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I. SUMMARY

On August 12-13, 1990, a heat stress evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) at Lehigh Portland Cement Company in Mason City, Iowa. This health hazard evaluation was requested by the Cement, Lime, Gypsum, and Allied Workers, Division of the International Brotherhood of Boilermakers, Local 106. The scope of the request was to evaluate the heat stress conditions that the kiln assistants were exposed to during the water blasting of the preheat tower riser.

Environmental assessment of this work location included measurement of the wet bulb globe temperature (WBGT) index, and an estimation of the metabolic heat load of the task. Basic physiologic monitoring of the workers was performed prior to and following the water blasting, which included body weight, blood pressure, pulse rate, and oral temperature.

Despite the mild weather for August (84°F), environmental monitoring revealed WBGT values that ranged from 87-103°F. Dry bulb and black globe temperatures approached 123°F and 140°F, respectively. The metabolic heat load of the water blasting was determined to be medium to high. The task required full body movements, lifting the water blasting gun (25-30 lbs.) with extended arms, and applying force to trigger and aim the blasting gun. The workers' ability to remove heat by evaporation of perspiration was impeded by the use of personal protective equipment (PPE) which consisted of flame retardant wrist sleeves and gloves, flame resistant cover-alls, outer wristlets, helmet, face shield, shroud, and aluminized boots. The heat stress potential was supported by the workers' physiologic indices - pulse rates increasing by 100 beats, oral temperatures approaching 100°F, and body weight reductions up to 4 pounds.

The environmental conditions of the water blasting exceeded the WBGT evaluation criteria published by NIOSH and the American Conference of Governmental Industrial Hygienists (ACGIH). A significant radiant heat load was present, the PPE impeded evaporative loss, and the air stream of the "cooling" fans exceeded 100°F which increased the heat burden. The recommendations presented in Section IX of this report include the installation of additional radiant heat shields, refractory linings, and cooling air ventilation, repositioning area fans, 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 3241 (Portland cement manufacturer), water blasting, calcining preheat tower, kiln assistants, heat stress, wet bulb globe temperature index, radiant heat, convective heat, personal protective equipment.

II. INTRODUCTION

On August 12-13, 1990, a heat stress evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) at Lehigh Portland Cement Company in Mason City, Iowa. This health hazard evaluation (HHE) was requested by the Cement, Lime, Gypsum, and Allied Workers, Division of the International Brotherhood of Boilermakers, Local 106. The scope of the request was to evaluate the heat stress conditions that the kiln assistants were exposed to during the water blasting of the preheat tower riser. The labor union reported that the air temperature in the preheat tower has exceeded 150°F and that employees have experienced headaches, nausea, and exhaustion.

Environmental assessment of this work location included measurement of the wet bulb globe temperature (WBGT), an assessment of the air velocity, and an estimation of the metabolic heat load of the work task(s). Basic physiologic monitoring of the workers was also performed prior to and following the water blasting; measurements included body weight, blood pressure, pulse rate, and oral temperature.

Following the on-site evaluation, an interim letter was sent to the company and union in September 1990, which identified the heat stress potential to be high and preliminary recommendations included improved access to cool potable water, use of auxiliary body cooling equipment, and continuation of self-regulated rest schedules. These issues were also discussed during the closing conference on August 13, 1990.

III. BACKGROUND

Lehigh Portland Cement Company manufactures portland cement utilizing the flash calcining preheat process. Cement is a dry complex mixture of calcium silicate-aluminate-ferrite. The raw materials include limestone, sand, clay (and/or shale), and a small amount of iron. The manufacturing processes and sequence are as follows: mining the raw materials; crushing to reduce rock size; drying to remove moisture; grinding/blending the raw materials; calcining to convert the powdered materials into "clinker" (fused calcium alumina-silicate); and final milling of the finished product.

The HHE request was concerned with the water blasting of the preheat tower, which is a necessary step in the calcining process. In order to convert the raw materials into portland cement clinker, the blended materials must be heated to 2900°F in long rotary kilns. The use of a preheat tower makes this process more efficient. The raw material feed is pumped to the top of the tower and sequentially flows (via gravity) through four cyclones. Coal is combusted, which preheats the feed mix to 1800-2000°F before it enters the rotary kiln, thereby reducing the required length of the kiln necessary to produce clinker. Hardened deposits form on the internal surfaces of the preheat tower riser (junction between the cyclone stages and the rotary kilns). These deposits must be removed at least once per work shift, with a water blasting gun. This gun, which is approximately six feet in length and weighs 25-30 lbs., is inserted into ports to water blast the inside of the riser. In order to cut through the hardened residue, a narrow diameter (0.5 millimeter) stream of water is projected from this gun at a force of 6000 pounds per square inch (psi).

Two kiln assistants perform the water blasting on each shift. The company employs four rotating shifts. Hence, eight employees water blast as a part of their normal job duties. There are eight other employees who may occasionally substitute for the kiln assistants to complete this task. The preheat tower is a concrete block and steel structure containing 8 floors with a number of quarter and half floors (platforms), and has wall openings which face east and west. Access ports for the water blasting are located on the 2½, 2¾, and 3rd floors. At this height, the west wall openings of the preheat tower open into the kiln building.

