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I. SUMMARY

On August 25-26, 1993, a heat stress evaluation was conducted by a National Institute for Occupational Safety and Health (NIOSH) investigator at Consolidated Aluminum Company in Hannibal, Ohio. This health hazard evaluation was requested by the United Steelworkers of America, Local 5760. The scope of the request was to evaluate the heat stress conditions that workers were exposed to during normal production and maintenance activities in the casting plant and the preheat building.

Environmental assessment of this work location included measurement of the wet bulb globe temperature (WBGT) index, an estimation of the metabolic heat load of the tasks, and characterization of the work–rest cycles. On the day of the survey, the weather was representative for a hot August day in this southeastern Ohio location (hazy/sunny, 93 degrees Fahrenheit [°F], mild breeze). The environmental monitoring of occupied production areas in the cast plant identified WBGT values that ranged from 83–108ºF. WBGT measurements obtained in selected maintenance locations of the preheat building and casting plant ranged from 89–94°F. The mean WBGT at two furnace operators' desks obtained at five–minute intervals over a six–hour period was 85°F. Dry bulb and black globe (radiant) temperatures recorded in front of an open furnace door exceeded 115ºF and 180ºF, respectively. The metabolic heat production due to the job tasks were characterized as moderate work loads in accordance with published occupational heat stress criteria. The job tasks required full body movements, walking, standing, bending, and operation of fork trucks, and other equipment that may require extended arms. The heat stress potential in the casting plant was increased by the work–rest cycles that could require the workers to be present in the exposure areas for extended periods in order to accommodate the production demands.

The environmental and work conditions observed at this facility may result in heat exposure that exceeds the WBGT evaluation criteria published by NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH). A significant radiant heat load was present in some locations. Additionally, the air stream of the "cooling" fans exceeded 100ºF which could increase the heat burden. The recommendations presented in Section VIII of this report include the installation of additional radiant heat shields, maintaining closed furnace doors, providing cooling air ventilation, improved access to cool potable water, implementation of a heat stress management program, and the use of body cooling and heat reflective personal protective equipment.

Keywords: SIC 3353 (aluminum rolling mill), aluminum sheet coil, furnaces, ingot pouring, heat stress, wet bulb globe temperature index, WBGT, radiant heat, convective heat.

II. INTRODUCTION

On August 25–26, 1993, a heat stress evaluation was conducted by a National Institute for Occupational Safety and Health (NIOSH) industrial hygienist at Consolidated Aluminum Company in Hannibal, Ohio. This health hazard evaluation (HHE) was requested by the Steelworkers of America, Local 5760. The scope of the request was to evaluate the heat stress conditions that the workers were exposed to during the normal production in the casting plant and during maintenance activities in the casting plant and preheat building.

The labor union reported that the air temperature in the plant has exceeded 120°F and that employees have experienced headaches, nausea, and exhaustion. Job consolidations in the casting plant and increased furnace sizes have resulted in less workers present to operate the casting plant and longer exposure to hot locations. In addition, the average age of the work force at this facility has been increasing.

Environmental assessment of this work location included measurement of the wet bulb globe temperature (WBGT), an assessment of the work–rest patterns, and an estimation of the metabolic heat load of the work task(s).

III. BACKGROUND

Consolidated Aluminum Company manufactures over 30 types of aluminum alloys at this rolling mill in Hannibal, Ohio. The basic process at the mill includes melting the raw materials (aluminum metal and scrap), adding alloy agents, casting the alloy into ingots, and roll compressing the ingots into sheet coil form for shipment. The HHE request concerned manufacturing activities in the casting plant as well as maintenance work in both the preheat building and the casting plant.

Seven melting furnaces and seven holding furnaces were present in the casting plant. Four of the melting furnaces were older units with 70,000 lb. charging capacity and maximum operating temperatures of 1400°F. The three newer melting furnaces had a much larger charging capacity (100,000 lb.) and a maximum operating temperature of 1600°F. In addition to job consolidations, larger furnaces were reported to have increased the heat exposure durations.

The cycle times for the melting furnaces ranged between 6–8 hours. The "charging operators" use fork trucks to load the furnaces with molten and solid aluminum (and some scrap metal) during the front end of the furnace cycle. Each of the charging loads weigh approximately 2,000–4,000 lb. which necessitates many loads to fill the furnace to capacity. The molten material is skimmed and stirred; after alloy agents are added it is re–skimmed and stirred. The timing of these steps is critical and cannot be interrupted. These activities occurred with the use of a fork truck through a large open door in the side of the furnaces.

The molten alloy is then transferred between the melting and holding furnaces in an open trough.

After the molten material is transferred into the holding furnace, the "complex operator" controls the final alloying and fluxing process. The work sequence includes skimming, sampling, alloying and fluxing, setting stations, and ingot pouring and monitoring. After the ingot is allowed to cool (for approximately 45 minutes), the ingot is hoisted out of the pouring pit and transferred out of this area. The charge operator then must clean the "sniff vent" prior to receiving the next transfer from the adjacent melting furnace.

There were four pusher and three car preheat furnaces in the preheat building. The function of this step is to heat and soften the ingot so it is more easily rolled and compressed into sheet coil form. The heat exposure of the production employees was not of concern since this process is more automated and these workers spend a substantial amount of the time in air–conditioned control rooms. Maintenance workers, however, must work throughout this building, including above or adjacent to operating furnaces.

The manufacturing process at this plant is a continuous operation (3 shifts/day, 7 days/week). A standard "21 swing" shift rotation scheme is implemented for work scheduling.

