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ARKANSAS ALUMINUM ALLOYS, INC.
HOT SPRINGS, ARKANSAS

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SUMMARY

On May 9, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate exposure to contaminants generated during the scrap aluminum recycling process at Arkansas Aluminum Alloys, Inc. (AAAI) in Hot Springs, Arkansas. The confidential employee request indicated workers had experienced nausea, tingling in the hands, and a feeling of light-headedness at the furnace and product stacking stations. The request also indicated employees were exposed to excessive heat loads in various manufacturing areas.

On July 20, 1995, an initial site visit was conducted at the AAAI facility. The purpose of this visit was to review manufacturing processes and develop an appropriate evaluation strategy. The Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200), and environmental monitoring records, were reviewed.

On September 6-7, 1995, NIOSH investigators conducted a followup visit at AAAI. During this visit, full-shift and activity-specific personal breathing zone (PBZ) air sampling was conducted to evaluate employee exposures to metal dust and fume (both gravimetric and element-specific), at furnaces #2 and #4, during pouring and skimming operations, and during cleanup activities. Instantaneous monitoring was conducted to assess airborne concentrations of carbon monoxide (CO). Environmental monitoring to assess heat stress was conducted at the furnace pouring and skimming area, product stacking, and furnace #2 and #4 operator stations.

The personal air monitoring did not show an inhalation exposure hazard for the employees sampled during the monitoring period; all results were below NIOSH recommended exposure limits (RELs). The metal dust and fume sampling results were lower than those found during previous monitoring surveys; possibly due to improved work practices, engineering enhancements (additional ventilation), or a lower than usual level of activity. The area monitoring for carbon monoxide also showed that concentrations were below recommended limits. Propane-powered forktrucks are the primary source of CO at AAAI.

Heat loads exceeding the one-hour NIOSH REL for acclimatized workers were measured at the Furnace #2 "doghouse" and the northeast side of Furnace #4. The REL was also exceeded for some work periods at the ingot pouring station. The overexposures measured at the furnaces, however, were based on continuous work at these monitoring stations. Due to the varied tasks and high mobility of employees it is unlikely that workers remain at these stations at the estimated work rate continuously for 60 minutes. As such, the REL determinations should be considered "worst-case" estimates.

A high level of attention to safety and health by management and employees was evident at the AAAI facility. A safety committee program was in place, and measures to improve safety and health were apparent (e.g., cooling ventilation at various workstations). There was good employee adherence to the use of personal protective equipment.

Environmental monitoring showed personal breathing zone exposures to the contaminants sampled were below applicable limits during the monitoring period. Heat loads in excess of NIOSH RELs were measured at various workstations. Management and employee attention to safety and health is excellent. Recommendations to improve the heat stress management and respiratory protection program are provided in this report.

KEYWORDS:	SIC 3341(Secondary smelting and refining of nonferrous metals) heat stress, WBGT, aluminum, carbon monoxide, metal fume, nausea

INTRODUCTION

NIOSH received a confidential employee request on May 9, 1995, to evaluate exposure to heat stress and contaminants generated during secondary aluminum smelter operations at the Arkansas Aluminum Alloy, Inc. (AAAI) facility in Hot Springs, Arkansas. Reported health problems noted on the request included nausea, dizziness, and tingling in the fingers.

On July 20 and September 6-7, 1995, NIOSH investigators conducted site visits to review the secondary aluminum manufacturing process and monitor exposure to heat stress, metal fume and dust, and carbon monoxide. Employee work practices, and facility safety and health programs were also assessed.

On August 3, 1995, a letter describing actions to date and planned activities was sent to AAAI management.

BACKGROUND

Facility Description

Arkansas Aluminum Alloys, Inc. is an aluminum recycling facility (secondary, or reverberatory, aluminum smelter) that has been in business since 1974. AAAI produces aluminum stock with varied elemental composition depending on customer specifications. Approximately 165 employees (administration and production) work at the facility. Approximately half of the workers belong to the United Brotherhood of Carpenters and Joiners Union Local 2186. The facility operates 24 hours per day, 355 days per year, with four rotating work shifts. Employees receive two 10-minute breaks and a 30-minute lunch period each shift. There are three gas-fired furnaces at the smelter. However, except for times of extreme production demands, only two furnaces are operated at one time. Office, warehouse, and production space occupies 57,130 square feet, situated on nineteen acres. Smoking is permitted in the manufacturing areas.

Process Description

AAAI receives and processes all types of reclaimable aluminum scrap except cans. Most (98%) of the scrap aluminum is delivered by tractor-trailer truck, where it is weighed, scanned for radioactivity, unloaded, and spread in the storage area. The scrap is then placed on a conveyor where it is visually inspected and manually sorted. Iron, stainless steel, zinc, brass, and other materials are removed at this station. The scrap is then sampled and analyzed, and placed in storage bins based on elemental composition. AAAI has an on-site laboratory with a sophisticated elemental analyzer that requires very little sample preparation and provides rapid results. Some of the sorted scrap is shredded and crushed, and screened to remove dirt. A magnet is used to separate iron from the aluminum. The shredded scrap is then placed in bins. A gas fired kiln located at the back of the facility is used to dry machine turnings prior to processing in the furnace.

There are three 220,000 lb capacity gas-fired furnaces at AAAI. Each furnace is equipped with exhaust ventilation to control flue gas, as well as fume control (canopy hoods). Fume exhaust is conveyed to a roof mounted baghouse system. Furnace runs last approximately 20 hours, followed by a 4½ hour pour time. The pour temperature of the melt is approximately 1380°F. About 80,000 lbs of molten aluminum are left in the furnace to prime the next run. To charge the furnace, the furnace operator will open large overhead doors on one side of the furnace, and place the scrap into wells adjacent the furnace with a front end loader. After charging, the overhead doors are closed, and the scrap melts and flows into the main furnace body. Samples are periodically taken from the melt with a ladle and analyzed to ensure the final product meets customer specifications (elements are added if necessary to meet customer requirements). Copper and silicon are the major elements added (by placing into a hopper at the front of the furnace). The majority (over 95%) of AAAI customers purchase the finished aluminum in 30 lb ingots. AAAI will also accommodate those few customers who request 1000 lb aluminum "sows."

Magnesium is a common contaminant that must be scavenged (demagging) from the melt to reduce concentrations to below 0.1%. At AAAI, this is accomplished by injecting chlorine gas into the melt (piped from a 55 ton tank car, through vaporizers, to each furnace) via a graphite pump and carbon tubes. The chlorine combines with the magnesium ($MgCl_2$), which is then skimmed off the top of the melt. If necessary, aluminum fluoride can be used instead of chlorine for this “demagging” operation. According to AAAI, aluminum fluoride is rarely used. Salt (NaCl), potash, and cryolite are added to every charge as a flux to remove dirt and prevent oxidation of the melt.

Iron is considered a major detriment to the product, and every attempt is made to eliminate it during initial inspection and by the use of magnets prior to processing. However, some iron inevitably gets into the furnace, sinks to the bottom, and must be manually removed. Periodically (2X/shift), furnace operators manually drag a large rake along the bottom of the melt to pull the iron out of the furnace. Each raking event takes about 30 to 45 minutes.

During pouring, the furnaces drain into an insulated open trough. To start the pour, a furnace plug is removed and the molten metal flows continuously through the trough into 1½ feet long, 30 lb molds (or 1000 pound molds if necessary). The 30 lb molds are on a carousel/conveyor system and pouring occurs as the molds move sequentially through a water bath. This area is shielded because of the potential for violent reactions in the event molten aluminum contacts the water. After the molds have passed through the water, two workers stand adjacent the conveyer line and skim dross from the ingots using hoe-like hand tools. The ingot molds are then elevated on the carousel and rotated to release the ingots onto a conveyor belt. Graphite is used as a moldrelease agent. An automated pneumatic hammer is used to remove the ingots from the molds if necessary.