IV. METHODS

A. Industrial Hygiene

Environmental measurements were obtained using a Reuter Stokes RSS 211D 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. Measurements were collected about four feet from the floor after the meter was allowed to stabilize.

Air velocity was approximated to the nearest 50 feet per minute (fpm) using the information provided in Occupational Exposure to Hot Environments, Revised Criteria 1986 and the subjective sensation of air movement as described by no air movement, light, moderate, or heavy breezes:[1]

Description	Air velocity (feet per minute)
No sensation of air movement	< 50
Sensing light breezes	50-200
Sensing moderate breezes	200-250
Sensing heavy breezes	> 250

Metabolic heat produced during the water blasting operations 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]

B. Medical

Concurrent with the industrial hygiene survey of the environmental heat exposure, two kiln assistants from each of the first and second shifts were evaluated for heat stress/strain. This evaluation consisted of personal interviews, as well as measurements of pulse rate, oral temperature, blood pressure, and body weight. Each worker served as his own control in this pre- and post-exposure comparison.

In addition to demographic information, the employee's past medical history was obtained, including any episodes of heat-related disorders. Pulse rate was counted by palpating the carotid or radial artery for 15 seconds and multiplying by 4 to obtain the rate per minute. Oral temperature was measured with an electronic clinical thermometer that uses disposable probe covers. Blood pressure was taken above the elbow in a standard manner with the participant in a sitting position. Body weight was measured using a portable bathroom scale. These measurements were taken at the beginning and near the end of the shift. Additionally, pulse rate and oral temperature were measured as soon after each water blasting task as practical. Measurements were made within one minute of the worker stopping work.

V. EVALUATION CRITERIA

A. Industrial Hygiene

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 wet bulb globe temperature (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

79°F (26°C) 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 and social 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 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).

5. Female - subtract 1.8°F (1°C). This adjustment, which is based on a supposedly lower sweat rate for females, is questionable since the thermoregulatory differences between the sexes in groups that normally work in hot environments are complex.[12] Seasonal and work rate considerations enter into determining which sex is better adapted to work in hot environments.[13]

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 a 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 kcal/hr,

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

3. Heavy work - 350 to 500 kcal/hr.

B. Medical

There are a few general guidelines for recommended maximum heart rate under physical exertion. Maximum heart rate should not exceed
120 beats per minute for an 8-hour exposure, 140 beats per minute for a 4-hour exposure,
160 beats per minute for a 2-hour exposure, or
180 beats per minute for any exposure duration.[14] Another method is to establish a maximum heart rate equal to 220 beats per minute minus the individual's age.[14]

For body core temperature, heat stress guidelines typically list 38°C (100.4°F) 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 is 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 0.5°C (0.9°F).[15] Thus 37.5°F (99.5°F) provides an adequate margin of safety as the upper limit of an acceptable body temperature as measured by an oral thermometer.

VI. <u>RESULTS</u>

A. Industrial Hygiene

The heat stress potential that the kiln assistants were exposed to while water blasting the preheat tower riser was evaluated on the first and second shifts of August 12, 1990. During this evaluation, WBGT measurements were collected near the workers while they water blasted on the 2½, 2¾, and 3rd floors as well as schematically throughout these locations following completion of the water blasting. Environmental heat (WBGT) measurements were also obtained when the kiln assistants conducted walkthroughs of the preheat tower (and associated equipment rooms) for preventive maintenance and observation.

The WBGT data collected during the water blasting on the first and second shifts is presented in Table 2 and Table 3, respectively. A total of 34 measurements were taken near the worker when operating the water blasting gun. The **WBGT** measurements on the **first shift** ranged from **87-103°F**, with the dry bulb air temperature as high as 123°F and the radiant temperature reaching 140°F. This operation was initiated shortly after 10:00 AM and was completed around 12:30 PM (with a 30 minute rest break). A **time weighted average** (TWA) WBGT exposure for the duration of the water blasting operation (including the resting time in the break room on the 6th floor) was calculated to be **88.5ºF**. However, the WBGT readings could have underestimated the workers true heat exposure since the readings were collected as close to the worker as possible without interfering with the operation. Often the worker was between the WBGT meter and the heat radiating surface which may have provided some shielding and lower WBGT values. Furthermore, the temperature outside was observed to be 73ºF before the start of the water blasting and 84ºF following completion. Although it was not cool on the day of this evaluation, it was mild for mid-summer, especially since a steady breeze was present.

On the **second shift**, the water blasting was completed in less than an hour and a half (lasting from 7:05 to 8:30 PM). WBGT measurements ranged from 89-100.5ºF, dry bulb temperatures from 99-119ºF, and globe (radiant) temperatures from 110-136.5ºF. The **TWA** WBGT exposure was **90.5ºF** during the entire period (including break time exposure away from the hot areas) necessary to complete the water blasting on the second shift. Outside temperatures were recorded to be 82ºF at 5:20 PM and 72ºF at 10:30 PM.

