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USS/USX GARY WORKS
NO. 2 Q-BOP SHOP
GARY, INDIANA

NIOSH INVESTIGATORS
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I. SUMMARY

In April 1992, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation of the No. 2 Quick Basic Oxygen Process (Q-BOP) shop at USS/USX Gary Works, a steel manufacturer, in Gary, Indiana. The requesters were concerned about air contaminants, noise, heat stress, and ergonomic problems. NIOSH investigators conducted a field survey at the Q-BOP shop on November 16-19, 1992. The survey included all parts of the Q-BOP shop except the caster area.

Air monitoring of workers' exposures to metals was conducted at the mixer and desulfurization stations, at the ladle metallurgy facility (LMF), and in the ladle preparation area using NIOSH Method 7300. Air monitoring of exposures to sulfur dioxide (SO_2) using direct-reading diffusion tubes was conducted at the mixer and desulfurization stations.

The air concentrations for all but one of the samples for metals were below the NIOSH Recommended Exposure Limits (RELs). The concentration of iron (6.4 milligrams per cubic meter [mg/m^3]) in the area sample collected on the third level above the South mixer exceeded the REL of 5.0 mg/m^3, but probably does not represent a health hazard because workers do not spend much time in this area. Sulfur dioxide (SO_2) concentrations measured by the diffusion tube method ranged from 0.5 to 2.1 parts per million (ppm) as 8-hour time-weighted averages (TWAs). However, simultaneous measurements made by Gary Works industrial hygiene consultants using NIOSH Method 6004 ranged from 0.05 to 0.1 ppm. The diffusion tube method is less specific for SO_2 than NIOSH Method 6004, and could explain the differences between the two sets of results.

Reports from employees during confidential interviews indicate that some employees were experiencing nasal discharge, sinus congestion, and chest congestion — symptoms consistent with exposures to airborne irritants, such as lime (calcium oxide [CaO]), SO_2, and possibly nitrogen dioxide. Employee reports of tinnitus (ringing in the ears) related to work schedules and long-term hearing problems suggest that the hearing conservation program might not be effective. Some employees reported early symptoms of heat exposure — heat-related headache, sweating, and thirst. A few employees reported more serious symptoms of heat stress — heart palpitations and lightheadedness or dizziness. A few employees reported intermittent numbness and tingling or pain in the hands related to hand-held vibration sources, and others reported joint or muscle pain that they attributed to work in awkward positions. During the site visit, NIOSH investigators observed workers performing tasks that could result in low back disorders, such as twisting of the torso while lifting heavy, unbalanced weights.

The observations and findings of this health hazard evaluation indicate that Q-BOP shop employees are potentially exposed to airborne irritants, noise, heat, and ergonomic risk factors. Some of the symptoms reported by interviewed employees are consistent with known effects of exposure. In the Q-BOP shop environment, where safety is critical, certain symptoms, such as those related to noise and heat, could also contribute to injuries.

Recommendations include evaluation of workers' exposures to air contaminants to monitor the effectiveness of engineering controls; monitoring and controlling other air contaminants that are reported to be causing symptoms; reevaluation of the hearing conservation program; guidelines for the use of hearing aids in noisy environments; guidelines for preventing heat stress; and guidelines for ergonomic evaluations (including the NIOSH lifting equation) for high-risk job tasks and for employee reports of ergonomic problems. Recommendations also include improving health and safety communications with employees by involving both the medical department and the union; and active participation of the medical department in identifying, evaluating, and addressing health concerns.

SIC 3312 (Steel Works, Blast Furnaces [including coke ovens], and Rolling Mills), air contaminants, metals, sulfur dioxide (CAS No. 7446-09-5), noise, hearing aids, heat stress, ergonomics, vibration, lifting.

II. INTRODUCTION

In April 1992, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation of the No. 2 Quick Basic Oxygen Process (Q-BOP) shop at USS/USX Gary Works, a steel manufacturer, in Gary, Indiana. The requesters were concerned about air contaminants, noise, heat stress, and ergonomic problems. NIOSH investigators conducted a field survey at the Q-BOP shop on November 16-19, 1992. The survey included all parts of the Q-BOP shop except the caster area. During the NIOSH site visit, some employees requested guidelines for use of hearing aids in noisy environments.

In March 1994, NIOSH received another confidential employee request for a health hazard evaluation (HETA 94-0203) of the No. 2 Q-BOP shop. The requesters were specifically concerned about their risk of developing silicosis related to the use of silica-containing materials throughout the Q-BOP shop, metal fume fever related to smoke and fumes (such as manganese fume) generated during burning of the tap hole in the ladle preparation area, and asbestosis related to preheater insulation materials. They also raised concerns about noise, carpal tunnel syndrome, and symptoms of chest pains, insomnia, nose bleeds, headaches, dermatitis, nasal congestion, chest wheezing, and cough.

This final report is based on the November 1992 site visit and reviews of records provided by the union and the company. It addresses issues raised by both requests and includes the results and recommendations previously presented in a letter dated December 30, 1993, and an interim report issued in January 1994.

III. BACKGROUND

USS/USX Gary Works is an integrated steel manufacturing facility where three major steel-making processes (producing iron, converting iron to steel, and casting liquid steel into solid slabs) take place. At Gary Works, two basic oxygen process (BOP) shops — No. 1 BOP and No. 2 Q-BOP — convert iron to steel. (The difference in shop names is related to differences in how oxygen is added to the BOP vessels.) The No. 2 Q-BOP shop is capable of producing 50 "heats" (batches) per day (three 8-hr shifts). Each heat produces 240 tons of steel.

Process Description

The process in the Q-BOP shop begins in the mixer area, where molten iron from the blast furnaces is brought in by railcar, then directly transferred to either the North or South mixer. The molten iron is transferred into a ladle at the desulfurization station, where lime (calcium oxide [CaO]) is added to remove sulfur from the metal. The lime and iron are mixed by injecting nitrogen gas into the ladle. After the desulfurization process, calcium sulfide (CaS, the byproduct of calcium from lime binding to sulfur from iron) is skimmed from the top. The ladle is transferred by overhead crane to the furnaces where the desulfurized iron is poured into a BOP vessel. After the vessel is charged with steel scrap, fluxes, and other additives, oxygen is injected from the bottom of the vessel. The temperature is raised to 2950°F to convert the vessel's contents to steel. The heat of molten steel is then "tapped" (poured) into another ladle. The ladle is transferred by railcar and overhead crane to the vacuum degasser, where dissolved gases are "vacuumed" out of the molten steel by use of negative pressure over the ladle. Argon gas is introduced through the argon plug in the bottom of the ladle to keep the contents moving. After degassing, the ladle is transferred to the ladle metallurgy facility (LMF), where final changes to the formula are made. First, various fluxes and alloying constituents, such as antimony and aluminum, are added. Then, electrodes are placed in the ladle and an electric current (arc) is discharged to raise the batch's temperature to nearly 3000°F. When the steel-making process is complete, the ladle is moved by overhead crane into the caster area, where the ladle's slide gates (metal plates that cover the nozzle and tap hole) open to pour molten steel into the caster. The ladle is then transferred by overhead crane to an open space east of the LMF area. Slag (the semi-solid waste remaining in the ladle) is poured from the ladle onto the ground, cooled, then, approximately once an hour, cleared from the area by earth-moving equipment.

