HETA 96–0119–2586
Melroe Company
Bismarck, North Dakota

C. Eugene Moss

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by C. Eugene Moss, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Ellen E. Blythe.

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Health Hazard Evaluation Report HETA 96–0119–2586
Melroe Company
Bismarck, North Dakota
July 1996

C. Eugene Moss

SUMMARY

In January 1990, the National Institute for Occupational Safety and Health (NIOSH) received the first of eventually two management requests from the Melroe Company (HETA 90–148, see Appendix A) seeking assistance in documenting optical radiation levels produced during plasma arc cutting (PAC) processes. Ultraviolet (UV), visible, and infrared (IR) radiation levels were measured under different operating conditions in March 1990 and, at that time, NIOSH investigators concluded "that operators using the PAC systems under normal use conditions should wear protective eyewear having a minimum shade 3 or 4 (3/4) filter." This report further stated, "If the amperage of the PAC system was to increase, or if the protective (plasma arc) shield should fail to operate in an appropriate manner, a higher filter shade number may be required." At the time of the 1990 evaluation the PAC current was in the 120 to 170 ampere range.

In May 1996, NIOSH received a request from the Melroe Company for a follow–up evaluation after the company had made two changes made in the PAC operations. The first change occurred when a different cutting torch was installed in the PAC units which operated at a higher current level (as high as 200 amperes) and therefore would produce more optical radiation. The second change was the installation of brake presses near the PAC systems, requiring workers to be involved visually with two different viewing situations. Workers were concerned about the degree of eye protection necessary to perform work in both areas.

Measurements of luminance levels were performed around two of the three PAC units operating at 200 amperes. The maximum luminance level documented was 33 candelas per square centimeter (cd/cm^2) and occurred when a cut was made along the edge of the metal. This exceeds the American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) of 1.0 cd/cm^2 for optical radiation in the visible spectrum of 400 to 760 nanometers (nm). The maximum IR irradiance level was less than 2 milliwatts per square centimeter (mW/cm^2) at a distance of 8 feet from the arc (this approximated the closest position which workers would stand while the PAC units were operating). This level is below the ACGIH TLV for IR of 10 mW/cm^2. No UV radiation mesurements were made since most of the eyewear used in the cutting industry absorbs appropriately in the UV region. Some Melroe workers were reporting erythemal responses when performing edge cutting.

NIOSH investigators have determined that workers performing plasma arc cutting at 200 amperes were exposed to visible radiation levels (400 to 760 nm range) which exceed recommended occupational limits. Infrared levels, however, were below applicable occupational limits. Recommendations include use of protective eyewear having at least a shade 4/5 filter.

Keywords: SIC 3531 (Construction Machinery and Equipment), infrared radiation, plasma arc cutting, optical radiation, welding.

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INTRODUCTION AND BACKGROUND

1990 NIOSH Evaluation

In January 1990, the National Institute for Occupational Safety and Health (NIOSH) received the first of two health hazard evaluation requests from the Melroe Company (HETA 90–148, see Appendix A) seeking assistance in documenting optical radiation levels produced during the plasma arc cutting (PAC) processes. The Melroe Company used the PAC systems in manufacturing the Bobcat® skid steer loader which is used in the agricultural and construction industries. Ultraviolet (UV), visible, and infrared (IR) radiation levels were measured under different operating conditions on March 27, 1990. At that time, NIOSH investigators concluded "that operators using the PAC systems under normal use conditions should wear protective eyewear having a minimum shade 3/4 filter." The report goes on to say, "If the amperage of the PAC system was to increase, or if the protective (plasma arc) shield should fail to operate in an appropriate manner, a higher filter shade number may be required." At the time of the 1990 evaluation, the PAC current was in the 120 to 170 ampere range.

1996 NIOSH Evaluation

In May 1996, NIOSH received a request for a follow–up evaluation following two plant changes. The first change came about when a different cutting torch was installed in the PAC units. This new torch operated at a higher current level (as high as 200 amperes) and therefore would produce more optical radiation. The second change involved the installation of brake presses near the PAC systems, requiring workers to be involved visually with two different viewing situations. Workers were concerned about the degree of eye protection necessary to perform work in both areas. At the time of the 1996 evaluation, there were four workers per shift (three shifts per day) at the PAC operations.

