HETA 95–0119–2554
Glass Schell Fused Glass Masks
Houston, Texas

C. Eugene Moss, H.P., C.S.S.
Gregory A. Burr, C.I.H.

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 or 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, H.P., and Gregory Burr, CIH, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Ellen E. Blythe.

Copies of this report have been sent to the representative at Glass Schell Fused Glass Masks, Houston, Texas, and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self–addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800–356–4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

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.

Health Hazard Evaluation Report 95–0119–2554
Glass Schell Fused Glass Masks
Houston, Texas
January 1996

C. Eugene Moss, H.P., C.S.S.
Gregory A. Burr, C.I.H.

SUMMARY

On December 15, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation (HHE) request from the owner of the Glass Schell Fused Glass Mask art studio, Houston, Texas. The request concerned potential physical and chemical hazards, including optical radiation, crystalline silica, metals, volatile organic compounds, and decomposition products generated in the production of handmade decorative glass items. One employee (the owner) produces these decorative masks from soda glass as well as dichroics using fusing techniques involving clay molds and such glass tools as kilns, glory holes, and gas torches. The owner/operator was also involved with crushing, sandblasting, and tumbling of glass material.

Personal breathing-zone (PBZ) and area air samples were collected for crystalline silica, total particulate, elements (both minerals and metals), and volatile organic compounds (VOCs). Thermal desorption (TD) tubes were used to collect air samples at locations within the studio to detect possible decomposition products released from the heating of clear and colored glass, waxes, and glazes. In addition, occupational exposure levels to ultraviolet (UV), visible, and infrared radiation (IR) were documented during the production of various glass products. Due to the concern about selecting the correct protective eyewear, spectral transmittance evaluations were made on selected eyewear to determine the best type to use at the facility.

All measured exposures were well below any pertinent occupational limits. Crystalline silica was not detected in either the air or bulk sample collected. Elements present in a *bulk* sample of crushed red glass at concentrations greater than 0.01% included aluminum, calcium, copper, iron, sodium, and zinc. The airborne concentrations of these elements were even lower. Based on the qualitative results from the TD samples (which identified only propane and butane), it was decided not to analyze the charcoal tube samples since it was unlikely that any other VOCs would be present in quantifiable levels.

UV and visible radiation exposures did not exceed the applicable standards and guidelines at the time of this investigation, although it was possible to be exposed to excessive IR levels when working with the kiln or glory hole equipment. Since work at Glass Schell is involved with exposure to particulate matter (i.e., sandblasting and glass crushing), as well as to optical radiation, eye protection is necessary.

Based on the data collected in this evaluation NIOSH investigators have determined that a health hazard did not exist. However, under some conditions the use of the glory hole and kiln oven might permit IR exposures to exceed American Conference of Governmental Industrial Hygienist (ACGIH) threshold limit values. Recommendations are made for selecting appropriate personal protective eye and face equipment.

Keywords: SIC 3229 (Pressed and Blown Glass and Glassware, Not Elsewhere Classified), crystalline silica, metals, volatile organic compounds, VOCs, elements, infrared radiation, ultraviolet radiation, UV, eye protection, personal protective equipment.

TABLE OF CONTENTS

INTRODUCTION

On December 15, 1994, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the operator of the Glass Schell Fused Glass Masks studio located in Houston, Texas. The request asked for an evaluation of optical radiation levels and air quality issues. On March 6-7, 1995, NIOSH investigators visited the studio and evaluated optical radiation levels and tested for environmental contaminants produced during various types of hot glass work. In addition, as a result of the interest in the optical radiation protection afforded by the various types of protective eyewear used in the studio to perform hot glass work, this report contains the spectral transmission levels for all eyewear used in the studio.

BACKGROUND

The Glass Schell Fused Glass Masks studio specializes in three-dimensional fused glass masks which can be as large as 12 x 15 inches. One employee (the owner) produces these decorative masks from soda glass as well as dichroics using fusing techniques involving clay molds and such glass tools as kilns, glory holes, a MAP gas torch, and a propane/oxygen torch. In addition, the owner/operator is also involved with crushing, sandblasting, and tumbling of glass material, all of which may be steps in the preparation of glass products. The evaluation performed by NIOSH investigators consisted of making appropriate environmental measurements during both the preparational and fusing stages as well as optical radiation measurements while the operator performed various glass fusing and heating scenarios.

CHEMICAL AGENT EVALUATION DESIGN

Because of the time required to produce each unique Glass Schell product, NIOSH investigators pre-arranged for the owner/operator to perform the major steps involved in producing the various glass artwork during this survey so environmental measurements (both personal breathing-zone and area air sampling) could be made. After inspecting the art studio and observing the work activities, NIOSH investigators suspected that the concentrations of most of the airborne contaminants would be low. This assumption was based on the small quantities of materials which were typically used in the various work tasks and the short duration of these activities.

Table 1 summarizes the work activities, collection and analytical methods, and results obtained from the air sampling conducted during this survey. The samples were generally collected for the duration of the activity which was being evaluated (typically less than 30 minutes). In some instances, the sampling time for some substances (elements and volatile organic compounds [VOCs]) was extended and covered several work activities.

Substances were selected for analysis based on the raw materials used in the various work activities. For example, since crystalline silica was suspected to be present in the sand used during the abrasive blasting and certain glass production techniques, samples were collected and analyzed for crystalline silica using X-ray diffraction according to NIOSH Sampling and Analytical Method 7500. An area air sample was also analyzed for the total amount of airborne particulate present (since it was suspected that the crystalline silica concentration may be too low to detect analytically). A bulk sample of paraffinic wax (used in a type of glass investment casting) was collected and submitted for thermal headspace analysis to determine what (if any) decomposition products may be released when the wax was melted. Since some of the glass pieces are colored (using metals such as cobalt and cadmium) air and bulk samples were collected and analyzed for 28 different minerals and metals. Finally, air samples were collected for VOCs which may be released during activities such as glass painting.

PHYSICAL AGENT EVALUATION DESIGN

The following equipment was used to measure levels of radiant energy produced by the various processes:

- Luminance or brightness levels were measured with a Spectra Mini-Spot photometer having a one degree field of view. The measurements were obtained in units of footlamberts (fl) which were 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 the source.

- An International Light radiometer, model 700, 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 microwatts per square centimeter ($\mu W/cm^2$), while the other detector measured near UV (320-400 nm) in units of milliwatts per square centimeter (mW/cm^2) with no biologic weighting factor.

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

- An 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 radiation fields had been calibrated within six months 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 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 health effects if 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 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 American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and (3) the U.S. Department of Labor (OSHA) occupational health standards.[1,2,3] 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. However, 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).

Chemical Agents

Evaluation criteria for crystalline silica, VOCs, and selected minerals and metals are not included in this report. This is based on the fact that some of these substances were not detected (crystalline silica) or present in extremely low concentrations (most of the minerals and metals). With the VOCs samples, the predominant compounds identified were butane and propane, two combustible gases which are generally considered to be simple asphyxiants. Neither of these gases would present in the art studio in concentrations sufficient to pose a risk from asphyxiation under normal working condition.