IV. METHODS

Environmental measurements were obtained using a Reuter Stokes RSS 214 Wibget® heat stress meter manufactured by Reuter Stokes, Canada. This direct reading instrument is capable of monitoring dry bulb, natural (unaspirated) wet bulb, and black globe temperatures in the range between 32° and 200°F, with an accuracy of ± 0.5–1.0°F. This meter also computes the indoor and outdoor WBGT indices in the range between 32° and 200°F. WBGT measurements were collected from selected locations in the cast house and preheat building and outdoors (east of the cast plant). In addition, WBGT measurements were logged by the meter at five-minute intervals near the operators' desk for melting furnace #3 and holding furnace #2 as well as on one of the fork trucks used in the melting area. Most measurements were collected about four feet from the floor after the meter was allowed to stabilize.

Metabolic heat produced during maintenance and production activities was estimated using energy expenditure tables and the guidelines provided in *Occupational Exposure to Hot Environments, Revised Criteria 1986*, and *Threshold Limit Values for Chemical Substances and Physical Agents*.[1,2] Using this method, the average energy expenditure for a "standard" male worker (body weight 70 kilograms; body surface area 1.8 square meters) can be estimated utilizing basal metabolism and specific task analysis information regarding body position, movement and type of work. Table 1 lists the average energy requirements for the task analysis components. Assessment of the metabolic heat demand of the job task(s) is essential to allow one to apply the appropriate WBGT evaluation criteria to the observed environmental conditions. It is important to note that errors in estimating metabolic heat from energy expenditure tables are reported to be as high as 30%.[1]

V. EVALUATION CRITERIA

There are a number of heat stress guidelines that are available to protect against heat–related illnesses such as heat stroke, heat exhaustion, heat syncope, and heat cramps. These include, but are not limited, to the WBGT, Belding–Hatch heat stress index (HSI), and effective temperature (ET).[3,4,5] The underlying objective of these guidelines is to prevent a worker's core body temperature from rising excessively. The World Health Organization has concluded that "it is inadvisable for deep body temperature to exceed 38°C (100.4°F) in prolonged daily exposure to heavy work."[6] Many of the available heat stress guidelines, including those proposed by NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH), also use a maximum core body temperature of 38°C as the basis for the environmental criterion.[1,2]

Both NIOSH and ACGIH recommend the use of the WBGT index to measure environmental factors because of its simplicity and suitability in regards to heat stress. The International Organization for Standardization (ISO), the American Industrial Hygiene Association (AIHA), and the U.S. Armed Services have published heat stress guidelines which also utilize the WBGT index.[7,8,9] Overall, there is general similarity of the various guidelines; hence, the WBGT index has become the standard technique for assessment of environmental conditions in regards to occupational heat stress.

The WBGT index takes into account environmental conditions such as air velocity, vapor pressure due to atmospheric water vapor (humidity), radiant heat, and air temperature, and is expressed in terms of degrees Fahrenheit (or degrees Celsius). Measurement of WBGT is accomplished using an ordinary dry bulb temperature (DB), a natural (unaspirated) wet bulb temperature (WB), and a black globe temperature (GT) as follows:

$$WBGT_{in} = 0.7\,(WB) + 0.3\,(GT)$$

for inside, or outside without solar load,

or

$$WBGT_{out} = 0.7\,(WB) + 0.2\,(GT) + 0.1\,(DB)$$

for outside with solar load.

Originally, NIOSH defined excessively hot environmental conditions as any combination of air temperature, humidity, radiation, and air velocity that produced an average WBGT of

79ºF (26ºC) for unprotected workers.[10] However, in the revised criteria for occupational exposure to hot environments, NIOSH provides diagrams showing work–rest cycles and metabolic heat versus WBGT exposures which should not be exceeded.[1] NIOSH has developed two sets of recommended limits: one for acclimatized workers (recommended exposure limit [REL]), and one for unacclimatized workers (recommended alert limit [RAL]). Refer to Figure 1 for the diagrams describing these limits.

Similarly, ACGIH recommends Threshold Limit Values® (TLV) for environmental heat exposure permissible for different work–rest regimens and work loads.[2] The NIOSH REL and ACGIH TLV criteria assume that the workers are heat acclimatized, are fully clothed in summer–weight clothing, are physically fit, have good nutrition, and have adequate salt and water intake. Additionally, they should not have a pre–existing medical condition that may impair the body's thermoregulatory mechanisms. For example, alcohol use and certain therapeutic drugs may interfere with the body's ability to tolerate heat.

Modifications of the NIOSH and ACGIH evaluation criteria should be made if the worker or conditions do not meet the previously defined assumptions. The following modifications to the WBGT criterion have been suggested:[11]

1. Unacclimatized or physically unconditioned – subtract 4°F (2°C) from the permissible WBGT value for acclimatized workers.

2. Increased air velocity (above 1.5 meters per second or 300 feet per minute) – add 4°F (2°C). This adjustment can not be used for air temperatures in excess of 90–95°F (32–35°C). This correction does not apply if impervious clothing is worn.

3. Impervious clothing which interferes with evaporation:

    a. Body armor, impermeable jackets – subtract 4°F (2°C).

    b. Raincoats, turnout coats, full–length coats – subtract 7°F (4°C).

    c. Fully encapsulated suits – subtract 9°F (5°C).