The metabolic demand of the water blasting task is estimated in Table 4. 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] The water blasting is performed with a two man crew; employees rotate between operating the blasting gun and assisting with moving the gun and hose as well as monitoring the work (while remaining in the exposure area). The water blasting gun is approximately 6 feet long and weighs about 25-30 lbs. The gun must be inserted into ports with extended arms and force must be applied to support, aim, and trigger the gun while cement feed flows through the vessel. The ports may be above the shoulders, below the knees, or at mid torso level requiring a variety of postures. The blasting occurs on three different levels which are connected by stairs. Based on this information, the metabolic work rate was estimated to be **330 kcal/hour, a moderate to high metabolic rate.**

Employees reported that the blasting operation is typically performed from 1-3 hours each shift depending on the level of the deposits within the vessel. (If a plug or blockage occurs it may take over 3 hours.) The workers self-regulate when a rest break is taken based on their heat tolerance. The work-rest regimen employed on the first and second shift was observed to be **75% work with 25% rest** during the time to complete the water blasting.

The **NIOSH Recommended Exposure Limit** (REL) to environmental heat for heat acclimatized workers functioning at a metabolic rate of 330 kcal/hr and a 75/25 work-rest cycle is a WBGT of **82.5ºF**.[1] The ACGIH Threshold Limit Value (TLV) WBGT for a moderate work rate and a 75/25 work-rest cycle is 82ºF. The TWA WBGT heat exposure (88.5 and 90.5ºF) for the duration of the water blasting **exceeded these criteria** for both the first and second shift workers. 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** for the metabolic rate and rest cycle of the blasting task is **97ºF**. There were a number of exposures during the water blasting where this **ceiling limit was exceeded**.

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 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, Lehigh Cement Company often required alternate workers to water blast who were **not** acclimatized. Hence, the NIOSH WBGT-REL and ACGIH WBGT-TLV for unacclimatized water blasters should be adjusted to 79.0 and 79.5ºF, respectively.

The NIOSH WBGT-REL (and ACGIH WBGT-TLV) should also be adjusted when workers wear personal protective equipment (PPE) which impede with evaporative heat loss. Water blasters must wear flame retardant Kevlar® wrist sleeves, flame resistant coveralls, outer wristlets, helmet, face shield, shroud, and aluminized boots for protection against physical contact with extremely hot cement feed. Under these conditions the NIOSH WBGT-REL must be reduced by 7ºF to compensate for the interference of evaporative heat loss. Therefore, the **adjusted NIOSH WBGT-REL/RAL** with consideration to the necessary PPE is **75.5 and 72ºF**, respectively for acclimatized and unacclimatized workers. **The WBGT TWA exposures (88.5 and 90.5ºF) of the water blasting were in excess of 13ºF over the appropriate NIOSH WBGT-REL, adjusted for protective equipment.**

Environmental heat measurements were also collected at various locations throughout the preheat tower floors where water blasting occurred. The WBGT ranged from 88 to 106.5ºF throughout these locations. [The highest DB temperature was 129ºF and the highest GT was 150ºF.] These readings were obtained near the latter part of the second shift following the water blasting. After these measurements were taken, the ambient temperature outside was 71.5ºF. [The readings may have been higher at the (heat) peak of the work day.] Although the WBGT levels were substantial throughout these locations, a number of "hot spots" were identified. One of these was on the exit (2½) floor where part of the vessel was eroded allowing a significant radiant heat emission.

Of particular interest are the DB temperatures of the fan air streams used to "cool" the workers. All of these temperatures were in excess of 100ºF. These levels 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 restore some of the evaporative cooling lost because of the protective gear. [The air velocity throughout these locations was estimated to be moderate (200-250 fpm), except in the immediate vicinity of the industrial-sized fans, and supply air ducts where the air velocity was high (>250 fpm).]

Tables 5 and 6 list the WBGT, DB, WB, and GT recorded during a walk- through of the preheat tower on the first and second shifts. Kiln assistants conduct these walkthroughs 2 or 3 times a shift to observe the equipment and perform preventive maintenance. Two locations which were particularly stressful include under the #1 gear of the kiln (WBGT-105ºF) and inside of the IBAU tower (WBGT-103.5ºF). The environmental heat in both of these locations exceeds the NIOSH ceiling limit for even a low metabolic work rate. Maintenance personnel perform preventive and corrective maintenance which requires substantial time to be spent in these (and other) extremely hot locations. These conditions 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).

B. Medical

The kiln assistants were performing moderate to heavy work while exposed to severe heat stress with substantial radiant heat levels. As a result, they were exhibiting various signs of heat strain which was confirmed by the workers' physiologic indices. Table 7 lists the information obtained during the medical evaluation of this HHE.

PULSE RATE

In general, the degree and rate of pulse increase would depend on the degree and length of physical exertion. After each "blasting" task, pulse rates went up sharply in most cases. (Refer to Figure 2 for diagrams of the pulse rate of workers on the 1st shift.) The time of operating the "blasting" gun ranged from a few minutes to the maximum of 20 minutes.

There is a great variation in pulse rates among people of different sex, age, body size, etc. A sedentary pulse rate of 100 beats per minute or more in adults is defined as tachycardia (rapid heart rate), which by itself is not pathologic. One worker had a pulse rate of 104 even before the heat exposed work.