The empty ladle is transferred to the ladle preparation area to be conditioned for reuse. Heavy equipment is used to scrape most of the remaining slag from the ladle and to punch an opening through the slag-filled tap hole. Ladle utility workers recondition ladles by replacing the argon plug and slide gates. Each shift has a crew of five to six workers who work in groups of two or three. Workers reported that they rotate responsibilities. During replacement of the argon plug, the ladle is on its side, with the plug approximately 5 feet from the ground. Workers loosen the nut that holds the plug to the ladle with a large wrench (approximately 3 feet in length), then remove the nut, cap, several plates, and, finally, the plug. A supervisor reported that each of these items weighs between 50 and 100 pounds. After a bonding paste is applied to the outer surface of the new plug, a worker manually lifts and heaves the plug into the ladle. Workers replace the plates, cap, and nut, then tighten the nut with the wrench. A complete operation takes approximately 20 to 30 minutes and is performed 13 to 15 times per shift. An overhead crane transfers the ladle next to a 20-foot high platform that workers stand on to work on the slide-gate mechanism, which is approximately 3 feet above the platform floor. The workers unbolt the slide gates from the bottom surface of the ladle, then manually remove the gates and place them in a metal crate on the ground. The workers "burn out" the tap hole with an oxygen lance, replace the slide gates, then layer sand onto the inside bottom surface of the ladle (to prevent the tap hole from plugging when molten iron is transferred to the ladle). The sand used in the ladle is transferred from two stations, one of which requires manual labor. At that station, the worker shovels sand from a barrel on the ground into an apparatus that is carried to the ladle by crane. At the other station, sand is fed by gravity directly from a hopper into the apparatus. After reconditioning, the ladle is transferred back to the furnace by overhead crane and rail. The ladle's nozzle needs to be replaced approximately once every 10 heats (approximately once per shift). Ladle utility workers remove the old nozzle, which is several feet from the ground, with an air chisel. They reported that this operation takes 5 to 15 minutes. They apply a bonding paste to the outer surface of the new nozzle, then manually lift and heave it into the opening.

IV. METHODS

A. Industrial hygiene evaluation

Before conducting the November 1992 field survey, NIOSH investigators reviewed relevant industrial hygiene reports of environmental monitoring conducted by Gary Works industrial hygiene consultants in the Q-BOP shop between 1988 and 1992. These reports summarized results of exposure evaluations for noise, heat, and various air contaminants including metals, sulfur dioxide (SO_2), and silica. During this health hazard evaluation, the NIOSH industrial hygienist sampled for air contaminants and took noise measurements using the methods described below. Heat was not measured because conditions at the time of the site visit (November) did not reflect the summer-time conditions that concerned the requesters. Recommendations for exposures (such as silica and heat) that were not sampled by NIOSH investigators were based on reviews of company records.

1. Air Contaminants

Metals

Air monitoring for metals was performed at the mixer and desulfurization stations, LMF, and ladle preparation area. Nine air samples for metals were collected and analyzed using NIOSH Method 7300 [NIOSH, 1984b] — five area samples at the mixer and desulfurization stations, two personal breathing-zone (PBZ) samples in the LMF, and two PBZ samples in the ladle preparation area.

Sulfur dioxide

Air monitoring for SO_2 was performed at the mixer and desulfurization stations. One area and four PBZ measurements were made using Dräger direct-reading diffusion tubes.

2. Noise

Area noise levels were measured at the mixer and desulfurization stations, LMF, and ladle preparation area using a Quest 2400 sound level meter.

B. Medical Evaluation

1. Confidential medical interviews

Of the 41 positions in a work shift, 21 employees, mostly from the day shift, were selected for interview. Because processes and exposures in the Q-BOP shop did not vary from shift to shift, shift-related differences in responses were not expected. At least one employee from each of the 19 job titles was selected for interview. When a job title was filled by only one employee per shift (9 of 19 job titles), employees working at the time of the interviews were selected. When a job title was filled by more than one employee per shift, an employee was randomly selected. When a selected employee was unable to leave the work station, the interview was conducted in private at the work station. When a selected employee was not available, the most conveniently available employee was selected. Interviewed employees were asked about issues raised in the request for the health hazard evaluation — air contaminants, noise, heat, and ergonomics; and health effects attributed to the workplace.

Job titles of the sources of employee comments will not be reported here because of the possibility that individuals could be identified and confidentiality would not be preserved.

Although some comments may appear to refer to a particular work area or job title, such assumptions may be incorrect. Often, employees in distant as well as nearby work areas had similar comments.

2. Review of records

The Occupational Safety and Health Administration (OSHA) Forms 200 (Logs and Summaries of Occupational Injuries and Illnesses) from January 1990 to November 1992 were reviewed.

At the request of the interviewed ladle utility workers, their audiometric test results were reviewed. The company's medical contractor provided test results of 18 ladle utility workers. The results were reanalyzed using American Academy of Otolaryngology (AAO) criteria [AAO, 1983] and the OSHA criteria for standard threshold shift (STS) [29 CFR 1910.95 (1992)].*

V. EVALUATION CRITERIA

A. General Guidelines

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators employ environmental evaluation criteria for assessment of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours/day, 40 hours/week for a working lifetime without experiencing adverse health effects. It is important to note, however, that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a preexisting medical condition, and/or a hypersensitivity (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 levels established by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus the overall exposure may be increased above measured airborne concentrations. Evaluation criteria typically change over time as new information on the toxic effects of an agent become available.

The primary sources of evaluation criteria for the workplace are NIOSH Criteria Documents and Recommended Exposure Limits (RELs) [NIOSH, 1992], the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs) [ACGIH, 1994], and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) [29 CFR 1910.1000]. These values are usually based on a time-weighted average (TWA) exposure, which refers to the average airborne concentration of a substance over an entire 8- to 10-hour workday. Concentrations are usually expressed in parts per

**Code of Federal Regulations.* See CFR in references.

million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). In addition, some substances have only a ceiling limit, a concentration that should not be exceeded during any part of a workday. Other substances have a short-term exposure limit (STEL) to supplement a TWA limit where there are recognized toxic effects from short-term exposures. A STEL is a 15-minute TWA concentration which should not be exceeded at any time during a workday even if the 8-hour TWA is less than the exposure limit. The ACGIH recommendation for a substance without a STEL is that "excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded" [ACGIH, 1994]. The basic concept is that excursions above a substance's 8-hour TWA exposure limit should be maintained within reasonable limits in well controlled processes.

NIOSH RELs are based primarily on the prevention of occupational disease. In contrast, PELs and other OSHA standards are required to take into account the economic feasibility of reducing exposures in affected industries, public notice and comment, and judicial review. In evaluating worker exposure levels and NIOSH recommendations for reducing exposures, it should be noted that employers are legally required to meet OSHA standards.

B. Air contaminants

1. Metals

Metal toxicities vary depending on the metal and compound. For example, overexposure to iron oxide, a compound of relatively low toxicity, may cause siderosis, which is known chiefly for abnormal changes on chest x-rays [Brooks, 1987]. Siderosis, however, is a benign pneumoconiosis* and does not typically cause symptoms or abnormal lung function. In contrast, nickel can cause allergic dermatitis, and is considered a potential occupational carcinogen [NIOSH, 1992]. Evaluation criteria for the metals selected for air sampling are provided in Table 1. Because fumes as well as dusts are generated during steel production and fumes sometimes cause disease at lower concentrations than dusts of the same compound, the criteria for fume is provided whenever a metal's evaluation criteria for fume and dust differ.

