65
			350	6.7	21	150
	Al	Ar	150	3.2	10	70
			300	5.0	16	110
		He	150	1.6	5.0	34
			300	3.2	10	69
GTAW	Mild steel	Ar	50	0.32	1.0	6.9
			150	0.90	2.8	20
			300	1.7	5.5	38
	Mild steel	He	250	3.0	9.5	66
	Al	Ar	50 AC	0.32	1.0	6.9
			150 AC	0.85	2.7	19
			250 AC	1.6	5.0	35
	Al	He	150 AC	0.94	3.0	21
PAW	Mild steel	Ar	200–260	1.5	4.9	34
		85% Ar + 15% H_2	100–275	1.7	5.5	38
		He	100	3.0	9.4	65
PAC (dry)	Mild steel	65% Ar + 35% H_2	400	1.4	4.4	31
			1000	2.4	7.5	52
PAC (H_2O)	Mild steel	N_2	300	3.3	10	72
			750	1.7	5.5	38

(a) These distances are approximate. To convert to feet, multiply the distance in meters by 3.3.
(b) The distances are based upon the worst-case exposure conditions; maximum UVR for exposure angle, arc gap, and electrode diameter.
(c) Invisible actinic UVR poses a potential hazard to cornea (called welder's flash) and skin (much like sunburn) and exposure is cumulative with each exposure over an 8-h workday per 24-h period.
(d) TLVs are published by the ACGIH, Cincinnati, Ohio.
(e) These distances were based upon data from Lyon, T. L. et al, 1976. *Evaluation of the Potential Hazards for Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs.* U.S. Army Environmental Hygiene Agency.

Exposure Effects

Since the beginning of arc welding, welders have known welding and cutting operations can cause acute effects such as severe "sunburn" (erythema) of the skin and painful "welder's flash" (photokeratitis) of the cornea of the eye. Consequently, early welders empirically selected protective clothing and eyewear for comfortable viewing. Also, the U.S. Army adopted a measure to prevent eye injuries in industrial areas. Ordinary safety glasses were prescribed for all Army personnel, including welders and their helpers. As a by-product of physical injury prevention, the eyewear resulted in a dramatic drop in the incidence of welder's flash. Any stray invisible actinic UVR was also blocked by the transparent lenses.

Exposure Limits

The first actinic UVR exposure guidelines were published by the American Conference of Governmental Industrial Hygienists (ACGIH) in 1972 (Ref. 1). These guidelines were intended to prevent the acute effects of actinic UVR. The International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) (Ref. 2) proposed similar guidelines in 1985. After considerable review, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Ref. 3) revalidated and endorsed those limits. Besides being concerned about acute effects, these standards have also been shown to minimize any adverse effects and pose an extremely small risk for delayed effects.

Instrumentation

By the early 1970s, several instruments were available to measure actinic UVR but many simpler instruments presented significant measurement errors primarily from a flaw called "stray light." The actinic UVR resulting in an acute injury followed a narrow range of wavelengths (from around 200–315 nm) with a varying "action spectrum" (peaking sharply at 270 nm). Producing an instrument with this wavelength response was difficult with known filters at that time. The better instruments were the traditional ultraviolet spectrometers that could manually scan UVR wavelengths, weigh the results against the exposure standard for each wavelength, then sum them for the net result.

Joint Effort

In 1974, a joint effort was planned to determine the optical radiation hazards from electric arc welding and cutting operations. Testing was planned for six processes: gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), plasma arc cutting (PAC), plasma arc welding (PAW), and shielded metal arc welding (SMAW). Organizations that provided personnel and equipment for the effort included Union Carbide Corp., the American Welding Society (AWS), Battelle Memorial Institute, National Institute of Occupational Safety and Health (NIOSH), and the U.S. Army Environmental Hygiene Agency (USAEHA, now U.S. Army Center for Health Promotion and Preventive Medicine [USACHPPM]).

In 1974 a joint effort was undertaken by various public and private organizations to determine the optical radiation hazards of electric arc welding and cutting operations.