The ingots are then conveyed to the stacking area where they drop onto a rotating table. The surface temperature of the ingots is approximately 230°F when received at the Stacking Station. Stacking is a 3- or 4-man labor-intensive operation (2 stackers, 2 fork-lift operators), and workers continuously rotate between stacking and fork-lift operation. As the ingots are deposited onto the table, the stacker will pick up the ingot and toss/place it in position on a stacking pallet. Stackers are also required to inspect the ingots and recycle those found to be defective. Each stacker will load one 2000 lb stack (approximately 18-20 minutes), and then switch jobs with the fork-lift operator. The fully stacked pallets are then moved to a cooling room, and finally to the warehouse. AAAI has a fleet of trucks for shipping product to customers.

EVALUATION PROCEDURES

Environmental

Air Sampling

Processes selected for monitoring were based on an assessment of the chemicals in use, employee work practices, and controls utilized. Activities of concern noted by the HHE requestors were also targeted for sampling.

On September 6, 1995, environmental monitoring was conducted to assess airborne personal exposures to various compounds potentially present in secondary aluminum furnace processes. Calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift. After sample collection, the pumps were post-calibrated and the samples submitted to the NIOSH contract laboratory (Data Chem, Salt Lake City, Utah) for analysis. Field blanks were submitted with the samples. Specific sampling and analytical methods used during this survey were as follows:

Metal Dust

Air samples were collected to assess exposure to operators at Furnaces #2 and #4, workers at the pouring/skimming line, and during cleanup and sweeping activities. Personal exposures to airborne metal dust and fume were monitored using Gilian HFS 513A sampling pumps. Flow rates of approximately 2 liters per minute (l/m) and collection times of 2-8 hours were used to obtain the samples. The samples were collected on 5 micrometer (µm) pore size poly-vinyl chloride (PVC) filters and analyzed gravimetrically to determine the total dust concentration according to NIOSH fourth edition Analytical Method 0500. An element specific analysis was also conducted according to NIOSH method 7300, to differentiate and quantify the different metal species.

Carbon Monoxide

A Metrosonics PM-7700 toxic gas monitor with a carbon monoxide (CO) sensor was used to measure instantaeous CO concentrations in various areas throughout the main furnace area and warehouse. The instrument was pre-calibrated prior to use with a known concentration of CO. Instrument sensor repeatability is ± 2% at an operating temperature of -5 to 40°C. CO measurements were obtained throughout the manufacturing and warehouse areas.

Heat Stress

Area heat stress monitoring was accomplished with two Reuter-Stokes RSS 214 WibGet® monitors. This type of monitor assesses environmental heat by the Wet Bulb Globe Thermometer (WBGT) method. The WBGT is an accepted standard method for determining environmental heat stress.[1-3] The WBGT combines the effect of humidity, air movement, air temperature and radiant heat into a single measurement.

Specifications provided by the manufacturer for the Reuter-Stokes RSS 214 monitor are as follows:

Accuracy: ±0.3°C
Sensor Range: 0-100°C
Sensor Response Time: <2.2 minutes (90%)
<4.5 minutes (95%)

The monitors were operated in the automatic logging mode and were programmed to record the measured parameters at 5 minute intervals.

WBGT measurements, in conjunction with metabolic heat production rates, can be used to estimate heat stress exposure for comparison to recommended standards. During this evaluation, metabolic heat production rates in kilocalories per hour (kcal/hr) were estimated via observation of body position and work activities, and compared to standard tables. WBGT and metabolic heat rates are expressed as 1-hour time-weighted averages. These recommended standards were developed to prevent workers from exceeding a deep body (core) temperature of 38°C (100.4°F).[1-4]

The WibGet® units were placed as close as possible to the workers. The monitors were also placed so that there was no restriction of free air flow around the thermometer bulbs. Before sampling, the wick of the wet-bulb thermometer was moistened with demineralized water and the thermometer reservoir filled. The monitors were allowed to equilibrate in each area monitored for at least 5 minutes prior to recording readings. Heat stress was evaluated at the Stacking Station, Furnaces #2 and #4, and during pouring/skimming operations.

Temperature/Relative Humidity, Air Velocity

Standard dry bulb temperature and relative humidity (RH) levels were determined at various intervals. Instrumentation consisted of a TSI, Inc. model 8360 VelociCalc® meter with a digital readout. This unit is battery operated and has humidity and temperature sensors on an extendable probe. The temperature range of the meter is 14 to 140° F and the humidity range is 20 - 95%. Temperature and RH, as determined via standard dry bulb, wet bulb, and psychrometric chart correlated well with levels determined via the VelociCalc® meter. This meter was also used for measuring air velocity at various systems used for cooling purposes. The instrument measures air velocity in feet-per-minute (fpm). For each system evaluated, multiple measurements were obtained and the results averaged to obtain the mean velocity.

EVALUATION CRITERIA

Environmental

To assess the hazards posed by workplace exposures, NIOSH investigators use a variety of environmental evaluation criteria. These criteria suggest exposure levels to which most workers may be exposed for a working lifetime without experiencing adverse health effects. However, because of wide variation in individual susceptibility, some workers may experience occupational illness even if exposures are maintained below these limits. The evaluation criteria do not take into account individual hypersensitivity, pre-existing medical conditions, or possible interactions with other workplace agents, medications being taken by the worker, or environmental conditions.

The primary sources of evaluation criteria for the workplace are: NIOSH Criteria Documents and Recommended Exposure Limits (RELs),[5] the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[6] and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs).[7] The objective of these criteria for chemical agents is to establish levels of inhalation exposure to which the vast majority of workers may be exposed without experiencing adverse health effects.

Occupational health criteria are established based on the available scientific information provided by industrial experience, animal or human experimental data, or epidemiologic studies. Differences between the NIOSH RELs, OSHA PELs, and ACGIH TLVs may exist because of different philosophies and interpretations of technical information. It should be noted that RELs and TLVs are guidelines, whereas PELs are standards which are legally enforceable. OSHA PELs are required to take into account the technical and economical feasibility of controlling exposures in various industries where the agents are present. The NIOSH RELs are primarily based upon the prevention of occupational disease without assessing the economic feasibility of the affected industries and as such tend to be conservative. A Court of Appeals decision vacated the OSHA 1989 Air Contaminants Standard in *AFL-CIO v OSHA*, 965F.2d 962 (11th cir., 1992); and OSHA is now enforcing the previous 1971 standards (listed as Transitional Limits in 29 CFR 1910.1000, Table Z-1-A).[5] However, some states which have OSHA-approved State Plans continue to enforce the more protective 1989 limits. NIOSH encourages employers to use the 1989 limits or the RELs, whichever are lower.

Evaluation criteria for chemical substances are usually based on the average PBZ exposure to the airborne substance over an entire 8- to 10-hour workday, expressed as a time-weighted average (TWA). Personal exposures are usually expressed in parts per million (ppm), milligrams per cubic meter (mg/m^3), or micrograms per cubic meter ($\mu g/m^3$). To supplement the 8-hr TWA where there are recognized adverse effects from short-term exposures, some substances have a short-term exposure limit (STEL) for 15-minute peak periods; or a ceiling limit, which is not to be exceeded at any time. Additionally, some chemicals have a "skin" notation to indicate that the substance may be absorbed through direct contact of the material with the skin and mucous membranes.

It is important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these occupational health exposure criteria. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, previous exposures, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, or with medications or personal habits of the worker (such as smoking, etc.) to produce health effects even if the occupational exposures are controlled to the limit set by the evaluation criterion. These combined effects are often not considered by the chemical specific evaluation criteria. Furthermore, many substances are appreciably absorbed by direct contact with the skin and thus potentially increase the overall exposure and biologic response beyond that expected from inhalation alone. Finally, evaluation criteria may change over time as new information on the toxic effects of an agent become available. Because of these reasons, it is prudent for an employer to maintain worker exposures well below established occupational health criteria.