4. Obese or elderly – subtract 2–4°F (1–2°C).

Selection of a protective NIOSH WBGT exposure limit from Figure 1 is contingent upon identifying the appropriate work–rest schedule and the metabolic heat produced by the work. The work–rest schedule is characterized by estimating the amount of time the employees work to the nearest 25%. The most accurate assessment of metabolic heat production is to actually measure it via calorimetry. However, this is impractical in industrial work settings. An estimate of the metabolic heat load can be accomplished by dividing the work activity into component tasks and adding the time–weighted energy rates for each component from Table 1. Because of the error associated with estimating metabolic heat, NIOSH recommends using the upper value of the energy expenditure range reported in Table 1, to allow a margin of safety.[1]

The ACGIH heat exposure TLVs are published for light, moderate, and heavy work load categories. Applying a conservative approach when estimating the metabolic work rate and selecting the work load category should result in an ACGIH WBGT heat exposure limit comparable to the one extrapolated from Figure 1. The work load categories are described by the following energy expenditure rates:[2]

1. Light work – up to 200 kilocalories per hour (kcal/hr),

2. Moderate work – 200 to 350 kcal/hr,

3. Heavy work – 350 to 500 kcal/hr.

The physiological response to an increasing heat load can include an increase in heart rate, an increase in body temperature, an increase in skin temperature, and an increase in sweat production.[1] The physiological response could vary dramatically between individuals and may be related to physical conditioning, level of acclimatization, weight, age, and gender. Measuring the physiological responses and comparing the response to acceptable increases have been proposed.[6,12,13,14]

There are a few general guidelines for recommended maximum heart rate under physical exertion. If the heart rate (pulse) exceeds 110 beats per minute at the onset of the rest period, then the next work cycle should be reduced by one–third and the rest duration should be maintained.[14]

For body core temperature, heat stress guidelines typically list 38ºC (100.4ºF) as the upper limit of body core temperature.[1,2,6] This is measured rectally in standard laboratory studies of work physiology. Because this is impractical in an industrial setting, however, oral temperature has been used in lieu of rectal temperature. In general, oral temperature is lower than core temperature, although the amount varies since oral temperature is influenced by various factors. It is generally accepted that oral temperature is lower than core temperature by 0.5ºC (0.9ºF).[12] Thus 37.5ºC (99.5ºF) provides an adequate margin of safety as the upper limit of an acceptable body temperature as measured by an oral thermometer. If oral temperature exceeds 99.6ºF at the beginning of a rest cycle, the next work cycle should be reduced by one–third and the rest duration maintained.[14]

Body water loss from sweat production and inadequate fluid replacement can be measured using a scale accurate to ± 0.25 lb. Body water loss should not exceed 1.5 percent of the total body weight in a workday.[14]

Additional supporting information regarding heat exchange factors, heat–related disorders, and general control principles can be found in Appendices A, B, and C, respectively.

VI. RESULTS

The heat stress potential that the charging and complex operators were exposed to while manufacturing aluminum ingots in the casting plant, and possible heat exposure locations for maintenance workers were evaluated during the first and second shift of August 26, 1993. During this evaluation, WBGT measurements were collected near production workers while they worked by the furnaces and pouring pits as well as spacially throughout the cast house. Environmental heat (WBGT) measurements were also obtained in locations representative of some maintenance exposures in the preheat building and on a manlift near the ceiling of the casting plant. In addition, WBGT meters were used to log data at five–minute intervals during the afternoon (and early evening) of August 26, 1993. The data logging was performed at the operator's desk for melting furnace #3, at the operator's desk for holding furnace #2, and on a fork truck used for charging the melting furnaces.

On the day of this survey, the weather was representative of a hot August day in southeastern Ohio. Table 2 provides the WBGT data that was obtained outside east of the casting plant during late morning, mid afternoon, and late afternoon. Overall, the day was sunny with a slight breeze and high temperature of 93°F.

The WBGT data collected at selected locations in the casting plant is presented in Table 3. The WBGT measurements ranged from 84° to 101°F, with the dry bulb air temperature as high as 104ºF and the radiant temperature reaching 145°F. The highest WBGT observed in the charging areas was near the ledge of the "run–around" trough for the #1 melting furnace. A level of 101°F (WBGT) was obtained at this location during the transfer of molten material. Moving six feet away from the trough ledge during this same transfer, the WBGT dropped over 10°F (to 89°F). The other WBGT measurements on the charging side of the cast house ranged from 84° to 88°F. Table 4 presents the environmental heat measurements collected at five–minute intervals near melting furnace #3. The WBGTs ranged from 83 to 87°F, dry bulb temperatures (DB) from 96° to 101°F, and globe (radiant) temperatures (GT) from 104 to 110°F. The mean temperatures at this location were 85°, 99°, and 107°F, respectively, for WBGT, DB, and GT.

Of particular interest are the DB temperatures of the fan air streams used to "cool" workers that were in excess of 100ºF, which could add to convective heat gain since it is greater than the mean skin temperature (95ºF). However, the convective heat gain may have been partially offset since the increased air velocity may increase evaporative cooling. (The air velocity throughout these locations was estimated to be moderate [200–250 fpm], except in the immediate vicinity of the industrial–sized fans where the air velocity was high [>250 fpm].)

Heat measurements collected on the fork truck are provided in Tables 5 and 6. The mean WBGT obtained from the data logging was 84°F (range from 82° to 86°F). This information was collected to indirectly evaluate the charging operators' exposure since they spend a considerable amount of time operating fork trucks when servicing the furnaces. The mean DB and mean GT on the fork truck were 100° and 105°F, respectively. Table 6 demonstrates the effectiveness of the fork truck's plexi–glass and hydraulic lift to absorb radiant heat. Measurements were collected in front of an open furnace and compared to environmental heat measurements obtained in the fork truck cab. The GT was reduced from 181° to 107°F and the WBGT decreased from 108° to 86°F.

Environmental heat measurements recorded from exposure locations of complex operators in the casting plant are listed in Table 7. WBGTs ranged between 109°F recorded when cleaning the sniff vent, to 83°F observed in an aisle 25 feet from a pouring pit. The WBGT at a resting and monitoring bench was 84°F. The WBGTs were 10°F higher in the mid afternoon than the early evening. It is unclear if the lower WBGTs were due to a cooler time of day or due to different pouring pits. The mean WBGT obtained from the data logging at the operator's desk near holding furnace #2 was 85°F (Table 8).

