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The Trane Company
Ft. Smith, Arkansas

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

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SUMMARY

On April 14, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Trane Company seeking assistance in documenting optical radiation levels produced during brazing processes performed at their facility in Ft. Smith, Arkansas. Ultraviolet (UV), visible, and infrared (IR) radiation levels were measured under different brazing conditions in July 1998. The request was partially prompted by complaints from workers involved in brazing processes that wearing shaded eye protectors decreased visibility. Optical radiation measurements were made on various brazing processes to determine the appropriate shade filter number that would allow adequate visibility and maximum protection from optical radiation emitted by the brazing processes.

The highest luminance levels measured at 35 different brazing locations was 0.32 candelas per square centimeter (cd/cm^2), while the maximum near and actinic UV levels were 100 microwatts per square centimeters ($\mu W/cm^2$) and 0.08 effective $\mu W/cm^2$, respectively. None of these measurements exceeded the American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH®) (TLV®) for luminance and UV radiation. The maximum IR irradiance level was 150 milliwatts per square centimeter (mW/cm^2), a level which did exceed the ACGIH® TLV® for IR of 10 mW/cm^2.

NIOSH investigators determined that unprotected workers performing brazing operations were overexposed to IR radiation. Several recommendations are included in the report, such as requiring the use of protective eyewear having at least a shade 3.0 filter.

Keywords: SIC 3531 (Construction Machinery and Equipment), infrared radiation, brazing, eye protection

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INTRODUCTION AND BACKGROUND

In April 1998, the National Institute for Occupational Safety and Health (NIOSH) received a management initiated health hazard evaluation request from the Trane Company seeking assistance in documenting optical radiation levels produced during brazing operations at their manufacturing facility in Ft. Smith, Arkansas. The Trane Company manufacturers industrial air conditioning units, and brazing is performed on various metal components during the manufacturing processes. Ultraviolet (UV), visible, and infrared (IR) radiation levels were measured under different operating conditions on July 7–8, 1998. Both management and workers were concerned about the shade filter number necessary to safely perform brazing processes in the facility.

At the time of the evaluation, there were approximately 20 workers performing brazing operations per shift (two shifts per day). The number of male and female workers performing brazing processes in the facility was about equal. Workers were represented by the United Auto Workers Local 716.

Brazing is a welding process that produces coalescence of material by heating to a temperature above 840^0 F in the presence of a nonferrous filler metal. The only type of brazing performed at this facility was gas torch brazing. About 80% of the torch brazing at this facility involved copper to copper, with about 20% of the work performed on copper to steel. Most of the brazing was conducted with a single torch, but on several operations, workers used a dual torch which permitted the flame to reach constrained or restricted areas. The fuel gases used for the brazing process were propylene and oxygen and the gas flow rate setting was individually controlled by each worker.

NIOSH investigators were informed that the company required its workers to wear some type of protective eyewear while brazing and maintained a supply of safety eyewear for use by the workers. These were typically plano [lenses without corrective focusing power] safety glasses with shade filters ranging from 2.0 to 3.0. However, some workers utilized prescription glasses that were tinted. Prior to the NIOSH visit, company policy supported the use of 3.0 shades for brazing processes. However, some brazers indicated that the darkness of this shade significantly restricted visibility and hindered their ability to perform required jobs. Management requested NIOSH's help to select the appropriate filter for brazing process.

METHODS AND EQUIPMENT

Equipment

The following equipment was used to measure levels of radiant energy produced by the brazing processes during this evaluation:

Luminance: Luminance was measured using a hand–held Spectra Mini–Spot photometer having a one degree field of view. The values obtained with this meter can be expressed in units of candelas per square centimeter (cd/cm^2). The luminance of a source, such as a cutting arc, is a measure of its brightness when observed by an individual without eye protection.

Infrared Radiation Irradiance: A Laser Probe model RM-3700 universal radiometer with special IR transmitting filters was used to measure irradiance in units of milliwatts per square centimeter (mW/cm^2) over the wavelength range from 760 to 2000 nanometers (nm).

UV Radiation Irradiance: An International Light (IL) model 1700 radiometer with specially calibrated detectors was used to measure the UV irradiance levels. One detector is designed to read the actinic UV region (200 to 315 nm) measuring in biologic effective units microwatts/square centimeters $(\mu W/cm^2)_{eff}$, while the other detector measures the near UV region (320–400 nm) in units of mW/cm^2 with no biologic weighting factor.

Optical density: A complete set of welding shade filters (ranging from 1.0 to 14) was used to confirm shade number calculations.

Illumination: A hand held model 500 Litemate photometer was used to measure illumination levels at various locations in the facility. The photometer reads out in units of lux over the wavelength region from 380 to 760 nm.

Measurements were performed during two shifts with the detectors aimed at the brazing event. The detectors were always pointed towards the brazing spot while positioned at the eye location of each worker, independently of how far away they stood for the process. Generally speaking, this distance was 20 inches, but would vary for different workers. Each worker performed their own brazing events at a minimum distance of about 1 meter from adjacent workers. Although typically it took from 30 seconds to approximately two minutes to braze a part, these brazing periods were long enough to insure reproducible optical radiation measurements.