<u>Heat Stress</u>

Heat stress is the total net heat load on the body that results from exposure to external sources (environmental heat) and internally generated heat (metabolic heat) minus the heat lost from the body to the environment.[1,3] The environmental factors of heat stress are air temperature and movement, humidity, and radiant heat. Exposure to heat stress conditions produces physiological responses referred to as heat strain and characterized by an increase in: "core" or deep body temperature; heart rate; blood flow to the skin, and; water and salt loss due to sweating.[3] These conditions can occur when the physical work is too heavy and/or the environment is too hot.

The body normally maintains a deep body temperature within narrow limits (about 37°C) by means of various adaptive mechanisms to either produce more heat, or rid the body of excess heat. This continuous heat regulation is an essential requirement for continued normal body function. The most important physiologic responses to heat include changes in blood flow to the skin, muscular activity, and sweating. Under excess heat conditions, blood flow to the skin increases, where heat dissipates into the environment. Muscular activity will increase if more heat is necessary (e.g., shivering), and will, if possible, decrease when less heat is needed. Sweating is a major heat dissipation mechanism that depends on the evaporation of sweat to produce a cooling effect. The rate and amount of evaporation is a function of humidity and the speed of air movement over the skin.

The major heat exchange mechanisms between the human body and the environment are convection, radiation, and evaporation.[1]

1. Convection heat exchange (C) is the gain or loss in heat as a function of the rate of air movement over the skin and the difference in temperature between the ambient air and the skin. When the dry bulb air temperature is lower than the skin temperature (about 35°C), heat is lost from the body. When ambient temperatures exceed the skin temperature, heat is gained by convection.

2. Radiant heat exchange (R) is the gain or loss in heat by radiation from warmer surfaces to cooler surfaces

3. The evaporation (E) of water (sweat) from the skin is an important cooling mechanism and always results in a net heat loss. In hot-moist environments, evaporative heat loss may be limited by the capacity of the ambient air to accept additional moisture.

The basic equation describing heat balance is: $S = M \pm C \pm R - E$, Where:

S = The net body heat gain or loss
M = Metabolic heat production
C,R,E are described above

Heat acclimatization is the enhanced tolerance to heat acquired by working in a hot environment.[8] The body's heat adaptive mechanisms can, through regular exposure to hot environments, significantly increase the ability to tolerate work in heat. This heat acclimatization process can usually be induced in 7-10 days of exposure to a hot environment.[1]

Acclimatized workers can perform with less increase in core temperature and heart rate, and less salt loss, then unacclimatized workers.

At this time, OSHA has not promulgated regulations or standards covering heat stress. OSHA has, however, issued a directive to OSHA field staff that provides technical information regarding the investigation of heat stress issues in industry.[9] This document draws heavily on NIOSH and ACGIH criteria. The NIOSH RELs and ACGIH TLVs present recommended heat exposure limits (WBGT) for a variety of work-rest regimens and worker energy costs (metabolic heat generation).[1,3] This criteria, presented in Figure 1, applies for the following conditions:

a. Healthy workers who are physically and medically fit
b. Workers who are heat-acclimatized to working in hot environments
c. An average worker size of 154 pounds (70 kilograms)
d. Workers who are wearing light summer clothing

If any of these parameters change, modifications must be made to the heat exposure evaluation criteria. Values are available for adjusting for worker weight and additional clothing.[1] In special cases where vapor-impermeable clothing (e.g., chemical protective suits) is worn, the WBGT is not the appropriate method for measuring environmental heat stress.

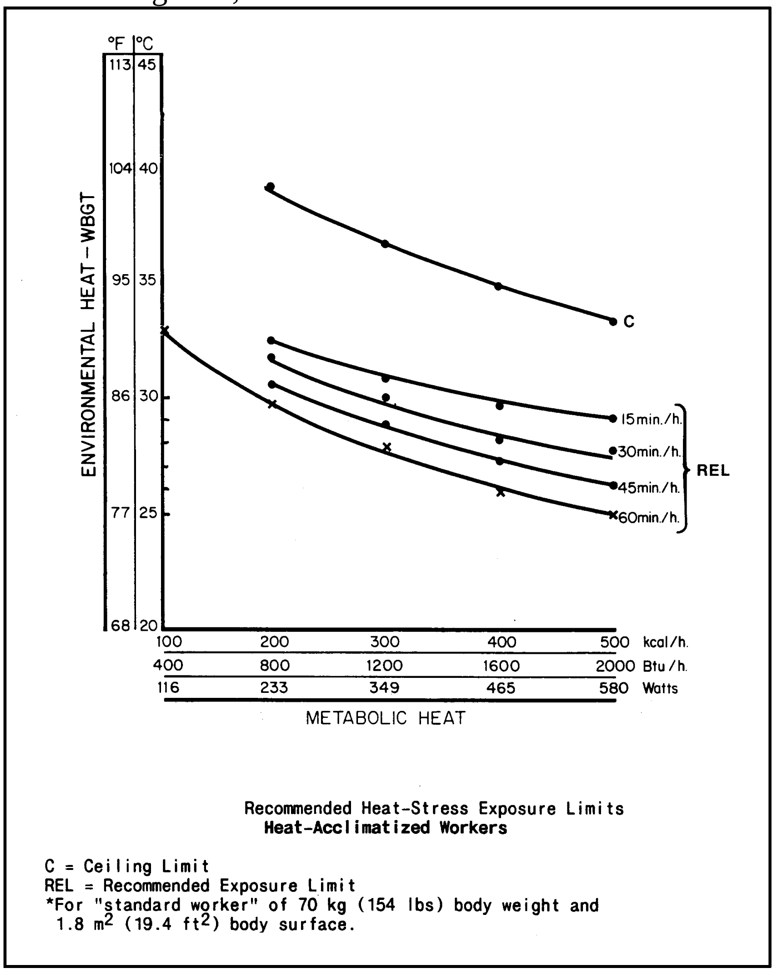

Figure 1

NIOSH has also established Recommended Alert Limits (RALs) for healthy workers who are not acclimatized to working in hot environments.[1] These limits are presented in Figure 2. A ceiling level has been recommended by NIOSH, for both acclimatized and un-acclimatized workers. Workers should not be exposed to temperatures reaching or exceeding this ceiling limit without adequate heat-protective clothing and equipment. These ceiling levels are indicated with a C in Figures 1 and 2.

These evaluation criteria have been established to prevent exposed workers from exceeding a deep-body or core temperature of 38°C (100.4°F). This temperature is considered to be a consensus among work physiologists and standard setting organizations as the value below which the body temperature must be maintained to reduce the risk of heat illness.[1-4]

Due to the impracticality of monitoring a worker's deep body temperature, the measurement of environmental factors that correlate with a worker's deep body temperature and other physiologic responses to heat is necessary. As mentioned, the WBGT is the accepted standard method for measuring these environmental factors for most situations. For indoor use only two measurements are needed: the natural wet bulb (nwb) and black globe temperatures (g). The calculation for the indoor WBGT is as follows:

$$WBGT = 0.7t_{nwb} + 0.3t_g$$

These measurements of environmental heat are expressed as 1-hour time-weighted averages (TWAs).