Table 9 lists the WBGT measurements collected at five selected locations where maintenance workers could be expected to work. The WBGTs observed at these maintenance locations ranged from 87° to 94°F. The highest WBGT was obtained on a manlift near the cast plant ceiling (94°F). The DB temperature at this location was 118°F. Environmental heat measurements were also collected at various locations throughout the preheat building. The WBGT ranged from 87 to 94°F throughout the preheat building locations. The highest WBGT reading in the preheat building was obtained near an electrical panel behind car furnace #8. The GT behind this furnace was 130°F. The highest DB temperature was above the #4 pusher furnace (113ºF).

The environmental heat in some of these locations exceeds the NIOSH ceiling limit if the maintenance employees were working at a high metabolic rate. These conditions would require the use of body cooling and/or heat protective clothing or equipment for employees to safely work for extended times (beyond a few minutes). Concern could also exist for longer duration exposures of personnel who perform preventive maintenance and repairs at lower metabolic rates, if the task requires substantially more time to be spent in these hot locations.

An occupational heat stress evaluation requires an assessment of the workers' environmental heat exposure, metabolic heat production, exposure durations, and work–rest cycles. The environmental heat measured throughout the plant is described above. However, the time weighted average exposure of the employees could be less if breaks are taken in cooler areas. The manufacturing workers' task schedules (and subsequent heat exposures) were quite variable as a result of fluctuating production demands. Some activities could not be postponed. Hence, if a relief operator was unavailable, the primary operator could not always have rest breaks on a routine schedule. It was reported that some operators may be out on the plant floor for up to three or four hours. However, at other times the worker can spend considerable time resting during part of the process cycle. Hence, the work–rest cycle could range from 100% work and 0% rest to 50% work and 50% rest. On average, the work–rest cycle over the entire work shift can be approximated by 75/25 work–rest regime.

The metabolic demand of the charging and complex operators' job is estimated in Table 10. This estimate is based on the summation of metabolic rates provided in Table 1 for body position, type of work, and basal metabolism.[1,2] Based on this information, the metabolic work rates for manufacturing jobs were estimated to be 225 kcal/hour, a moderate rate. The job activities for maintenance personnel can be extremely variable. Therefore, the metabolic heat production and the work–rest cycles would also fluctuate. For the most part, applying a moderate metabolic rate and a 75/25 work–rest regime for maintenance activities at this plant should provide a reasonable estimate.

Table 11 presents the WBGT evaluation criteria based on the NIOSH RELs (Figure 1), the ACGIH TLVs, and the observed workplace conditions. The NIOSH REL to environmental heat for heat acclimatized workers functioning at a metabolic rate of 225 kcal/hr is a WBGT of 84 and 86°F, respectively, for 75/25 and 100/0 work–rest cycles.[1] The ACGIH TLV WBGT for a moderate work rate and a 75/25 work–rest cycle is 82°F. The TWA WBGT heat exposure for the charging and complex operators exceeded or approached these criteria. NIOSH has also established a ceiling limit for environmental heat where workers should not be exposed without heat protective clothing and/or equipment. The NIOSH ceiling limit can be exceeded during some operations including cleaning the sniff vent (regardless of the metabolic rate). There were a number of potential exposure locations in the preheat building where this ceiling limit could be exceeded and longer duration exposures could also be of concern.

The NIOSH WBGT–RELs and ACGIH WBGT–TLVs are recommended limits to environmental and metabolic heat where it is believed that nearly all workers can be repeatedly exposed and function without adverse health effects.[1,2] These criteria assume the workers are fully clothed (in light weight pants and shirts), are physically fit, have adequate salt and water intake, and are acclimatized to heat. However, if workers are **not** acclimatized (i.e., during initial employment, during the onset of the summer, after an extended weekend or vacations, etc.), the NIOSH WBGT–RAL and ACGIH WBGT–TLV for 75/25 work–rest at a moderate metabolic rate should be adjusted to 82 and 79.5°F, respectively.

VII. CONCLUSIONS

1. The environmental heat exposure observed during this survey could exceed the NIOSH and ACGIH WBGT heat stress criteria.

2. The work activities generally resulted in a moderate metabolic heat production.

3. There was a significant radiant heat load present in many locations of casting plant and preheat building.

4. When the air temperature of the air stream provided by the space "cooling" fans is in excess of 95°F, it can contribute to convective heat gain if workers are present for prolonged periods.

5. Some locations and job tasks could exceed the NIOSH heat exposure ceiling limit requiring the use of personal protective equipment.

6. Although most employees will be heat acclimatized, some workers may not necessarily be acclimatized requiring extra caution for work scheduling.

7. A source of cool potable water was not easily accessible within the immediate vicinity where employees were exposed to heat.

8. The lack of a comprehensive heat stress management program, including effective medical examinations and policies as well as the use of body cooling equipment, exposed employees to risk of a heat–related illness or accident.

9. Self–regulation of work activity could not always be implemented because of production demands. Self–regulation of work activity is an important safeguard which reduces the potential for a serious heat related incident.