Particulates, not otherwise classified

Often the chemical composition of the airborne particulate does not have an established occupational health exposure criterion. It has been the convention to apply a generic exposure criterion in such cases. Formerly referred to as nuisance dust, the preferred terminology for the non-specific particulate ACGIH TLV criterion is now "particulates, not otherwise classified (n.o.c.)," [or "not otherwise regulated" (n.o.r.) for the OSHA Permissible Exposure Limit (PEL)].

The OSHA PEL for total particulate, n.o.r., is 15.0 milligrams per cubic meter (mg/m^3) and 5.0 mg/m^3 for the respirable fraction, determined as 8-hour averages.[3] The ACGIH recommended TLV for exposure to a particulate, n.o.c., is 10.0 mg/m^3 (total dust, 8-hour TWA).[2] These are generic criteria for airborne dusts which do not produce significant organic disease or toxic effect when exposures are kept under reasonable control.[4] These criteria are not appropriate for dusts that have a biologic effect.

Physical Agents

Infrared Radiation[5-9]

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

Some of the physical factors which influence this 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, since there is no such adequate warning mechanism in the eye, additional protective equipment is often necessary. Traditionally, safety personnel consider IR to be a cataractogenic agent, but recent literature has cast serious questions about whether IR cataracts can be produced in the workplace from non-coherent optical sources, such as glass furnace operations.

IR radiation beyond 1400 nm can produce corneal and eyelid burns, as well as 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 and intensity of exposure. If the radiation intensity is low enough, however, normal retinal blood flow 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[5,9,10-14]

Visible radiation, from either the sun or artificial sources, is an important occupational health consideration because of its major role in our daily life. When light levels are high at unique wavelength regions, retinal hazards arise that require the wearing of protective eye wear devices. These types of direct retinal effects from excessive light levels have been well known and documented for many years (i.e., staring at welding arcs or the sun). The ACGIH TLVs for visible radiation are intended to offer protection from retinal thermal injury and from photochemical injury that can occur from exposure to wavelengths in the region from 400-500 nm. While protective eyewear it absolutely essential under some conditions to protect the eye from ocular damage, often the luminous transmittance of the protective eyewear is so low that workers may not be able to see sufficiently well to perform a given task or job.

Ultraviolet Radiation[5,8,9,11]

Ultraviolet (UV) radiation is an invisible radiant energy produced naturally by the sun and artificially by arcs operating at high temperatures. Examples of these latter sources include 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 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 normally debilitating, but is a warning that conditions such as actinic keratosis, squamous cell epithelioma, and basal cell epithelioma may develop. Since UV is not visible, the worker may not be aware of an exposure at the time it is occurring. Absorption of the UV radiation by the eye and eyelids can cause conjunctivitis.

Lesions may also be formed on the cornea as a result of high exposure levels (photo keratitis). 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 also need to be aware that the presence of certain photosensitizing agents on the skin can produce exaggerated sunburn when exposed to certain UV radiation wavelengths.

RESULTS

Chemical Agents

Tables 1 and 2 summarize the analytical results of the air and bulk samples. All measured concentrations for crystalline silica, total particulate, elements, and VOCs were well below any pertinent occupational exposure limits. Crystalline silica was not detected in either the air or bulk sample collected. The elements which were present in the *bulk* sample of crushed red glass at concentrations greater than 0.01% included the following: aluminum, calcium, copper, iron, sodium, and zinc. All of these elements have relatively low toxicities and it would not be anticipated that any would be an occupational exposure problem in the glass handling activities observed in this evaluation. It should also be noted that the airborne concentrations of all 28 elements which were analyzed for were even lower than the levels present in the bulk sample of glass. Based on the qualitative results obtained from the airborne thermal desorption samples (which identified only propane and butane), it was unnecessary to analyze the charcoal tubes since it was unlikely that any other VOCs would be present in quantifiable levels.

Physical Agents

Luminance

The luminance levels measured on the days of evaluation ranged from 0.33 to 2.0 candela per square centimeter (cd/cm^2). All luminance measurements were made with the photometer aimed at the particular glass work event the operator was performing. Normally, the distance between the hot glass object and the photometer was 18 inches. The highest luminance was recorded when using the propane/oxygen torch during lampworking procedures. These exposures can be compared to the ACGIH TLV of 1 cd/cm^2. During some of the measurements, a bright yellow color would appear for a short time while heating the soda lime glass. This momentary event is denoted as a sodium flare since it results in the generation of yellow light at wavelengths around 590 nm. While the production of such light can be visually distracting while working on the glass item it does not cause deleterious biological effects.

Ultraviolet Radiation

Levels of both near (315 to 400 nm) and actinic (200 to 315 nm) UV radiation were documented on most of the processes. The actinic radiation levels were non-detectable for all hot glass events. The maximum level of near UV radiation was 0.5 mW/cm^2 at the operator face. These levels of near and actinic UV radiation are below the TLV and are not considered to be an optical or skin hazard to the unprotected worker. The operator wore protective eyewear and gloves during these tests.

The sunburn meter indicated non-detectable levels everywhere in the facility, except outside. The maximum reading obtained at noon outside (overcast day) was 0.5 SBU per hour.

Infrared Radiation

Exposure to IR could occur from the glory hole or kiln furnace (if the door was left open), and from handling the hot glass during lampworking procedures. IR levels could be as high as 50 mW/cm^2 at a distance of 2 feet from the opened kiln door (see Figure 1). The door must be left open for extended time periods to process heated glass samples during certain operations. During our measurements the kiln door was opened for 5 seconds.

Irradiance levels measured near the glory hole were over 100 mW/cm^2 at 18 inches. At a distance of three feet, typical worker exposure, the irradiance was 28 mW/cm^2. On the days of the evaluation, the operator spent about one hour in front of the glory hole typically at a distance of about three feet, as shown in Figure 2. However, the operator did mention that on some days he would work in front of the glory hole for longer time periods. The operator wore appropriate skin and eye protection while in the vicinity of the glory hole.

There were several types of lampworking procedures attempted by the operator on the days of measurement. All IR measurement results made for the various lampworking procedures were below 10 W/cm^2. In fact, the highest level, approximately 6 mW/cm^2, occurred while using the propane/oxygen torch.

DISCUSSION AND CONCLUSIONS

The chemical exposures measured during lampworking, glass crushing, sandblasting, glass painting, and other activities associated with producing decorative glass items were very low and do not appear to present a health risk to the owner/employee. The low exposures at this small studio could be attributable to several factors, including the small quantities of materials (such as crushed glass, glass paint) typically handled on a daily basis and the short duration of the individual tasks. However, it was possible to be exposed to excessive IR when working at the kiln or glory hole. Eye protection can be specified in terms of shade number which is a logarithmic notation of visual transmittance. The ANSI standard Z 87.1 (1989) sets transmission specifications for protective eyewear (excluding lasers) in the visible, UV, and IR radiation regions.[15] Since work at Glass Schell is involved with both exposure to particulate matter, i.e., sandblasting and crushing, as well as optical radiation then safety eye protective equipment is required.