METHODS

The following equipment was used to document levels of radiant energy produced by the PAC systems during this evaluation.

Luminance: Luminance was measured using a 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.

Irradiance: An Eppley Model 901 thermopile with a quartz window was used to measure irradiance in units of milliwatts per square centimeter (mW/cm^2) over the wavelength range from 200 to 4500 nanometers.

Optical density: A complete set of welding shade filters (ranging from 1 to 14) was used to confirm optical density and shade calculations.

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

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre–existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[1], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLV®s)[2], and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[3]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLV®s, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

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 TLV	NIOSH 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

Measurements of luminance levels were performed at several locations around two of the three PAC units operating at 200 amperes. The maximum luminance levels documented was 33 cd/cm² and occurred when a cut was made along the edge of the metal. The maximum IR irradiance level was less than 2 mW/cm² at a distance of 8 feet from the arc (this approximated the closest position which workers would stand while the PAC units were operating). No UV radiation mesurements were taken since most of the eyewear used in the cutting industry absorbs appropriately in the UV region. It was noted, however, that some Melroe workers were reporting some skin erythemal responses when performing edge cutting at current levels near 200 amperes.

DISCUSSION AND CONCLUSIONS

Using the same approach as outlined in the 1990 NIOSH report, these optical radiation exposures suggest that workers at the Melroe Company, when operating the PAC systems at 200 amperes, should wear protective eyewear having a minimum shade 4 or 5 (4/5) filter. If the amperage should again be increased in the future, a re–evaluation by the Melroe health and safety department will need to be done.

The use of eyewear with this shade did not appear to restrict viewing of the brake presses. Moreover, as long as cutting is not performed along the edges of the metal, a shade 3/4 filter appears to be sufficient. The shade 4/5 filter is only needed for the edge cutting situation. This finding was confirmed by using shade filters on several workers during this evaluation.

RECOMMENDATIONS

1. Workers operating the PAC systems at 200 amperes should wear protective eyewear having a minimum shade 4/5 filter.

2. All welding curtains used at this facility should be positioned to protect workers standing in the direct view of the arc.

3. At the time of this evaluation, several of the welding curtains which were in place immediately around the PAC torches were torn or otherwise damaged. These curtains should be replaced or repaired. In addition, in some situations it may be necessary to install additional welding curtain partitions farther from the PAC torch to absorb the UV produced at the higher current levels to help prevent erythemal problems in PAC operators as well as workers in surrounding areas.

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APPENDIX A

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for
Occupational Safety & Health
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati OH 45226-1998

June 5, 1990
HETA 90-148

Mr. Todd Schimke
Safety and Industrial Relations
Melroe Company
P. O. Box 1215
Bismarck, North Dakota 58502

Dear Mr. Schimke:

The attached evaluation represents the National Institute for Occupational Safety and Health (NIOSH) findings on your request for technical assistance (HETA 90-148). This request was performed to document potential occupational optical radiation exposure to Melroe Company personnel from plasma arc cutting systems.

BACKGROUND

On January 26, 1990 the National Institute for Occupational Safety and Health (NIOSH) received a request (HETA 90-148) seeking assistance in documenting optical radiation levels produced during plasma arc cutting processes (PAC). In particular, the request asked that measurements be performed to determine the protective eyewear necessary for PAC operators at the Bismarck facility. Optical measurements on two PAC systems were made at Melroe by NIOSH on March 27, 1990.

The Melroe Company uses the PAC systems in manufacturing the "Bobcat" skid steer loader which is used in the agricultural and construction industry. The two PAC systems that were measured were W. A. Whitney model 647 ATC units. These systems were used to cut mild steel and operated at 120 and 170 amperes on the day of measurements. The units required one operator per shift. At the time of this evaluation the facility operated daily on three shifts plus a weekend shift and the company employs about 550 workers.