VIII. RECOMMENDATIONS

Recommendations concerning engineering controls, administrative controls, and personal protective equipment are included in this section. Because the heat exposure at this plant contains significant contributions from all of the heat balance components (radiant heat gain, convective heat gain, evaporative cooling, and metabolic heat production), implementation of a single control will not adequately address the entire heat stress problem. In addition to modifying the workplace environmental conditions, the risk of a serious incident due to excessive heat exposure can be reduced by the implementation of a comprehensive heat stress management program. This is especially important when modification of the environmental conditions is not technically feasible. The elements of a **heat stress management program** are provided in Appendix D.[1] The following recommendations should be considered as control options and evaluated in regards to the feasibility of implementation at this manufacturing site:

1. Engineering Controls

a. Install additional heat shields on surfaces radiating heat especially along the sides of the furnaces and near the transfer troughs where employees frequently work. (Also, the existing furnace doors should remain closed when access into the furnace is not required.)

b. Install (additional) refractory brick linings within the engineering equipment transporting heated materials and gases to reduce radiant heat emissions.

c. Install ventilation to supply cool air near locations where workers are frequently present (i.e., "spot cooling" or air–conditioned rooms for resting or monitoring benches).

d. Install additional ceiling vents in the buildings.

2. Administrative Controls

a. It is essential for employees exposed to heat to be examined by a physician and receive medical approval to work in hot conditions. Physical examinations should be performed annually prior to the hot season and should include an assessment of the workers' medical history and physical conditioning. The medical evaluation should focus on any predisposing conditions that cause the employee to be at undue risk of a heat related disorder.

b. Perform the manufacturing operations with larger work crews during the summer season. This would not only reduce the metabolic heat production by spreading the work load, it would also allow employees to rest in a cool location without disrupting a "buddy" system when working in heat exposure locations.

c. Implement a comprehensive heat stress management program for all manufacturing employees and maintenance staff who may be exposed to hazardous levels of heat during routine operations or emergency conditions. Elements of an effective heat management program include but are not limited to environmental monitoring, medical examinations, emergency procedures, and worker training. Refer to Appendix D of this report for more details of an occupational heat stress management program.

d. Adjust the work–rest cycle to reduce the peak physiological strain and improve recovery. Some modifications may include:

(1) Even distribution of work over the entire workshift.

(2) Schedule hot jobs (or strenuous ones) during the coolest part of the workday.

(3) Provide breaks in cool rooms with ample drinking water. Drinking water should be cool, potable water that is available with individual drinking cups. The use of salt tablets or salted fluids should be avoided since this could irritate the stomach. The relatively high salt content of the average American diet should provide the workers adequate amounts of salt to replenish what is lost by perspiration. The use of commercially available electrolyte replenishment drinks is preferred over salted fluids.

e. Improve access to drinking water by locating a source of potable water in the immediate vicinity of the heat exposure (on the cast house floor) and by providing a mobile water supply for maintenance activities in hot locations. Employees working in hot environments should be encouraged to drink a cup of water every 15–20 minutes even in the absence of thirst.

f. Work schedules should be arranged to allow workers to be safely acclimatized to hot work environments when a worker is newly assigned or otherwise returns from an extended absence away from heat exposure. The length and degree of heat exposure should be increased gradually over a four or five day period until heat tolerance has been expanded. Because of the increased risk of a heat induced illness or accident, special provisions should be provided for unacclimatized workers who are required to work in hot conditions. These provisions should include reduced exposure time, less strenuous activities, increased recovery times, and careful observation to ensure that these employees are safely coping with the additional heat burden.

g. Whenever possible continue allowing workers to self–regulate their work–rest schedules. This is a very important safeguard since the worker is usually capable of assessing their individual heat tolerance. However, they must be instructed not to overestimate their heat tolerance; an early retreat at the initial signs of heat strain should be emphasized.

3. Personal Protective Equipment

a. Provide auxiliary body cooling vests or suits for cleaning the sniff, maintenance work, or any other activity that occurs in high heat exposure areas that exceed the NIOSH ceiling limits. A variety of auxiliary body cooling equipment is available, including ice vests, wetted coveralls, water cooled garments, and air supplied suits which use a vortex tube to cool the air.

b. When radiant temperatures are high and workers are present for extended durations, provide (radiant) reflective clothing suits or aprons to reduce the amount of radiant heat that is absorbed by the workers. Reflective clothing typically is "aluminized" and does not allow air to flow through it; therefore, reflective suits should be worn as loose as possible to minimize the loss of evaporative cooling. The amount of clothing worn under reflective suits should also be kept to a minimum for the same reason. When radiant and convective heat are both high, reflective clothing should only be used in conjunction with auxiliary cooling equipment such as an ice vest.

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1. Consolidated Aluminum Company, Hannibal, Ohio.

2. United Steelworkers of America, Local 5760, Sardis, Ohio.

3. OSHA Region V.

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

Table 1
Metabolic Heat Production Rates by Task Analysis
Consolidated Aluminum Company
HETA 93–0871

	Range[1] **(Kcal/min)**	**Average (Kcal/min)**
Body Position		
Sitting	0.3	
Standing	0.6	
Walking	2.0–3.0	2.5
Walking uphill	add 0.8 per meter rise	
Type of Work		
Hand work	0.2–1.2	
light		0.4
heavy		0.9
Work one arm	0.7–2.5	
light		1.0
heavy		1.8
Work, both arms	1.0–3.5	
light		1.5
heavy		2.5
Work whole body	2.5–9.0	
light		3.5
moderate		5.0
heavy		7.0
very heavy		9.0
Basal Metabolism	1.0	1.0
Summation		Σ

Notes:
1. For a standard male worker of 70 kg body weight and 1.8 m^2 body surface.
2. From Reference 1.