Immediately after the water blasting, pulse rates reached
150 beats per minute, and even as high as 180 beats per minute, depending on the individual worker. This is one of the body's physiologic responses to the stress of metabolic and environmental heat exposure. To maintain the required cardiac output demanded by the workload, the heart must beat faster. However, faster heart rates result in smaller stroke volumes (the amount of blood pumped out by each contraction of the heart); thus the heart becomes less efficient. While it is normal that a vigorous exercise produces rapid heart rate, it would be difficult for an average person to sustain a high degree of tachycardia for a long time. Additionally, the heat load requires that more blood flow be diverted to the skin to dissipate heat. Consequently, central blood volume is reduced, and peak cardiac output, maximal oxygen consumption and working capacity will become depressed.[16]

Using the maximum safe heart rate determined by age (220 minus age), the upper limit of the heart rate for the workers studied ranged from 164 beats per minute for the oldest worker to 186 beats per minute for the youngest. This limit was reached or exceeded twice by one worker. Another worker had a rate greater than 180, but this was within the age-dependent maximum.

These findings suggest that the combined effect of the heat stress and workload is approaching or exceeding the upper limit of the guidelines available for pulse rate. Since these guidelines are set for healthy and acclimatized workers and make no provisions for workers who are unacclimatized or have underlying chronic diseases, a more restrictive limit may have to be applied to some of these workers.

BODY TEMPERATURE

Body temperature, which reflects the overall balance of heat gain/loss, does not respond to the change of heat/work load as quickly as the pulse rate. As shown in Figure 2, the body temperature curve for each worker ascended gradually but steadily as long as he repeated the blasting work. This suggests that heat gain in the body is not sufficiently counterbalanced by the heat dissipating mechanism. The oral temperatures did not return to the pre-shift level promptly but instead kept climbing after each episode of operating the blasting gun. It started to descend only after the last blasting job was completed.

The upper limit of 38°C (100.4°F) for body temperature was not reached by any of the kiln assistants. However, this result must be considered in view of the fact that oral temperature was measured, not core body temperature. If it is assumed that oral temperature is lower than core temperature by 0.5°C (0.9°F), 99.5°F will be the upper limit by oral measurement. **This upper limit value for oral temperature was reached or exceeded by 3 of the 4 workers.**

WEIGHT LOSS

As shown in Table 7, workers lost weight over the shift ranging from 0 to 4 pounds. This data indicates that, with the exception of Worker D, all water blasters lost approximately 2 to 4 quarts of water during the shift. It was observed that workers did not have an easy access to drinking water during the water blasting.

Zero weight loss of Worker D may be explained by the fact that he was placed on the water blasting job directly from a job in an air-conditioned control room. Since he was not acclimatized to the hot job, he could not continue the blasting for more than several minutes at a time and had to retreat from the heat exposure frequently. Furthermore, due to his intolerance to heat, he had to discontinue the task early in the middle of the operation, leaving Worker C alone to complete the job. This fact may also explain why Worker C lost the most weight.

BLOOD PRESSURE

Although blood pressure is not usually included in heat exposure studies, it was included as part of the pre- and post-shift medical survey. As shown in Table 7, all kiln assistants with the exception of one worker, had at least one measurement of above normal blood pressure. Using the upper normal of 150 mmHg systolic pressure and 90 mmHg diastolic pressure, two workers were borderline hypertensive and one worker was hypertensive (and was currently under a physician's care).

Hypertension is caused by a variety of conditions, including but not limited to, kidney disease, hormonal or metabolic diseases, and arteriosclerosis (which is related to age, heredity, diet, etc.). The cause of most cases is unknown. Chronic exposure to heat has been reported as a possible cause of hypertension.[17] However, the results were preliminary and a more thorough analysis of this issue was suggested by the author. A serious concern exists when a hypertensive person with possible underlying conditions is placed on a stressful hot job without prior medical approval.

VII. DISCUSSION

HEAT STRESS

Heat stress is defined as the total net heat load on the body with contributions from environmental sources and from metabolic heat production.[17] 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 its 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. 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.

Prolonged exposure to excessive heat may cause increased irritability, lassitude, decrease in morale, increased anxiety, and inability to concentrate. The acute physical disabilities caused by excessive heat exposure are, in order of increasing severity: heat rash, heat cramps, heat exhaustion, and heat stroke.

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.[17] 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).[17]

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.[18]

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:[1,19,20]

<u>Metabolic heat</u> - 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).

<u>Radiant heat</u> - 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.

<u>Convective heat</u> - 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 lose 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).

