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ARMCO ADVANCED MATERIALS CORPORATION
BUTLER, PENNSYLVANIA

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I. SUMMARY

On March 19-22, 1990, investigators from the National Institute for Occupational Safety and Health (NIOSH) conducted a Health Hazard Evaluation (HHE) investigation at ARMCO Advanced Materials Corporation in Butler, Pennsylvania. This HHE was performed in response to a management request received on September 14, 1989. The request asked NIOSH to evaluate potential employee exposures to infrasound, electromagnetic radiation, and various dust exposures throughout the melt shop. The evaluation was expanded to include radiofrequency exposures at the Ultra-Rapid Annealing (URA) furnace located in the Strip Coating and Silicon Anneal Building (SCSAB).

Air samples for trace metals, free silica, and respirable dust were collected from workers in the melt shop. Additionally, evaluations of the infrasound, audible noise, ultraviolet radiation, visible radiation, infrared radiation, and electromagnetic field strengths in the melt shop, URA furnace, and an electrical substation were conducted during the survey. The results of the air samples for trace metals collected in the melt shop revealed that the NIOSH Recommended Exposure Limits for chromium VI and manganese were exceeded. Additionally, air samples exceeding the Occupational Safety and Health Administration's (OSHA) action level for lead were collected during the survey. The radiofrequency radiation measurements at the URA furnace and the visible radiation levels near the electric arc furnaces in the melt shop were found to exceed the appropriate evaluation criteria. The air samples collected for all other trace metals, respirable free silica, and respirable dust were less than the evaluation criteria. Levels of ultraviolet radiation, electromagnetic radiation, or ultrasound which were measured during the survey period were all below applicable exposure criteria.

Based on the results of measurements performed during the Health Hazard Evaluation, NIOSH investigators have determined that a health hazard existed during the survey period. The hazards to employees are from the excessive airborne levels of hexavalent chromium, manganese, and lead found in the melt shop. Additionally, the high levels of optical radiation measured at distances less than 30 feet from the electric arc furnaces pose a potential hazard to unprotected workers who work in close proximity to the furnaces. Finally, the radiofrequency radiation exposures measured at the URA furnace represent a health hazard to nearby workers. Recommendations are offered which will alleviate these potential health hazards to workers and for medical and environmental surveillance programs.

KEYWORDS: SIC 3312 [Steel Works, Blast Furnaces (Including Coke Ovens), and Rolling Mills], chromium, lead, manganese, optical radiation, radiofrequency radiation, electromagnetic radiation, infrasound, noise.

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation (HHE) on September 14, 1989, from ARMCO Advanced Materials Corporation, Butler, Pennsylvania. The request asked NIOSH to evaluate potential employee exposures to infrasound, electromagnetic radiation, and various dust exposures throughout the melt shop. In addition, the evaluation was expanded to include radiofrequency exposures at the Ultra-Rapid Annealing (URA) furnace located in the Strip Coating and Silicon Anneal Building (SCSAB). NIOSH investigators conducted these evaluations on March 19-22, 1990.

III. BACKGROUND

ARMCO Advanced Materials Corporation primarily produces specialty steel products. The melting facilities are housed in a rectangular structure 287 feet wide by 760 feet long. The structure contains four aisles: stockhouse aisle, alloy aisle, furnace aisle, and tapping aisle. The structure houses three two-phase electric-arc melting furnaces, one 175 ton argon-oxygen decarburization (AOD) vessel, and auxiliary equipment. The three electric furnaces were designed for a production rate of 75,000 tons per month.

ARMCO utilizes an indirect method of electric heating to make steel. The indirect method heats the charge with electrical radiation which is emitted from the arcing phenomena between the furnace electrodes. The process is initiated by top charging the furnace with scrap products. After a 30 minute electric heat, followed by a 20 minute oxygen burn, a second charge is added to the furnace. The charge is again heated and a 30 minute pure oxygen purge is initiated in order to react the oxygen in the charge with the silicon to form an exothermic reaction. Following the oxygen purge, a quality control sample of the molten steel is collected to verify that the melt meets appropriate specifications. If the quality control sample is acceptable, the furnace is tapped into the ladle and transferred via an overhead crane to the AOD vessel. Following argon stirring, the steel is transferred to the degassing operation and then cast into slabs.

The AOD process permits the oxidation of carbon from chromium bearing metals without excessive chromium oxidation or extremely high temperatures. This process is accomplished by diluting the oxygen with increasing quantities of inert gas as the carbon level of the heat decreases. The process takes 70-75 minutes to complete, resulting in a final product which contains approximately 0.05% carbon.

During all these processes, high levels of optical radiation (ultraviolet, visible, and infrared) can be produced. Audible sound and infrasonic energy may also be produced by the processes. Additionally, various environmental contaminants can be found throughout the melt shop.

In the SCSAB location, ARMCO has built a high temperature annealing system for steel products. The system uses 450 kilohertz (kHz) radiofrequency (RF) radiation to produce very high temperature levels, about 1000°F/second in 7-9 mil steel material. The URA system was mounted on a steel platform about eight feet off the ground floor. Workers had expressed concerns about possible RF radiation exposure from portions of the system that were not shielded. Figure 1 shows a schematic of the URA system.

IV. EVALUATION DESIGN AND METHODS

On March 20-21, 1990, environmental samples were collected in the melt shop, URA furnace, and an electrical substation. The melt shop was evaluated for potential employee exposure to infrasound and audible noise levels, ultraviolet, visible, and infrared radiation; and various dust and fume exposures including free silica, chromium VI, and trace metals. The URA facility was evaluated for potential RF radiation exposures. Finally, one of the facility's electrical substations was evaluated for potential exposures to 60 Hertz (Hz) electromagnetic radiation. In evaluating worker exposures to both environmental and physical agents, it should be noted that only silicon based steel was evaluated. Other types of steel produced by ARMCO may yield different findings.

A. Environmental

Air samples for total respirable dust and respirable free silica were collected by drawing air at a rate of 1.7 liters per minute (lpm) through a 10 millimeter (mm) nylon cyclone to remove the larger, non-respirable particles, followed by a tared polyvinyl chloride (PVC) filter connected, via tygon tubing, to a battery powered personal sampling pump. The samples were analyzed gravimetrically according to NIOSH Method 0600.[1] The total weight of each sample was determined by weighing the sample and filter and subtracting the previously determined tare weight of the filter. The filters were then dissolved in tetrahydrofuran and further analyzed for free silica using X-ray Diffraction (XRD), according to NIOSH Method 7500.[2]

Air samples for chromium VI analysis were collected by drawing air at a rate of 2.0 lpm through a PVC filter connected via tygon tubing to a battery powered personal sampling pump. The filters were extracted with a sodium hydroxide-sodium carbonate solution and analyzed for chromium VI by visible spectroscopy according to NIOSH Method 7600.[3]

Air samples for trace metals analyses were collected by drawing air at a rate of 2.0 lpm through a mixed cellulose ester (MCE) filter connected via tygon tubing to a battery powered personal sampling pump. The filters were digested according to NIOSH Method 7300[4] and diluted to 25 milliliters (ml) after digestion. A simultaneous scanning inductively coupled plasma (ICP) emission spectrometer was used for the analysis. The spectrometer scans 30 different trace metals during the analysis.

All of the air samples, with the exception of one area sample, were collected as workers wore a pump and filter during their work shift and thus represent breathing zone samples. Furnace workers, crane operators, and maintenance employees were asked to voluntarily wear the sampling pumps for the duration of the shift. The one area sample was collected at the overhead crane level in the southwest corner of the melt shop.

B. Optical Radiation

Optical radiation measurements were made during this evaluation at various distances from the three electric arc furnaces. It became apparent to the NIOSH investigators while performing these measurements that the furnaces had the capability of producing high levels of optical radiation for long periods of time and at varying intensity levels. These findings were confirmed for electric arc furnaces in a previous NIOSH evaluation.[5] However, at this facility it was observed that only a few furnace workers were closer than 20 feet from the furnaces for any length of time. Moreover, all furnace workers, who had to work at very close proximity to the furnaces wore either eye and skin protection or special heat-reflecting suits. As a result of these observations, it was decided to document levels of optical radiation at those unprotected locations where workers could be found, rather than document optical radiation levels in areas where they were adequately protected.

The following equipment was used to document 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 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 the 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 from 200 to 315 nanometers (nm) in biologically effective units of microwatt per square centimeter ($\mu W/cm^2$). The other detector measured near UV (320-400 nm) in units of milliwatt per square centimeter (mW/cm^2) with no biologic weighing factor.

A Solar Light Sunburn meter was used to document the presence of any erythemal 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 $\mu W/cm^2$ over the wavelength range of 200 to 4500 nm. Illumination measurements were performed with a calibrated model 500 Litemate photometer system manufactured by Photo Research, Inc. that reads out in units of lux over the wavelength region of 380 to 760 nm.

C. Extra Low Frequency Fields

An Integrity Electronics model IER-109 60 Hz Magnetic Dosimeter was employed to document worker exposure to magnetic flux density levels near one of the sub-stations close to the melt shop and in the vicinity of the furnaces. The dosimeter can record levels as high as 2 gauss (G) and has a lowest meter indication level (LMIL) of 0 milligauss (mG). At least two readings were made at each measurement location, and the highest reading was recorded. All measurements made with the dosimeter were recorded at four feet above the ground, and at locations where workers were observed to be working.