All equipment used to document exposure to optical fields had been calibrated within six months of use either by NIOSH or the respective manufacturer.

Medical

Informal interviews were conducted with workers at their workstations performing line, subassembly, and torch brazing operations on the evening shift. Sixty air conditioning units are scheduled for assembly during this shift and this production output is usually achieved. The range of work experience for the individuals interviewed varied from two months to sixty years.

EVALUATION CRITERIA

Health Effects of Exposure to Optical Radiation[1-3]

Infrared Radiation

All objects having temperatures above absolute zero emit IR as a function of temperature. In biological systems, the major insult of IR occurs as a result of a temperature rise in the absorbing tissue. The physical factors associated with this temperature rise are the wavelength, heat conduction parameters, exposure time, and total amount of energy delivered to the exposed tissue.

Since the primary effect of IR on biological tissues is thermal, the skin provides its own warning mechanism by having a pain threshold below that of the burn threshold. However, there is no such adequate warning mechanism in the eye, and so protective equipment is often necessary.

Historically, IR radiation has long been associated with cataracts. Cataracts may be produced by prolonged exposure to wavelengths at energy levels that do not normally burn the skin. IR-induced cataracts is thought to be directly correlated with the amount of energy initial absorbed by the iris and then transferred to the lens. The threat of cataract formation is primarily from wavelengths below 1400 nm. IR wavelengths beyond 1400 nm can produce corneal and eyelid burns leading to dry eye and skin conditions, and under some conditions may cause retinal and choroid damage.

Visible Radiation

Visible radiation from either the sun or artificial sources is probably one of the more important occupational health considerations because of its major role in our daily life. When light levels are high at certain wavelength regions, luminance levels may pose a retinal insult requiring the use of protective eyewear devices. Another issue which can arise is related to low or inadequate room or task lighting levels, which can lead to or cause asthenopia or eye strain. Older workers may encounter more symptoms associated with eye strain, such as headaches, tired eyes, and/or irritation, since, they require more illumination to perform a similar job than younger workers.

Recommended illumination levels are given by the Illumination Engineering Society (IES) of North America and these levels can vary considerably according to the task demands of the worker. In general, illumination of 200 to 500 lux is recommended for visual tasks of high contrast or large size.

Ultraviolet Radiation

Ultraviolet (UV) radiation is an invisible radiant energy produced naturally by the sun and artificially by arcs operating at high temperatures. Since the eyes and skin readily absorb UV radiation, they are particularly vulnerable to injury. The severity of injury depends on factors such as exposure time, intensity of the source, distance, wavelength, sensitivity of the individual, and presence of sensitizing agents.

Sunburn is a common example of the effect of UV radiation on the skin. Repeated UV radiation exposure of lightly pigmented individuals can result in actinic (dry, brown, inelastic, and wrinkled) skin. Although not harmful in itself, actinic skin is a warning that skin cancer could develop from UV exposure.

Since UV radiation is not visible, the worker may not be aware of the danger at the time of exposure. Absorption of UV radiation by the corneal epithelium and conjunctiva of the eye can cause kerato-conjunctivitis (commonly known as "welder's flash"). This type of injury usually manifests itself within 6 to 12 hours after high exposure. The injury may be very painful and incapacitating, but visual impairment is usually temporary.

Occupational Exposure Limits

The following table shows the optical radiation exposure limits that are used by NIOSH investigators to evaluate optical radiation exposure.

Optical Radiation Evaluation Criteria and Health Effects Summary

Physical Agent	Evaluation Criteria†			Primary Health Effect
	ACGIH[4] TLV	NIOSH[5] REL	OSHA PEL	
Ultraviolet (200 to 315 nm)	0.1 µW/cm² (effective)‡	0.1 µW/cm² (effective)‡	None	Photo–keratitis and erythema
Ultraviolet (315 to 400 nm)	1.0 mW/cm²	1.0 mW/cm²	None	Erythema
Visible (400 to 760 nm)	1.0 cd/cm²	None	None	Retinal burns
Infrared (760 nm to 1 mm)	10 mW/cm²	None	None	Dry eye/skin, cataracts

† These values represent 8–hour exposure, but higher exposures are permitted in certain cases for shorter time periods.
‡ Biological effective units.
nm = nanometer mm = millimeter mW = milliwatt
µW/cm² = microwatts per square centimeter cm² = square centimeter

RESULTS

Optical Radiation

The highest luminance levels documented at 35 different locations was 0.32 cd/cm² while the maximum occupational near and actinic UV levels were 100 µW/cm² and 0.08 effective µW/cm², respectively. These measurements do not exceed the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) for luminance and UV radiation for a work day.