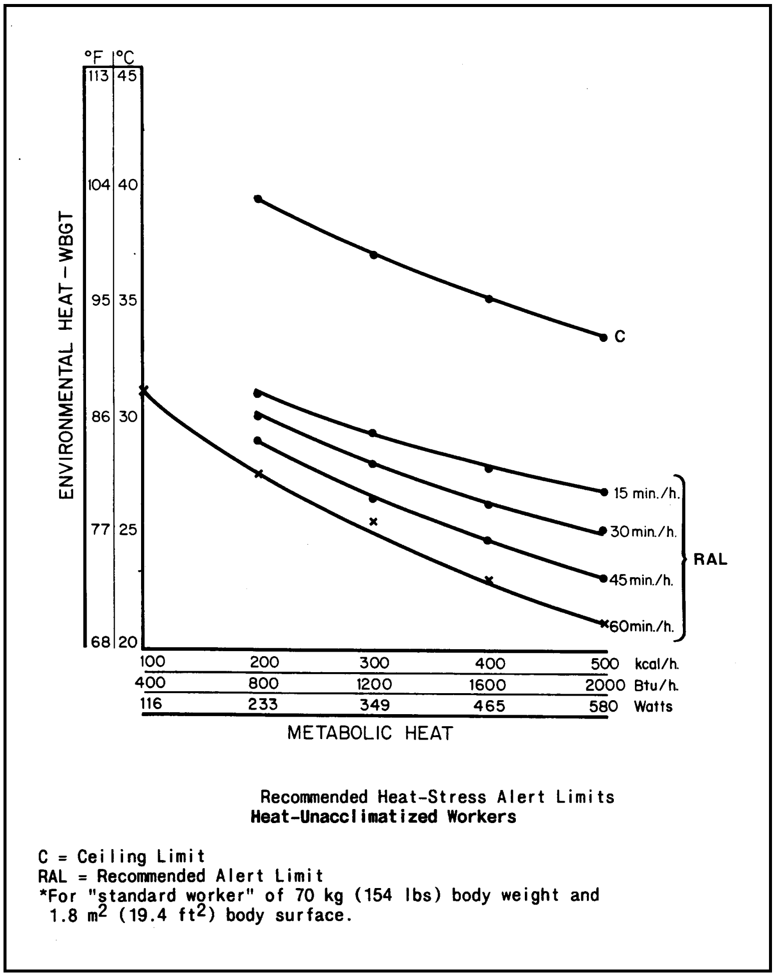

Figure 2

As both metabolic and environmental heat together determine the total heat load, the work load category of each task must be established to determine the applicable heat exposure limit. For this evaluation, metabolic heat rates for each task monitored were estimated from established references (Table 1).[1,3] This was accomplished by observation of the worker performing the task, and categorizing body position, type of work, and degree of work-rest regimen (e.g., continuous, 50%, etc.). Metabolic heat production was then estimated in kilocalories per hour (kcal/hr). The WBGT measurements, estimates of metabolic heat production (kcal/hr), and the degree of work-rest regimen were used to determine the appropriate REL for each task monitored.

Heat Stress: Health Effects

When heat gain exceeds the ability of the body to compensate through heat loss mechanisms, the core temperature will begin to rise and heat stress disorders are possible. There are a variety of outcomes that could occur, ranging from somewhat mild behavioral disorders (heat fatigue) to very severe health problems such as heat stroke. In addition to the environmental temperatures and metabolic rates, there are numerous other factors that will influence the potential for a heat related disorder to occur. These include the following:

1. Fluid intake and electrolyte replenishment
2. Degree of acclimatization
3. Diet
4. Age
5. Gender
6. Body Fat
7. Alcohol and drug (therapeutic and social) use
8. Individual variation
9. Physical fitness

The primary physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.[10]

Table 1

Estimating energy cost of work by task analysis

A. Body position and movement	**kcal/min***
Sitting	0.3
Standing	0.6
Walking	2.0-3.0
Walking uphill	add 0.8 per meter rise

B. Type of work	**Average kcal/min**	**Range kcal/min**
Hand work		
light	0.4	0.2-1.2
heavy	0.9	
Work one arm		
light	1.0	0.7-2.5
heavy	1.8	
Work both arms		
light	1.5	1.0-3.5
heavy	2.5	
Work whole body		
light	3.5	2.5-9.0
moderate	5.0	
heavy	7.0	
very heavy	9.0	

C. Basal metabolism	1.0

D. Sample calculation**	**Average kcal/min**
Assembling work with heavy hand tools	
1. Standing	0.6
2. Two-arm work	3.5
3. Basal metabolism	1.0
Total	5.1 kcal/min

* For standard worker of 70 kg body weight (154 lbs.) and 1.8 m^2 body surface (19.4 ft^2).
**Example of measuring metabolic heat production of a worker when performing initial screening.

Heat Rash

Heat rash ("prickly heat") occurs as a result of unrelieved exposure to humid heat with the skin continuously wet with unevaporated sweat. This often occurs when clothing traps moisture against the skin. The sweat gland ducts can become plugged which leads to inflammation of the glands. This causes profuse, visible, tiny red vesicles in the affected skin area and can substantially impair sweating. Therefore, it is not only a nuisance due to discomfort but can diminish the workers' capacity to tolerate heat.

Heat Cramps

Heat cramps can occur after prolonged exposure to heat with extensive perspiration and inadequate replacement of salt. Cramps usually occur in the abdomen and extremities.

Heat Exhaustion

Predisposing factors for heat exhaustion include sustained exertion in a hot environment, lack of acclimatization, and failure to replace water and/or salt lost in sweat. These factors can result in dehydration, depletion of circulating blood volume and circulatory strain from competing demands for blood flow to the skin and active muscles. Signs and symptoms include fatigue, nausea, headache, and giddiness. There may be an increase in body temperature. The affected individual's skin will be clammy and moist.

Heat Stroke

Heat stroke is considered a serious medical emergency. A major predisposing factor is excessive physical exertion in a hot environment. Classical heatstroke includes: (1) major disruption of the central nervous function (convulsions, unconsciousness); (2) a lack of sweating; and (3) a very high body temperature (>105°F). Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin (due to cessation of sweating), confusion, collapse, delirium, and coma. If cooling of the victim's body is not started immediately, irreversible damage to vital organs may develop.

In addition to the above, prolonged exposure to excessive heat may cause increased irritability and anxiety, decreased morale, and an inability to concentrate. This often results in a general decrease in production efficiency and quality.[10]

<u>Carbon Monoxide</u>

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. Engine exhaust, tobacco smoking, inadequately ventilated combustion products from heaters that use hydrocarbon fuel are sources of exposure to CO. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[3, 10-14]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not been exceeded.[6,15] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[11] The ACGIH recommends an 8-hour TWA-TLV of 25 ppm.[7] The OSHA PEL for CO is 50 ppm for an 8-hour

TWA exposure.[6] In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[16]

Metal Dust and Fume

Metals comprise the majority of the known elements and have widespread natural occurrence in the environment. Aluminum, for example, is the third most abundant element in the earth's crust.[17] Metals have a wide range of properties, uses, and toxicity. Some metals are essential for life while others have no known biologic function. Other metals are capable of producing disease. Some metals that are essential nutrients can be toxic at higher concentrations. Allowable daily intake (food), maximum contaminant level (drinking water), and industrial exposure (e.g., NIOSH RELs) guidelines and regulations have been established for a number of metals.

Inhalation is usually the exposure pathway of concern in industry. However, some metals (e.g., nickel, beryllium, arsenic) can cause skin effects, or, if the metal is in a certain form (e.g., alkyl lead), can be absorbed through the skin.[18] In addition to the species of metal, the toxicity of a metal, and the mode of toxicity, is influenced significantly by its chemical state. The elemental form of a metal, for instance, rarely interacts with biologic systems.[18] Metal hydrides (e.g., arsine) are generally far more acutely toxic than other forms. Soluble salts of metals are usually more readily absorbed and are possibly more hazardous. The toxic properties of methyl mercury are very different from inorganic mercury.