Metal fume fever is an acute respiratory disease that is caused by inhalation of metal oxide fumes. It often begins with thirst and a metallic taste in the mouth. Symptoms, which last from 6 to 24 hours, resemble those of influenza, including fever, chills, increased sweating, nausea, muscle aches, weakness, headache, and cough. Resistance to the illness increases with repeated exposure, but absence from exposure quickly results in loss of resistance. This syndrome is common on Mondays, following a weekend without exposure. Metal fume fever is most commonly reported as a result of zinc oxide exposure, but has also been

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*Some pneumoconioses are the result of lung tissue inflammation and scarring caused by deposition of substantial amounts of inhaled dusts, such as asbestos, coal, or silica. Benign pneumoconiosis (unlike asbestosis, coal worker's pneumoconiosis, and silicosis) is characterized by minimal scarring.

related to oxides of copper and magnesium. Other metals that have also been implicated include aluminum, antimony, cadmium, iron, manganese, nickel, selenium, silver, and tin [NIOSH, 1988a; Gantz, 1988]. Although no specific exposure concentrations have been associated with metal fume fever, most reported cases have occurred in workers exposed to welding fumes while working in confined or other poorly ventilated spaces [NIOSH, 1988a].

2. Sulfur dioxide

Acids are formed when SO_2 comes into contact with moist membranes, such as the conjunctivae of the eyes and the mucous membranes of the respiratory tract. Therefore, exposure to SO_2 in the air can be intensely irritating, with burning and tearing of the eyes, burning of the throat, and coughing. Some individuals may develop asthma-like responses and experience chest tightness [Frank, 1987]. The NIOSH REL and ACGIH TLV for SO_2 are 2 parts per million (ppm). The OSHA PEL is 5 ppm.

C. 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 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 [Ward, 1986]. 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, the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have still higher frequency components [Ward et al., 1961].

The OSHA standard for occupational exposure to noise [29 CFR 1910.95] specifies a maximum PEL of 90 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 and ACGIH propose an exposure limit of 85 dB(A) for 8 hours [NIOSH, 1972; ACGIH, 1992], 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 shown in the following table.

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*	—
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*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 of 85 dB(A) which stipulates that an employer shall administer a continuing, effective hearing conservation program when the TWA value exceeds the action level. 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. In addition, the standard requires implementation of a continuing, effective hearing conservation program.

D. Heat

Many factors contribute to heat stress. Measurable environmental factors include air temperature, air velocity, relative humidity, and radiant temperature. Human factors and individual factors, such as work load, are more difficult to determine. Susceptibility to heat stress can be affected by factors such as age, state of health, physical conditioning, and acclimatization to heat. Certain conditions, such as acute illness, increase in work load, acute dehydration (including heavy sweating from physical exertion), lack of sleep, and drinking alcohol, may increase the risk for heat stress even in acclimatized workers. Symptoms of heat exhaustion, a form of heat stress, include headache, nausea, dizziness, weakness, thirst, and giddiness. These symptoms may also occur in the early stage of heatstroke, the most severe heat-related disorder.

Heatstroke can result in death and is, therefore, a medical emergency. Late signs of heatstroke include alteration of consciousness, lack of sweating, and core body temperature in excess of

105.8°F [NIOSH, 1986b]. Simple postural heat syncope (fainting) can occur in the heat-unacclimatized worker and may result in injury. Heat exhaustion, which can occur in the acclimatized as well as unacclimatized worker, can also increase the risk of injuries, because the neurobehavioral effects may cause exposed workers to act unsafely.

Because multiple factors contribute to the development of heat stress, NIOSH recommends evaluating work load as well as the environment. NIOSH recommendations include exposure limits for heat-acclimatized workers and alert limits for heat-unacclimatized workers (Figures 1 and 2) [NIOSH, 1986b]. The recommendations also include physiologic monitoring of potentially exposed employees to account for individual factors that could contribute to the development of heat stress.

VI. RESULTS

A. Air contaminants

Most (76%) of the 21 interviewed employees reported exposures to air contaminants. Some were concerned about dusty conditions throughout the Q-BOP shop. Others were concerned about exposures in specific work areas. Specific concerns included the dusts generated from the use of silica-containing materials throughout the shop; air contaminants related to the desulfurization process; air contaminants rising with heat-generated drafts to the overhead cranes throughout the shop; lack of air filters in some enclosed areas, such as crane cabs, pulpits, and shanties; dusts generated from electric arcing in the LMF; a solvent-like odor in the ladle preparation area; and use of the shanty as a lunch room in the ladle preparation area. Five (24%) of the interviewed employees reported symptoms that they attributed to air contaminants. These included respiratory symptoms such as nasal discharge, sinus congestion, chest congestion, and chest pain. At and around the desulfurization station, however, headaches and burning sensations of the eyes and skin were attributed to "desulf powder." A few of the asymptomatic employees reported that they occasionally used dust respirators.

Metals

Table 1 shows the results of air sampling for metals during the NIOSH site visit. Air volumes, sample periods, and minimum detectable concentrations (based on a 640-liter sample volume) are provided for each result. The air concentrations for all but one of the metal samples were below the NIOSH RELs for 8- to 10-hour TWA exposures. The concentration of iron (6.4 milligrams per cubic meter (mg/m^3)) from the area sample collected on the third level above the South mixer exceeded the REL of 5.0 mg/m^3. Air concentrations of metals in all samples were below the OSHA PELs and the ACGIH TLVs.

Sulfur dioxide

Sulfur dioxide concentrations at the mixer and desulfurization stations measured by the NIOSH industrial hygienist ranged from 0.5 to 2.1 parts per million (ppm) as 8-hour TWAs. The highest SO_2 concentration was slightly higher than the NIOSH REL of 2 ppm. However, simultaneous measurements made by Gary Works industrial hygiene consultants using a different method (NIOSH Method 6004) ranged from 0.05 to 0.1 ppm.

Silica

In September 1990, NIOSH investigators visited the No. 2 Q-BOP shop in response to a union request for a health hazard evaluation (HETA 90-316) of the LMF and the caster area. The union was concerned about air contaminants, reports of eye and nose irritation, and dermatitis. The findings and recommendations of the site visit were presented in a letter dated January 21, 1991. Based on a review of environmental monitoring by Gary Works industrial hygiene consultants, potential for overexposure to respirable quartz (silica) dust and CaO were noted in the caster area. Recommendations included local exhaust ventilation and medical monitoring of potentially exposed workers.

Environmental sampling conducted in the ladle preparation area by Gary Works industrial hygiene consultants on July 25, 1991, showed that air concentrations of respirable silica were below the NIOSH REL of 0.05 mg/m^3 for crystalline silica [NIOSH, 1992]. Indiana OSHA conducted a survey of the Q-BOP LMF and caster area on January 14, 1992. The company was found to be in compliance with OSHA regulations for silica. The compliance officer reported that the company had begun to install new ventilation systems on the caster mold machines and had changed to fluxes with lower silica content. Environmental sampling conducted in the pit side of the Q-BOP shop by Gary Works industrial hygiene consultants on March 3, 1992, showed that air concentrations of respirable silica were below the NIOSH REL of 0.05 mg/m^3 for crystalline silica [NIOSH, 1992]. Cristobalite was not detected in any of these air samples. During the November 1992 NIOSH site visit, Gary Works management reported that the engineering controls under installation in the caster area at the time of the Indiana OSHA inspection were already in place.