The major issue in the selection of appropriate eyewear is the degree of optical attenuation needed to protect the worker, yet provide sufficient luminous transmittance levels. The requirements placed on the visible wavelengths in working with fused glass material is that the radiation intensity associated with both the blue light wavelengths (400 to 500 nm) and the sodium flare wavelengths (588 to 590 nm) should be minimized. The blue light radiation can be associated with retinal concerns while the sodium flare contributes to loss of vision.

Table 3 shows the maximum IR transmittance percent permitted by selected filter shades. If a IR irradiance of about 100 mW/cm^2 is assumed (as reported earlier), then a filter shade of #3/#4 affords reasonable IR ocular protection based on the ACGIH TLV of 10 mW/cm^2. While one can use higher filter shades to reduce the ocular exposure, it should be noted that the higher the shade number, the darker the tint, and the more difficult to see the work environment.

It should be noted that there are other types of eye protectors, besides those rated as shade numbers, are available for glass workers to use. The owner of Glass Schell loaned the NIOSH investigators several of these different eye protectors to determine their spectral transmittance levels. Several of these spectral transmittance plots are shown in Figures 3-6. While it was determined that most of the eyewear would be satisfactory for use with the type of emissions found at the facility on the days of measurements, there were several eyewear devices which gave better protection than others. In general, those eyewear devices that eliminated the UV, blue light, and sodium flare wavelengths while minimizing the IR wavelengths would obviously warrant more consideration for occupational use. However, it is not possible to select a "best eyewear protector" since the quality and quantity of visibility is such an individual characteristic. Several eyewear protectors that might be used for this type of work would utilize gold coatings and might be made of didymium. Since the levels of optical radiation measured at the facility were below occupational exposure levels, except for the glory hole and open kiln, need for eyewear is questioned based on optical radiation exposure factors.

REFERENCES

1. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

2. ACGIH [1995]. 1995-1996 threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Code of Federal Regulations [1989]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

4. ACGIH [1986]. Documentation of threshold limit values and biological exposure indices for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

5. NIOSH [1977]. Occupational diseases: a guide to their recognition. U.S. Department of Health and Human Services, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 77-181, Revised June 1977.

6. WHO [1980]. Infrared radiation. In manual on Health Aspects of Exposure to Nonionizing

Radiation by Moss, C.E. (et al.) World Health Organization Regional Office for Europe. Copenhagen, Denmark.

7. ACGIH [1995]. Threshold Limit Values (TLVs) and Biological Exposure Indices for 1995-96. American Conference of Governmental Industrial Hygienists.

8. Moss CE, et al. [1982]. Biological effects of infrared radiation. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 82-109.

9. Optical Radiation and Visual Health, edited by Waxler, M. and Hitchins, V.M., CRC Publications, Inc. Boca Raton, Florida 1986.

10. NIOSH [1973]. Criteria for a recommended standard: occupational exposure to ultraviolet radiation. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11009.

11. IES Lighting Handbook, Reference Volume, edited by Kaufman, J.E., Illuminating Engineering Society of North America, New York, N.Y., 1981.

12. Sliney DH and Wolbarsht M [1980]. Safety with lasers and other optical sources. Plenum Press, New York, N.Y.

13. Wilson DS and Wilson DR [1983]. Protective curtain for radiation curing. Radiation Curing 10(2):35-39.

14. Sliney DH, Moss CE, Miller CG, Stephens JP [1981]. Semitransparent curtains for control of optical radiation hazards. Applied Optics 20(14): 2352-2361, 1981.

15. ANSI [1989]. Standard Practice for Occupational and Educational Eye and Face Protection Z 87.1 American National Standards Institute.

Table 1: Environmental Sampling Methods and Results (from Air and Bulk Samples) Glass Schell Art Glass Studio, Houston, Texas (HETA 95-0119) Samples Collected on March 7, 1995				
Sample	**Work Activity**	**Analyte**	**Collection & Analytical Method**	**Results**
94-5183	Sandblasting of glazed glass part	Crystalline Silica (Air Sample)	Air sample collected on tared PVC filter. Sampling flow rate of 3.0 lpm. Analysis by NIOSH Method 7500 (X-Ray Diffraction). MDC = 0.04 mg/cubic meter MQC = 0.13 mg/cubic meter	Quartz was present in the PBZ air sample at the MQC of 0.13 mg/cubic meter. Cristobolite (another form of crystalline silica) was not detected.
GB-10	Red glass, crushed to a powder-like consistency	Crystalline Silica (Bulk Sample)	Bulk sample of crushed glass powder. Analysis by NIOSH Method 7500 (X-Ray Diffraction) LOD = 0.75% (Quartz in bulk) LOQ = 1.5 % (Quartz in bulk)	Neither quartz nor cristobalite were detected in the bulk sample of crushed glass.
94-5183	Sandblasting of glazed glass part	Total Particulate	Air sample collected on tared PVC filter. Sampling flow rate of 3.0 lpm. Analysis by NIOSH Method 0500 (Gravimetric Analysis of Tared PVC Filter)	Total particulate was measured at a concentration of 0.6 mg/cubic meter. This concentration is well below the OSHA Permissible Exposure Limit of 15 mg/cubic meter.
GB-1	Lampworking, PBZ sample collected between 9:42 to 10:25 am	Elements (Air sample)	Air sample collected on MCE filters. Sampling flow rate of 3.0 lpm. Analysis by NIOSH Method 7300 (via ICP). MDC and MQC for individual elements are shown in Table 2.	Only trace amounts of aluminum, beryllium, copper, iron, sodium, and zinc were identified. All results were well below any applicable occupational health limits. See Table 2 for complete elemental results.
GB-2	Crushing red glass to a powder-like consistency. The PBZ sample was collected between 10:25 to 11:50 am	Elements (Air sample)	Air sample collected on MCE filters. Sampling flow rate of 3.0 lpm. Analysis by NIOSH Method 7300 (via ICP). MDC and MQC for individual elements are shown in Table 2.	Only trace amounts of aluminum, barium, beryllium, calcium, copper, iron, sodium, titanium, yttrium, and zinc were identified. All results were well below any applicable occupational health limits. See Table 2 for complete elemental results.
GB-3	Area air sample in glass studio, near overhead garage door, collected between 9:38 am to 12:08 pm	Elements (Air sample)	Air sample collected on MCE filters. Sampling flow rate of 2.0 lpm. Analysis by NIOSH Method 7300 (via ICP). MDC and MQC for individual elements are shown in Table 2.	Only trace amounts of aluminum, iron, sodium, silver, yttrium, and zinc were identified. All results were well below any applicable occupational health limits. See Table 2 for complete elemental results.
GB-6	Red glass, crushed to a powder-like consistency	Elements (Bulk Sample)	Bulk sample of crushed glass powder. Analysis by NIOSH Method 7300 (via ICP)	Sodium, calcium, iron, aluminum, and zinc were the predominant elements present in this bulk sample of crushed glass. See Table 2 for complete elemental results.
GB-5	Analysis of paraffin wax used in investment casting of glass objects	(Bulk Sample)	Thermal Headspace Analysis. A wax sample is heated to 212° F and the effluent is analyzed by GC-MSD.	The major compounds detected included paraffins and alkanes in the C_{10} to C_{20} range.