Despite these differences, there are some toxicologic similarities among the group of metals. Many absorbed metals will accumulate in the kidneys and the bones, and many have long half-lives.[17] Inhalation of high concentrations of metals is irritating and may result in severe respiratory tract damage, including bronchitis, chemical pneumonitis, and pulmonary edema.[19]

Aluminum

Aluminum is widely used in industrial and building applications because of its light weight, corrosion resistance, and good working and forming properties. Metallic aluminum dust is considered a relatively benign "inert dust."[13] Inhalation of very high concentrations of very fine aluminum powder has caused pneumoconiosis in some circumstances.[13] Absorption of aluminum is limited, and urinary excretion is rapid.[17] Shaver's disease, a lung disorder that formerly occurred among workers who manufactured aluminum abrasive, apparently results from exposures to bauxite fume, which contains aluminum oxide and silica.[17] Symptoms include weakness, fatigue, and respiratory distress, and X-ray findings often indicate a fibrosis. The NIOSH REL for aluminum metal is 10,000 micrograms per cubic meter (µg/m3) for total dust, and 5000 µg/m3 for the fume.[5]

Health effects associated with exposure and NIOSH RELs for other elements of toxicological importance that were detected in the environmental samples at AAAI are shown in the following table. Exposure may occur from fume during furnace operations, or dust during cleanup activities.

Element	NIOSH REL[5] ($\mu g/m^3$)	Principle Health Effects[13,20]
Magnesium	NE*	Magnesium oxide fume is an eye and nose irritant
Cadmium	LFC**	pulmonary edema, emphysema, pneumonitis, headache, muscle ache, nausea, vomiting, renal injury; lung cancer
Copper	100 (fume)	Copper fume exposure has resulted in upper respiratory tract irritation, metallic taste in the mouth, and nausea. Exposure has been associated with the development of metal fume fever
Manganese	1000	Manganese fume exposure has been associated with chemical pneumonitis and central nervous system effects (manganism).
Titanium	LFC (titanium dioxide)***	Pulmonary irritation. Titanium dioxide caused lung cancer in heavily exposed experimental animals.
Iron	5000	"Benign pneumoconiosis" (siderosis), an X-ray finding not associated with symptoms
Zinc (zinc oxide fume)	5000 (TWA, 15000 (Ceiling)	Metal fume fever (an influenza-like illness), dry or irritated throat, metallic taste

$\mu g/m^3$ = micrograms per cubic meter
* NE = not established. The OSHA PEL for magnesium oxide fume (total particulate) is 10000 $\mu g/m^3$. NIOSH did not adopt a REL for magnesium and concluded after a limited review that adverse health effects could occur at the OSHA PEL.
** = NIOSH considers cadmium to be a potential human carcinogen and recommends controlling exposure to the lowest feasible concentration (LFC).

*** = NIOSH considers titanium dioxide to be a potential human carcinogen and recommends controlling exposure to the LFC.

RESULTS AND DISCUSSION

Workplace Observations/Industrial Hygiene Programs

Management concern and awareness of safety was apparent in many areas of the workplace. Procedures had been developed and engineering controls implemented for various activities and processes. These included chlorine handling, battery charging, and forklift safety. Efforts to maintain a clean and orderly work environment were also evident. Furnace operators engage in cleanup and sweeping activities when not directly working on production tasks. An environmental consultant knowledgeable about the secondary aluminum industry has been assisting AAAI management develop and implement various safety and health programs.

A safety committee has been established with members and officers from the workforce and management. Each department has monthly safety meetings. The committee meets monthly to discuss current safety issues.

Worker adherence to personal protective equipment (PPE) requirements (hearing, eye, foot protection, hard-hat, etc.) was good throughout the facility. All employees observed were wearing the required PPE. Specialized PPE is required for certain tasks (e.g., tarsal protection during stacking). Iron raking is a labor-intensive task requiring considerable strength to pull the rake through the melt. Proper technique is also critical, and certain experienced workers are much more adept at this task. During raking of the melt to remove iron, workers stand close to the furnace well and lean over to grasp the rake handle. Although workers wear PPE including hard hats, eye protection, gloves, etc., there is a potential for molten metal (splashes) to contact the worker's midriff.

Air monitoring and noise exposure surveys have been previously conducted at the facility, either by regulatory agencies, the state OSHA consultation program, or AAAI consultants. Area samples (300 minute) collected in 1992 showed respirable dust concentrations of 2.3 mg/m^3 (Furnace #2) and 4.4 mg/m^3 (Furnace #4), as well as low concentrations of aluminum, silica, and chromium. Sampling conducted in 1986 found a total dust exposure of 12.17 mg/m^3 at the shaker line (scrap conveyor), and 15.38 mg/m^3 at the baghouse. The current OSHA PEL for total dust, particulate not-otherwise regulated (PNOR) is 15 mg/m^3.[6] NIOSH has not established a REL for PNOR. However, during the 1989 OSHA PEL update project, NIOSH did not adopt the proposed OSHA PEL of 10 mg/m^3 for total PNOR; NIOSH concluded that adverse health effects could occur at the proposed PEL for some of the compounds included in the category PNOR.[5] OSHA consultation recommendations in 1985 to control noise at air-actuated hammers had been implemented, and engineering designs for noise attenuation at the shredder had also been implemented.

Workers receive annual audiograms and hazard communication training. Respirators are available and are used for maintenance activities such as baghouse cleaning. Additionally, approximately 15 workers participate in the facility emergency response team and have received training on self-contained breathing apparatus (SCBA), CPR, and first-aid. Pulmonary function tests and respirator fit-testing is conducted for potential respirator users by a contractor. A no-beard policy is in effect at the AAAI facility. Although some procedures have been developed, a comprehensive written respiratory protection program has not been implemented at AAAI. Exposure assessments have not been conducted for some tasks where respiratory protection is required.

Chlorine for demagging is delivered from a 55-ton rail car. A limited review of the system found a pressure relief valve missing (pipe had been capped) at the vaporizer system, and the chlorine delivery lines were not labeled. A valve to isolate gauges was present on one of the chlorine distribution panels, but missing on the other (south distribution panel). Procedures had been developed for disconnecting and connecting chlorine lines from the rail car. A comprehensive safety review of the chlorine system was not conducted. One-ton chlorine cylinders are available for use as a back-up, and eight cylinders were stored uncovered at the back of the AAAI facility. Sheets of plywood had been placed over some of the cylinders to protect them from direct sunlight.

A review of company OSHA 200 Logs from September 1994 through July 1995 showed a total of 22 recordable injuries and 1 case of heat exhaustion (furnace operator).

Environmental Monitoring

Eight personal breathing zone (PBZ) samples were collected to assess worker exposure to total dust and metals. The results of the environmental monitoring are shown in Tables 2-3. Shorter-term samples to assess specific cleanup tasks are also presented in these tables. All sample results showed employee exposures to be below NIOSH RELs during the monitoring period. However, some employees monitored indicated there was less than normal-level activity during the sampling period. Furnace #4 was not operational until approximately 1:00 p.m.; operators at this furnace performed cleanup and furnace maintenance activities, and assisted with furnace #2 operation during the time furnace #4 was down. Activity at Furnace #2 was judged by workers to be slightly lower than normal in the morning, and busier than normal during charging in the afternoon. The furnace operators and associated workers engage in a variety of tasks, including sweeping, maintenance, assisting others, and operating heavy equipment (front-end loaders). The employees monitored were very mobile and worked throughout the furnace area.

Aluminum was found on all samples collected and at higher concentrations than any of the other elements detected. The highest aluminum (371 $\mu g/m^3$) and total dust (3.24 mg/m^3) concentrations were found on a 125 minute sample collected during cleanup activities at the pouring area. A titanium concentration of 21.2 $\mu g/m^3$ was also detected on this sample. NIOSH considers titanium dioxide to be a potential occupational carcinogen, and recommends controlling exposure to the lowest feasible concentration.[5] However, the species of titanium was not determined by this analytical method, and was likely elemental titanium, which has markedly different toxicity characteristics, and is not considered to be highly toxic.[17] The OSHA PEL and ACGIH TLV for titanium dioxide (total dust) is 10 mg/m^3.[(6,7)]

Other elements detected on the personal air samples included zinc (5/8 samples), magnesium (8/8 samples), manganese (5/8 samples), iron (8/8 samples), and copper (8/8 samples). Cadmium was found on two samples at concentrations between the analytical limit of detection (LOD) and limit of quantification (LOQ). No chromium, lead, or nickel was detected on the samples collected.

