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CONE GEOCHEMICAL, INC.
LAKEWOOD, COLORADO

NIOSH INVESTIGATOR:
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I. SUMMARY

On January 24, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request from management of Cone Geochemical, Inc. in Lakewood, Colorado, to evaluate occupational optical radiation levels produced by laboratory furnaces used in commercial fire assay operations.

On March 14, 1991, an evaluation of the optical radiation levels was made at the Lakewood facility. During this evaluation, measurements were made of the ultraviolet, infrared, and visible radiation levels produced by both gas and electric furnaces.

The results of this evaluation showed that the furnaces did not produce ultraviolet radiation levels above the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) of 0.1 effective microwatts per square centimeters ($\mu W/cm^2$) in the wavelength region from 200 to 315 nanometers (nm) or 1 milliwatt per square centimeters (mW/cm^2) in the wavelength region from 315 to 400 nm. However, the furnaces could produce luminance and infrared radiation as high as 1.9 candela per square centimeter (cd/cm^2) and 130 mW/cm^2, respectively. These levels could exceed the ACGIH TLVs for an unprotected worker which are established at 1 cd/cm^2 for luminance (400 to 760 nm) and 10 mW/cm^2 for infrared radiation in the wavelength region from 760 to 3000 nm.

On the basis of measurements data, it was determined that a health hazard did not exist from overexposure to optical radiation on the day of measurement at Cone Geochemical, Inc. However, if furnace workers do not wear protective clothing, a health hazard may exist from chronic exposure to infrared radiation. Recommendations are offered in Section VIII for minimizing these exposures. At present there are no current NIOSH Exposure Criteria and only limited information from OSHA on exposure criteria for workers exposed to optical radiation.

Keywords: SIC:7397 (commercial testing laboratories) Assaying service, optical radiation, infrared radiation, visible radiation.

II. INTRODUCTION

On January 24, 1991, the National Institute for Occupational Safety and Health (NIOSH) received a request seeking assistance in documenting optical radiation levels produced by furnaces during fire assay operations at a commercial geochemical laboratory. In particular, the request asked that measurements be performed to determine the protective eyewear necessary for operators in performing these gold assay procedures at the Lakewood facility. Optical measurements on two furnace types, gas and electric, were made at Cone Geochemical, Inc. by NIOSH on March 14, 1991.

III. BACKGROUND

A. General Description of Fire Assaying

The fire assaying process separates noble metals, such as gold and silver, from their ores using dry reagents and heat. While this process is quite old, it is still used today due to its ability to concentrate minute amounts of precious metals from relatively large ore samples. There are several steps involved in the process.

The first step in the process is called "sample preparation" where the various ore samples are ground, milled, and crushed to a predetermined size. The second step is known as the "charge" preparation. "Charges" are prepared in a fireclay crucible by adding dry reagents (flux) to a finely crushed sample of the ore. The third step is called "crucible fusion." In this process the "charged" fire clay crucibles are placed in a furnace and heated to about 1600^{o} F for about an hour. It is during this third step that the noble metals, along with lead, are partially separated out from the rest of the charge. The fourth step involves separating the noble metals from the lead by heat in a process called "cupellation."

B. Description of Operations

Cone Geochemical, Inc., located in Lakewood, Colorado, has provided commercial fire assay services for about 14 years for determination of gold and silver content in ore samples. At the time of measurement there were approximately thirty people involved with the operations, but only two employees were working on or near the furnaces in the laboratory. There were 10 furnaces, both electric and gas, in the laboratory, but on the day of measurement, only 3 furnaces were in operation. NIOSH was informed that a set of crucibles (totalling 24) requires ten minutes in the furnace. The number of sets per day averages 20 which gives an approximate total time of 200 minutes of furnace time daily. Gloves and a helmet with a face shield were worn on the day of measurement to work with the furnaces.

IV. 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 units 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.

An 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 nanometers (nm)) in biologically effective units of microwatt per square centimeter ($\mu W/cm^2$), 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.

V. 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 workers will be protected from adverse effects even if their 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 the following: 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. The OSHA standards 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 are no current NIOSH Exposure Criteria and only limited information from OSHA on exposure criteria for workers exposed to optical radiation. Criteria for optical radiation not regulated by OSHA come from either ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI) or other standard setting groups.

A. 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 considered IR to be a cataractogenic agent but recent literature has raised 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 eyes 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 and intensity 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]

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, obvious hazards to retinal tissues arise that require protective eye wear devices. These types of direct effects 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 only 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 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 job similar to that of 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[6,8-9]

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.

Absorption of UV 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). Since UV radiation is not visible, the worker may not be aware of the danger at the time of exposure. 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 an 8-hour exposure level.