The PAC systems do not operate continuously since the metal stock must be removed after it is cut and replaced with a new piece. In addition, since the PAC systems are computerized it takes time to set up each piece of stock for uniformity of cuts. It was estimated that the systems operate about 50 to 60% of the time during a particular shift.

The manufacturer of the PAC systems had recommended in the safety section of their operations manual that during operation a filter shade #8 be used for eye protection. Unfortunately, the wearing of such a high shade number may make it visually difficult for the operators to perform their tasks. Both Melroe and NIOSH were informed by the manufacturer that this shade #8 filter recommendation had been made many years ago and that they were unable to supply documentation for their selection. Therefore, in order to properly document the appropriate filter shade under operating conditions it would be necessary to document the radiation emissions produced by the PAC systems.

EVALUATION DESIGN AND METHODS

The following equipment was used to document levels of radiant energy produced by the PAC systems:

Luminance or brightness levels were measured with a Spectra Mini-Spot photometer having a one degree field of view. The values were obtained in terms of footlamberts (fL) which are converted to candela per square centimeter (cd/cm^2). The luminance of a source is a measure of its brightness when observed by an individual without eye protection, regardless of the distance from source.

A International Light model 730A radiometer, with specially calibrated detectors, was used to evaluate the ultraviolet (UV) radiation levels. One detector was designed to read the actinic UV radiation (200 to 315 nm) in biologically effective units of microwatt per square centimeter (uW/cm^2), while the other detector measured near UV (320-400 nm) in units of milliwatt per square centimeter (mW/cm^2) with no biologic weighting factor.

A Solar Light Sunburn meter was used to document the presence of any erythermal producing radiation in the 290 to 320 nm wavelength region. This meter reads in sunburn units per hour.

A Eppley model 901 calibrated thermopile with a quartz window was used to measure irradiance in units of mW/cm^2 over the wavelength range from 200 to 4500 nm.

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

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed without experiencing adverse health effects. It is, however, important to note that not all exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity situation.

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects, even if the occupational exposures are controlled at the level set by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus, potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information about chemical and physical agents become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH criteria documents and recommendations, 2) the ACGIH's Threshold Limit Values (TLV), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and the recommendations for reducing these levels found in these reports, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

At present there is limited information from OSHA on exposure criteria for workers exposed to physical agents. Criteria for physical agents not covered by OSHA come from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

OPTICAL RADIATION

Infrared Radiation [1-5]

All objects having temperatures above absolute zero emit infrared radiation (IR) as a function of temperature. In biological systems, the major insult of IR appears to occur as a result of a rise in temperature of the absorbing tissue.

The physical factors associated with temperature rise are the wavelength, heat conduction parameters, exposure time, and total amount of energy delivered to the exposed tissue. Since IR photons are low in energy, they would not be expected to enter into photochemical reactions with biological systems. Molecular interactions with radiation in the IR regions are characterized by various vibrational-rotational transitions resulting in an increase in thermal energy of the molecule.

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 hence additional protective equipment is often necessary. Traditionally, safety personnel consider IR to be a cataractogenic agent but recent literature (see References) has cast serious questions about the etiology of IR cataracts that could occur in the workplace from non-coherent optical sources.

Wavelengths of IR beyond 1400 nm can produce corneal and eyelid burns leading to the conditions of dry eye and skin. The primary biological effect of IR on the retina and choroid is thermal in nature, with the amount of damage being proportional to the length of exposure. If the radiation intensity is low enough, however, the normal retina blood may be sufficient to dissipate any heat generated. Nevertheless, due to the focusing effect of the anterior ocular components, small amounts of IR can produce a relatively intense point energy distribution on the retina resulting in a lesion.

Visible Radiation [4,6,8-9]

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 certain obvious retinal issues arise that require protective eye wear devices. These types of direct effect have been well known for many years and documentation exists within the scientific literature, i.e., staring at welding arcs or the sun.