Preheater insulation

Asbestos was not listed as an ingredient on the Material Safety Data Sheets for the refractory materials used to insulate the preheaters. One of the refractory materials contains a small amount (0.1-1.0%) of crystalline silica.

B. Noise

The interviewed employees identified the following sources of noise: warning sirens and horns, scrap dropping into the charge, plates hitting the floor, furnaces, mixers, discharge of the electric arc, preheaters, heavy equipment such as grade-alls and cranes, air hammers, and poorly functioning air-conditioning units. Thirteen (62%) of the interviewed employees reported a hearing problem. Six (29%) of the interviewed employees reported tinnitus (ringing in the ears) that began during work and ended after leaving work. Six (29%) reported that their family members frequently asked them to turn down the volume of the radio or television set. Six (29%) reported abnormal audiometric test results or use of hearing aids.

During the NIOSH site visit, peak area noise measurements ranged from 80 to 106 dB(A), depending on the area. These values are consistent with measurements of previous surveys in the Q-BOP shop. Eight-hour TWA exposures measured by Gary Works industrial hygiene consultants have ranged up to 98 dB(A), which is above the OSHA PEL of 90 dB(A). The mixer and desulfurization stations, LMF, and ladle preparation area are included in the Gary Works hearing conservation program and use of hearing protection devices are required in these areas. Disposable ear plugs from E ! A ! R® and Howard Leight Industries, and muffs from E ! A ! R® and Bilsom® are provided to workers in these areas. Based on limited observation during the NIOSH survey, workers appeared to be using hearing protection in the designated areas. Company policy does not permit employees to wear hearing aids in areas where the noise level is above 85 decibels (dB).

All 18 ladle utility workers whose audiometric test results were provided to NIOSH had been employed by Gary Works for more than 10 years (range 13-24). Only five (28%) of these employees had records of audiometric tests within the first two years of employment. Company records showed that none of the results from the first two years of employment and none of the pre-1980 results were used as baselines for calculating the OSHA-required STS [29 CFR 1910.95]. The company's medical director reported that only results that could be documented to comply with the OSHA standard were selected as baselines. As a result, all of the selected "baselines" were performed from 5 to 20 years after dates of hire. Although some later results were better than the selected baselines, significantly improved results were not routinely used as new baselines. Test times were not regularly recorded. When they were recorded, most test times appeared to be before the workshift, or five or more hours after the end of the workshift. The test dates indicated that ladle utility workers were not tested yearly until 1991. On the 1992 reports, the audiometry contractor identified five STSs, two of which were interpreted as nonoccupational.

Using the earliest audiometric test results as baselines, reanalysis by NIOSH investigators showed that 13 (72%) of the 18 ladle utility workers had evidence of an STS according to the OSHA criteria. Nine of these STSs persisted in later tests and three did not. One had not yet been retested. For some STSs, a worsening trend was suggested before STS criteria were met. Some of the worsening trends continued into the 1990s.

C. Heat

The interviewed employees identified the following factors as contributors to heat-related problems: work with or near heat sources, such as furnaces, ladles, and mixers; work in elevated areas, such as the overhead cranes; summer; nonfunctioning or poorly functioning air-conditioning units; lack of air-conditioning units; lack of nearby drinking water. Nine (43%) of the twenty-one interviewed employees reported symptoms that they attributed to heat. The most frequently reported symptom was fatigue (5 [24%]). Other symptoms included headache, increased sweating, heart palpitations, lightheadedness or dizziness, increased thirst, and increased irritability. Most of the affected employees stated that they tried to rest in cooler areas, decreased their work load, or increased their fluid intake whenever they were symptomatic.

Two cases of heat stress in the Q-BOP shop were recorded in the OSHA Form 200 logs covering 1990 through November 1992. Both cases occurred in 1991.

On August 15, 1991, Gary Works industrial hygiene consultants monitored environmental heat in the ladle preparation area. Heat exposure of ladle utility workers was measured at 78°F WBGT. This measurement was based on a 50%-50% work-rest cycle of approximately 30 minutes of work followed by 30 minutes of rest. The following tasks, durations, and temperature measurements were used in calculating the result: cleaning the tap hole, 15 minutes, 84°F WBGT; filling the sand carrier, 10 minutes, 93°F WBGT; and mechanically transporting the sand carrier, 5 minutes, 89°F WBGT. For acclimatized workers who work a 50%-50% work-rest cycle and have a high level of work activity (500 kcal/h), the calculated index of 78°F WBGT is below the estimated NIOSH REL of 81°F WBGT for acclimatized workers, but above the NIOSH REL of 77°F WBGT for unacclimatized workers (Figure 1).

At the time of the NIOSH site visit, Gary Works management and the medical provider were developing a program to prevent heat stress.

D. Ergonomics

Vibration

The interviewed employees identified the following sources of vibration: cranes, forklifts, air hammers in the ladle preparation area, and temperature and sample poles in the LMF. Two of the interviewed employees who reported intermittent numbness and tingling or pain in the hands attributed their symptoms to vibration from hand-held sources (such as air hammers and temperature and sample poles).

Awkward positions

Three (14%) of the interviewed employees reported joint or muscle pain that they attributed to working in awkward positions. During the survey of the Q-BOP shop, NIOSH investigators observed that some employees assume awkward positions during certain job tasks. Overhead-crane operators lean forward from a sitting position to watch activities below them. Ladle utility workers use body weight and postural changes to pull and push the 3-foot-long wrench during the removal of the ladle's nozzle, and twist their torso, shoulders, and arms to angle the air chisel during removal of the ladle's nozzle.

Lifting

NIOSH investigators also observed potentially hazardous lifting conditions in the ladle preparation department, such as lifting weights of up to 100 pounds from ground level to shoulder height or higher and pivoting during the lift. Work processes of concern include changing the argon plug and slide gates (described in Section IV [Background] of this report).

VII. DISCUSSION

Although some of the recently installed engineering controls have probably improved the work environment of the Q-BOP shop, the findings of the NIOSH site visit suggest other occupational health problems that should be addressed. Some problems were suggested by documented exposures, while others were suggested by symptoms consistent with overexposure.

A. Air contaminants

Reports from employees during the confidential interviews indicated that some employees were experiencing symptoms consistent with exposures to airborne irritants — nasal discharge, sinus congestion, and chest congestion. Although these symptoms are nonspecific and could have a variety of occupational and nonoccupational causes, they are similar to respiratory symptoms reported by workers during NIOSH health hazard evaluations at other steel mills [NIOSH, 1978, 1981, 1984a, 1988b, 1990b], as well as those reported by employees during a previous NIOSH health hazard evaluation at the Gary Works Q-BOP shop (HETA 90-316). At these steel mills, the air contaminants responsible for the irritant effects were not always identified with certainty and were not always quantified by air sampling. Potential causes of symptoms can sometimes be identified during a walk-through survey or from a review of the company's air sampling records. During the previous NIOSH investigation of the Q-BOP shop, these methods were used to identify CaO dust and fluorides as potential causes of respiratory symptoms. Cause-and-effect relationships can sometimes be recognized by specific symptoms that occur immediately upon exposure to a specific substance. Such a relationship was reported at and around the desulfurization station, where acute headache and a burning sensation of the eyes and skin were attributed to "desulf powder." The principal component of "desulf powder" is lime (CaO), which is a skin and mucous membrane irritant. Magnesium oxide and magnesium, which are present in small quantities, can also contribute to skin and mucous membrane irritation. Sulfur dioxide and possibly nitrogen oxide emissions from the desulfurization process could also explain mucous membrane irritation (see discussion on SO_2 below). After the NIOSH site visit, Gary Works management reported that an exhaust ventilation system had been installed to control emissions from the desulfurization process. Such engineering controls may prevent the occurrence of these symptoms in and around the area.