Table 1: Environmental Sampling Methods and Results (from Air and Bulk Samples) Glass Schell Art Glass Studio, Houston, Texas (HETA 95-0119) Samples Collected on March 7, 1995				
Sample	**Work Activity**	**Analyte**	**Collection & Analytical Method**	**Results**
Y-7	Area air sample in glass studio, near overhead garage door, collected from 9:50 am to 10:25 am	VOCs (Air Samples)	Carbotrap® 300 stainless steel thermal desorption (TD) tubes, configured for the Tekmar® 5010 thermal desorber system. Each TD tube contained three beds of sorbent materials: (1) a front layer of Carbotrap C; (2) a middle layer of Carbotrap; and (3) a back section of Carbosieve S–III. The samples were analyzed using the Tekmar thermal desorber interfaced directly to a gas chromatograph and a mass selective detector. Each sample tube was desorbed at 400NC for ten minutes. While the extremely sensitive TD method can identify VOCs present in the parts per billion range, it does not indicate the quantity of these chemicals. To quantitate the airborne levels of the VOCs, air samples were collected using activated charcoal as the sorbent material (See Samples Nos. GB-4 and GB-7)	The only major compounds detected on the thermal desorption samples were propane and traces of butane. Both of these combustible gases probably originated from the gas fuel used with the burners used in lampworking and other glass heating activities.
Y-8	Area background sample, outside of the art studio	VOCs (Air Samples)		
Y-12	Area air sample in glass studio, near spray cabinet, collected from 10:45 am to 12:03 pm	VOCs (Air Samples)		
GB-4	Area air sample in glass studio, near overhead garage door, collected between 9:50 am to 12:03 pm	VOCs (Air Samples)	Area air sample collected on activated coconut charcoal tubes (100mg/50mg size). A sample flow-rate of 100 cc/min was used.	This sample was not analyzed since the only major compounds detected on the thermal desorption qualitative air samples were propane and butane.
GB-7	Sandblasting of glazed glass part	VOCs (Air Samples)	Area air sample collected on activated coconut charcoal tubes (100mg/50mg size). A sample flow-rate of 100 cc/min was used.	This sample was not analyzed since the only major compounds detected on the thermal desorption qualitative air samples were propane and butane.

Table 1: Environmental Sampling Methods and Results (from Air and Bulk Samples) Glass Schell Art Glass Studio, Houston, Texas (HETA 95-0119) Samples Collected on March 7, 1995				
Sample	**Work Activity**	**Analyte**	**Collection & Analytical Method**	**Results**

Description of Terms:

Lampworking: The production of beads and stringers (long, thin strings of glass) by heating the glass pieces in a table-mounted burner which used methyl-acetylene-propadiene fuel (MAP gas). In some situation (such as bead producing) the glass objects would be immediately placed in a floor mounted ceramic annealer.

Glass Crushing: Glass (clean and colored) was crushed in a table-mounted tumbler which was powered by an electric motor. The rubber tumbler container was filled with ceramic balls which, depending on the tumbling time, would, in some cases, produce a crushed glass with powder-like consistency. The glass powder could then be used to decorate other glass pieces.

Abbreviations:

VOCs = Volatile organic compounds
mg = milligrams
mg/sample = milligrams of analyte per sample
LOD = Limit of Detection
LOQ = Limit of Quantitation
ICP-AES = Inductively coupled plasma atomic emission spectrometry
GC-MSD = Gas chromatography-Mass spectrometry detector

Source for NIOSH Analytical Methods:

Molhave L, Nielsen GD [1992]. Interpretation and limitations of the concept "Total Volatile Organic Compounds" (TVOC) as an indicator of human responses to exposures of volatile organic compounds (VOC) in indoor air. Indoor Air, Vol. 2, pp. 65-77.

Table 2: Elemental Analysis of Air and Bulk Samples
Glass Schell Art Glass Studio, Houston, Texas (HETA 95-0119)
Samples Collected on March 7, 1995

Analyte	**MDC (mg/m^3)**	**MQC (mg/m^3)**	**Sample Concentrations (milligrams per cubic meter)**			
			PBZ Sample (Lampworking)	PBZ Sample (Glass Crushing)	GA Sample (In Studio)	Bulk Sample (Crushed Red Glass)
Aluminum	0.002	0.006	Trace	0.01	Trace	Present‡
Arsenic	0.004	0.01	ND	ND	ND	ND
Barium	0.0001	0.0002	ND	0.0002	ND	Present
Beryllium	0.0001	0.0003	Trace	Trace	ND	ND
Calcium	0.008	0.016	ND	0.18	ND	Present‡
Cadmium	0.0003	0.0008	ND	ND	ND	Present
Cobalt	0.0008	0.002	ND	ND	ND	ND
Chromium	0.002	0.005	ND	ND	ND	Trace
Copper	0.0002	0.0006	Trace	Trace	ND	Present‡
Iron	0.002	0.008	Trace	Trace	Trace	Present‡
Lithium	0.002	0.007	ND	ND	ND	ND
Magnesium	0.003	0.009	ND	ND	ND	Present
Manganese	0.0001	0.0003	ND	ND	ND	Present
Molybdenum	0.0008	0.002	ND	ND	ND	ND
Sodium	0.02	0.07	Trace	Trace	Trace	Present‡
Nickel	0.002	0.005	ND	ND	ND	ND
Phosphorus	0.016	0.044	ND	ND	ND	ND
Lead	0.002	0.007	ND	ND	ND	Present
Platinum	0.008	0.016	ND	ND	ND	ND
Selenium	0.004	0.01	ND	ND	ND	Present
Silver	0.0002	0.0005	ND	ND	Trace	ND
Tellurium	0.003	0.009	ND	ND	ND	ND
Thallium	0.008	0.016	ND	ND	ND	ND
Titanium	0.0002	0.0008	ND	Trace	ND	Present
Vanadium	0.0008	0.002	ND	ND	ND	ND
Yttrium	0.0001	0.0002	ND	Trace	Trace	ND
Zinc	0.0003	0.0009	0.002	0.003	Trace	Present‡
Zirconium	0.0008	0.001	ND	ND	ND	Trace

Comments:

mg/m^3 = milligrams of material per cubic meter of air

MDC = Minimum Detectable Concentration (assuming an air sample size of 250 liters). This represents the smallest amount **detectable** by this method for this sample set.