Table 2
Environmental Heat Measurements
Outside, East of Cast House
Consolidated Aluminum Company
HETA 93–0871

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
10:23 a.m.	88.7	75.9	109.3	84.0	Wind Slight, Sunny
1:36 p.m.	93.2	75.4	116.6	85.6	Wind Slight, Sunny
5:45 p.m.	92.4	70.6	93.8	77.6	Shade, Use $WBGT_{inside}$

Table 3
Environmental Heat Measurements
Cast House, Charging Operator's Exposure Areas
Consolidated Aluminum Company
HETA 93–0871

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
10:20 a.m.	86.2	75.3	106.0	84.7	Outside, Rest Bench East of #3 Melting Furnace
10:30 a.m.	90.3	77.6	97.4	83.6	East of #6 Melting Furnace
1:41 p.m.	98.5	78.4	109.5	87.7	East of #6 Melting Furnace
1:45 p.m.	99.0	77.3	109.5	87.1	Between #6 & #7 Melting Furnace
1:52 p.m.	98.8	76.7	103.7	84.8	By #3 Melting, When Charging
1:58 p.m.	103.8	82.2	144.9	101.2 97.0*	#1 Furnace, Runaround Ledge, Space fan nearby
2:03 p.m.	99.6	77.6	116.0	88.8 87.2*	#1 Furnace, Runaround 6' Back from Trough
6:05 p.m.	102.7	76.8	109.2	86.6	#1 Melting Furnace with Recent Charge. Not "hot" yet, 20' Back

*GT >> DB: use $WBGT_{out}$

Table 4
Summary of Environmental Heat Measurements
Operator Desk, Melting Furnace #3
Consolidated Aluminum Company
HETA 93–0871

	DB	WB	GT	WBGT
Mean	99.2	75.7	106.6	84.9
High	101.3	77.6	109.7	86.9
Low	95.9	73.1	104.1	82.8

Table 5
Summary of Environmental Heat Measurements
Melting Furnace Fork Truck
Consolidated Aluminum Company
HETA 93–0871

	DB	WB	GT	WBGT
Mean	99.8	74.9	105.4	84.0
High	102.6	76.7	111.6	86.3
Low	96.5	72.8	100.4	81.7

Table 6
Environmental Heat Measurements
Evaluation of Fork Truck Effectiveness as a Radiant Heat Shield
Consolidated Aluminum Company
HETA 93–0871

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
5:50 p.m.	115.2	86.9	181.4	108.3*	15' in Front of Opened Melter Furnace
6:35 p.m.	102.5	76.6	106.6	85.8	In Fork Truck Cab (Behind Hydraulic Lift and Plexiglass); Approximately 15' from Opened Melter Furnace

*GT >> DB: use $WBGT_{out}$

Table 7
Environmental Heat Measurements
Cast House, Complex Operator's Exposure Areas
Consolidated Aluminum Company
HETA 93–0871

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
2:08 p.m.	103.4	79.9	113.7	90.0	#5 Pit, Between Ingot & Flue
2:13 p.m.	121.0	83.9	126.4	96.6	#5 Pit, Flue
2:20 p.m.	137.8	89.6	160.4	108.6*	#5 Pit, Clean Sniff
3:20 p.m.	102.4	78.4	123.5	90.9*	#1 Holder Furnace, Open Door, 20' Away
6:08 p.m.	102.3	75.7	106.7	85.0	#1 Pit, 20' East of Column R–12
6:12 p.m.	99.9	74.3	102.7	82.8	#3 Pit, 25' East of Column Z–12
6:18 p.m.	99.5	75.8	107.8	85.3	#3 Pit, Pouring
6:25 p.m.	102.8	75.7	103.8	84.1	#2 Pit, Rest Bench

*GT >> DB: use $WBGT_{out}$

Table 8
Summary of Environmental Heat Measurements
Operator Desk, Holding Furnace Pit #2
Consolidated Aluminum Company
HETA 93–0871

	DB	WB	GT	WBGT
Mean	103.0	75.8	105.7	84.7
High	105.3	79.3	108.6	86.2
Low	99.3	74.3	101.2	83.8

Table 9
Environmental Heat Measurements
Cast House & Pre–Heat Building, Maintenance Locations
Consolidated Aluminum Company
HETA 93–0871

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
12:15 p.m.	117.9	84.7	116.7	94.2	Cast House; Manlift; near ceiling
2:36 p.m.	104.4	81.2	108.0	89.2	Inside #3 Pusher Furnace, Down for One Day
2:50 p.m.	106.5	81.4	130.0	93.6*	Near Electrical Panel Behind #8 Car Furnace
2:58 p.m.	106.0	80.1	108.7	88.6	#3 Pusher Furnace, Down for 3/4 Day.
3:06 p.m.	112.9	82.7	117.9	93.3	#4 Pusher Furnace, Above Middle of Furnace on Catwalk

*GT >> DB: use $WBGT_{out}$

Table 10
Metabolic Heat Production Estimates for Manufacturing Jobs
Consolidated Aluminum Company
HETA 93–0871

	Range[1] (Kcal/min)[2]	Estimate (Kcal/min)
Body Position		
Standing and some walking	0.6 2.0–3.0	1.0
Type of Work[2]		
Light work, both arms and light work, whole body	1.5 3.5	2.5
Basal Metabolism	1.0	1.0
Summation		4.5
Hourly Estimation		270[3]
Metabolic Rate Work Category		220[4] (Moderate)

NOTES:
[1] From Table 1 (Reference 1).
[2] kcal/min = kilocalories per minute.
[3] Based on a 100/0 work rest regimen.
[4] Based on a 75/25 work rest regimen.

Table 11
WBGT Occupational Heat Stress Criteria
Consolidated Aluminum Company
HETA 93–0871

Criteria	75% Work/25% Rest	100% Work/0% Rest
NIOSH REL†	84°F	86°F
ACGIH TLV‡	82°F	

† Extrapolated from Figure 1 using a metabolic rate of 225 kcal/hr
‡ Moderate work rate

Appendix A
Heat Exchange Factors
Consolidated Aluminum Company
HETA 93–0871

Heat stress is defined as the total net heat load on the body with contributions from environmental sources and from metabolic heat production.[15] Four factors influence the exchange of heat between the human body and the environment. These are air temperature, air velocity, moisture content of the air, and radiant temperature. The fundamental thermodynamic processes involved in heat exchange between the body and the environment may be described by the basic equation of heat balance:

$$S = M - E \pm R \pm C$$

where:

S = the change in body heat content (heat gain or loss);

M = metabolic heat gain associated with activity and physical work;

E = heat lost through evaporation of perspiration;

R = heat loss or gain by radiation (infrared radiation emanating from warmer surfaces to cooler surfaces);

C = heat loss or gain through convection, the passage of a fluid (air) over a surface with the resulting gain or loss of heat.