Enclosed areas (such as pulpits and shanties) may offer some protection against air contaminants, but would not be effective if air supply sources are contaminated and intake air is unfiltered. Particulate filters alone, however, would not be effective in protecting workers from contaminant gases, such as carbon monoxide, nitrous oxides, and SO_2. In hot workplaces with dilution ventilation, such as the Q-BOP shop, heat-generated drafts carry air contaminants toward the ceiling. Thus, overhead crane operators may have higher exposures to airborne contaminants than employees working on the shop floor.

Metals

The concentration of iron (6.4 mg/m^3) from the sample collected on the third level above the South mixer exceeded the REL of 5.0 mg/m^3. However, this is not necessarily a hazard because employees do not spend a substantial portion of the workshift in this area.

Some ladle utility workers were concerned about the possibility of developing metal fume fever from smoke and fume generated while burning out the tap hole with an oxygen lance. Although metal oxide fumes may be generated during this process, the risk for these employees cannot be predicted. Individual risk would not necessarily be predicted by air sampling results since specific air concentrations have not been associated with metal fume fever [NIOSH, 1988a]. In addition, ladle utility workers are exposed to fumes from the tap hole for short, intermittent periods in an open environment, unlike the welding fume exposures in confined or poorly ventilated spaces that have resulted in most of the reported cases of metal fume fever [NIOSH, 1988a]. Metal fume fever may be difficult to recognize because its respiratory symptoms, fever, and chills may be attributed to other causes, such as influenza. At other times, symptoms may not occur after overexposure because of the development of resistance. Thus, diagnosis depends on the recognition of short-term flu-like symptoms that may not consistently be related to exposure. Recognition of metal fume fever in ladle utility workers would require the medical department to obtain careful histories of exposure and symptoms over time. Because environmental monitoring would not necessarily predict risk for metal fume fever, controlling exposures at the source would be a more practical approach to address these employees' concerns.

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Sulfur dioxide

The differences between the NIOSH and the Gary Works consultant's results for SO_2 could be explained by differences in the methods used. Diffusion tubes, which were used by the NIOSH industrial hygienist, are inexpensive, lightweight, easy to use, and provide immediate results (the concentration is determined by comparing an observed colorimetric change with that of an unused tube). However, this method is not specific for SO_2 (color changes can occur in the presence of other acidic substances). NIOSH Method 6004, which was used by Gary Works industrial hygiene consultants, is more specific for SO_2 and is reported to have a higher level of precision than the diffusion tube method. For these reasons, actual SO_2 concentrations at the time of the NIOSH site visit are probably more accurately represented by the Gary Works results than the NIOSH results. The Gary Works results indicated that air concentrations of SO_2 were well below the NIOSH REL and ACGIH TLV of 2.0 ppm and the OSHA PEL of 5.0 ppm. However, when using Method 6004, NIOSH investigators have sometimes found results of media and field blanks to be variable or higher than they should have been. For these reasons, multiple media and field blanks are recommended to validate sampling results.

The diffusion tube results of the NIOSH sampling suggest that an unidentified contaminant (which positively interferes with this method) might have been present at the mixer and desulfurization stations. Nitrogen dioxide (NO_2) is a likely candidate because nitrogen (used to mix lime into the molten iron) can combine with oxygen (released from lime) during the desulfurization process. Nitrogen dioxide is reported to interfere with the colorimetric method for SO_2 [Dräger, 1992]. The symptoms of NO_2 exposure include respiratory and eye irritation (similar to those of SO_2), and could explain some of the symptoms reported by employees in the mixer area.

Silica

Despite the use of silica-containing materials in the Q-BOP shop, results of air sampling previously conducted by Gary Works industrial hygiene consultants did not indicate that silica was a health hazard for ladle utility and pit utility workers. These findings probably reflect the effectiveness of engineering controls and substitution of materials in reducing workplace exposures.

B. Noise

Hearing conservation

The findings of this health hazard evaluation suggest that the hearing conservation program may not be adequately protecting Q-BOP shop employees from the adverse effects of workplace noise exposure. Short-term effects were suggested by reports of work-related tinnitus in 29% of interviewed employees. Long-term effects were suggested by hearing difficulties reported by 29% of the interviewed employees, the high prevalence (50%) of STSs among ladle utility workers, and the worsening trends in audiometric test results over time among ladle utility workers. Although some of the STSs might be unrelated to work, these findings are consistent with adverse effects of noise exposures in the Q-BOP shop, which were measured as high as 106 dB(A) during the NIOSH site visit. Although the hearing protection devices provided by Gary Works should provide adequate protection, NIOSH field studies have demonstrated that noise reduction provided by hearing protection devices in the workplace may be substantially less than laboratory-generated noise-reducing ratings predict [Lempert BL et al., 1983]. The findings among Gary Works Q-BOP shop employees suggest that availability or use of these devices does not guarantee protection. Possible explanations include nonuse, inconsistent use, or improper use of the hearing protection devices.

Results of annual audiometric testing can be used to assess the effectiveness of hearing conservation programs. The sensitivity of audiometry in detecting noise- related problems, however, depends on the selection of baseline results. Review of the ladle utility workers' audiometric test results showed that the medical contractor's choice of baselines was not always consistent with criteria in the OSHA noise regulation, which allows substitution of an annual audiogram for the baseline under two conditions — when the hearing threshold in the annual audiogram indicates significant improvement over the baseline audiogram or when the STS revealed by the audiogram is persistent. For some ladle utility workers, later tests showed improvement over the selected baselines, suggesting that the selected baselines were temporary threshold shifts (TTSs) or that technical problems occurred during the earlier testing. Yet significantly improved results were not routinely used as new baselines. Because STSs are determined by the size of the difference between the periodic and baseline results, falsely elevated baselines make true STSs difficult to recognize and delay recognition of work-related hearing deficits. The difference in sensitivity between the two baseline selection methods is illustrated by the discrepancy between the number of STSs detected by the company's consultant (5) and the number of STSs detected during reanalysis using earliest results as baselines (9 persisting, 1 unrepeated, 3 temporary). Use of baseline results from audiograms performed before employment or before onset of noise exposure would provide the greatest protection to workers [NIOSH, 1990a]. When such results are unavailable, as was the case for these ladle utility workers, the earliest or best results should be selected for baselines. The sensitivity of audiometry in detecting noise-related problems is also affected by the timing of tests. TTSs are indicators of noise exposure and may persist for up to 14 hours after removal from noisy environments. Therefore, periodic audiometric testing immediately after work would be most sensitive for evaluating the effectiveness of the hearing conservation program.

In conclusion, the findings of this investigation indicate noise-related problems are occurring in the Q-BOP shop, and are not limited to the ladle preparation area. When evidence of noise-related hearing problems occur in a workforce, workplace exposures should be reevaluated and the hearing conservation program reassessed. When these problems occur in programs relying on hearing protection devices, the effectiveness of the devices should be reevaluated.