D. Radiofrequency Radiation

The RF measurements were performed with two different equipment systems due to the frequency range being measured. Measurement of the magnetic (H) field was performed with a Holaday Model 3005 survey meter using a Model LFH-02 probe. The H-field probe is designed to measure frequencies as low as 300 kHz and measures the magnetic field strength in units of amperes squared per meter squared (A^2/m^2). Measurement of the electric (E) field was documented with a Narda Model 8616 Radiation Monitor and a Model 8662B Monitor. The E field monitor is also designed to measure frequencies as low as 300 kHz and its readings can be converted to read in units of volts squared per meter squared (V^2/m^2). Measurements were made at selected locations representative of employees' exposures. All equipment used to document exposure to optical and magnetic fields had been calibrated within six months prior to use in the field by either NIOSH or the equipment's manufacturer. Measurements were made in and around locations where workers had been seen working by the NIOSH investigators.

E. Acoustic Measurements

All infrasonic and sonic acoustic measurements were made with a Larson-Davis Laboratories Model 800B Precision Integrating Sound Level Meter (SLM). The SLM was fitted with a Larson-Davis Laboratories Model 2540 ½" Precision Free Field Microphone which has a lower frequency response limit of 4 Hz. Equivalent sound levels (L_{eq}) at **a**-octave and 1-octave bands, as well as single number measurements adjusted by the A-weighting network, were made at various locations in the Melt Shop near the furnaces. All acoustic measurements were general area samples conducted over short sampling intervals, generally 1 minute or less for each band or scale.

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 health effects if 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 (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 to the limit 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 Recommended Exposure Limits (RELs),[6] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[7] and 3) the U.S. Department of Labor, Occupational Safety and Health Administration's (OSHA) Permissible Exposure Limits (PELs).[8] The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used. The NIOSH-recommended limits, by contrast, are based primarily on concerns relating to the prevention of occupational diseases. In evaluating the exposure levels and the recommendations for reducing the levels found in this report, it should be noted that employers are legally required to meet those levels specified by an OSHA PEL.

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 may come from either the ACGIH, NIOSH, or in some cases from consensus standards promulgated by the American National Standards Institute (ANSI).

A. Environmental

1. Chromium

Chromium exists in a variety of chemical forms depending upon its valence state, a term simply describing the compound's atomic arrangement. It is necessary to specify the form of chromium because of the range of health effects that chromium compounds may cause. For example, elemental (metallic) chromium is relatively nontoxic and does not produce allergic dermatitis.[9] Other chromium compounds can cause primary skin irritation. Skin contact with concentrated hexavalent chromium (CrVI) can cause severe local irritation which could allow extensive CrVI compounds to be absorbed through the skin, leading to possible kidney damage or fatal poisoning.[10] These conditions are associated with prolonged exposure and would be less likely to occur following an isolated, low level exposure.[9] Exposure to chromate salts has also been associated with the development of allergic asthma. This association has been seen in metal platers, who have a prolonged occupational exposure.[9] Chronic exposure to non-respirable dust can produce lesions in the upper respiratory tract, including chronic bronchitis, chronic rhinitis, perforated nasal septum, and occasional papillomas, polyps, and sinusitis.[10] NIOSH has no REL for chromium as a metal. The OSHA PEL is currently set at 1.0 mg/m^3 as a time-weighted average (TWA) and ACGIH recommends a TLV of 0.5 mg/m^3.

In the hexavalent state (CrVI), chromium compounds are irritating, corrosive, and carcinogenic. Until recently, the less water-soluble CrVI forms (i.e., lead and zinc chromate) were considered carcinogenic, while the water-soluble forms were not. Inhalation of high concentrations of CrVI compounds produces coughing, wheezing, pain on inspiration, fever, and loss of weight and, depending on particle size, may cause chemical pneumonitis.[10] Recent epidemiological evidence indicates carcinogenicity among workers exposed to soluble CrVI compounds. Based on this new evidence, NIOSH recommends that all CrVI compounds be considered as occupational carcinogens and have a REL of 0.001 mg/m^3.[11] The ACGIH TLV for both water soluble and water insoluble CrVI is 0.05 mg/m^3, while OSHA has a PEL for hexavalent chromium (referred to as chromic acid and chromates) of 0.1 mg/m^3 as a ceiling concentration.

Trivalent chromium compounds (CrIII), such as chromium oxide, are considerably less toxic than the hexavalent compounds. There is limited evidence of the toxicity of these compounds, probably because of poor penetration into skin and mucous membranes.[9] NIOSH does not have occupational limits for CrIII; however, the ACGIH and OSHA have set limits of 0.5 mg/m^3 as eight-hour TWAs.

2. Lead

Inhalation (breathing) of dust and fume, and ingestion (swallowing) resulting from hand-to-mouth contact with lead-contaminated food, cigarettes, clothing, or other objects are the major routes of worker exposure to lead. Once absorbed, lead accumulates in the soft tissues and bones, with the highest accumulation initially in the liver and kidneys.[12] Lead is stored in the bones for decades, and may cause toxic effects as it is slowly released over time. Overexposure to lead results in damage to the kidneys, gastrointestinal tract, peripheral and central nervous systems, and the blood-forming organs (bone marrow).

The frequency and severity of symptoms associated with lead exposure increase with increasing blood lead levels (BLLs). Signs or symptoms of acute lead intoxication include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort, colic, anemia, high blood pressure, irritability or anxiety, fine tremors, pigmentation of the gums ("lead line"), and "wrist drop."[9,13,14]

Overt symptoms of lead poisoning in adults generally begin at BLLs between 60 and 120 micrograms per deciliter (:g/dl). Neurologic, hematologic, and reproductive effects, however, may be detectable at much lower levels, and the World Health Organization (WHO) has recommended an upper limit of 40 :g/dl for occupationally exposed adult males.[15] The mean serum lead level for U.S. men from 1976-1980 was 16 :g/dl.[16,17] However, with the implementation of lead-free gasoline and reduced lead in food, the 1991 average serum lead level of U.S. men will probably drop below 9 :g/dl.[18]

An increase in an individual worker's BLL can mean that the worker is being overexposed to lead. While the BLL is a good indication of recent exposure to, and current absorption of lead, it is not a reliable indication of the total body burden of lead.[19] Lead can accumulate in the body over time and produce health effects long after exposure has stopped. Long-term overexposure to lead may cause infertility in both sexes, fetal damage, chronic kidney disease (nephropathy), and anemia.

Under the OSHA standard regulating occupational exposure to inorganic lead in general industry, the PEL is 50 $\mu g/m^3$ as an eight-hour TWA.[20] The standard requires semi-annual monitoring of BLL for employees exposed to airborne lead at or above the Action Level of 30 $\mu g/m^3$ (eight-hour TWA), specifies medical removal of employees whose average BLL is 50 µg/dl or greater, and provides economic protection for medically removed workers. The NIOSH REL for lead is less than 100 $\mu g/m^3$ as a TWA for up to 10 hours. This REL is an air concentration to be maintained so that worker blood lead remains below 60 µg/100 grams of whole blood. NIOSH is presently reviewing literature on the health effects of lead to re-evaluate its REL. The OSHA PEL for general industry is currently recommended by NIOSH investigators as a more protective criteria.

Recent studies suggest that there are adverse health effects at BLLs below the current evaluation criteria for occupational exposure. A number of studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dl. Male BLLs are associated with increases in blood pressure, with no apparent threshold through less than 10 µg/dl. Studies have suggested decreased fertility in men at BLLs as low as 40 µg/dl. Prenatal exposure to lead is associated with reduced gestational age, birthweight, and early mental development at prenatal maternal BLLs as low as 10 to 15 µg/dl.[21]

In recognition of the health risks associated with exposure to lead, a goal for reducing occupational exposure was specified in *Healthy People 2000*, a recent statement of national consensus and U.S. Public Health Service policy for health promotion and disease prevention. The goal for workers exposed to lead is to eliminate, by the year 2000, all exposures that result in BLLs greater than 25 µg/dl.[22]

In homes with a family member occupationally exposed to lead, lead dust may be carried home on clothing, skin, and hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust, have been found in the homes of workers employed in industries associated with high lead exposure.[23] Particular effort should be made to ensure that children of workers with lead poisoning, or who work in areas of high lead exposure, are tested for lead exposure (BLL) by a qualified health-care provider.

3. Respirable Particulates

Respirable particulates generated during foundry work consists of solid particles of metals, silica, and other materials which may be suspended in air and inhaled into the deep portions of the lung (the air sacs, or alveoli). The current OSHA PEL for respirable nuisance dust (particulates not otherwise regulated) is 5 milligrams per cubic meter (mg/m^3) of air.[8] The 1991-1992 ACGIH TLV for total nuisance dust, Particulates Not Otherwise Classified (PNOC), is 10 mg/m^3.[7] These evaluation criteria were established to minimize mechanical irritation of the eyes, nose, throat and lungs. Because the particulates in a foundry may consists mainly of silica and metals, the nuisance dust criteria would not be considered protective enough.

4. Silica

Crystalline silica, usually referred to as free silica, is defined as silicon dioxide (SiO_2) molecules arranged in a fixed pattern, as opposed to a nonperiodic, random molecular arrangement referred to as amorphous silica. The three most common forms of free silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common form.