In addition to modifying the work place environmental conditions, the risk of a serious incident due to excessive heat exposure can be reduced by the implementation of a heat stress management program. This is especially important when modification of the environmental conditions is not technically feasible. The elements of a comprehensive **heat stress management program** is provided in Appendix A.[1]

Although Lehigh Cement Company did not have a formal heat stress management program, the company has implemented some controls in an effort to address the heat problem during the water blasting of the preheat tower riser. To minimize heat from traveling into the preheat tower from the adjacent kiln building, the company installed roof vents over the kiln area, as well as a radiant shield in a wall opening of the tower which borders the kiln building. Radiant heat near the preheat tower riser was reduced by installing additional refractory brick lining within a 7-foot-diameter duct leading into the riser, and a few heat shields were placed in selected locations. Air movement was increased with the use of large industrial fans positioned near wall openings as well as on a work platform, and by ducting untempered air along the riser in a few locations where workers stood while water blasting. Air cannons were connected to the riser and were intended to periodically air blast the residue from the walls. (This should reduce the water blasting duration, but employees reported that these air cannons didn't work properly and caused the water blasting to be more difficult.) The environmental and physiological measurements collected during this survey suggest that these measures were insufficient to adequately control the heat exposures. Fortunately, the company permitted a self-regulated work schedule, allowing the workers to remove themselves from exposure when it became unbearable.

Heat stress is a potentially serious problem for workers who water blast or perform maintenance in hot locations. The company did not have an established heat stress management program. Medical examinations with specific approval to work in hot environments were not performed annually and the company did not monitor the environmental heat conditions. Although employee training includes first aid procedures, a training program specifically addressing heat stress was not included. The drinking water was not located in the immediate vicinity of the preheat tower riser, significantly affecting accessibility. (The kiln assistants must ride a very slow and often inoperable elevator, or traverse at least 6 flights of stairs to obtain drinking water.) Furthermore, unacclimatized workers (alternates) are often required to water blast. Body cooling vests or other heat protective equipment has not been provided for use in hot environments.

CARPAL TUNNEL SYNDROME

During the course of the evaluation of heat stress/strain, it was discovered that two blasters (not among the workers who were studied for this HHE) had developed carpal tunnel syndrome (CTS). Based on the MSHA Form 7000-1, one employee reported the problem in October 1989, and another reported the same in March 1990. The right hand and wrist were involved in both cases. For the small size of the worker population (8 kiln assistants), two cases in a period of 10 months is a cause for concern.

Although the NIOSH investigators did not conduct a detailed ergonomics evaluation, they made some relevant observations of the ergonomic stresses associated with water blasting. There are four major stress factors in hand/wrist work which may be causally related to tenosynovitis and CTS - repetitiveness, musculoskeletal force, wrist posture, and vibration.[21] In water blasting, the repetition of work does not appear to be very high, but the task may require high static forces to aim and trigger the gun. Furthermore, the trigger of the water gun seems to require high finger force, since the trigger spring is set tight for safety so that it can not be accidentally pulled.

In addition, the water gun must be aimed and shot at various directions inside the furnace. Therefore, the worker must position the end (which is connected to the pressure hose) of the water gun to his right or left, and above his head or below his knees to shoot. This necessitates the worker to bend the wrist frequently with force. When the worker aims downward, he has to pull the trigger while raising the arm upward with the wrist flexed to the maximum. Such positions of the hand/wrist increases friction within the carpal tunnel, and leads to inflammation of the tendons and tendon sheaths; the resulting pressure on the median nerve produces the CTS. Therefore, it is quite conceivable that water blasting job could contribute to the development of CTS.

VIII. CONCLUSIONS

1. The environmental heat during the water blasting operation of the preheat tower riser exceeded the NIOSH and ACGIH WBGT heat stress criteria.

2. The work activities of the water blasting resulted in medium to high metabolic heat production.

3. There was a significant radiant heat load present in the preheat tower locations where the water blasting occurred.

4. The air temperature of the air stream provided by the space "cooling" fans was in excess of 100°F, thereby contributing to convective heat gain.

5. The personal protective equipment necessary for the water blasting operation impedes evaporative heat loss.

6. The physiologic indices suggested that employees were subjected to severe heat strain during the water blasting.

7. The employees required to water blast may not necessarily be acclimatized to hot environments.

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

9. 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.

10. Self-regulation of work activity utilized by the water blasting employees is an important safeguard which reduced the potential for a serious heat related incident.

11. Two workers were reported to have signs of carpal tunnel syndrome.

IX. RECOMMENDATIONS

A. HEAT STRESS

A number of recommendations will be proposed in this section which include engineering controls, administrative controls, and personal protective equipment. Because the heat exposure during the water blasting contains significant contributions from all of the heat balance components (radiant heat gain, convective heat gain, loss of evaporative cooling, and metabolic heat production), implementation of a single control will not adequately address the entire heat stress problem. The following recommendations should be considered as control options and evaluated in regards to the feasibility of implementation at this manufacturing site:

Engineering Controls

1. Install additional heat shields on surfaces radiating heat especially along the sides of the preheat tower riser where employees are positioned during the water blasting.

2. Install additional refractory brick linings within the engineering equipment transporting heated materials and gases.

3. Modify the existing vented air supply near the water blasting ports so that cool air is provided in lieu of untempered outside air.