MQC = Minimum Quantifiable Concentration (assuming an air sample size of 250 liters). This represents the smallest amount **than can actually be reliably measured (i.e., quantifiable)** by this method for this sample set.

PBZ = Personal breathing-zone air sample

GA = General area air sample

Trace = Amount detected is between the minimum detectable and minimum quantifiable concentrations

‡ = Denotes the elements which were present in the bulk sample **at concentrations greater than 0.01%.** All remaining elements which were detected in this sample were present in concentrations less than 0.01%

NOTE: Lampworking refers to the production of glass beads and "stringers" (long, thin strings of glass.) Both items are produced by heating small, handhold glass pieces in a table-mounted burner which uses methyl-acetylene-propadiene (MAP) gas as a fuel.

Table 3

Transmittance Requirements for Clear Lenses and General-Purpose Filters

Shade Number	Luminous Transmittance: Maximum %	Luminous Transmittance: Nominal %	Luminous Transmittance: Minimum %	Maximum Effective Far-Ultraviolet Average Transmittance %	Maximum Infrared Average Transmittance %
CLEAR	100	—	65	—	—
1.5	67	61.5	55	0.1	25
1.7	55	50.1	43	0.1	20
2.0	43	37.3	29	0.1	15
2.5	29	22.8	18.0	0.1	12
3.0	18.0	13.9	8.50	0.07	9.0
4	8.50	5.18	3.16	0.04	5.0
5	3.16	1.93	1.18	0.02	2.5
6	1.18	0.72	0.44	0.01	1.5
7	0.44	0.27	0.164	0.007	1.3
8	0.164	0.100	0.061	0.004	1.0
9	0.061	0.037	0.023	0.002	0.8
10	0.023	0.0139	0.0085	0.001	0.6
11	0.0085	0.0052	0.0032	0.0007	0.5
12	0.0032	0.0019	0.0012	0.0004	0.5
13	0.0012	0.00072	0.00044	0.0002	0.4
14	0.00044	0.00027	0.00016	0.0001	0.3

NOTES: (1) The near-ultraviolet average transmittance shall be less than one-tenth of the luminous transmittance,