Indirect effects of light, however, can occur not from absorption of light energy in tissues but from the action of chemical signals liberated by cells in the body. In many cases such indirect effects occur at much lower intensities than the direct effect. As a result such effects often are not considered a major occupational health hazard. Examples of this relationship of light to biological rhythms include physical activity, sleep, food consumption, etc. Another well-known indirect effect is the inhibition of melatonin synthesis by the pineal gland which in turn affects maturation and activity of the sex gland. Only within the last few years have investigators begun to discover the various subtle physiological and biochemical responses to light.

Another issue which often arises is that associated with poor room or task lighting conditions. Such conditions lead to or cause aesthenopia (eye strain). Although the etiology of eye strain is debatable, it appears that repeated occurrences probably do not lead to any permanent eye damage. Workers over 40 years of age will probably encounter more symptoms of eye strain (headache, tired eyes, irritation) since they require more light to perform a similar job than younger workers.

The ACGIH TLVs for visible radiation provide protection from retinal thermal injury and from photochemical injury that can occur from exposure to wavelengths in the region from 400-500 nanometers.

Ultraviolet Radiation [6-7,9]

Ultraviolet (UV) radiation is an invisible radiant energy produced naturally by the sun and artificially by arcs operating at high temperatures. Some of these sources are germicidal and blacklight lamps, carbon arcs, welding and cutting torches, electric arc furnaces, and various laboratory equipment.

Since the eyes and skin readily absorb UV radiation, they are particularly vulnerable to injury. The severity of radiation injury depends on factors which include exposure time, intensity of the radiation source, distance from the source, 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 exposure of lightly pigmented individuals may result in actinic skin, a dry, brown, inelastic, wrinkled skin. Actinic skin is not harmful in itself, but is a warning that conditions such as senile keratosis, squamous cell epithelioma, and basal cell epithelioma may develop.

Since UV radiation is not visible, the worker may not be aware of the danger at the time of exposure. Absorption of the radiation by the mucous membranes of the eye and eyelids can cause conjunctivitis (commonly known as "welder's flash"). Lesions may also be formed on the cornea at high exposure levels (photokeratitis). Such injuries usually manifest themselves 6 to 12 hours after exposure. The injuries may be very painful and incapacitating, but impairment is usually temporary. Workers need to be aware that there can exist within their workplace photosensitizing agents that, upon contact with the skin, produce exaggerated sunburn when exposed to UV at certain wavelengths.

Table 1 shows the optical radiation exposure limits that are used by investigators to determine occupational insult. The levels shown are based on a 8-hour exposure level.

RESULTS

Measurements of luminance levels were performed at many different locations around both PAC systems. Levels were measured at different amperages, angles of cut, and cut speeds. The maximum luminance documented was 1.1 cd/cm^2. This level was measured when a cut was made along the edge of the metal. It was also observed that luminance levels were higher near the initial phase of the cutting event. The PAC systems contained inherent shielding material, in the form of a metal barrier, that would become activated and surround most of the cutting process from direct view. The luminance of the cutting process, as well as other radiation levels, was greatly reduced after the arc was surrounded by the metal barrier. It took less than a second after arc initiation before the arc was covered with a barrier. It should be noted that the recorded luminance values were probably lower than actual levels due to the inability of the meter to proper adhere to a rapidly changing luminance field (i.e. quick descent of the system's shielding). Based on personal experience and prior measurements made by one of the investigators, it was estimated that the luminance might be 10 to 20 times higher.

Maximum levels from both systems of both near and far UV radiation, as well as solar levels, were found to be 0.01 mW/cm^2, 1.0 effective uW/cm^2, and non-detectable, respectively. These result were measured at approximately eight feet from the cutting surface. This distance was the operator's closest point of contact to the cutting event due to the movement of the metal stock as it was being cut. The maximum range of IR irradiance, from both systems, was 30 to 50 mW/cm^2 at eight feet away. It is noted that the maximum UV and IR levels were observed during the edge cutting events. In addition to the arc not being contained during the edge effect, it was also noted that the metal stock was bent more during this particular event, causing the emitted radiation to scatter.