The principal adverse health effect of crystalline silica is the dust-related respiratory disease, silicosis. Silicosis is a form of diffuse interstitial pulmonary fibrosis resulting from the deposition of respirable crystalline silica in the lung. Conditions of exposure may affect both the occurrence and severity of the disease. Although silicosis usually occurs after fifteen or more years of exposure, latent periods of only a few years are well recognized and are associated with intense exposures to respirable dust high in free silica. Tunnellers and sandblasters may develop rapidly progressive symptoms in their thirties or even late twenties.[10]

In its early stages, simple silicosis usually produces no symptoms, with the disease not progressing beyond isolated silicotic nodules, the characteristic lesion found in the upper lobes of the lung.[24] In some individuals, the silicotic nodules form large masses of fibrous tissue, a process called progressive massive fibrosis (PMF). The PMF lesions tend eventually to contract, resulting in an overall shrinkage of the lungs. Accelerated silicosis, seen in circumstances of heavier silica exposures, has similar pathologies to the chronic type of the disease. However, the progression is faster with PMF being more common in the middle and basal portions of the lung. Acute silicosis, a rare condition associated with extraordinarily heavy exposures to respirable free silica, is characterized by lungs with diffuse fibrosis and consolidation in the lower and middle zones. With both acute silicosis and PMF, shortness of breath, intolerance for exercise, and a marked reduction in measured pulmonary function are the most common symptoms. In advanced cases, the respirations are labored even at rest.[10] Diagnosis is most often based on a history of occupational exposure to free silica and the characteristic appearance of the disease on chest X-rays. Respiratory failure and premature death may occur in advanced forms of the disease. Individuals with silicosis are also at increased risk of developing tuberculosis. No specific treatment is available for silicosis, and the disease may progress even after the worker's exposure to silica has ceased.[25]

Several epidemiological studies have shown an association between silicosis and lung cancer.[26-28] In its 1987 Monograph on silica, the International Agency for Research on Cancer (IARC) reviewed the data regarding crystalline silica and determined that there is sufficient evidence for the carcinogenicity in laboratory animals and limited evidence for human carcinogenicity.[29] The data meet OSHA's definition of a potential occupational carcinogen as defined in 29 CFR 1990. Based on this recent evidence, NIOSH has revised its policy on crystalline silica exposure criteria and has recommended that OSHA consider crystalline silica as a potential occupational carcinogen.[11]

The current OSHA PEL for crystalline silica (cristobalite and tridymite) as quartz (respirable dust) is 0.05 mg/m^3 as an eight-hour TWA.[8] The OSHA PEL for crystalline silica (crystalline quartz) as quartz (respirable dust) is 0.1 mg/m^3 as an eight-hour TWA.[8] The 1991-1992 ACGIH TLVs are identical to the OSHA PELs for these compounds.[7] Because of the ubiquitous nature of exposure to crystalline silica and often concomitant occupational exposure (or through tobacco smoking) to one or more carcinogenic chemicals, it is recommended that the greatest degree of protection could be gained by the adherence to the NIOSH REL of 0.05 mg/m^3 (for all forms of crystalline silica) which approaches the lowest quantifiable limit of detection.[6] This rationale would apply to protection against silicosis as well as the reported potential carcinogenicity from exposure to certain crystalline silica.

5. The following table is a list of the current occupation health criteria for the remaining airborne particulates measured in this evaluation:

Table 1

Current Time-Weighted Average Exposure Levels

Compounds	OSHA PEL[8]	ACGIH TLV[7]	NIOSH REL[6]
	(all in mg/m^3)		
Iron	10	5	NA
Manganese	5	5	1

NA - Not Applicable (NIOSH does not have a recommended criteria, therefore, the lower criteria, either by OSHA or ACGIH, is recommended.

B. Optical Radiation

1. Infrared Radiation[7, 30-32]

All objects having temperatures above absolute zero (0°K) 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. 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 increased 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 has cast serious doubts upon 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 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 of exposure. If the radiation intensity is low enough, the normal retinal blood supply 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.

2. Visible Radiation[7, 33-35]

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 have high intensities at certain wavelengths, the possibility that retinal damage may occur requires the use of protective eye wear devices. These types of direct effects, i.e., staring at welding arcs or at the sun, have been well known for many years and documentation exists within the scientific literature.

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

Another issue concerning visible radiation is associated with poor room or task lighting conditions. Such conditions can lead to asthenopia (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, and irritation) since they require more light to perform a similar job than younger workers.

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

3. Ultraviolet Radiation[7, 35,36]

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 including exposure time, intensity of the radiation source, distance from the source, wavelength, sensitivity of the individual, and the presence of sensitizing agents.

Sunburn is a common example of the effect of UV radiation on the skin. Repeated UV exposure to lightly pigmented individuals may result in actinic skin, characterized as dry, brown, inelastic, and 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 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 also need to be aware that photosensitizing agents may exist in the workplace which, upon contact with the skin, produce exaggerated sunburn when simultaneously exposed to UV at certain wavelengths.

C. Radiofrequency Radiation[7, 30, 37,38]

Absorption of radiofrequency (RF) radiation can adversely affect a worker's health since it produces heating of body tissues. RF radiation can penetrate the body and cause heating of internal tissues. The body's heat sensors are located in the skin and do not readily sense heating deep within the body. Therefore, workers may absorb large amounts of radiation without being immediately aware of the presence of such energy. There have been reports that personnel exposed to RF fields from radar equipment, RF heaters and sealers, and radio/TV towers have experienced a warming sensation some time after being exposed. Absorption of RF energy may also result in "non-thermal" effects on cells or tissues, which occur without a measurable increase in tissue or body temperature. Such effects are reported to occur from exposure to RF energy at levels lower than those sufficient to cause thermal effects.

Exposure of pregnant animals to thermal levels of RF energy can cause birth defects and kill the fetus. RF exposures have also been associated with human miscarriages, irregular menstrual cycles, and decreased lactation in nursing mothers. There is little supportable evidence that RF radiation can cause cancer. However, recent evidence suggests that it may act as a cancer promoter in animals. There is no consensus on the potential hazard of low-level chronic RF radiation exposure, but biological changes definitely occur during, or following, relatively low intensity exposure.

There is agreement that the incidence and severity of RF biological effects are related to the magnitude of radiation power absorbed by the body. This absorption depends strongly upon the frequency and intensity of the radiation, the size and shape of the exposed worker, and the worker's orientation in the radiation field. The human body maximally absorbs RF radiation in the frequency range of 30 to 300 Megahertz (MHz). Outside of this frequency range, much less energy is absorbed by the body.

The ACGIH TLV for 450 kHz radiation for an 8-10 hour exposure is 3.77×10^5 V^2/m^2 (E-Field) and 2.65 A^2/m^2 (H-Field). The OSHA regulation for E- and H-Fields is 4.0×10^4 V^2/m^2 and 0.25 A^2/m^2, respectively. Exposures for the OSHA regulation are averaged over a six-minute period.

D. ELF Radiation[7, 39,40]

It is known that E- and H-fields resulting from extra low frequency (ELF) radiation can produce a variety of effects in biological systems. Whether such effects can pose significant health risks from an occupational exposure has not yet been established. Workers in the United States have been exposed to ELF (60 Hz) fields for many years without reports of major health concerns other than electrocutions. However, within the last decade there have been several epidemiological studies that have raised issues about such risks as cancer, especially leukemia and brain tumors, developmental abnormalities, endocrine and nervous system disorders.

Humans can perceive E-fields above 4 to 12 kilovolts per meter (kV/m) from the stimulation of sensory organs in skin. Perception of H-fields at 10 gauss (G) and above result from stimulation of the visual system.

The ACGIH has published TLVs for sub-radiofrequency electric and magnetic fields. At 60 hertz, electric field strength should not exceed 25 kV/m and magnetic flux density should not exceed 10 G. It should be noted that both of these levels are normally far in excess of the reported typical exposure levels found in the environment and/or workplaces.

E. Acoustic Energy

Occupational deafness was first documented among metalworkers in the sixteenth century.[41] Since then, it has been shown that workers have experienced excessive hearing loss in many occupations associated with noise. Noise-induced loss of hearing is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. This noise-induced loss is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, cannot be treated medically.[42]

While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 200 Hz to 2000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist", have still higher frequency components.[43]

1. Audible Noise

The OSHA existing standard for occupational exposure to noise (29 CFR 1910.95)[44] specifies a maximum permissible exposure level (PEL) of 90 decibels on the A-weighting network [dB(A)]-slow response for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship. This means that in order for a person to be exposed to noise levels of 95 dB(A), the amount of time allowed at this exposure level must be cut in half in order to be within OSHA's PEL. Conversely, a person exposed to 85 dB(A) is allowed twice as much time at this level (16 hours) and is within his daily PEL. Both NIOSH, in its Criteria for a Recommended Standard,[45] and the American Conference of Governmental Industrial Hygienists (ACGIH), in their Threshold Limit Values (TLVs),[7] propose an exposure limit of 85 dB(A) for eight hours, 5 dB less than the OSHA standard. Both of these latter two criteria also use a 5 dB time/intensity trading relationship in calculating exposure limits.

Time-weighted average (TWA) noise limits as a function of exposure duration are presented in Table 2.

Table 2

	Duration of Exposure (hrs/day)	Sound Level (dB(A)) NIOSH/ACGIH
OSHA		
16	80	85
8	85	90
4	90	95
2	95	100
1	100	105
1/2	105	110
1/4	110	115 *
1/8	115 *	-**

* No exposure to continuous or intermittent noise in excess of 115 dB(A).

** Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

The OSHA regulation has an additional action level (AL) of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the AL. The program must include monitoring, employee notification, observation, an audiometric testing program, hearing protectors, training programs, and recordkeeping requirements. All of these stipulations are included in 29 CFR 1910.95, paragraphs (c) through (o).

The OSHA noise standard also states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dB(A), feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels. Also, a continuing, effective hearing conservation program shall be implemented.

2. Infrasound

Acoustic energy below the audible range of human hearing is called infrasound. This includes frequencies below 16-20 Hz that are transmitted through the air. Structure-borne energy in this frequency range is usually described as vibration. Environmental infrasound is the result of transportation vehicles, industrial processes, and the operation of machinery. Car noise has been measured at 92 - 117 dB Sound Pressure Level (SPL) at frequencies less than 1 Hz up to 28 Hz.[46-47] There are also natural occurrences of infrasound resulting from earthquakes, waves in water, waterfalls, air turbulence, and thunder. Activities pursued by human beings will also produce infrasonic energy. Walking, jogging, and swimming all produce infrasound that has been measured at levels up to 140 dB.[48]

Leventhall[49] measured several sources of infrasound in the workplace. Certain foundry operations were found to have infrasound components which had peak frequencies at 25 Hz. Infrasound measured on the charging platform of a Tuyère furnace was found to have intensity levels at 125 dB SPL. Also, infrasonic intensities at the shaker tables in a foundry knock-out plant were measured up to 129 dB SPL. A blast furnace produced levels of 115 dB SPL at a peak frequency of 7 Hz.

Exposure to infrasound will elicit a variety of nonauditory and auditory responses in human listeners. The nonauditory responses have been described as an apparent gentle massage of the tympanic membrane through pressure build-up to a sensation of pain.[48] The auditory sensation is frequently described as a chugging or motorboat sound. This auditory component is the result of nonlinear distortion products produced by the middle ear.[50-51] Laboratory studies that have investigated the amount of hearing change as a result of exposure to intense infrasound have generally found little or no temporary change in hearing thresholds as a result of these exposures.[52-54] Johnson,[55] in a review of this literature, found that infrasound apparently does not cause temporary threshold shift (TTS) in human listeners from exposures less that 140 dB which continue for less than 30 minutes.

Animal studies have investigated tissue damage as a result of intense infrasound. Gordeladze, Glinchikov, and Usenko[56] exposed guinea pigs and rats to an infrasonic field of 8 Hz at 120 dB. These authors reported that the infrasound caused damage to the myocardium, primarily involving the cardiomyocytes and disturbances to the microcirculation process. The damage was dependent on the duration of the exposure. A second study[57] looked at the effects of variable frequency and intensity infrasonic fields on lung tissue in white mice. Their research showed that exposure to 2 or 4 Hz energy at 90 to 110 dB can induce lung damage to the animals. Other studies[58-60] have reported damage to the liver and to the middle and inner ear of laboratory animals exposed to infrasound.

There are reports of the effects of infrasound on human physiology and psychological functioning. Danielsson and Landstrom[61] report that infrasound exposures reduced both systolic blood pressure and pulse rate, while increasing diastolic blood pressure. Lidstrom, et al.[62] reported similar changes in blood pressures resulting from exposure to 125 dB of infrasound. Other authors[63-65] investigated infrasound exposure effects on psychological functioning in human subjects. The studies report minimal or no effects on performance resulting from the infrasound.

There are currently no standards for occupational exposures to infrasound. The ACGIH has listed infrasound as a physical agent under study in the most recent TLV booklet.[7] The level that infrasound becomes dangerous to humans is still unknown. Levels of infrasound up to 150 dB have been declared safe for humans by researchers in this field.[55, 66-67] Recommended exposure levels for infrasound were proposed by von Gierke and Parker[48] in their review of the literature.

Maximum exposure durations for selected frequencies of infrasound were derived from extrapolation of reported data and thus, should be used with caution. Their proposed standard is given in Table 3.

Table 3

Recommended maximum permissible exposures to infrasound

	Frequency			
Duration (hours)	1 Hz	5 Hz	10 Hz	20 Hz
1	145 dB	138 dB	135 dB	132 dB
8	136 dB	129 dB	126 dB	123 dB
24	131 dB	124 dB	121 dB	118 dB

VI. RESULTS

A. Environmental

Table 4 presents the air sampling results for respirable dust and free silica. Respirable dust concentrations ranged from 0.35 mg/m^3 to 1.72 mg/m^3, levels which are all less than applicable evaluation criteria. Only one of the six respirable quartz samples revealed a trace level, between the limit of detection (LOD) and the limit of quantitation (LOQ), of free silica (LOQ = 0.03 mg).

Table 5 presents the air sampling results for chromium VI. CrVI concentrations ranged from 0.31 to 1.92 µg/m^3. The results where personal samples exceed the NIOSH REL of 1.0 µg/m^3 include a ladle crane operator and employees working at Furnace #2. The area sample taken in the southwest corner of the melt shop also exceeds the REL.

Table 6 presents the air sampling results for the significant airborne trace metals identified by the ICP analysis. Lead levels were found to range between 1.3 and 44.2 µg/m^3. Three samples exceed the OSHA action level for lead of 30µg/m^3. These samples were collected on a maintenance employee, a ladle crane operator, and a laborer engaged in cleaning during the work shift. Total chromium concentrations ranged from 2 to 257 µg/m^3 and iron concentrations ranged from 0.04 to 2.98 mg/m^3. These values are below all of the appropriate evaluation criteria. Manganese concentrations ranged from 0.00 to 14.32 mg/m^3. The highest value of manganese exposure was measured for a maintenance worker engaged in unloading metal alloys from trucks. This measurement exceeds the OSHA ceiling level for manganese. Additionally, very low levels of aluminum and zinc were detected.

B. Optical Radiation

A total of 35 measurements of both near and far UV levels were made at distances greater than 25 feet from all operating furnaces during the survey. All of the results were found to be below the TLVs for UV exposure. Measurements were made with both the furnace door open and closed, with the detector located four feet above the floor. The sunburn meter indicated non-detectable levels of UV everywhere in the facility beyond 25 feet from the furnaces. The only detectable readings obtained with the meter were taken outside, with an average of 0.9 sunburn units (SBU). Illumination measurements were performed at many sites in the vicinity of the furnaces. The majority of light sources used at the plant were medium wattage mercury and sodium vapor lamps. The illumination levels ranged from 30 to 700 lux in control booths, along walkways, in offices, equipment room area, and rest areas. The measurements generally represent adequate amounts of lighting for the tasks performed according to the relevant evaluation criteria.

Luminance levels in front of the open furnaces ranged anywhere from 10 to 200 cd/cm^2 at distances 20 feet from the furnace. The high range luminance levels occurred during the early heating phase when the material shifted rapidly during breakdown. The high value was over a short time interval, lasting no more than half a minute total time. Luminance levels in the crane cabinet ranged from 3 to 17 cd/cm^2 during the time filled ladles were lifted and transported from one of the building to the other end. The low range value occurred with the crane windows closed. The luminance levels measured in several locations exceeded the ACGIH TLV for broad-band light exposures (1.0 cd/cm^2).

Measured infrared radiation levels at the facility at distances up to 30 feet exceeded 100 mW/cm^2 during various phases of furnace operations. Measurements made 45 feet from the furnaces exceed the ACGIH TLV when the doors of the furnaces were open. Levels in the furnaces' control booths (approximately 10 feet from the furnace but positioned perpendicular to the furnace) did not exceed the TLV. However, at locations where cracks in control booths occur, the potential exists for employees to be overexposed to IR radiation. Only when the crane windows were open was there any cause for concern about IR exposures to the crane operators. Levels did exceed 10 mW/cm^2 in some cases, depending on how long the ladle was carried and at what distance from the crane the material was positioned.

C. RF Radiation

Radiofrequency measurements at several worker locations on the Ultra-Rapid Annealing (URA) system (Figure 1) were in excess of both the ACGIH TLV and ANSI standard. Radiofrequency radiation levels varied from 0.5×10^3 V^2/m^2 to 1.0×10^6 V^2/m^2 for the E-field and from 2 A^2/m^2 to 4 A^2/m^2 for the H-field. The entire URA system had been installed on a large metal platform about eight feet off of the ground and was accessible by a stairway. While the system was out of the way for other workers, the location off of ground created unique grounding problems. The metal housing surrounding the RF generator had visible gaps in the cabinet and will require additional shielding to prevent the leakage of RF radiation. This prototype annealing system had just been installed at ARMCO. Unfortunately, the ARMCO safety office, at the time of the NIOSH evaluation, did not have any RF monitoring equipment and little expertise in making RF measurements. Due to the presence of high electric and magnetic fields in the vicinity of the workers, the need for additional shielding of the generator housing, and better grounding for the system, the NIOSH investigators recommended during the investigation that the system not be made operational until the company called in consultants to resolve these problems.

D. ELF Radiation

A limited number of ELF (60 Hz) magnetic field measurements were made near the furnaces, in the control rooms, and in a nearby electrical sub-station yard. Magnetic field intensity levels ranged from 30 to 800 mG at distances of 20 feet from the furnaces and from 30 to 40 mG existed in two of the control booths. No measurements were taken any closer than 20 feet from the furnace since the meter would saturate its maximum level of 2 G.