$$T(NUV) < T_L/10$$

(2) The blue-light transmittance shall be less than the luminous transmittance,

$$T_B < T_L$$

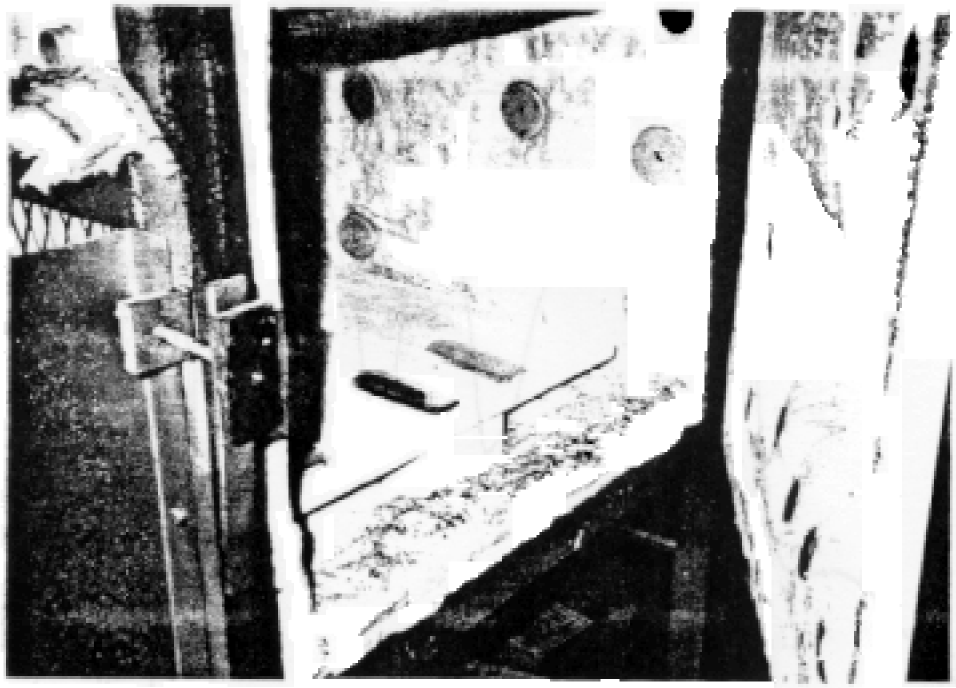


Figure 1. Open kiln door

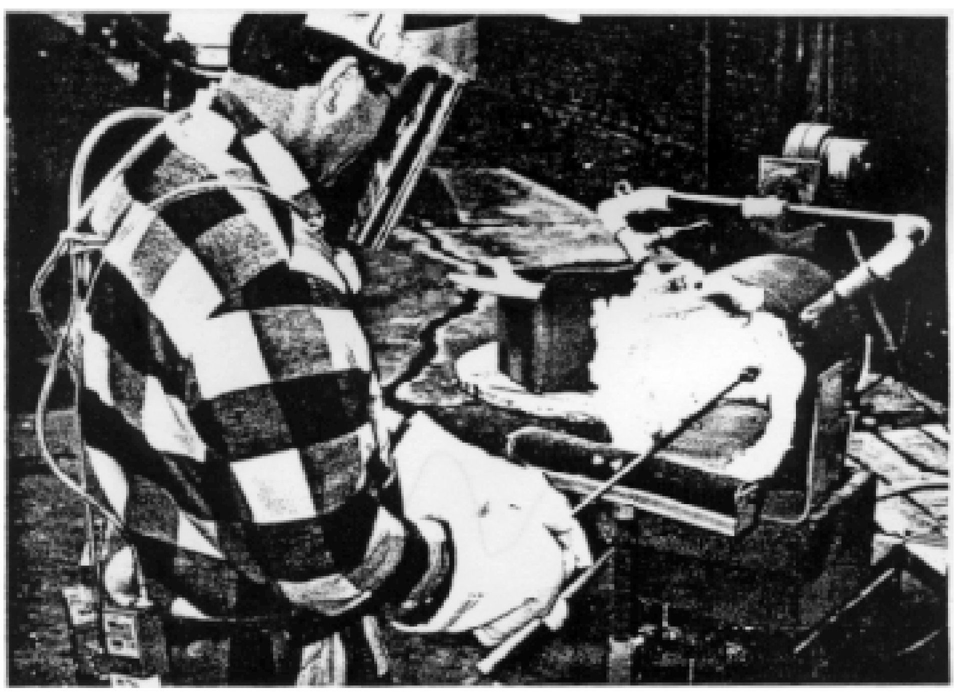
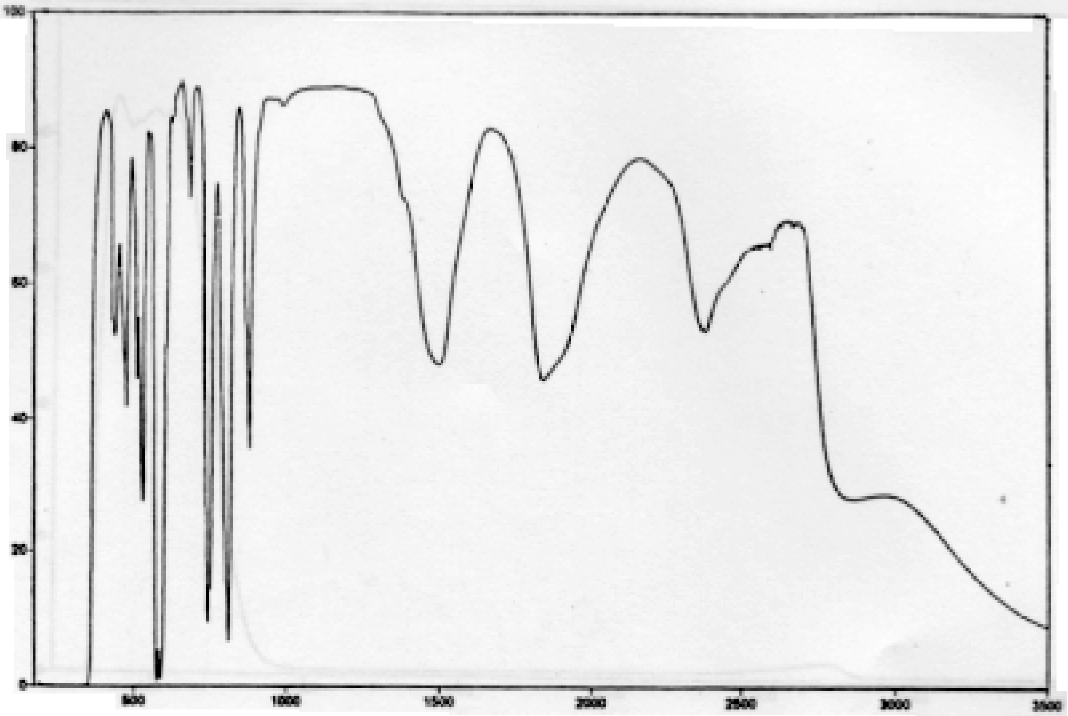
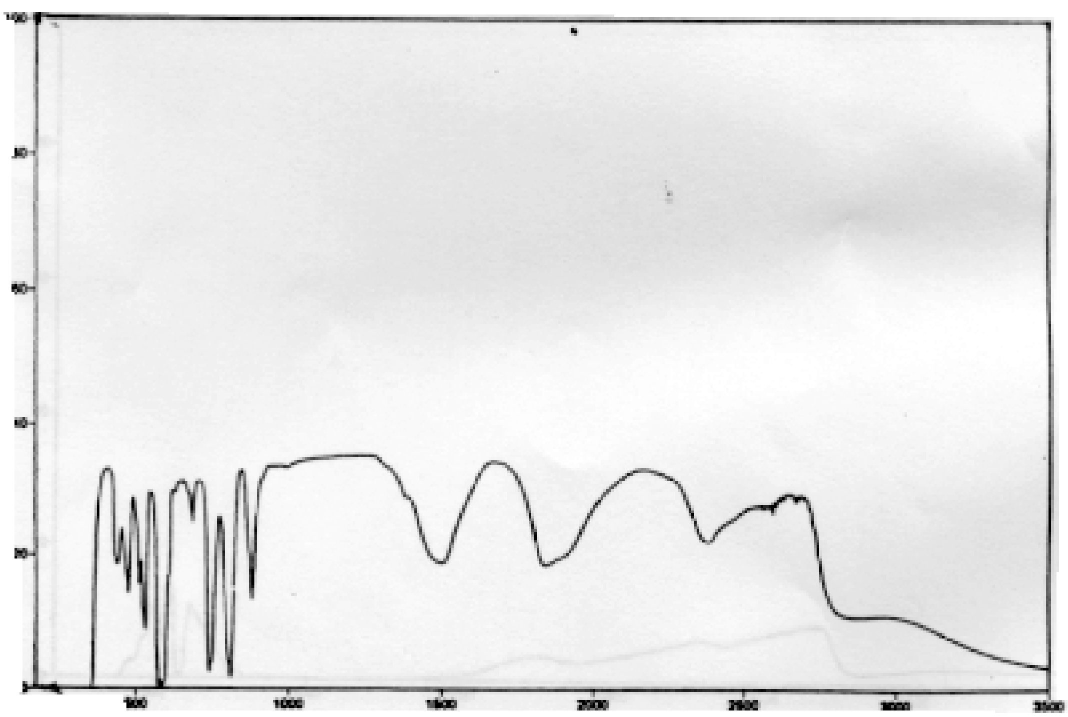


Figure 2. Worker operating glory hole



Transmittance / Nanometers

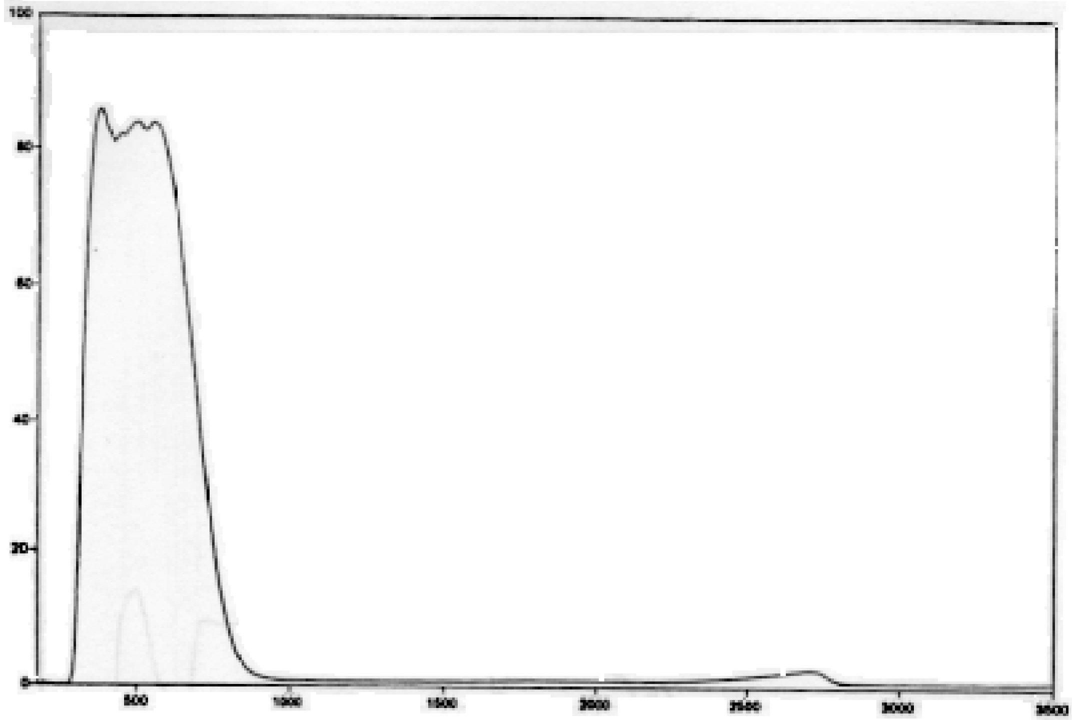
Protective eyewear having high UV, VIS, Blue, Sodium, Flare, and IR transmittance