Instantaneous area measurements to evaluate CO levels at AAAI did not suggest a problem with excessive concentrations of CO during the monitoring period. The highest CO concentration measured was 14 ppm at the Ingot Stacking Station (11:40 a.m.). There was one propane-powered lift-truck idling at this station during the measurement, and other lift-trucks operating nearby (the route between the warehouse and loading dock is adjacent the Stacking Station). A sample collected at this station at 8:45 a.m. showed a concentration of 6 ppm. Measurements obtained at the furnaces, front-office, employee break room, pouring and skimming station, and the shipping/receiving office were all below 4 ppm.

Heat Stress Evaluation Results

Facility Ventilation and Heat Control Programs

Most of the production and warehouse areas of the facility are open-sided with high ceilings and are not air-conditioned. Forced cooling or unconditioned air systems have been installed at the stacking (conditioned) and the pouring/skimming (unconditioned) stations to provide heat relief for workers. Radiant heat is the major environmental heat source at AAAI, primarily from the furnaces and the freshly prepared ingots (stacking and cooling), which require considerable cool-down time. Because of the large influence of radiant heat sources, ambient temperature may not be a significant contributor to total heat stress loads.

An air-conditioned room is used by employees during the scheduled break and lunch periods. Room conditions at 2:15 p.m. on September 6 were 81°F and 40% RH.

Employees handling ingots and other potential hot sources are provided with reversible heavy-duty insulated Kevlar® gloves for thermal protection. All employees wore long pants, and most wore short-sleeve shirts during the NIOSH survey. Electrolyte tablets are also provided for employees, and water and electrolyte-containing fluids (Gatorade®) are provided at stations located in various production and warehouse areas. Access to these fluid-replenishment stations is not restricted.

Informal interviews with employees indicated they had received heat stress awareness training. No written procedures or training program for heat stress have been developed. However, management indicated employees are provided verbal training at the time of hire, and that heat stress is a covered topic at the periodic department safety meetings. Although there is no formal acclimatization policy, management indicated new employees are gradually provided increasing work loads when hired.

Heat Stress Monitoring Results

Table 4 depicts the results of the environmental heat stress monitoring and corresponding RELs. The WBGT monitoring results, compared to the calculated RELs, are also graphically depicted in Figures 3-6. As previously noted, these RELs apply to healthy, acclimatized workers wearing light summer clothing, working on a continuous basis (except where otherwise noted in the table). Additionally, these RELs are based on workers with an average body weight of 154 pounds. These results do not include any adjustments for body weight or clothing.

Outdoor conditions (sunny day - no cloud cover) on the day of the monitoring were as follows:

Time	Temperature	Relative Humidity
9:10 a.m.	76°F	51%
2:14 p.m.	81°F	32%

Figure 3 compares the continuous WBGT indoor measurements at the Stacking Station with the calculated REL of 29 °C. The energy costs of this task were estimated to be approximately 310 kilocalories/hour. This was based on observation of body position and movement, and a work regimen of 15-18 minutes stacking/15-18 minutes of forklift operation. Because the Globe Temperature sensor was not properly seated during the first 55 minutes of sampling (08:25 - 09:20), the results from this time period were discounted. The monitoring results show no overexposures to heat during the sampling period at the Stacking Station. Two workers stack ingots at this station, and conditioned (61°F) supply-air ventilation was measured to be 800-1000 cfm at each station.

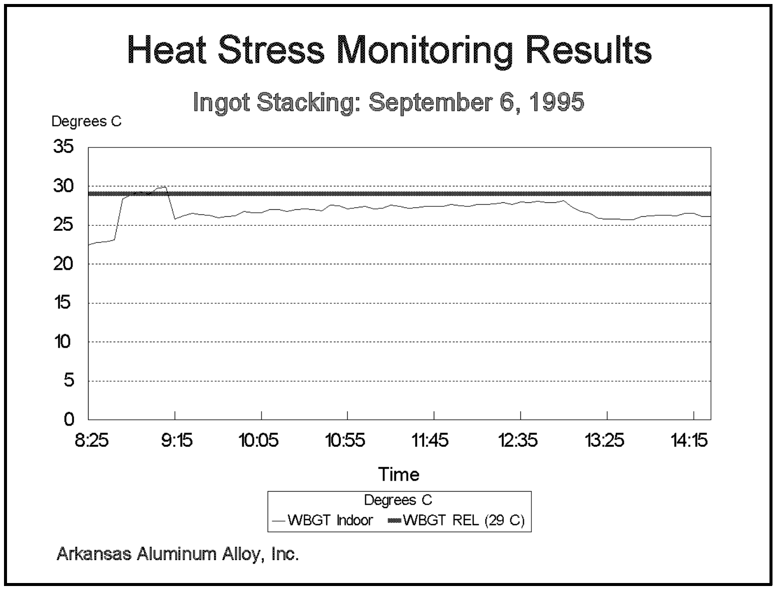

Figure 3

The results of the monitoring conducted at the Furnace #2 "Doghouse" are depicted in Figure 4. The REL at this station (26°C) was calculated from an estimated energy cost of approximately 480 kilocalories per hour. These area WBGT levels and metabolic work

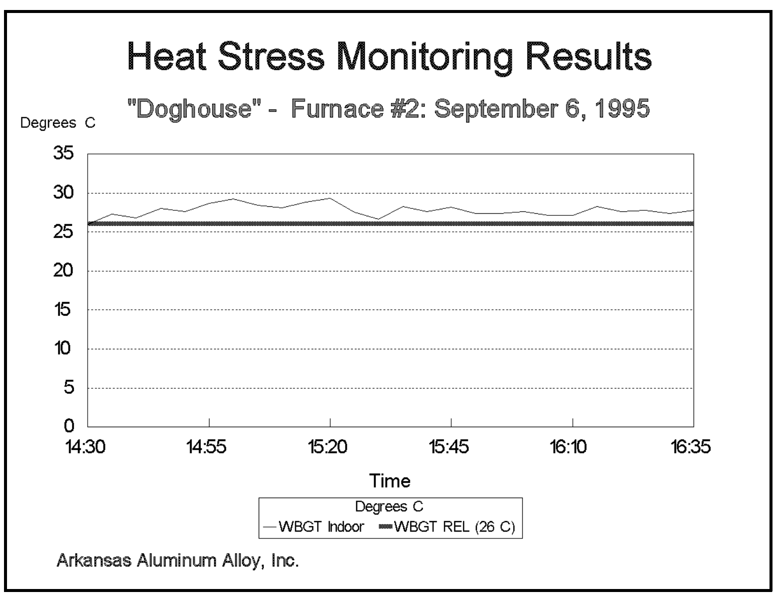

Figure 4

rates are estimates of the heat stress burden that would be present during 60 minutes of continuous work (at the estimated work rate) at this station. However, because the furnace operators tasks are varied, workers are not typically continuously present at this station for long periods. Additional tasks conducted by furnace operators include raking, charging, moving scrap, assessing furnace performance, assisting other furnace operators, etc. At any given time there may be 1-3 workers at this station. Fluid replenishments are available, and workers may sit during periods of inactivity at this station. However, given the assumption of 60 minutes of continuous work at the estimated metabolic work rate, these results suggest that heat levels at this station exceed the NIOSH REL.