Magnetic field strengths in the sub-station yard ranged from 30 to 700 mG and 1 to 3 mG in two offices adjacent to the yard. Levels at the sub-station were directly influenced by the distance the meter was held from transformers and large current-carrying wires. While none of the measurements exceeded 700 mG in the yard, it was obvious to the NIOSH investigator that certain locations around the transformers and wires may yield higher field strengths.

E. Acoustical Energy

The area noise measurements made in various locations in the melt shop revealed that the infrasonic levels were well below the proposed evaluation criteria. Both the **a**-octave and 1-octave noise measurements (Figures 2-4) showed noise in the infrasonic range was less than 95 dB. The maximum noise energy was consistently found at 125 Hz in all measurement locations. When A-weighted noise measurements were made in the various locations, they were found to range from 87 dB(A) in the overhead crane cab to 102 dB(A) on the melt shop floor between furnace #2 and #3.

VII. DISCUSSION

A. Environmental

During the collection of the environmental samples, employees expressed a concern that the airborne exposures may not have been typical of a normal production shift. Many of the employees felt that the airborne dust levels were not as "thick" during the periods when our samples were collected. Upon review of the previous three weeks' production sheets, it does appear that our samples represented exposure levels collected during normal production days. The three previous weeks' production sheets revealed an average of 15 heats on a typical day when the AOD is not in operation and 12 heats a day when the AOD is in operation. During our sample collection on March 20, 1990, when the AOD was not in operation, there were 17 heats tapped. During March 21, 1990, when the AOD was in operation, there were 13 heats tapped. Therefore, we feel that the airborne samples are representative of normal production shifts.

The results of air samples collected in the melt shop revealed exposures which were in excess of the established occupational health criteria. One over-exposure sample to manganese was collected on the laborer who was responsible for unloading the bulk manganese from the truck bed outside of the melt shop. The sample results for chromium VI show that it is present and should be of concern, since all forms of CrVI are potential occupational carcinogens. Excess levels of CrVI were found for two of the helpers on Furnace #2 and for a ladle crane operator. Additionally, an area sample from the southwest corner of the melt shop was also in excess of the NIOSH REL for hexavalent chromium. The lead sample results are also of concern, since three of the samples are above the OSHA lead standard's action level of 30 $\mu g/m^3$, which requires the employer to initiate exposure monitoring, medical surveillance, and training/education of the employees. The sample results for total respirable particulates and free silica were below the occupational health criteria and do not represent a serious health hazard. Finally, the sample results for iron, aluminum, and zinc in the melt shop are also below the relevant occupational health criteria.

The NIOSH investigators were concerned about how well the crane operators were able to view their work area from the cranes. The airborne dust levels do considerably reduce the crane operators' ability to view their task at times, thereby constituting a serious safety hazard to the workers below. The concern is for those workers that direct the crane operator while picking up the ladle. Many of the crane operators stated that they cannot see the workers below on many occasions. After riding in the cranes, the NIOSH investigators agreed that at times it is difficult to see the workers below and that the potential for a serious accident to occur does exist.

One final area of concern expressed by the employees during our investigations, was that they are not informed of the results of air sampling conducted by the company. NIOSH investigators agree with the employees that any sampling results should be reported to the affected employees. In some instances, OSHA regulations require that affected employees be informed of the results of air sampling. Management stated that they do report the results to the appropriate supervisors, and it is up to the supervisors to inform their workers. NIOSH investigators did see the reports issued by the ARMCO safety office, but feel that a communication problem may exist and that the supervisors are not informing the employees of the sampling results. NIOSH investigators also feel that the supervisors may not be the best choice to inform the workers of the sampling results and to provide any explanations which may be necessary. The task would be better handled by ARMCO's safety office.

B. Optical Radiation

Based on the results obtained in this evaluation, two problems need to be addressed by ARMCO. One is the magnitude of occupational IR exposure and the other is the use of appropriate eye protection.

The measurements clearly indicate that high levels of IR exist at ARMCO. It should be noted that workers exposed to high levels of IR can experience ocular and skin problems, as well as drying of the mucous membranes, upper respiratory difficulties, and shortness of breath. Since all of these symptoms were reported to NIOSH by workers in the melt shop, the control of exposure to excessive IR should be attempted. Some degree of protection from excessive optical radiation is provided by control booths. However, it was noted that the windows in some of the booths are in need of replacement or repair. A determination of the equivalent optical density protection afforded by the existing window material in the booth using spectrophotometric techniques needs to made by ARMCO. Moreover, an evaluation of the spectral transmission levels of the existing booth windows should be made by ARMCO. The determination of transmission levels will indicate the possible occupational exposure potential to workers in these areas. Samples of the window materials can be tested for equivalent optical density protection with typical spectral photometry.

A control measure that needs to be investigated is the use of heat treated plastic face shields to reduce the IR exposure to the unprotected face. While workers wore eye protection, many of them had "red-faces" from walking around the furnace area during its operation. These "red-faces" were caused by the IR photons being absorbed on unprotected skin which causes erythema. It is necessary that the face shields be heat-treated since they may warp or become distorted from the excessive heat produced in the melt room.

One work practice that needs to be eliminated is the wearing of blue-cobalt lenses as universal eye protection. These lenses are designed to be used to check the temperature of the material inside of the furnace. In order to perform the task, the blue-cobalt lenses are designed to transmit wavelengths as shown in Figure 5. The lenses do not attenuate the intensity of hazardous blue light produced by the electric arc. Hence, the workers must be careful to look at the melt for only short time periods and avoid direct viewing of the arc. Since the luminance levels associated with this practice were also above the TLV, exposure to workers could potentially produce retinal damage from both blue light and IR contributions. One method of reducing the number of exposed workers to this hazard would be to limit the number of such lenses issued to workers. During the time of the evaluation, it was apparent that almost all workers either wore or possessed blue-cobalt lenses. NIOSH investigators believe that the number of these lenses issued is greater than the number of workers who actually have the responsibility for determining the temperature of the furnaces. If a worker does not have this responsibilty, then he or she should not possess or use the blue-cobalt lenses.

Another problem arises when workers wearing what they believe to be the universal ARMCO eye protection for optical radiation perform operations that emit high energy levels of blue light, such as welding. On several occasions, NIOSH investigators observed welding processes being conducted by ARMCO workers wearing the blue-cobalt lenses. The ARMCO safety office was informed during the evaluation that this practice should cease immediately and appropriate welding filters be issued to the affected employees.

C. ELF Fields

While none of the results of ELF magnetic field measurements exceeded the ACGIH TLV, it should be noted that only a limited number of measurements were documented in this evaluation. It is suggested that the measurements reported in this evaluation be considered as evidence that magnetic fields do exist near the furnaces at ARMCO and that additional measurements should be performed by the ARMCO safety personnel.

D. Radiofrequency Radiation

The magnitude of electric and magnetic fields documented at the URA facility definitely require more attention by ARMCO. On the day of measurement the NIOSH investigators suggested that ARMCO consider the use of RF consultants to help with the shielding design and grounding problems. Several consultant names were given to ARMCO personnel. The ARMCO safety office informed the NIOSH investigators in a telephone conversation after the evaluation that consultants have already been called in and that all of these problems have been resolved.

E. Acoustic Energy

No hazardous levels of infrasound were measured during the site visit. However, this does not mean that infrasound cannot exist on the melt shop floor. High levels of infrasound have been described in foundry operations by other authors.[49] It is possible for the 60 Hz electrical current from adjacent arc furnaces to interact in such a manner that very low frequencies of sound energy will be produced. The conditions on the days of the survey may not have been optimal for this phenomenon to occur.

Short-term, A-weighted measurements made on the melt shop floor revealed exposures in excess of 100 dB(A). Current OSHA noise regulations allow only a two hour daily exposure time to noise levels of this magnitude. Noise measurements made inside of the furnace control rooms showed that the rooms offer good attenuation of the noise energy from the furnace operations. Previous full-shift noise samples made by ARMCO have shown that melt shop employees are exposed to noise levels in excess of 90 dB(A) TWA.

VIII. CONCLUSIONS

NIOSH investigators found excess employee exposures to chromium VI, manganese, and lead in the melt shop on the days of the evaluation. Also, high levels of IR and RF radiation were measured in the melt shop and at the URA furnace. A potential safety hazard exists to workers on the floor of the melt shop because of the limited visibility of the overhead crane operators. Based on the results, the NIOSH investigators have determined that a potential health hazard existed at the time of the evaluation.

IX. RECOMMENDATIONS

The following recommendations are offered to reduce potentially significant occupational exposures and safety risks at Armco.

1. An enclosure should be constructed outside of the melt shop to contain and reduce the levels of manganese and other dusts that are produced when raw materials are unloaded from trucks.

2. Crane operators need to be made aware of the fact that when the windows in the crane cab are opened, both the luminance and smoke levels to which they are exposed can rapidly increase. This strongly supports the need for crane cabinets that remain air conditioned and have windows with sufficient optical density glass to attenuate the optical radiation produced by the suspended ladles filled with molten metal transported by the cranes.