4. Design and install flanges around the perimeter of the space cooling fans (which are located near the wall openings) to minimize the amount of interior (heated) air that is pulled out of the building and re-entrained into the fans make-up air. Flanges that are designed and installed in accordance with accepted ventilation design principles should allow the fans to more effectively transfer outside air into the building (or exhaust interior air from within building).[19]

5. Reposition one or more of the space cooling fans so that the fan stream direction exhausts heated air out of the preheat tower. It was observed that the cement floors of the second and fourth levels, along with the north, south and east walls enclose the water blasting area of the preheat tower. This arrangement restricts air movement into this area from the outside. Both of the fans near the west wall were attempting to move air into the tower, a situation which may further contain the air within this space. Redirecting the fan on the third floor to exhaust air out of the tower, while maintaining a supply of outside air from the fan on the second floor, may allow a more effective transfer of air through this area. If this option is considered, it should be implemented on an experimental basis to ensure that the exhausted air is replaced by outside air and not by heated air from within the kiln building.

6. Evaluate the feasibility of providing wall openings in the north and south walls and/or the ceiling of the third level (which also serves as the floor for the fourth level) to allow heated air to escape. Naturally, this control option is feasible only if the structural integrity of the building can be maintained (i.e. with steel I-beams for support).

7. Install additional ceiling vents in the adjacent kiln building.

Administrative Controls

1. It is essential for employees exposed to heat to be examined by a physician and received 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.

2. Perform the water blasting operation with three (or more) person work crews instead of two worker crews. 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 the "buddy" system when working in this heat hazard location.

3. Implement a comprehensive heat stress management program for the kiln assistants, alternatives, 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 A of this report for specific details of a heat stress management program.

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

    a. Even distribution of work over the entire work shift.

    b. Schedule hot jobs (or strenuous ones) during the coolest part of the work day.

    c. 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 that which is lost by perspiration. The use of commercially available electrolyte replenishment drinks is preferred over salted fluids.

5. Improve access to drinking water by locating a source of potable water in the immediate vicinity of the heat exposure (on the floors where the water blasting occurs) 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.

6. 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 4 or 5 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. Unacclimatized individuals will include all workers at the beginning of the hot season, employees returning from a vacation or extended weekend, alternates who water blast on occasion, or any other worker who does not have continued and prolonged exposure to hot environmental conditions.

7. 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.

Personal Protective Equipment

1. Provide auxiliary body cooling vests or suits for water blasting, maintenance work, or any other activity that occurs in high heat exposure areas. 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. In view of the work duration (30-60 minutes) and requirement for maneuverability, the use of ice vests appear to be the most practical and cost effective.

2. Provide (radiant) reflective clothing suits or aprons for the water blasting operation 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 possibly 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. Since the radiant and convective heat are high during the water blasting, reflective clothing should only be used in conjunction with auxiliary cooling equipment such as an ice vest.

B. CARPAL TUNNEL SYNDROME

The company should consult with a qualified ergonomist to evaluate the water blasting operation to assess the potential for cumulative trauma disorders (such as CTS and tenosynovitis) as well as to recommend engineering controls. Forceful (and repeated) bending of the wrist should be avoided as much as possible. To the extent possible, the wrist joint should be kept in a neutral position, especially when the water blasting gun trigger is pulled. Although the NIOSH investigators did not conduct an investigation of cumulative trauma disorders at this facility, a few possible control recommendations may include:

1. Modify the water blasting gun so that two hand grips are provided (approximately 2 feet apart which are perpendicular to the gun shaft).

2. Employees should use both hands alternately to support the gun and pull the trigger to reduce the frequency of pulling the trigger exclusively by the same hand.

3. Reduce the trigger switch tension so that the required force of operation is minimized. (A double trigger switch or supplemental key ignition could be used to address the safety concern regarding inadvertent activation.)

4. Provide an overhead guide wire and hoist (or mounting tripod) to support and pivot the water blasting gun during aiming and triggering the gun. (This will also reduce the metabolic heat production of this task since the entire weight of the gun will not be supported by the worker.)

5. Rotate additional workers to reduce the daily (water blasting) exposure time.

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1. Lehigh Portland Cement Company, Mason City, Iowa.

2. Cement, Lime, Gypsum, and Allied Workers, Division of the International Brotherhood of Boilermakers, Local 106, Mason City, Iowa.

3. MSHA 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.

Appendix A.
Elements of a Comprehensive Heat Stress Management Program.
HETA 89-274

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, and 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 all 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 (50-60°F) 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 95°F or when the daily maximum temperature exceeds 90°F and is at least 9°F 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-induce 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-induce accident or illness is also crucial for correcting program deficiencies.

Table 1.
Metabolic Heat Production Rates by Task Analysis
HETA 89-274

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.

Reference 1.