Hearing aids in noisy environments

The company policy of restricting the use of hearing aids in areas with noise levels above 85 dB is less protective than a recommendation that hearing aids be turned off when noise levels are above 80 dB(A) [Berger, 1986]. However, the use of hearing aids in noisy environments is a complex issue that involves multiple factors. Therefore, no single set of recommendations can be applied to all hearing-impaired workers in all work settings. Hearing specialists in occupational safety and health have identified some factors that should be considered in making recommendations. These factors include the type and amount of hearing loss of the individual worker, the type of hearing aid or earmold and the accuracy of its fit, the type and amount of noise in the work environment, and the hearing requirements and communication needs of the individual worker's particular job. In conclusion, recommendations should be made on a case-by-case basis — based on evaluations of specific workers in specific work environments by a qualified hearing specialist.

C. Heat

To interpret the results of environmental monitoring for heat stress in the ladle preparation area, Gary Works used an exposure criterion of 85°F WBGT, which was selected from the ACGIH TLV table for permissible heat exposures based on a 50%-50% work-rest cycle and moderate work load. Gary Works estimated a moderate work load for cleaning the tap hole and transporting the sand carrier. These activities, however, may actually involve heavier work loads. Because estimating work loads without measurements is subjective on the part of the assessor, any bias should allow for a margin of safety. Conservative overestimating of work load is one way to provide such a margin of safety.

Two cases of heat stress in the Q-BOP shop were reported in the OSHA Form 200 logs for 1990 through October 1992. However, symptoms reported during the NIOSH survey suggested that other employees might have experienced heat stress. Headache, increased sweating, and increased thirst, which were reported during the interviews, are symptoms of heat exposure. But some employees reported more serious symptoms of heat stress — heart palpitations and lightheadedness or dizziness. These symptoms were not limited to the ladle preparation area. In an environment where safety is critical, such as in the Q-BOP shop, these symptoms could contribute to injuries.

Symptomatic employees who took more frequent breaks, decreased their work loads, moved to cooler areas, and drank more fluids were taking appropriate measures to prevent the more serious forms of heat stress. However, individual actions are only one part of a comprehensive workplace program to prevent heat stress. Employee reports of lack of air conditioning, nonfunctioning or poorly functioning air conditioning, and lack of nearby drinking water indicate the need for improved environmental controls and proactive administrative measures. The difference between the number of cases reported on the OSHA Forms 200 and the number of interviewed employees reporting symptoms could be related to a number of factors, such as early recognition of heat stress with appropriate preventive actions, lack of reporting of heat stress to the medical department, no lost work days by reported cases, or lack of recognition that symptoms are related to heat exposure.

If the temperature and humidity conditions measured in the ladle preparation area by Gary Works industrial hygiene consultants in August 1991 are representative of extreme high-temperature ("worst-case") conditions, heat stress should be preventable by implementing measures such as acclimatizing workers, adjusting work loads, using breathable clothing, drinking adequate amounts of water, and warning supervisors and workers when temperatures exceed those of typical conditions. Because symptoms were reported in other areas of the Q-BOP shop, the rest of the Q-BOP shop should be evaluated. Areas identified as high risk should be included in the heat-stress program. In addition, the program should address the multiple factors that can contribute to heat stress.

D. Ergonomics

The symptoms reported by some individuals were consistent with work-related ergonomic problems. Symptomatic employees were in different job titles working in different areas of the Q-BOP shop. Some problems could be alleviated by redesigning tools, some by redesigning work stations, and some by changing processes. These findings indicate a need for an ergonomic survey of the Q-BOP shop.

VIII. RECOMMENDATIONS

Because some of the concerns raised by employees during this investigation were related to miscommunication or lack of information, Gary Works management should develop a more proactive approach to address these concerns. An integrated health and safety program with participation by the union and the medical department would provide a mechanism for employees to communicate their concerns to management and allow management to address these concerns appropriately. In addition, the medical department should be more involved with occupational health programs, especially to identify symptoms and health concerns, and to provide input on the health effects of exposures in training programs. Supervisors and managers should receive the same training as workers to make them aware of workers' concerns.

A. Air contaminants

Even without identifying specific contaminants that might be responsible for irritant symptoms, some symptoms may be alleviated by general improvements in air quality and environmental controls. When primary sources are identifiable, Gary Works management should continue to control air contaminants with local exhaust ventilation, such as the ventilation systems installed in the caster mold area and at the desulfurization station. If employees continue to report symptoms, Gary Works should perform air monitoring to determine the cause of the symptoms. For example, nitrogen dioxide, which was not previously sampled for, could have been contributing to symptoms in and around the desulfurization station. Air sampling can also help determine whether newly installed engineering controls are effective, whether older engineering controls are no longer effective, and whether engineering controls should be installed in areas that have none. When air sampling results do not predict risk (such as for metal fume fever), or when health effects are not immediately obvious at the time of exposure (such as silicosis or metal fume fever), the medical department should be involved to determine whether medical monitoring would be useful. If new sources of airborne crystalline silica are identified, local exhaust ventilation systems, such as those installed in the caster mold area, should be installed to control any possible overexposures. Personal respiratory protection, if necessary, and medical monitoring should be provided to employees potentially exposed to crystalline silica.

Air supplied to all enclosed work and rest areas (such as pulpits, overhead cranes, and shanties) should be uncontaminated. Because particulate filters would not be effective in removing contaminant gases, such as carbon monoxide, nitrous oxides, and SO_2, other types of controls should be investigated if these gases present a health hazard. One possible solution is to supply air from an uncontaminated source at a rate adequate to pressurize the enclosed area.

B. Noise

Hearing conservation program

Although the following recommendations were initially made for the ladle preparation area,* they should be applied to all work areas in the Gary Works hearing conservation program.

1. Noise exposures in the Q-BOP shop should be reevaluated.

2. Preventive measures of the hearing conservation program, including the use of hearing protection devices, should be reassessed to determine where improvements can be made to better protect the hearing of Q-BOP shop employees.

3. The audiometric testing program of the hearing conservation program should be revised to provide maximum protection of workers' hearing.

*In the interim report of January 1994.

a. Criteria for baseline audiometry results should be consistent with OSHA regulations (29 CFR 1910.95). Results that are not confirmed by later tests, thus indicating technical problems or TTSs, should not be used as baselines.

b. Annual audiometric tests should be scheduled well into the workshift so that comparisons with baseline audiograms will reveal any early indications of hearing loss or TTSs [NIOSH, 1990a; Accredited Standards Committee, 1991].

c. Each individual's results should be examined for worsening trends over time to identify possible STSs and to prevent future STSs.

d. Group results of individuals within each work area should be analyzed to determine whether the hearing conservation program adequately protects workers in the area [Accredited Standards Committee, 1991].

e. Criteria for determining whether a hearing loss is related to workplace noise exposure should be reexamined, because mistakenly attributing hearing losses to other causes may delay reevaluation and preventive efforts in the workplace.

Hearing aids in noisy environments

When evaluating the use of hearing aids by individual workers in noisy environments, multiple issues should be taken into consideration. Thus, these workers should have their hearing protection needs evaluated on a case-by-case basis by a qualified hearing specialist. Guidelines for use of hearing aids in noisy environments include the following:

1. Hearing aids usually supply 20 to 50 dB of maximum gain. Use of hearing aids in the presence of sustained high-level noise can potentially cause additional noise-induced hearing loss [Berger, 1986].