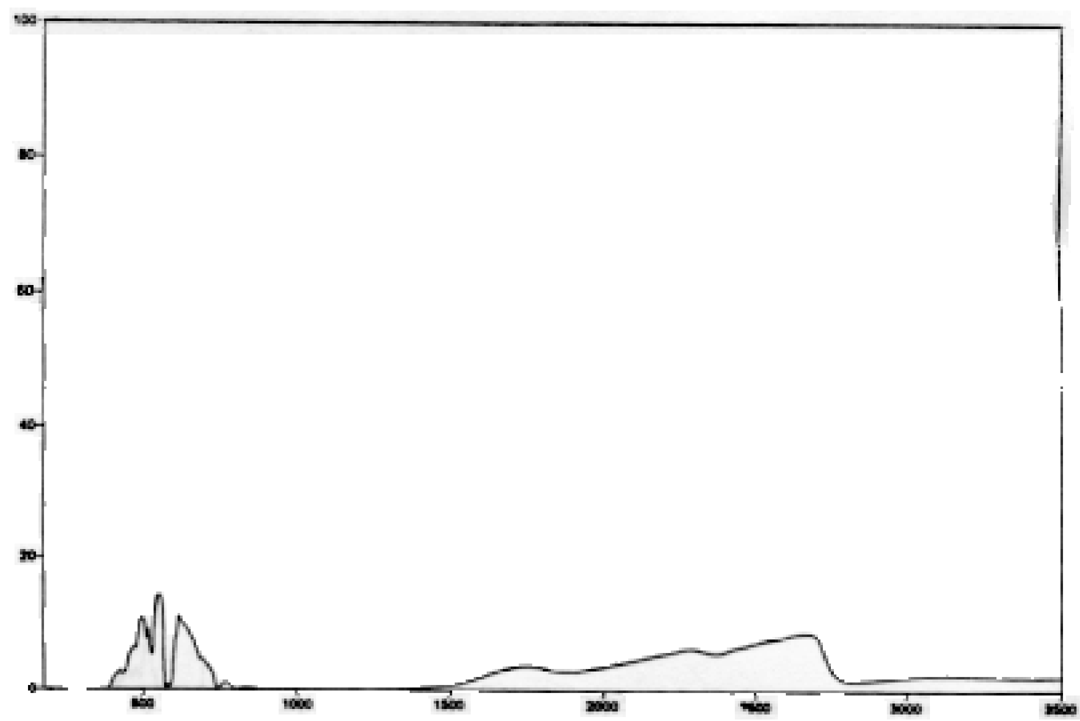
Transmittance / Nanometers

Protective eyewear having moderate UV, VIS, Blue, and IR transmittance

Figure 3

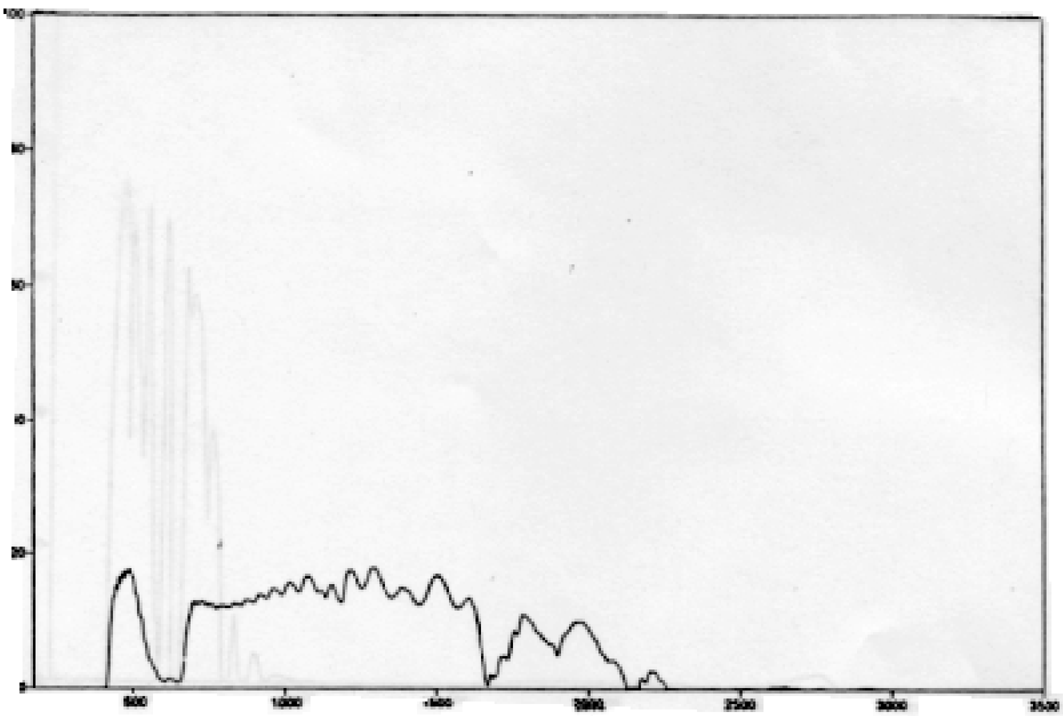


Transmittance / Nanometers **Protective eyewear having low IR transmittance**

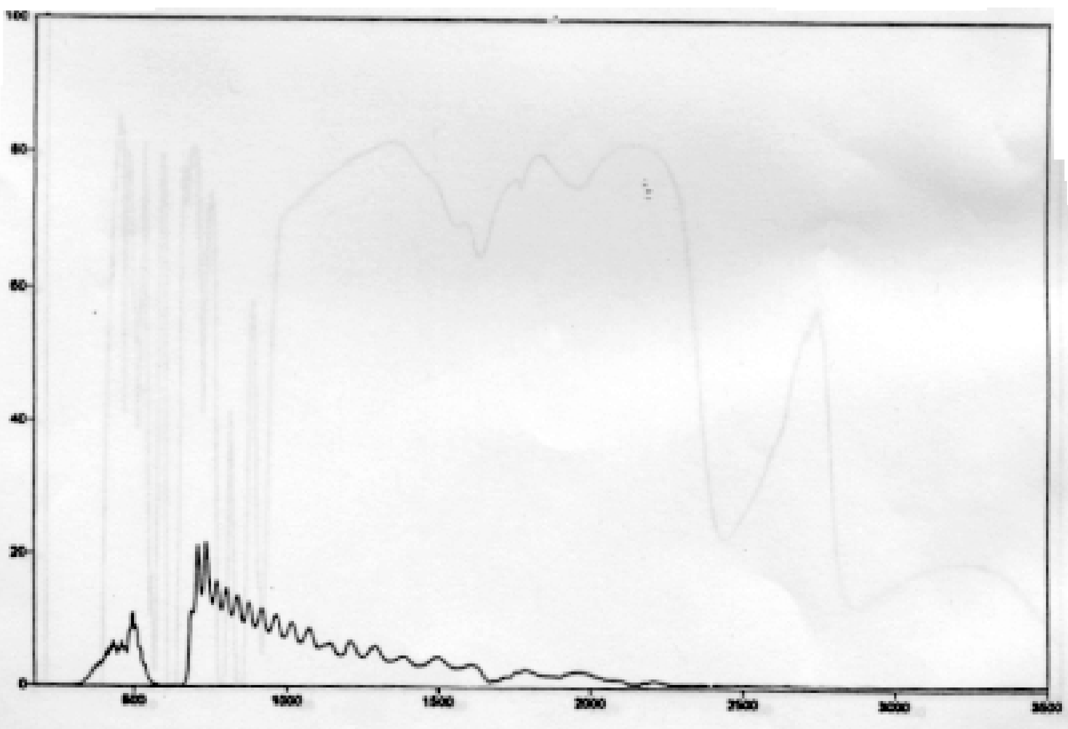


Transmittance / Nanometers **Protective eyewear having low UV, VIS, Blue, and IR transmittance**

Figure 4

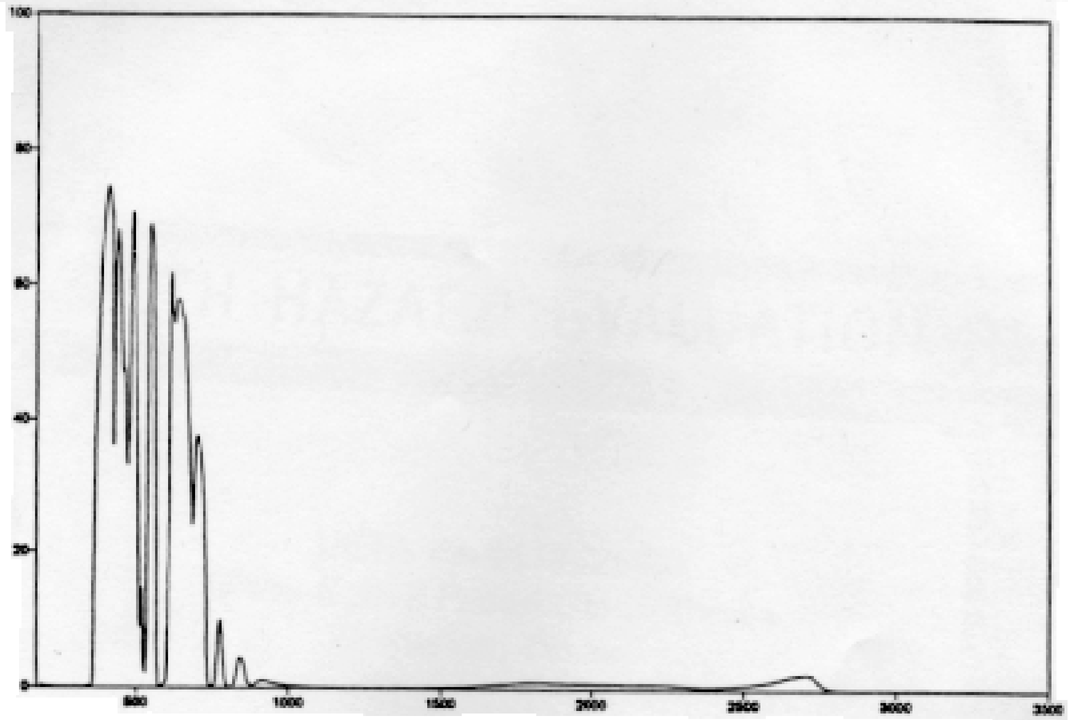