Under conditions of thermal equilibrium (essentially no heat stress), heat generated within the body by metabolism is completely dissipated to the environment, and deep body or core temperature remains constant at about 98.6°F (37°C). When heat loss fails to keep pace with heat gain, the body's core temperature begins to rise. Certain physiologic mechanisms begin to function in an attempt to increase heat loss from the body.[1,16] First, the body attempts to radiate more heat away by dilating the blood vessels of the skin and subcutaneous tissues and diverting a large portion of the blood supply to the body's surface and extremities. An increase in circulating blood volume also occurs through the withdrawal of fluids from body tissues. The circulatory adjustments enhance heat transport from the body core to the surface. If the circulatory adjustments are insufficient to adequately dissipate excessive heat, sweat glands become active, spreading fluid over the skin; this removes heat from the skin surface through evaporation.

Appendix B
Acute Heat Related Disorders
Consolidated Aluminum Company
HETA 93–0871

Prolonged exposure to excessive heat may cause increased irritability, lassitude, decrease in morale, increased anxiety, and inability to concentrate.[1,15] The acute physical disabilities caused by excessive heat exposure are, in order of increasing severity – heat rash, heat cramps, heat exhaustion, and heat stroke. Descriptions of these heat related disorders are provided below:

> ***Heat rash*** (prickly heat) may be caused by unrelieved exposure to hot and humid air. The openings of the sweat ducts become plugged due to the swelling of the moist keratin layer of the skin; this leads to inflammation of the glands. Tiny red vesicles (fluid filled bumps) are visible in the affected area and, if the affected area is extensive, sweating can be substantially impaired. This may result not only in discomfort, but in a decreased capacity to tolerate heat.
>
> ***Heat cramps*** may occur after prolonged exposure to heat with profuse perspiration and inadequate replacement of salt. The signs and symptoms consist of spasm and pain in the muscles of the abdomen and extremities, especially in the muscles which are working the hardest. Albuminuria (protein in the urine) may be a transient finding.
>
> ***Heat exhaustion*** may result from physical exertion in a hot environment when vasomotor control (regulation of muscle tone in the blood vessel walls) and cardiac output are inadequate to meet the increased demand placed upon them by peripheral vasodilation or the reduction in plasma volume due to dehydration. Signs and symptoms of heat exhaustion may include pallor, lassitude, dizziness, syncope, profuse sweating, and cool moist skin. There may or may not be mild hyperthermia (increased body temperature).
>
> ***Heat stroke*** is a medical emergency. An important predisposing factor is excessive physical exertion. Signs and symptoms may include dizziness, nausea, severe headache, hot dry skin due to cessation of sweating, very high body temperature [usually 106°F (41°C) or higher], confusion, delirium, collapse, and coma. Often circulation is compromised to the point of shock. If steps are not taken to begin cooling the body immediately, irreversible damage to the internal organs and death may ensue.

Chronic heat illnesses may occur as after–effects of acute heat illnesses, or they may be brought on by working excessively hot jobs for some time without the occurrence of acute effects. Chronic after–effects associated with acute heat illnesses can include reduced heat tolerance, dysfunction of the sweat glands, reduced sweating capacity, muscle soreness, stiffness, reduced mobility, chronic heat exhaustion, and cellular damage in different organs, particularly in the central nervous system, heart, kidneys, and liver.[15] Chronic heat illnesses not associated with acute effects of heat may fall into one of two categories, depending upon the duration of exposure. After several months of exposure to a hot working environment, chronic heat exhaustion may be experienced. Symptoms which may develop include headache, gastric pain, sleep disturbance, irritability, tachycardia, vertigo, and nausea. After many years in a hot job, cumulative effects of long term exposure that may develop are hypertension, reduced libido, impotence, myocardial damage, nonmalignant diseases of the digestive tract, and hypochromia (decreased hemoglobin in the red blood cells).[15]

There are other concerns besides health effects from excessive exposure to heat stress. Ramsey et al. describe an increase in unsafe acts associated with exposure to environmental heat.[17]

Appendix C
General Control Principles for Preventing Heat Related Disorders
Consolidated Aluminum Company
HETA 93–0871

The control of occupational heat exposure can be accomplished by addressing the heat balance components which contribute to heat gain (stress). The four environmental heat exchange components which contribute to heat stress are metabolic heat production, radiant heat gain or loss, convective heat gain or loss, and evaporative heat loss. Possible methods of control of these factors are provided below:[1,18,19]

***Metabolic heat* –** Metabolic heat can be reduced by mechanization of some or all tasks, increasing rest time, and sharing the work load with additional workers (particularly during peak heat periods).

***Radiant heat* –** Radiant heat gain can be reduced by minimizing the worker line of sight to the radiant source with shielding, insulating furnace walls with refractory brick, using reflective screens, wearing radiant reflective clothing (especially if the worker directly faces the source), and covering exposed body parts.