Table 2.
Environmental Heat Measurements[1] - Water Blasting, 1st Shift
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
9:48	73.0	68.0	76.0	70.0	Outside, Shaded
9:55	83.0	71.5	85.5	76.0	6th Floor, Break Room, Donning PPE
10:10	95.0	77.5	110.0	87.0	3rd Floor, West Side
10:15	94.5	78.0	109.5	87.5	3rd Floor, West Side
10:20	97.0	78.5	110.5	88.0	3rd Floor, West Side
10:25	99.0	79.5	113.0	89.5	3rd Floor, West Side
10:35	109.0	83.0	128.5	96.5	2¾ Floor, South Side[2]
10:40	105.0	82.5	127.5	96.0	2¾ Floor, South Side[2]
10:45	106.0	80.5	111.5	90.0	2¾ Floor, West Side
10:50	110.5	79.5	108.5	88.0	2¾ Floor, West Side, Resting, Fan Stream
10:55	104.0	80.0	109.5	89.0	2¾ Floor, West Side
11:10	--	--	--	--	Break - 6th Floor
11:40	105.0	79.0	113.0	89.0	2¾ Floor, North Side
11:45	105.5	79.0	113.0	89.0	2¾ Floor, North Side
11:50	104.0	80.0	109.0	89.0	2¾ Floor, North Side
11:55	122.0	85.0	128.0	98.0	2¾ Floor, Northeast Corner
12:00	123.0	85.0	130.5	98.5	2¾ Floor, Northeast Corner
12:05	102.5	79.0	106.0	87.0	2½ Floor, North Side, Resting
12:10	116.0	84.0	134.0	99.0	2½ Floor, West Side
12:15	118.0	86.5	135.0	101.0	2½ Floor,. West Side
12:20	121.0	87.0	140.0	103.0	2½ Floor, West Side
12:20	--	--	--	--	Stop
12:25	101.5	79.0	106.58	87.0	2½ Floor, West Side, Fan Air Stream
12:40	84.0	75.0	102.5	81.5	Outside, Sunshine

NOTES:
[1] Values reported in degrees Fahrenheit.
[2] Under duct with refractory brick lining.

Table 3.
Environmental Heat Measurements[1] - Water Blasting, 2nd Shift
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
5:20	82.0	74.0	85.0	77.5	Outside, Shaded
7:10	103.5	81.0	112.0	90.5	2½ Floor, North Side
7:15	106.0	81.0	111.5	90.0	2½ Floor, North Side
7:20	110.0	85.0	123.0	96.5	2½ Floor, West Side
7:25	108.5	81.5	114.0	91.0	2¾ Floor, West Side
7:30	110.5	82.0	115.5	92.0	2¾ Floor, West Side Resting
7:30	--	--	--	--	Break - 2¾ Floor
7:40	113.5	85.0	136.5	100.5	2¾ Floor, South Side[2]
7:45	107.5	81.5	112.0	90.5	2¾ Floor, West Side
7:50	116.0	85.0	128.5	98.0	2¾ Floor, West Side[3]
7:55	119.0	87.0	132.5	100.5	2¾ Floor, Northeast Corner
8:00	--	--	--	--	Break - 6th Floor
8:20	99.0	80.0	110.0	89.0	3rd Floor, West Side
8:30	86.0	74.5	88.5	79.0	6th Floor, Break Room

NOTES:
[1] Values reported in degrees Fahrenheit.
[2] Under duct with refractory brick lining.
[3] Near donut holes.

Table 4.
Estimated Metabolic Rate, Water Blasting
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

	Range[1] **(Kcal/min)**	**Estimate (Kcal/min)**
Body Position		
1. Always standing and some walking (with stairs)	0.6 2.0-3.0	1.5
Type of Work[2]		
1. Water Blasting Heavy work, both arms and moderate work, whole body	2.5 5.0	
2. Assisting Light work, both arms and light work, whole body	1.5 3.5	3.0[2]
Basal Metabolism	1.0	1.0
Summation		5.5
Hourly Estimation		330
Metabolic Rate Work Category		Moderate to high

NOTES:
1 From Table 1, Reference 1. .
2 Two workers -- half of time worker water blasts (4.0 Kcal/min) and other half worker assists (2.0 Kcal/min); average estimate (for type of work) is 3.0 Kcal/min.
3 kcal/min = kilocalories per minute.

Table 5.
Environmental Heat Measurements[1] - Walkthrough Preheat Tower, 1st Shift
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
8:05	80.5	69.5	87.5	75.0	8th Floor, Upper Feed Elevator
8:12	85.5	72.5	103.0	81.5	6½ Floor, Bottom of 2nd Stage
8:22	90.0	73.0	94.0	79.5	Top of IBAU Silo
8:32	81.0	71.5	89.5	77.0	5½ Floor, Lower Feed Elevator
8:39	92.5	75.5	107.0	85.0	5½ Floor, 3rd Stage, Tipping Valves
8:45	101.5	79.5	103.5	87.0	5th Floor, Spray Tower Pump Room
8:53	92.5	80.0	129.5	95.0	4th Floor
9:00	91.0	76.0	101.5	83.5	3rd Floor
9:06	107.5	78.5	110.0	88.0	2¾ Floor, Donut Hole Floor
9:12	111.0	81.5	122.0	93.5	2½ Floor, Exit Floor
9:17	101.5	81.5	110.0	90.0	2nd Floor, Near Kiln
9:23	80.0	73.0	88.5	77.5	2nd Floor, Near Open Wall
9:29	73.5	68.5	76.0	71.0	1st Floor
9:35	102.0	78.5	102.5	86.0	IBAU Tower, Electric Rm
9:41	127.0	89.0	129.5	101.0	IBAU Tower, Top of Mix Bin
9:48	73.0	68.0	76.0	70.0	Outside, Shaded

NOTES: [1] Values reported in degrees Fahrenheit.