VI. RESULTS

The maximum occupational optical radiation levels measured from different furnace types at Cone Geochemical are shown in Table 1. All results were obtained at a distance of 1.5 meters from the furnace in order not to disturb furnace operations and for the investigator's personal comfort. At least two measurements were made on every parameter shown in Table 1.

VII. DISCUSSION

Occupational exposure to UV (both actinic and near regions) does not appear to be a problem at the facility. However, exposure to infrared and visible radiation may represent occupational hazards.

Luminance levels exceed recommended exposure levels only for the electric furnaces. It should be noticed that the maximum level measured (1.93 cd/cm^2) is almost twice the ACGIH exposure limit of 1.0 cd/cm^2. If it is assumed that the furnaces follow black-body radiation theory, then for furnace temperatures near 2000 °F, the dominant wavelength of emitted optical radiation are much longer than 500 nm. The wavelength region from 400-500 nm, the blue-light hazard region, has been strongly associated with retinal damage. Since the measured luminance level (1-2 cd/cm^2) for this dominant infrared source does not present a strong visual stimulus (in terms of blue-light) to the worker, then a spectral analysis to determine exposure time is not required. It is concluded, therefore, that the measured maximum luminance levels do not represent an occupational hazard.

The infrared levels greatly exceed the recommended TLV of 10 mW/cm^2 for both types of furnaces. It was noticed that on the day of measurements workers were wearing heat-protective equipment when handling the gas furnace, but not for the electric furnaces. The normal mode of operation for the gas furnaces is to completely shut the door leading to the heating area, whereas if the electric furnaces are used, the door is lowered slightly from its fully seated position to permit workers to view the samples. This means that electric furnace workers' can receive unnecessary exposure to IR radiation. Some workers did wear some form of eyewear protection to absorb the radiation emitted by the furnaces, but there were other workers that did not wear any. It must be realized that exposure to IR can cause dry throat, upper respiratory, and possible ocular problems. Interviews with four workers did reveal that two of them often had dry throats and upper respiratory symptoms. The two reporting minor symptoms often worked on the electric furnaces. Hence, while workers did wear protective equipment, such as face shields, gloves, and overalls, when working with the gas furnaces, exposures to the optical radiation from the electric furnaces could constitute occupational concern.

Another protective measure that could be used is the wearing of special dyed glasses for viewing the gold assays to determine when the samples were ready for removal. The use of such tinted glasses (at least equivalent to shade 3 filters) would greatly reduce IR exposures for the electric furnaces. However, a spectral analysis of the furnace emission would be necessary in order to further specify the nature of the tint. In addition, the use of a plastic or metal shield over the open area of the furnace might also reduce ocular and facial exposure.

Since NIOSH has performed many evaluations of similar workplaces, questions were also asked of the company about blood lead levels. The company had the blood lead levels of its employees tested on a routine basis by an appropriate outside contractor and at the time of this evaluation all past data were reported to be below applicable OSHA standards. It was also observed that exhaust hoods were above all furnaces and were in good operating condition.

VIII. CONCLUSIONS AND RECOMMENDATIONS

As a result of high levels of infrared radiation present on the day of measurements at Cone Geochemical, Inc. the following recommendations are offered to reduce potentially significant occupational exposures and safety risks:

1. The plastic face shields that are provided by the company were found to be warped and distorted from exposure to the intense heat generated by the ovens. It is suggested that all the face shields used at the facility be of the heat-treated variety. In addition, attention could be given towards developing a spectral tinted filter that would help in determining when to remove samples from the furnace.

2. The use of metal or plastic covers mounted (perhaps at some angle) over the aperture of the electric furnaces should be investigated as a means to reduce operator exposure.

IX. REFERENCES

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

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1. Cone Geochemical Inc., Lakewood, Colorado
2. NIOSH
3. OSHA, Region VIII

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE 1

Comparison of maximum emitted gas and electric furnace
radiation levels at 1.5 meters
with ACGIH optical radiation TLVs

Cone Geochemical, Inc.
Lakewood, Colorado
HETA 91-095
March 14, 1991

	Maximum Measured Level		
Optical Indicator	Gas	Electric	TLVs
Actinic UVR (200-315 nm)	ND	ND	0.1 eff mW/cm^2 in 8-hour day
Near UVR (320-400nm)	< 1 μW/cm^2	< 1 μW/cm^2	1.0 mW/cm^2 for periods > 16 minutes
Luminance (400-760 nm)	0.7 cd/cm^2	1.93 cd/cm^2	1.0 cd/cm^2 in 8-hour day
Infrared (760-1400 nm)	130 mW/cm^2	70 mW/cm^2	10 mW/cm^2 in 8-hour day