3. ARMCO should restrict the number of blue-cobalt lenses available to workers. In addition, welders need to be trained to insure that they use welding filters and not blue-cobalt lenses. The OSHA welding standard (29 CFR 1910.252)[68] stipulates that welders shall use helmets or hand shields during all arc welding or arc cutting. Helpers or attendants are to be provided with the proper eye protection. Cobalt-blue lenses do not fall into the category of proper eye protection.

4. The requirements of the OSHA lead standard (29 CFR 1910.1025) may have to be initiated. The NIOSH air monitoring results showed that three employees exceeded the OSHA action level of 30 $\mu g/m^3$. These findings should prompt the ARMCO safety office to perform an initial determination using their own air monitoring to see if any employee is exposed to lead levels above the action level. If it is determined that employees are exceeding the action level for lead exposure, then ARMCO is required to follow the requirements set forth in the OSHA lead standard when such conditions do exist.

5. Air monitoring for metals in the melt shop should be continued by ARMCO. Based on the results of the NIOSH survey, particular attention should be directed to monitoring the airborne levels of chromium VI to which the employees are exposed.

6. The general ventilation system for the melt shop should be improved to reduce airborne dust levels and increase visibility for the crane operators so that they can better see the work floor around the furnaces. As was discussed during the closing conference on March 22, 1990, the ventilation system might be altered so that the exhaust dampers above each of the furnaces could be individually controlled to open to full capacity when

that furnace is opened and to reduce the capacity of the dampers over the other furnaces during that period.

7. The results of environmental monitoring for chemical or physical agents in the workplace should be reported immediately to the workers. The sample results should be posted in a location accessible to all the affected employees. A representative of the ARMCO safety office, rather than floor supervisors, should explain any sampling results to the workers during their weekly safety meetings.

8. ARMCO's medical department should determine if any additional eye exams should be performed for those workers who are required to work at very close distances to furnaces.

9. The safety office should purchase appropriate ELF monitoring instrumentation to evaluate areas near the furnaces (i.e. at distances less than 20 feet).

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1. Senior Safety & Industrial Hygiene Engineer, Armco Advanced Materials Corporation
2. Union Representative, Butler Armco Independent Union
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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 4

Respirable Dust and Quartz Concentrations
ARMCO Advanced Materials
Butler, Pennsylvania
HETA 89-364
March 20-21, 1990

Job Description	Sample Period (hh:mm)	Air Volume (liters)	Respirable Dust (mg/m^3)	Quartz Concentration (mg/m^3)
Maintenance	07:24	733	0.74	ND
3rd Helper Furnace #4	05:58	591	0.41	ND
2nd Helper Furnace #3	06:26	637	0.97	Trace
Ladle Crane	06:58	677	0.83	ND
Floor Crane	07:17	721	0.35	ND
Laborer (Cleaning)	07:17	721	1.72	ND
Environmental Criteria		NIOSH REL OSHA PEL ACGIH TLV	NA 5.0 NA	0.05 0.10 0.10

ND = None Detected NA = Not Applicable (No standard has been issued.)

Trace = Concentration falls between the Level of Detection and Level of Quantification.

TABLE 5
Selected Trace Metal Concentrations
ARMCO Advanced Materials
Butler, Pennsylvania
HETA 89-364
March 20-21, 1990

Job Description	Sample Period (hh:mm)	Air Volume (liters)	Chromium (μg/m³)	Lead (μg/m³)	Aluminum (mg/m³)	Iron (mg/m³)	Manganese (mg/m³)	Zinc (mg/m³)
Maintenance	06:58	815	135.00	44.17	0.16	1.59	0.11	0.37
Charge Operator	04:09	498	4.02	6.02	ND	0.08	0.01	0.04
2nd Helper Furnace #4	05:57	678	10.32	7.37	0.01	0.16	0.01	0.04
1st Helper Furnace #3	06:31	782	7.67	15.34	0.01	0.17	0.01	0.08
1st Helper Furnace #2	06:58	815	24.54	3.68	ND	0.12	0.01	0.04
AO Operator	06:42	784	5.10	1.28	ND	0.04	0.00	0.01
Environmental Criteria		NIOSH REL OSHA PEL ACGIH TLV	500 1000 500	100 50 150	NA 15 10	5 10 5	1 5(C) 5	NA 10 10

ND = None Detected NA = Not Applicable (No standard has been issued.) C = Ceiling Level

TABLE 5 (Continued)
Selected Trace Metal Concentrations
ARMCO Advanced Materials
Butler, Pennsylvania
HETA 89-364
March 20-21, 1990

Job Description	Sample Period (hh:mm)	Air Volume (liters)	Chromium ($\mu g/m^3$)	Lead ($\mu g/m^3$)	Aluminum (mg/m^3)	Iron (mg/m^3)	Manganese (mg/m^3)	Zinc (mg/m^3)
Ladle Crane	06:48	816	2.45	7.35	ND	0.10	0.01	0.05
Ladle Crane	07:12	842	29.69	35.63	0.02	0.22	0.04	0.12
Crane R-4	07:10	828	20.53	13.28	ND	0.14	0.01	0.14
Laborer (Cleaning)	07:18	854	257.61	31.62	0.05	0.70	0.21	0.44
Truck Unloader	06:59	838	95.46	4.77	0.08	2.98	14.32	0.01
Area Sample - Southwest Corner, Crane Level	06:51	801	84.89	21.22	0.04	0.51	0.04	0.14
Environmental Criteria		NIOSH REL OSHA PEL ACGIH TLV	500 1000 500	100 50 150	NA 15 10	5 10 5	1 5(C) 5	NA 10 10

ND = None Detected NA = Not Applicable (No standard has been issued.) C = Ceiling Level

TABLE 6

Chromium VI Concentrations
ARMCO Advanced Materials
Butler, Pennsylvania
HETA 89-364
March 20-21, 1990

Job Description	Sample Period (hh:mm)	Air Volume (liters)	Chromium VI Concentration (μg/m^3)
1st Helper - Furnace #4	06:09	738	0.31
1st Helper - Furnace #3	06:30	760	0.47
2nd Helper - Furnace #2	07:00	819	1.15
3rd Helper - Furnace #2	07:02	823	1.94
Senior Melter	06:36	792	0.57
AO Helper	06:39	758	0.59
Ladle Crane	07:07	811	1.23
Floor Crane	06:20	741	0.43
Maintenance	07:03	825	0.54
Utility Man	06:00	720	0.40
Laborer (Cleaning)	07:17	830	0.58
Area Sample - Southwest Corner, Crane Level	06:51	781	1.92
Environmental Criteria		NIOSH REL OSHA PEL ACGIH TLV	1 100(C) 50

C = Ceiling Level

TABLE 7

Comparison of Maximum Radiation Fields with
Occupational Exposure Limits
ARMCO Advanced Materials
Butler, Pennsylvania
HETA 89-364
March 20-21, 1990

Radiation Field (wavelength/frequency)	Maximum Measured Level	Occupational Exposure Limit*	Primary Health Effect
Actinic UVR (200-315 nm)	None Detected	0.1 eff $\mu W/cm^2$ in 8-hour day	photokeratitis and erythema
Near UVR (320-400 nm)	$< 1\ \mu W/cm^2$	1.0 mW/cm^2 for periods > 16 min	photo-sensitivity
Luminance (400-760 nm)	200 cd/cm^2	1.0 cd/cm^2 in 8-hour day	retinal burns
Illumination (380-760 nm)	700 lux	200-500 lux	visibility
Infrared (760-1400 nm)	130 mW/cm^2	10 mW/cm^2 in 8-hour day	dry eye/skin, cataracts
ELF (60 Hz)	800 mG	10 G in 8-hour day	stimulation of visual system
Radiofrequency (450 kHz)	$1.0 \times 10^6\ V^2/m^2$ & 4 A^2/m^2	$4 \times 10^4\ V^2/m^2$ & 0.25 A^2/m^2 in 6-min interval	body currents & thermal effects

* All of the exposure limits are taken from the 1991-1992 edition of the ACGIH TLVs for Physical Agents, except for illumination and radiofrequency. The illumination value is from the Illuminating Engineering Society Handbook. The radiofrequency criteria are the limits set by OSHA.