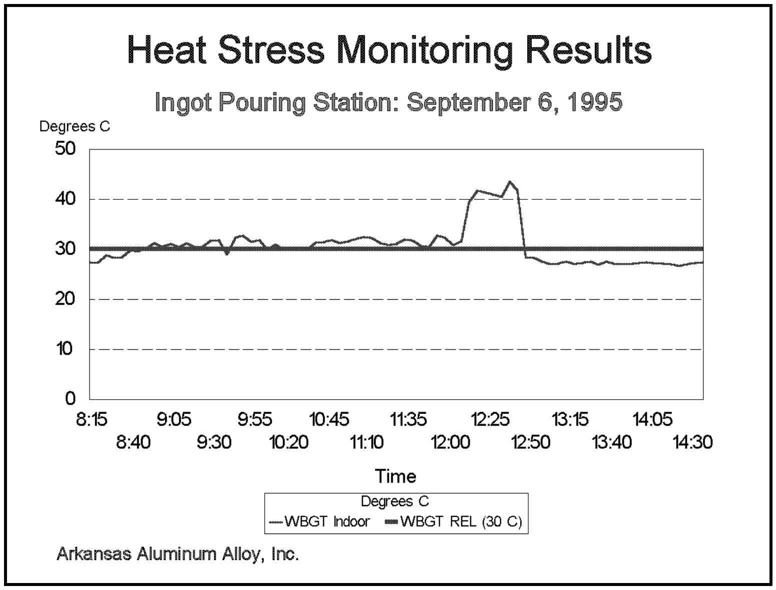

Figure 5

Figure 5 depicts the WBGT monitoring conducted on the pouring line where two employees skimmed dross from the freshly poured ingots. The WBGT REL of 30°C was calculated from an estimated energy cost of 186 kilocalories per hour at this station (workers standing, light work, both arms). The WibGet® monitor was placed on a rail adjacent the workers, and out of the direct line of a fixed high-volume supply duct providing unconditioned air (obtained at roof level) for cooling purposes. The air supply louver was located directly (2 ft) behind the area where the workers stand. During the monitoring period, the temperature of the discharge air was 82.5°F. Between 11:30 and 12:30, the wet bulb wick was not completely moistened, and the results are artificially skewed high during this time period and are discounted. The effect of this can be seen in Figure 5. As shown in the illustration and in Table 4, the WBGT monitoring suggests that the REL was exceeded for some time periods during pouring activities. Note that pouring operations ceased at 12:45, and this accounts for the decrease in WBGT readings.

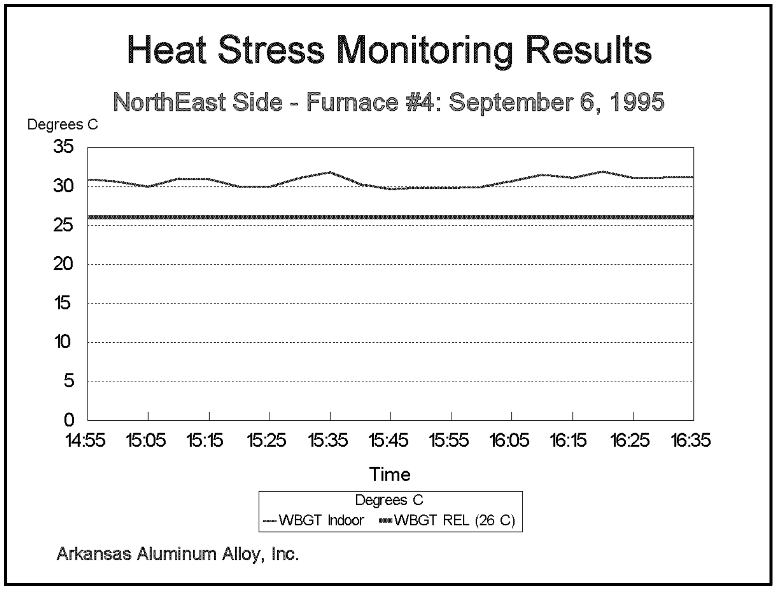

Figure 6

Afternoon WBGT area measurements obtained on the Northeast side of Furnace # 4 compared with the corresponding REL are shown in Figure 6. Energy expenditures (480 kilocalories per hour) and the resultant REL (26 °C) were considered to be the same as those for the Furnace #2 Doghouse. As noted in Figure 6 and Table 4, the results indicate that the WBGT REL was exceeded during the monitoring period. However, this area is not considered a routine workstation, and is only accessed during periods of furnace maintenance or charging. Because of the variability of tasks, the number of workers, or time spent at this location cannot be predicted. Therefore, as with the furnace "Doghouse," although the REL and measurements are applicable for 60 minute time-weighted averages, there may only be few occasions when workers would actually be present in this area for 60 continuous minutes.

DISCUSSION AND CONCLUSIONS

An industrial hygiene evaluation was conducted to assess worker exposure to contaminants during the processing of recycled aluminum at the AAAI facility in Hot Springs, Arkansas. Exposure to heat stress was evaluated during furnace operations, aluminum pouring, and ingot stacking. A process review, facility inspection, and a limited review of company health and safety programs was conducted.

A high level of attention to safety and health by management and employees was evident at the AAAI facility. A safety committee program has been implemented and efforts to improve safety and health were noted (e.g., cooling ventilation at various workstations). There was good employee adherence to the use of personal protective equipment. Although no formal training programs had been developed, informal interviews with workers indicated they had been informed by management about the hazards associated with heat stress. Employees have unrestricted access to fluid replenishment stations located throughout the facility. A review of company records indicated one employee (furnace operator) had experienced heat exhaustion in the summer of 1995.

Respiratory protection is used for certain non-routine tasks and some procedures have been developed for the use of respirators. However, a comprehensive written respiratory protection program has not been implemented at AAAI. Exposure assessments have not been conducted for some tasks where respiratory protection is required.

Procedures for chlorine handling have been developed. A limited review of the system, however, indicated some improvements are warranted (pipe labeling, pressure relief).

The personal air monitoring did not show an inhalation hazard for the employees sampled during the monitoring period. The gravimetric sampling results were lower than those found during previous monitoring surveys; possibly due to improved work practices, engineering enhancements (additional ventilation) or a lower than normal level of activity. The area monitoring for carbon monoxide also indicated that concentrations were below recommended limits. Propane-powered forktrucks are the primary source of CO at AAAI.

The environmental heat monitoring indicated high heat stress conditions can occur at the AAAI facility. The WBGT monitoring indicated heat loads exceeded the one-hour NIOSH REL for acclimatized workers at the Furnace #2 "doghouse" and the Northeast side of Furnace #4. The REL was also exceeded for some periods at the ingot pouring station. The overexposures at the furnaces, however, were based on continuous work at these monitoring stations. Due to the varied tasks and high mobility of employees it is unlikely that workers will remain at these stations at the estimated work rate continuously for 60 minutes. As such, the REL determinations should be considered "worst-case" estimates.

The accuracy of metabolic heat expenditure estimates made by trained observers may vary by ±10-15%, and this method of evaluation is generally viewed as a screening technique.[1] Measurement of workers metabolic heat (e.g., using the indirect open-circuit method) was not conducted during this evaluation.

Because of high internal heat sources, radiant heat is considered the primary source of heat load, with ambient temperature a secondary factor. However, the impact of climatic conditions on internal heat loads was not assessed, as weather conditions were mild during the day of the monitoring.

RECOMMENDATIONS

1. Although many of the elements of a good heat stress management program have been implemented at the AAAI facility, a formal written program should be developed to ensure consistency. The elements of a good heat management program include:

   (a) Training of employees in safety and health procedures for work in hot environments, including the signs and symptoms of impending heat illness and initiation of first aid and/or corrective procedures. Additionally, the effects of nonoccupational factors such as drugs, alcohol, obesity, etc., on tolerance to occupational heat stress should be covered. The need for fluid replenishment, and that reliance on the thirst mechanism is insufficient, are other important elements of worker heat stress training.

(b) Limiting exposure time to hot environments (e.g., scheduling hot jobs for the cooler parts of the day, altering the work-rest regimen, etc.).

(c) Ensuring all workers are fully acclimatized for working in hot environments. Acclimatization efforts should begin at the start of the hotter months of the year, and should include both new employees and employees returning from vacation or newly transferred to a hot area. Note that there is a wide difference in the ability of people to adapt to heat. In general, for workers who have had previous experience with the job, the acclimatization regimen should be exposure for 50% on day 1, 60% on day 2, 80% on day 3 and 100% on day 4. For new workers the schedule should be 20% on day 1 and a 20% increase on each additional day.