***Convective heat* –** Heat can be gained or lost by convection depending on the air temperature. If the air temperature exceeds the mean skin temperature (considered to be 95°F), then increasing air movement across the skin will contribute to convective heat gain. Control of convective heat gain under these conditions will require reducing the air temperature, reducing air velocity (as long as the temperature exceeds 95°F), and wearing loose fitting (single layer) clothing. If the air temperature is below 95°F, increasing the convective loss can be accomplished by increasing air velocity across the skin, removing clothing (maximizing exposed skin surface), and decreasing the air temperature.

***Evaporative heat loss* –** The maximum evaporative cooling capacity of the environment can be expanded by increasing the air velocity and by decreasing the water vapor pressure of the work atmosphere (humidity). Consideration must be given to the potential of convective heat gain when increasing air velocity, since the benefit of evaporative cooling may be overcome by the convective heat gain due to higher temperature air ($\geq$95°F).

Appendix D
Elements of a Comprehensive Heat Stress Management Program.
Consolidated Aluminum Company
HETA 93–871

1. ***Written program*** **–** A detailed written document is necessary to specifically describe the company procedures and policies in regards to heat management. The input from management, technical experts, physician(s), labor union, <u>and</u> the affected employees should be considered when developing the heat management program. This program can only be effective with the full support of plant management.

2. ***Environmental monitoring*** **–** In order to determine which employees should be included in the heat management program, monitoring the environmental conditions is essential. Environmental monitoring also allows one to determine the severity of the heat stress potential during normal operations and during heat alert periods.

3. ***Medical examinations and policies*** **–** Preplacement and periodic medical examinations should be provided to <u>all</u> employees included in the heat management program where the work load is heavy or the environmental exposures are extreme. Periodic exams should be conducted at least annually, ideally immediately prior to the hot season (if applicable). The examination should include a comprehensive work and medical history with special emphasis on any suspected previous heat illness or intolerance. Organ systems of particular concern include the skin, liver, kidney, nervous, respiratory, and circulatory systems. Written medical policies should be established which clearly describe specific predisposing conditions that cause the employee to be at higher risk of a heat stress disorder, and the limitations and/or protective measures implemented in such cases.

4. ***Work schedule modifications*** **–** The work–rest regime can be altered to reduce the heat stress potential. Shortening the duration of work in the heat exposure area and utilizing more frequent rest periods reduces heat stress by decreasing the metabolic heat production and by providing additional recovery time for excessive body heat to dissipate. Naturally, rest periods should be spent in cool locations (preferably air conditioned spaces) with sufficient air movement for the most effective cooling. Allowing the worker to self–limit their exposure on the basis of signs and symptoms of heat strain is especially protective since the worker is usually capable of determining their individual tolerance to heat. However, there is a danger that under certain conditions, a worker may not exercise proper judgement and experience a heat–induced illness or accident.

5. ***Acclimatization*** **–** Acclimatization refers to a series of physiological and psychological adjustments that occur which allow one to have increased heat tolerance after continued and prolonged exposure to hot environmental conditions. Special attention must be given when administering work schedules during the beginning of the heat season, after long weekends or vacations, for new or temporary employees, or for those workers who may otherwise be unacclimatized because of their increased risk of a heat–induced accident or illness. These employees should have reduced work loads (and heat exposure durations) which are gradually increased until acclimatization has been achieved (usually within 4 or 5 days).

6. ***Clothing*** **–** Clothing can be used to control heat stress. Workers should wear clothing which permits maximum evaporation of perspiration, and a minimum of perspiration run–off which does not provide heat loss, (although it still depletes the body of salt and water). For extreme conditions, the use of personal protective clothing such as a radiant reflective clothing, and torso cooling vests should be considered.

7. ***Buddy system*** **–** No worker should be allowed to work in designated hot areas without another person present. A buddy system allows workers to observe fellow workers during their normal job duties for early signs and symptoms of heat intolerance such as weakness, unsteady gait, irritability, disorientation, skin color changes, or general malaise, and would provide a quicker response to a heat–induced incident.

8. ***Drinking water*** **–** An adequate amount of cool (50–60ºF) potable water should be supplied within the immediate vicinity of the heat exposure area as well as the resting location(s). Workers who are exposed to hot environments are encouraged to drink a cup (approximately 5–7 ounces) every 15–20 minutes even in the absence of thirst.

9. ***Posting*** **–** Dangerous heat stress areas (especially those requiring the use of personal protective clothing or equipment) should be posted in readily visible locations along the perimeter entrances. The information on the warning sign should include the hazardous effects of heat stress, the required protective gear for entry, and the emergency measures for addressing a heat disorder.

10. ***Heat alert policies*** **–** A heat alert policy should be implemented which may impose restrictions on exposure durations (or otherwise control heat exposure) when the National Weather Service forecasts that a heat wave is likely to occur. A heat wave is indicated when daily maximum temperature exceeds 95ºF or when the daily maximum temperature exceeds 90ºF and is at least 9ºF more than the maximum reached on the preceding days.

11. ***Emergency contingency procedures*** **–** Well planned contingency procedures should be established in writing and followed during times of a heat stress emergency. These procedures should address initial rescue efforts, first aid procedures, victim transport, medical facility/service arrangements, and emergency contacts. Specific individuals (and alternatives) should be assigned a function within the scope of the contingency plan. Everyone involved must memorize their role and responsibilities since response time is critical during a heat stress emergency.

12. ***Employee education and training*** **–** All employees included in the heat management program or emergency contingency procedures should receive periodic training regarding the hazards of heat stress, signs and symptoms of heat–induced illnesses, first aid procedures, precautionary measures, and other details of the heat management program.

13. ***Assessment of program performance and surveillance of heat–induced incidents*** **–** In order to identify deficiencies with the heat management program a periodic review is warranted. Input from the workers affected by the program is necessary for the evaluation of the program to be effective. Identification and analysis of the circumstances pertinent to any heat–induced accident or illness is also crucial for correcting program deficiencies.