While one IR irradiance reading was 150 mW/cm², a more representative IR irradiance level would range from 80 to 100 mW/cm². All of these levels exceeded the ACGIH® TLV® for IR of 10 mW/cm². It was observed that IR levels were higher for those operations where larger pieces were being brazed. This suggests the need for management to insure training that requires brazing performed using the lowest heating (to reduce the IR level). For example, this training could emphasize the need to better control gas flow levels to minimize heat and, consequently, IR emission.

Illumination levels at many locations in the plant were less than 50 lux. This level is low compared to the IES recommended level of 200 to 500 lux for activities requiring performance of visual tasks of high contrast or large size. While there were overhead illumination sources near brazing stations, many sources were not mounted to effectively illuminate the brazing stations.

Medical

The workers did not object to wearing protective eyewear in the plant. However, employees were dissatisfied with wearing shade 3.0 filters while working at poorly lit brazing stations. The workers performing brazing processes while wearing 3.0 shades described significant visibility impairment even when brazing, and they associated this visual impairment for inadvertently catching their gloves on fire and contributing to thermal burns caused by brushing their skin against hot, brazed pieces. Similar complaints were voiced by workers with brazing flame exposure who performed other tasks which required optimally corrected vision to ascertain that the brazing processes resulted in properly sealed pieces.

One of the nurses employed by the company was also interviewed. The nurses maintain a record of injury or illness incidents in a log book kept in the plant's health clinic. Incidents dating back to March 1998, were reviewed by the NIOSH investigators. Most clinic visits were related to back pain. Over the same time period, two incidents involving foreign bodies entering the eye were recorded. Only one of those two incidents was work related. The nurses also noted that only forklift drivers were required to have preemployment vision screening.

DISCUSSION AND CONCLUSIONS

The major concern in this evaluation for both management and workers was the determination of the appropriate filter shade number necessary in the protective eyewear used for brazing operations. Eye protection can be specified in terms of shade number based on percent transmission through the eyewear for various portions of the optical radiation spectrum. The American National Standard Institute (ANSI) Z87.1 (1989) standard entitled "Practice for occupational and educational eye and face protection"[6] sets transmission requirements for different filter shade numbers. Based on the optical radiation measurements made in this evaluation, no visible or UV hazard existed, but did exist for IR radiation. ANSI Z87.1 states that a shade number 3 shall not allow more than 9% IR transmittance for wavelengths from 780 to 2000 nm. If one assumes an average brazing IR irradiance of 100 mW/cm^2, then a shade 3.0 filter would transmit only 9 mW/cm^2, a level under the ACGIH® TLV® of 10 mW/cm^2. Any lesser shade would provide inadequate protection.

One of the NIOSH investigators has published a article investigating optical radiation levels produced in related welding processes including torch brazing.[7] While the parameters such as gas type, base material, and distances were different the findings reported in that article are similar to those of this evaluation. The maximum results from 8 brazing events reported in the article indicated that all optical radiation levels, including IR, were below exposure guideline values. The findings also suggested the use of a filter shade 3.0 to 4.0 would be appropriate for use. The conclusion suggests that if appropriate safety equipment is used, the optical radiation levels associated with the brazing process should not be a major occupational hazard. Nevertheless, it is pointed out that the use of fluxes, large tip sizes, and certain base materials such as stainless steel and copper could cause the brazing to exceed optical radiation levels.

It was observed that when brazing larger metal pieces it required more heating or higher IR levels. Conversely, less IR would be emitted during heating of small pieces. Such an observation demands that more attention be given for control of IR levels when brazing larger tubing or pipe.

While measurements were made at the location where the worker stood or sat while brazing, it was quite apparent that in some situations workers could be extremely close to the material being brazed. The closer to the heated object, the more intense the IR levels. The low illumination levels in and around the brazing operations may be one reason why workers stood close to the brazed object.

The NIOSH investigators were informed that in the spring and summer months new brazers are hired because of increases in seasonal workload. Several times the NIOSH investigators noted new brazers heating metal to incandescent, or an almost welding–like condition. More experienced workers may be able to braze more quickly, using less heat and, thereby minimizing excessive IR levels. Training courses must emphasize the need to reduce heat during this initial learning phase.

Finally, the NIOSH investigators believe that the facility needs to improve its illumination levels in the brazing related areas. Not only would appropriate illumination levels help brazers work while wearing the shade 3.0 filters, the improved illumination would help to minimize other potential safety issues, such as low–hanging gas torches and movement of air conditioning units.

RECOMMENDATIONS

1. All brazers should wear protective eyewear having a minimum shade 3.0 filter. While such a recommendation is based for conditions observed at the plant on the days of this evaluation, it may be necessary in the future to revisit this recommendation if brazing conditions change.

2. Task lighting should be provided at all brazing workstations to increase illumination levels to at least 200 lux.

3. Facility training courses need to emphasize that all brazing shall be performed at the lowest heating (minimal IR) levels possible, workers must adequately control gas flow levels, IR levels increase the closer one stands to the brazed object, and higher exposures will occur during training periods.

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