2. A turned-off hearing aid should not be worn in place of conventional hearing protection unless its attenuation can be tested on the individual worker and shown to be adequate for the noise environment. Even unvented earmolds may fail to provide adequate noise attenuation [Berger, 1986].

3. For some individuals, speech messages and some warning signals may be attenuated below the hearing threshold when using a hearing protection device without use of a hearing aid [Berger, 1986]. Special types of hearing protection, such as amplitude-sensitive devices and communication headsets, may be useful in meeting some individuals' needs.

C. Heat

Gary Works should continue to develop and implement a heat-stress prevention program for heat-exposed workers. The program should address the multiple contributing factors to heat stress and should include the following measures:

1. Workers with obvious exposures to heat (such as those who work near heat sources or in elevated areas, such as overhead cranes) should be included in the program.

2. Cool rest areas should be provided. Although no conclusive information is available on the ideal temperature for a rest area, a temperature near 76°F appears to be adequate [NIOSH, 1986a].

3. Enclosed work areas should be cooled if frequent rest breaks or easily accessible rest areas are not feasible (such as in the overhead cranes).

4. Work-rest cycles should take metabolic work loads as well as environmental conditions into consideration. Rest periods should be long enough to allow workers to recover [NIOSH, 1986b]. For the temperatures measured in the ladle preparation area (index of 78°F WBGT), acclimatized workers with moderate to heavy work loads should maintain work-rest cycles of 50%-50%.

5. Drinking water should be easily accessible within the immediate work area. The water should be protected from environmental contamination. It should be cool, but not warm or cold. Since thirst may not be an adequate guide to the need for water, workers in hot jobs should be encouraged to drink water throughout the work day. Regular schedules may be helpful. Although feasibility of these schedules will depend on job tasks, and water requirements will depend on factors such as air temperature, humidity, and work load, drinking water as frequently as every 15 to 20 minutes may be necessary [NIOSH, 1986b].

The heat-stress prevention program should also include environmental measurements, a heat-alert program to prevent emergencies when environmental temperatures rise above usual temperatures, medical evaluations to assess individual needs, surveillance of heat-related health events, and worker education and training [NIOSH, 1986b]. Surveillance of health events should not be limited to heat stress, but should include events that may be precipitated by heat stress (such as injuries and near-injuries) or aggravated by heat (such as heart attacks and other acute medical conditions).

D. Ergonomics

Ergonomic issues, such as vibration, lifting, and awkward postures, should be further evaluated by Gary Works. Tasks with exposures to ergonomic risk factors should be identified and evaluated, and risk factors controlled. Measures to control vibration in hand-held tools include use of energy-damping materials for handles, offset or spring-loaded handles, and shock-absorbing exhaust mechanisms [NIOSH,1989]. Measures to control risk factors during lifting include reducing the vertical distance of lifts (such as placing parts on tables instead of on the ground) and reducing the weight of a worker's load and the angle of twist during the lift (such as using mechanical devices to lift and place heavy objects into position). NIOSH has published criteria for a recommended standard for occupational exposure to hand-arm vibration [NIOSH, 1989] and guidelines for lifting [Waters et al., 1994]. (Appendix I of this report contains the NIOSH lifting equation [Waters et al., 1994].) Some of the ergonomic guidelines for metalcasting published by the American Foundrymen's Society may be applicable or adapted for use in steel production [Ergonomics Task Force, 1992].

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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USS/USX Gary Works
Confidential requestors
United Steel Workers of America, Local 1014
U.S. Department of Labor, OSHA, Region V

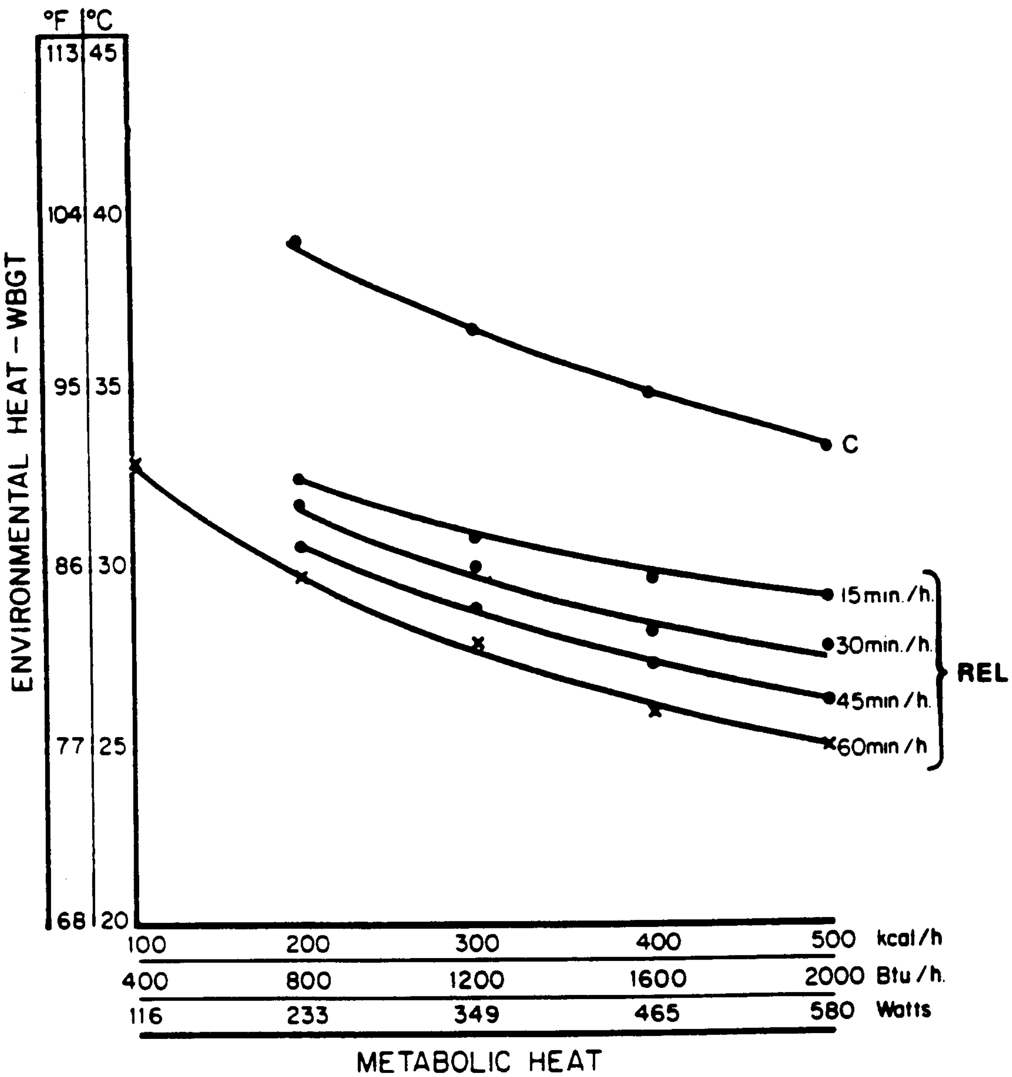
In order to comply with the NIOSH regulation that affected employees shall be notified about the determination of this health hazard evaluation (CFR, Title 42, Part 85, Section 85.11), the employer shall post copies of this report in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1. Air Sampling Results*
HETA 92-0230-2471 — USS/USX Gary Works
November 17-18, 1992