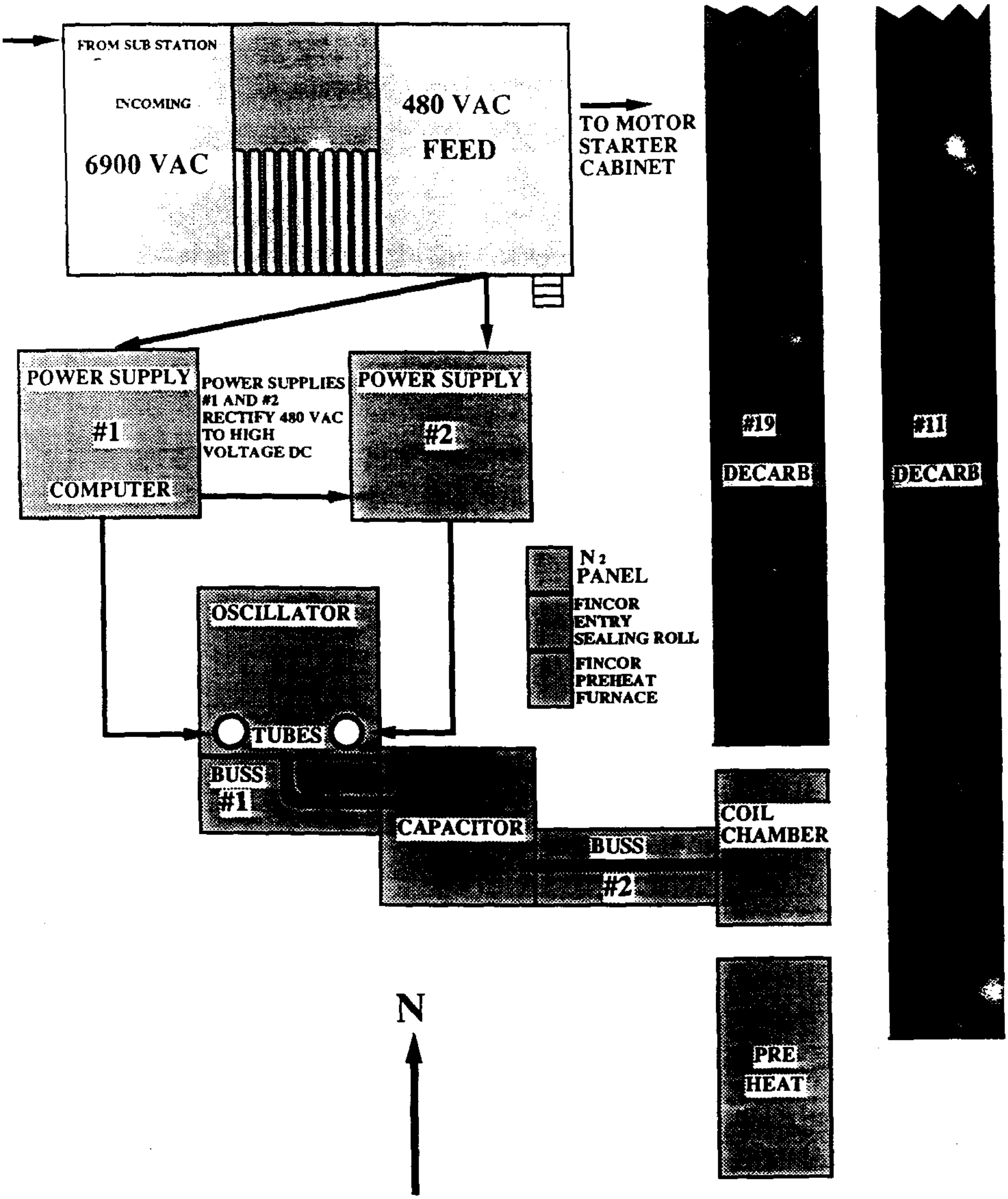
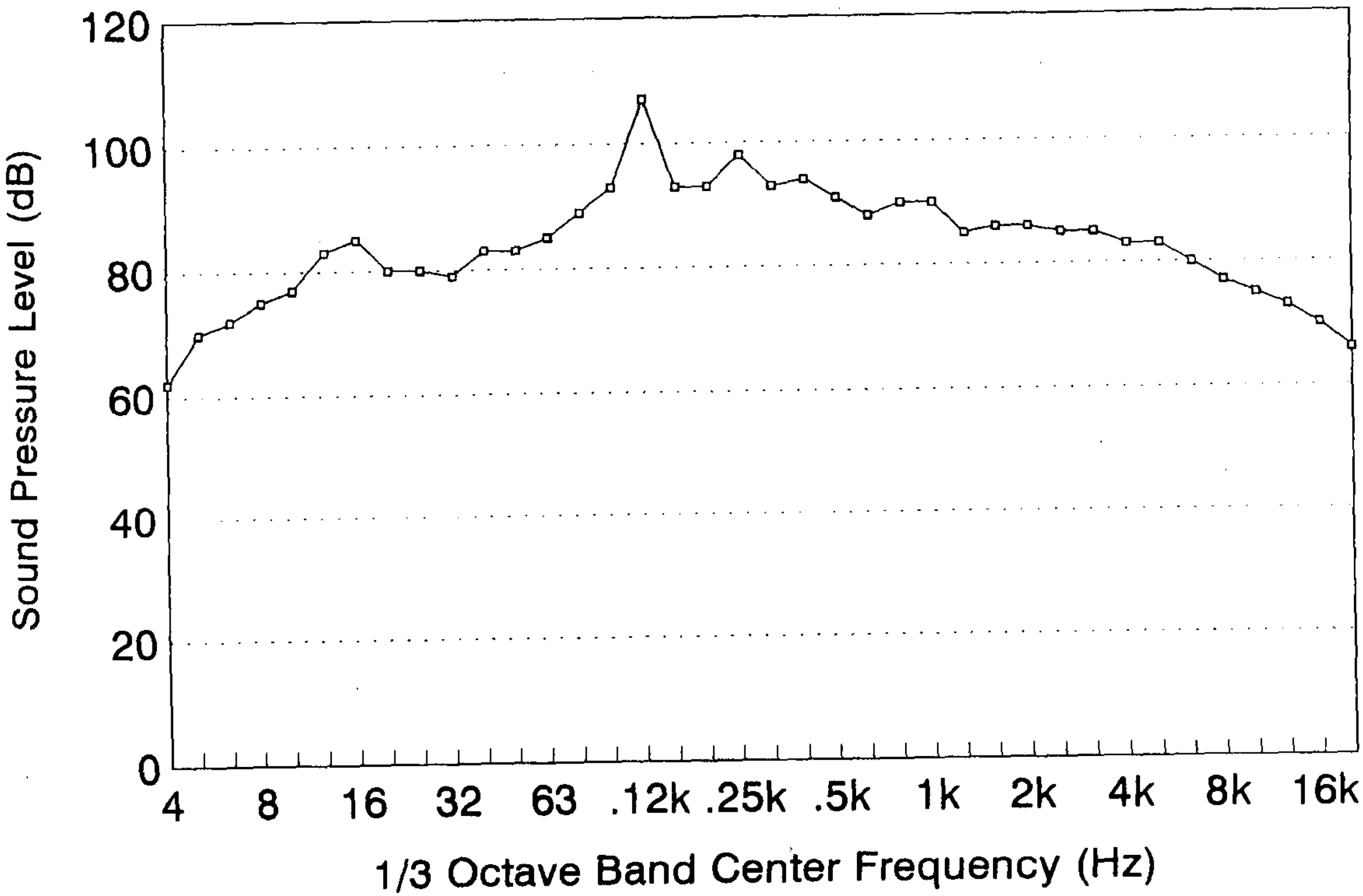


Figure 1. Electrical Flow Schematic of the
Ultra Rapid Annealing Furnace.

Noise Level in Melt Shop Between Furnace #2 & #3
Armco Advanced Materials Corporation
HETA 89-364
March 21, 1990

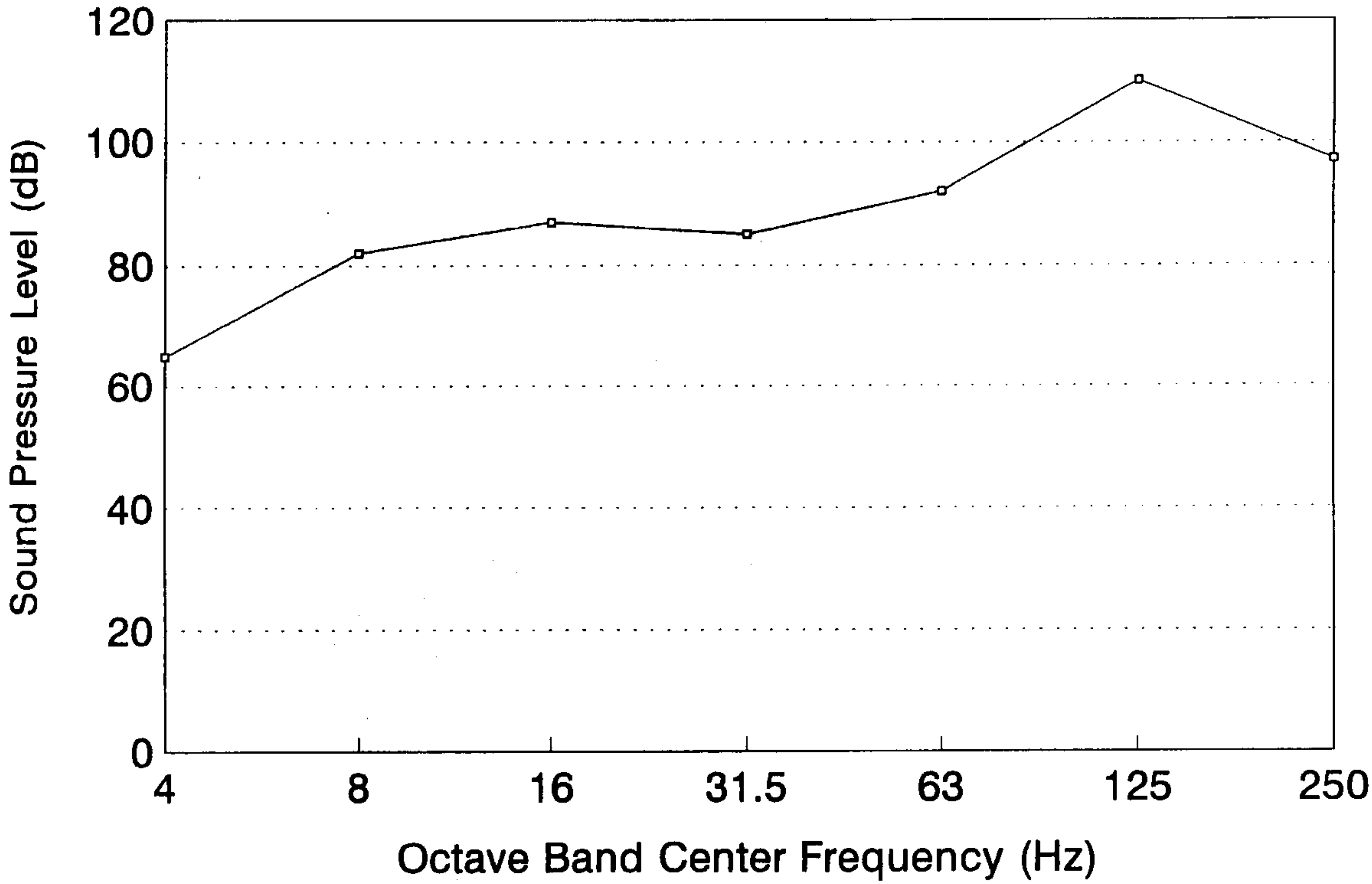
Figure 2



Noise Level in Melt Shop At Furnace #4
Armco Advanced Materials Corporation
HETA 89-364