DISCUSSION

One of the major issues to be determined was the appropriate filter shade number to be used in the eyewear for PAC operators. Eye protection can be specified in terms of shade number which is a logarithmic notation of visual transmission. ANSI standard Z87.1 (1989) sets transmission specifications in the visible, UV, and IR radiation regions. Sometimes ocular protection can be designated in terms of optical density (OD). OD can be evaluated using the relationship

$$OD = \log_{10} I_0 / I$$

where I_0 is the incident visible radiation level and I is the level of visible radiation that has been filtered. If the value of 1.0 is assumed for the luminous level (from ACGIH TLV), then the results of the measurements obtained at Melroe indicate that the maximum OD necessary for a filter would be 1.34. From Table 2 this level of OD corresponds to a filter shade around 4.0. It was also noted that one of the two PAC system operators was wearing a shade 4 filter, as well as the NIOSH investigators. The other PAC operator, reported that he was very sensitive to bright lights and therefore, wore tinted prescription glasses in addition to tinted safety filters. While one can use higher filter shades to further reduce the IR ocular exposure, it should be noted that the higher the shade number, the darker the tint, and thus more difficult to see.

Often the proper selection of filter shades depends also on the measured IR levels. However, the IR levels in this situation were low.

CONCLUSIONS

Operators that use the PAC systems under normal use conditions at Melroe should wear protective eyewear having a minimum shade 3/4 filter. However, if the amperage is increased, or the protective shield fails to operate in an appropriate manner, then a higher filter shade number may be required.

RECOMMENDATIONS

1. It was noted that many of the welding curtains used at the facility for walkway protection against arc radiation were torn and in need of repair or replacement.

2. It is recommended that the small segment of welding curtain on system #2 be removed in order not to cause jamming of the metal stock during cutting. This curtain segment was installed by the operator to provide additional protection from optical radiation emitted by the PAC event.

3. Another approach that could be used, if the operator believes that additional ocular protection is necessary over that provided by the above recommended filter shade number, would be to obtain safety eyewear that utilizes the same degree of combined protection as the welding curtain and existing eyewear now affords.

4. One could also consider installing operator booths made of orange/yellow tinted plastic sheets (1/2 to 3/4 inch thick) at distances of 8 to 9 feet from the PAC systems as a possible optional approach.

This letter closes out this evaluation. In accordance with NIOSH regulations, the employer must post a copy of this letter for a period of 30 calendar days at or near the workplace(s) of affected employees. Should you have any questions regarding this information, you can contact this office at the above address, or at (513) 841-4374.

Sincerely yours,

C. Eugene Moss
Health Physicist

Robert F. Mouradian
Industrial Hygienist
Industrial Hygiene Section
Hazard Evaluations and Technical
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HETA 90-148 (Close-out)
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TABLE 1

Optical Radiation Evaluation Criteria and Health Effects Summary

Melroe Company
Bismarck North Dakota
HETA 90-148
March 27, 1990

Physical Agent	Evaluation Criteria[a]			Primary Health Effect
	ACGIH TLV	NIOSH REL	OSHA PEL	
Ultraviolet (200 -315 nm[c])	0.1 eff[b] uW/cm^2	0.1 eff uW/cm^2	-	Photokeratitis and erythema
(315 -400 nm)	1.0 mW/cm^2	1.0 mW/cm^2	-	Erythema
Visible (400 -760 nm)	1.0 cd/cm^2	-	-	Retinal burns
Infrared (760 nm -1 mm)	10 mW/cm^2	-	-	Dry eye/skin cataracts

a Values represent 8-hour exposure, but higher exposures are permitted in certain cases at shorter time periods.

b Biologically effective units

c nanometer

TABLE 2

Recommended Tolerance in Optical Density
of Various Shades of Filter Lenses*

Melroe Company
Bismarck, North Dakota
HETA 90-148
March 27, 1990

Shade Number	Optical Density Maximum	Optical Density Minimum
1.5	0.26	0.17
1.7	0.36	0.26
2.0	0.54	0.36
2.5	0.75	0.54
3.0	1.07	0.75
4.0	1.50	1.07
5.0	1.93	1.50

* Modified from ANSI Z87.1 (1989)

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