nittance / Nanometers Protective eyewear having low UV, VIS, and Blue transmittance

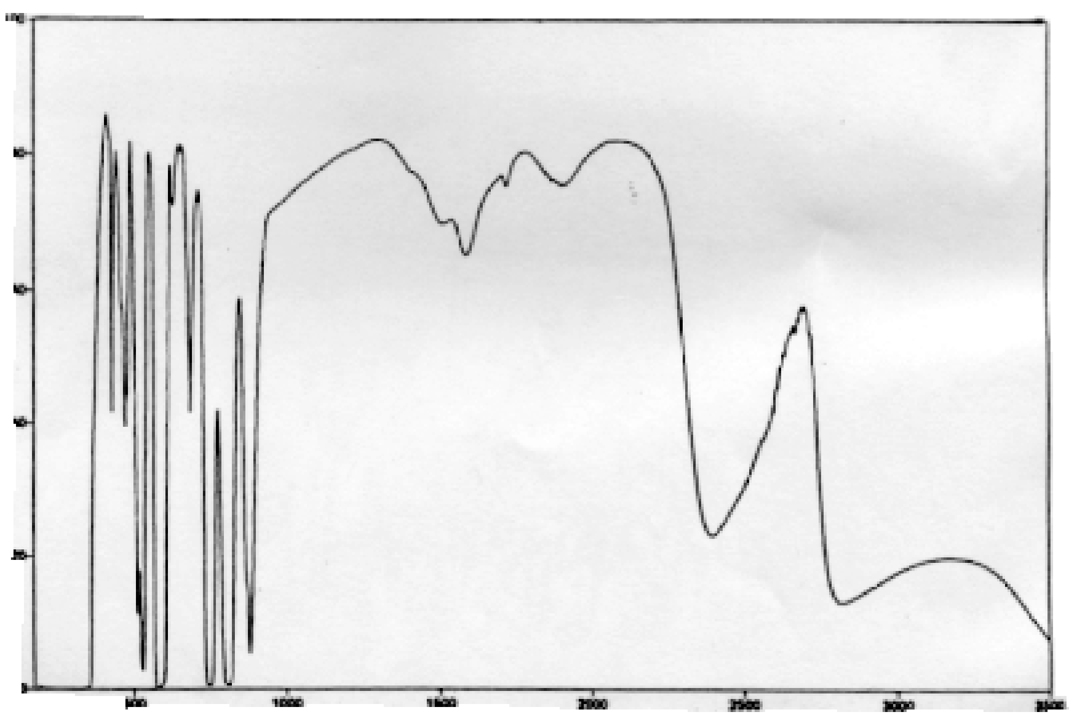


Transmittance / Nanometers Protective eyewear having low UV and Blue transmittance

Figure 5



Transmittance / Nanometers **Protective eyewear having high UV, VIS, and Blue light transmittance**



Transmittance / Nanometers **Protective eyewear having high UV, VIS, Blue, and IR transmittance**

Figure 6