Job title or location	Sample period (time)	Sample volume (liters)	Aluminum (µg/m³)	Chromium (µg/m³)	Copper (µg/m³)	Iron (µg/m³)	Magnesium (µg/m³)	Manganese (µg/m³)	Lead (µg/m³)	Zinc (µg/m³)
MIXER**										
in cab of #2 crane	09:27-15:23	730	ND†	ND	ND	151	23	2	ND	30
3rd level above South Mixer	10:39-16:21	701	26	2	1	6,418	556	33	1	300
1st level: South Desalt Park	10:50-16:20	677	ND	ND	ND	340	34	3	ND	25
2nd level: outside west door of mixer pulpit	10:31-16:23	722	21	1	ND	2,633	430	19	ND	194
LMF††										
assistant LMF operator	11:30-15:20	472	47	3	ND	66	45	12	ND	4
assistant LMF operator	11:13-15:20	506	69	ND	ND	85	63	13	ND	4
LADLE PREPARATION										
ladle utility	10:58-16:30	681	26	ND	ND	56	24	6	ND	1
ladle utility	11:02-16:10	631	22	ND	ND	44	21	5	ND	2
Minimum detectable concentration			8	1	2	2	8	1	2	2
Evaluation criteria										
NIOSH REL			5,000	500	100	5,000		1,000	<100	5,000
OSHA PEL			15,000	1,000	100	10,000	15,000	5,000‡	50	5,000
ACGIH TLV			10,000	500	200	5,000	10,000	1,000	150	5,000

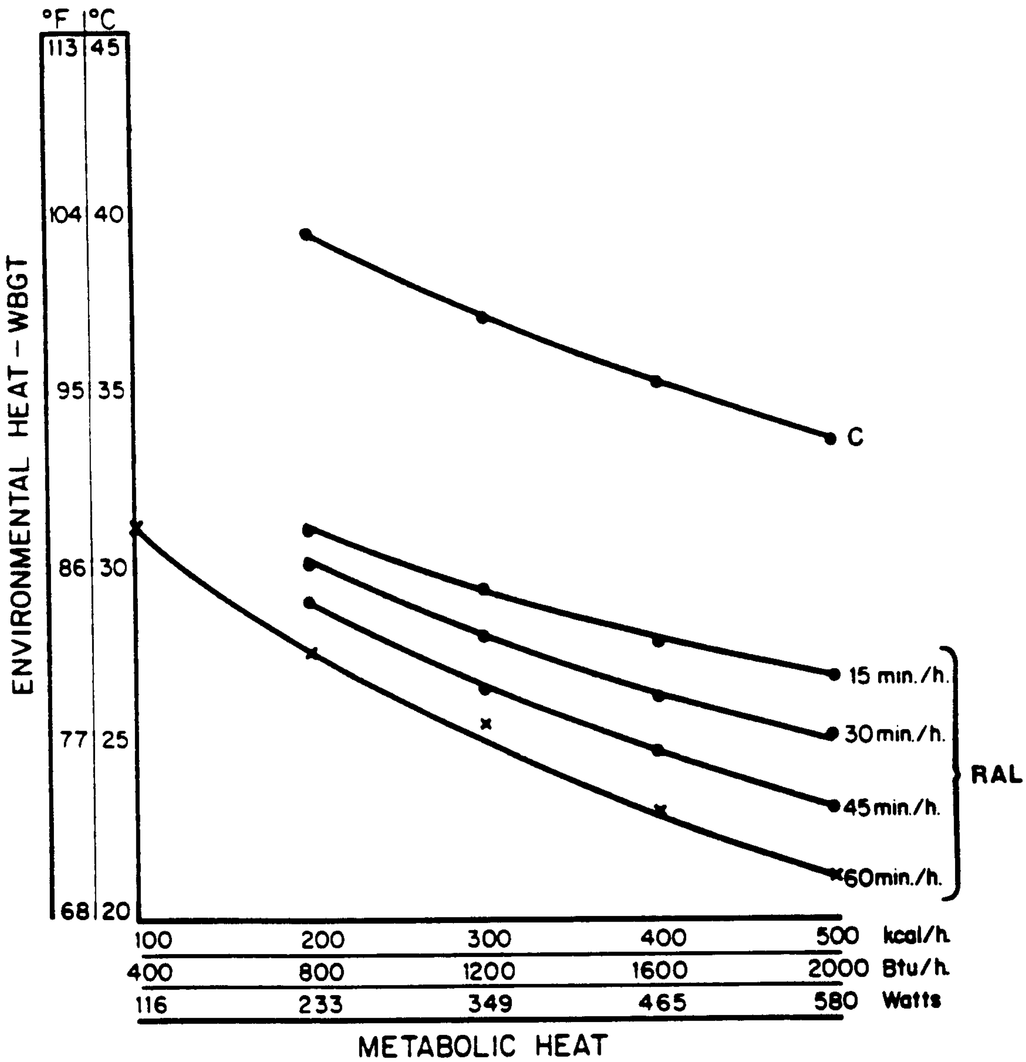
*NIOSH Method 7300 obtains results for 30 different metals. Results for selected metals are reported.
**Includes mixer and desulfurization stations.
†Not detected.
††Ladle metallurgy facility.
‡15-minute exposure.

Figure 1
NIOSH Recommended Heat-Stress Exposure Limits for Heat-Acclimated Workers
[SOURCE: NIOSH, 1986b]



C = Ceiling Limit
REL = Recommended Exposure Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

Figure 2
NIOSH Recommended Heat-Stress Exposure Limits for Heat-Unacclimatized Workers
[SOURCE: NIOSH, 1986]



C = Ceiling Limit
RAL = Recommended Alert Limit
*For "standard worker" of 70 kg (154 lbs) body weight and 1.8 m^2 (19.4 ft^2) body surface.

Appendix 1
NIOSH Lifting Equation*

Calculation for Recommended Weight Limit (RWL)

RWL = LC x **HM** x **VM** x **DM** x **AM** x **FM** x **CM**

Component			Metric	U.S. Customary
LC	=	Load Constant	23 kg	51 lbs
HM	=	Horizontal Multiplier	10/H	25/H
VM	=	Vertical Multiplier	$1 - (0.003\lvert V - 75\rvert)$	$1 - (.0075\lvert V - 30\rvert)$
DM	=	Distance Multiplier	0.82 + (4.5/D)	0.82 + (1.8/D)
AM	=	Asymmetric Multiplier	1 − 0.0032A	1 − 0.0032A
FM	=	Frequency Multiplier	(See Appendix 1, Table 1)	
CM	=	Coupling Multiplier	(See Appendix 1, Table 2)	

Where:

H = Horizontal location of hands from midpoint between the ankles.
Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands from the floor.
Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry: Angular displacement of the load from the sagittal plane.
Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min.
Duration is defined to be $\leq$ 1 hour; $\leq$ 2 hours; or $\leq$ 8 hours,
assuming appropriate recovery allowances (See Appendix 1, Table 1).

*Instructions are in the Applications manual for the revised NIOSH lifting equation, [Waters, 1994].

Appendix 1
NIOSH Lifting Equation

Table 1
Frequency Multiplier (FM)

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V* < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

*Values of V are in cm; 75 cm = 30 in.

Appendix 1
NIOSH Lifting Equation

Table 2
Coupling Multiplier

Couplings	V < 75 cm (30 in)	V ≥ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90