March 21, 1990

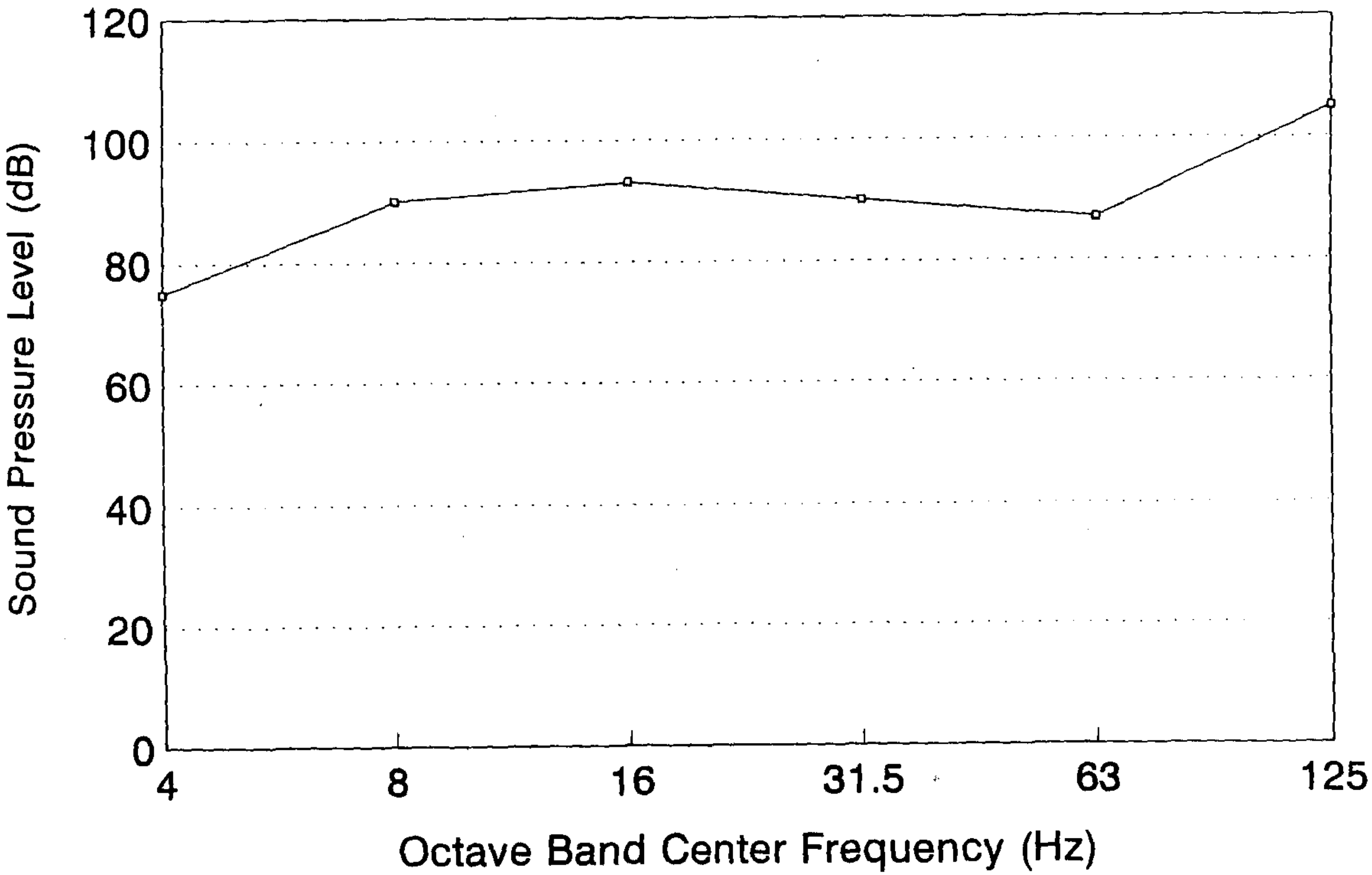
Figure 3



Noise Level in Melt Shop in Overhead Crane
Armco Advanced Materials Corporation
HETA 89-364

March 21, 1990

Figure 4



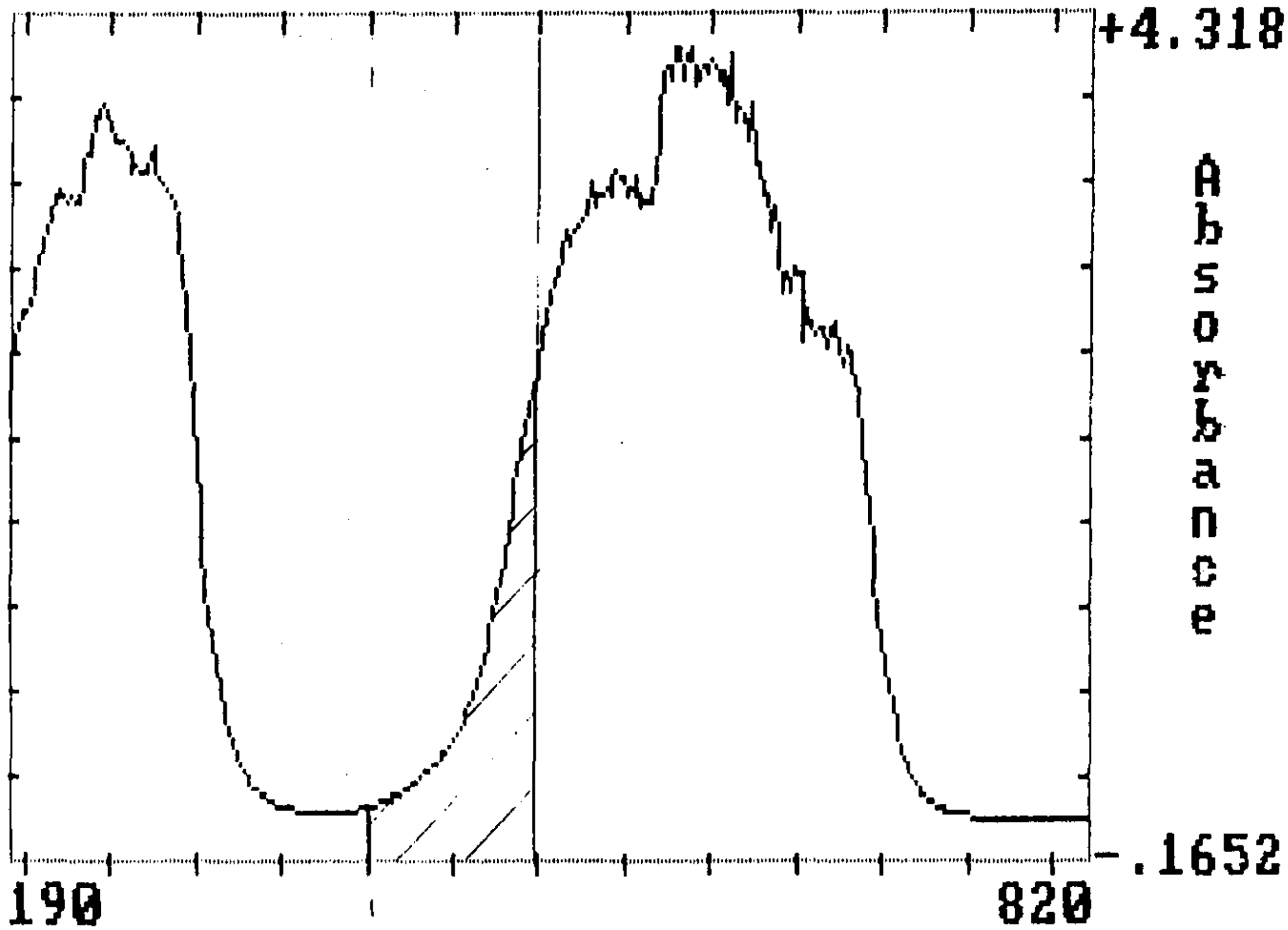


Figure 5. Typical Spectral Absorbance of Blue-Cobalt Eye Protection worn at ARMCO. Note the low absorption (high transmission) associated with the 400-500 nm spectral region (shaded area).