(d) Implementation of a Heat-Alert Program (HAP) for predicted hot spells. This program should be used to alert workers of impending hot spells, and initiation of heat control efforts (e.g., additional breaks, increased ventilation, shorter work cycles).

(e) Medical screening of workers to eliminate individuals with low heat tolerance. The capacity to tolerate heat has been shown to be related to physical fitness (the higher the degree of physical fitness, the greater the ability to tolerate heat) and physical work capacity (those with low physical work capacity are more likely to develop higher body temperatures than are individuals with high physical work capacity). Medical screening should also include a history of any previous heat illness. Workers who have experienced a heat illness may be less heat tolerant.

2. Heat stress monitoring during outdoor temperature extremes should be conducted. This will provide information on the impact of outdoor conditions on the heat loads being experienced by employees. This data would be useful in refining the heat stress management program, identifying target areas for control and, evaluating the effectiveness of implemented controls.

3. Although some elements of a respiratory protection program (RPP) have been developed, a comprehensive written RPP should be implemented. An RPP is necessary even if the use of respirators is voluntary or for non-specific tasks (dross loading, chlorine unloading, emergency response, etc.). The elements of a comprehensive RPP include a written program, exposure monitoring, proper respiratory selection, user training and fit-testing, medical clearance of users, and periodic program reviews. Federal Occupational Safety and Health regulation (OSHA 29 CFR 1910.134) contain specific requirements for respirator programs. For those specific tasks where respirators are required, objective air monitoring data should be collected to determine the appropriate respirator.

4. A process safety management (PSM) review should be conducted for the chlorine system to ensure all necessary safeguards have been implemented. Information on the OSHA PSM Standard (OSHA 29 CFR 1910.119) was provided to AAAI. Other resources that may be helpful include the Chlorine Institute recommendations for the safe use of chlorine, and procedures/evaluations conducted by other users of chlorine (e.g,. water treatment plants, pulp and paper mills). Ensure the chlorine piping system has adequate pressure relief and component isolation, and is properly labeled.

5. Conduct a job safety analysis of the iron raking activity and assess the need for additional PPE during this task (e.g., midriff protection, faceshield). It may be appropriate to utilize the area safety committee for conducting this analysis.

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3. Department of Labor/OSHA Region VI
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Table 2
Personal Sampling Results: Metal Fume
Arkansas Aluminum Alloys, Inc,
September 6, 1995
HETA 95-0244

Activity Sampled	Time (min)	Concentration Detected (TWA), Micrograms per Cubic Meter (µg/m^3)										
		Al	Zn	Cr	Cd	Pb	Ni	Mg	Mn	Fe	Cu	Ti
Skimming/Pouring Furnace # 2	08:10-14:16 (366)	40	<0.1	<0.5	(0.2)	<0.5	<0.5	(2.9)	0.16	6.3	0.8	1.6
Skimming/Pouring Furnace #2	08:10-14:14 (364)	18	<0.1	<0.6	<0.1	<0.6	<0.6	(2.4)	<0.04	2.5	0.4	0.6
Furnace #4 Operator, South Side	08:12-15:55 (463)	57.3	0.1	<0.5	<0.08	<0.7	<0.5	5.5	0.2	19.4	1.5	0.8
Furnace #4 Operator, North Side	08:14-16:14 (480)	12.3	3.1	<0.4	<0.07	<0.6	<0.4	(2.4)	<0.03	4.0	0.59	0.18
Furnace #2 Operator, South Side	08:15-16:21 (486)	50	2.3	<0.4	<0.07	<0.6	<0.4	4.8	0.44	10.4	1.5	0.48
Furnace #2 Operator, North Side	08:53-14:35 15:02-16:19 (420)	36.7	1.9	<0.48	<0.1	<0.7	<0.5	8.8	(0.1)	12	1.4	0.4
General Area Sweeping/Cleaning	14:15-16:13 (118)	29	7.7	<1.7	<0.3	<1.0	<1.7	(5.1)	<0.13	8.9	2.0	0.9
Cleaning/Sweeping in Pouring Area	14:16-16:21 (125)	371.2	<0.3	<1.6	(0.3)	<2.4	<1.6	11.6	5.2	48.8	1.9	21.2

Note: TWA = Time-Weighted Average Concentration for the Sampling Period

Table 3
Personal Sampling Results: Total Dust (Gravimetric)
Arkansas Aluminum Alloys, Inc,
September 6, 1995
HETA 95-0244

Activity Sampled	Time (min)	Concentration Detected (TWA), Milligrams per Cubic Meter (mg/m^3)
Skimming/Pouring Furnace # 2	08:10-14:16 (366)	0.45
Skimming/Pouring Furnace #2	08:10-14:14 (364)	0.26
Furnace #4 Operator, South Side	08:12-15:55 (463)	0.64
Furnace #4 Operator, North Side	08:14-16:14 (480)	0.46
Furnace #2 Operator, South Side	08:15-16:21 (486)	0.62
Furnace #2 Operator, North Side	08:53-14:35 15:02-16:19 (420)	0.55
General Area Sweeping/Cleaning	14:15-16:13 (118)	0.60
Cleaning/Sweeping in Pouring Area	14:16-16:21 (125)	3.24

Note: TWA = Time-Weighted Average Concentration for the Sampling Period
The OSHA PEL for Particulate Not Otherwise Regulated (PNOR) is 15 mg/m^3.
NIOSH has not established an REL for PNOR

Table 4
Area Heat Stress Measurements
Arkansas Aluminum Alloys, Inc,
September 6, 1995
HETA 95-0244

Location/Activity	#Workers	Time	WBGT/TWA[1]	REL[2]
Ingot Stacking, WibGet® placed on rail adjacent stacking table	2-4	9:20-10:20	26.4	29
		10:20-11:20	27.2	
		12:20-12:20	27.5	
		12:20-13:20	27.4	
		13:20-14:20	25.7	
Furnace #2 Operator, WibGet® placed on top of "doghouse"	1-3	14:30-15:30	**27.7**	26
		15:30-16:30	**28.3**	
Pouring and Skimming during Furnace #2 Pour. WibGet placed on rail adjacent skimming area, out of direct line of fan. Pouring operation stopped at 12:45	2	8:15-9:15	29.8	30
		9:15-10:15	**30.9**	
		10:15-11:15	**31.5**	
		11:15-12:15	36*	
		12:15-13:15	28.6	
		13:15-14:20	27	
Northeast side of Furnace #4	Variable	14:55-15:55	**30.1**	26
		15:55-16:35	**30.6**	

Data from stacking before 9:20 was invalid due to an improperly seated sensor. Stackers worked approximately 15 minutes and then rotated tasks with the forklift operator for 15 minutes. The NIOSH REL for this activity was adjusted to 30 min/hour.

*=Wet bulb wick was not completely moistened during this monitoring period and results are skewed high

1) WBGT = Wet Bulb Globe Thermometer/Time-Weighted Average in degrees centigrade. These are approximately hourly TWAs based on a series of 5-minute integrated measurements recorded by the WibGet®.

The WBGT measurement is, for indoor applications, a combination of the natural wet bulb (NWB) temperature and the Globe Temperature (GT). The WBGT is calculated as follows: WBGT (indoor) = 0.7NWB + 0.3 GT

This measurement incorporates the environmental factors of air temperature and movement, humidity, and radiant heat

2) REL = NIOSH Recommended Exposure Limits to heat stress for acclimatized workers. These RELs are determined from a combination of WBGT environmental measurements and estimates of worker energy costs (metabolic heat generation). These RELs apply for the following conditions:

a) acclimatized, healthy workers
b) average worker size of 154 lbs (70 kilograms)
c) unless otherwise noted, a continuous work regimen
d) workers wearing light summer clothing