Joint Effort Results

Arc measurements were conducted in 1975 at Union Carbide Corp. in Florence, S.C., and later at Plasma in Lebanon, N.H., and Caterpillar in Peoria, Ill. A variety of detectors were employed but the final results of the first study were based upon traditional UVR spectrometer results. The arc location and root opening were stabilized for measurements by employing a rotating pipe fixture, and all measurements were made at a measurement distance of one meter and at the worst-case angle for emissions. The results of that study were published as a USAEHA report (Ref. 4) in 1976 employing the ACGIH threshold limit value. That study contained results for more than 100 different conditions and processes and yielded the relationships between arc current, arc length, shielding gas, base metal, and actinic UVR that resulted in the derivation of formulas for those relationships.

Table Summary

A summary of actinic UVR hazards posed to persons working around electric arc welding and cutting operations are contained in Table 1 and are summarized as follows.

- **Hazardous Exposure.** The level of hazardous exposure affecting welders' helpers and other personnel (forklift and overhead crane operators, for example) located in the vicinity of open arc welding and cutting operations can now be determined. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors such as the process type, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base material. Some processes such as resistance welding, cold-pressure welding, and submerged arc cutting ordinarily produce negligible quantities of radiant energy. Later, Europeans conducted UVR measurements on pulsed welding.
- **Exposure Time.** Exposure to actinic UVR is considered to be cumulative with each exposure over an 8-h workday and within a 24-h period. Therefore, two 5-min exposures during a workday could be considered as a single 10-min exposure.
- **Reflections.** Actinic UVR can reflect significantly from some common surfaces and these reflections might also create potentially harmful exposure to unprotected personnel. Unpainted metals (particularly aluminum) and concrete floors readily reflect actinic UVR. On the other hand, lightly colored paints often use pigments of zinc oxide or titanium oxide and have a low reflectance of actinic UVR. Therefore, even lightly pigmented paints are good absorbers of actinic ultraviolet radiation (Ref. 5).
- **Safety Information.** Welders, welders' helpers, and their supervisors should periodically include a discussion of actinic UVR hazards in normal safety reviews and within written safety procedures. Concern for actinic UVR is especially important to discuss with new employees and personnel who work in the vicinity of open arcs.
- **Nearby Persons.** Persons in the vicinity of welding operations can be protected from exposure to actinic UVR by use of screens, curtains, or adequate distance from aisles, walkways, etc. Welders' helpers, overhead crane operators, and forklift operators who have a line of sight to any open arcs should consider wearing appropriate safety equipment such as safety glasses with sideshields or even a clear, full-face shield and long-sleeved shirts.
- **Skin Protection.** While standards exist for welders and their helpers, skin protection has not been uniformly prescribed for other personnel who work in the vicinity of open arcs. Fabric measurements have shown that natural materials (leather, cotton, wool) are better for absorbing actinic ultraviolet radiation than synthetic materials (polyester, nylon) (Ref. 6). Incidental personnel should consider wearing a long-sleeved shirt.
- **Warning Signs.** Warning signs are useful when persons unfamiliar with actinic UVR and other welding hazards are nearby. Such warnings are especially important to have on portable welding screens that can be used at field sites near the general population. A suitable sign could simply state "Danger" or "Warning" and be posted conspicuously at entry points or doors to welding areas. Such signs might also include the warning "Avoid Exposure of Eye and Skin to Arc and Harmful Ultraviolet Emissions."

Retinal Exposure

In addition to actinic UVR measurements, another study was published as a USAEHA report (Ref. 7) in 1977 containing an evaluation of potential retinal exposure hazards. The eye can focus an open arc onto the retina where an injury might result that was photochemical or thermal in nature. Photochemical injury is the result of exposure to intense blue light sources, whereas thermal injury can result from all visible and some near-infrared radiation, which is largely invisible. Measurements of blue light and other retinal-thermal emissions suggest momentary viewing of electric welding and cutting arcs does not exceed retinal exposure limits; however, staring at an open arc can readily exceed these standards. While staring at the arc should never be permitted, actual retinal injuries are rare (Ref. 8) and would likely result only from chronic staring.

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