Table 6.
Environmental Heat Measurements[1] - Walkthrough Preheat Tower, 2nd Shift
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

TIME	DB	WB	GT	WBGT	LOCATION/COMMENTS
3:50	92.5	75.5	96.0	81.5	Cooler Floor, Kiln Bldg.
3:56	114.0	87.5	146.0	105.0	#1 Gear, Under Kiln
4:08	88.0	76.0	94.0	81.5	8th Floor, Upper Feed Elevator
4:14	83.5	72.5	90.0	78.0	7th Floor
4:20	85.0	73.5	90.5	78.5	5½ Floor, 3rd Stage, Air Cannon
4:26	102.5	80.0	102.5	87.0	5th Floor, Spray Tower Pump Room
4:32	91.0	78.0	106.5	86.5	4th Floor
4:38	100.0	80.0	112.0	89.5	3rd Floor
4:44	127.0	85.5	132.5	99.5	2¾ Floor, Donut Hole Floor
4:50	107.5	83.0	116.0	93.0	2½ Floor, Exit Floor
4:55	92.5	78.0	99.0	84.5	2nd Floor
5:02	94.5	78.0	96.0	83.5	1st Floor, Electra-Saver Room
5:08	106.0	81.0	106.5	88.5	IBAU Tower, Electrical Room
5:13	130.0	91.0	133.5	103.5	IBAU Tower, Top of Mix Bin
5:20	82.0	74.0	85.0	77.5	Outside, Shaded

NOTES: [1] Values reported in degrees Fahrenheit.

Table 7.
Medical Information for Kiln Assistants
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

A. **Number and gender of workers:** 4, all males.

B. **Age:** minimum 34; maximum 56; mean 44

C. **Length of employment at this company:** 10 to 30 years.

D. **Length of furnace helper job:** 2 to 10 years, on and off.
No worker has done this work continuously the over years.

E. **Medical History:**

One worker was hypertensive (pre-shift blood pressure of 180/100) and was taking medication for this condition. He stated that he could do the work, and his personal physician did not advise him against taking the hot job.

Another worker had a history of nephritis at age 10, from which he has recovered without sequelae.

F. **History of heat-related disorders:**

Each participant reported that he had experienced headache and dizziness when exposed to severely hot working conditions of the water blasting job during the hot season. Two workers also reported experiencing nausea. However, none of them experienced any serious adverse conditions such as heat stroke or collapse requiring emergency medical treatment. The workers are allowed to use their own judgment and withdraw from the hot job to take a rest whenever there is an onset of acute symptoms, or when they "cannot take it any longer."

G. **Weight loss over the shift:**

Worker A, 2 lbs.
Worker B, 2 lbs.
Worker C, 4 lbs.
Worker D, 0 lbs.

Table 7. (continued)
Medical Information for Kiln Assistants
Lehigh Portland Cement Company, Mason City, Iowa
HETA 89-274

H. **Pulse rate and body temperature:**

	Pulse Rate per min. Pre-shift	Pulse Rate per min. End-shift	Body Temperature(°F) Pre-shift	Body Temperature(°F) End-shift
Worker A	80	84	96.4	97.8
Worker B	80	104	98.1	98.5
Worker C	88	80	99.2	99.1
Worker D	104	108	98.9	99.1

I. **Blood Pressure:**

	Systolic/Diastolic Pre-shift	Systolic/Diastolic End-shift
Worker A	152/86	138/86
Worker B	120/70	110/70
Worker C	180/100	176/104
Worker D	140/98	148/106

No blood pressure measurements were taken during the shift.

NOTE: The comparison of pre- and post- "blasting" pulse rates and body temperatures is a more effective evaluation of the physiological response to heat stress. (Refer to Figure 2.)

Figure 1.
Heat Stress Exposure Limits Recommended by NIOSH
HETA 89-274

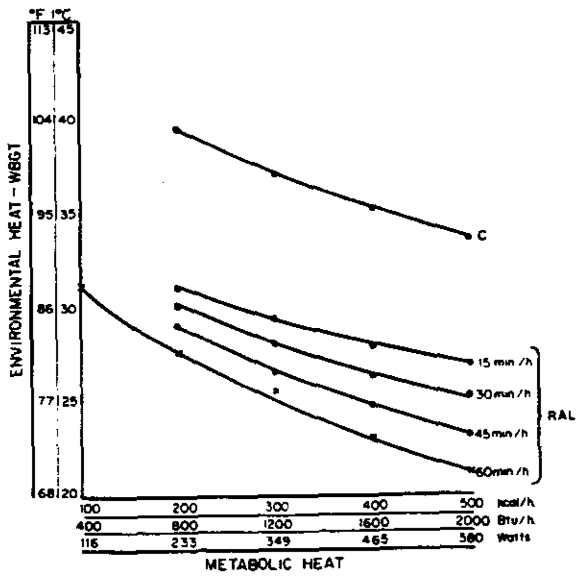


Figure 1. Recommended Heat-Stress Alert Limits
Heat-Unacclimatized Workers

C = Ceiling Limit
RAL = Recommended Alert Limit

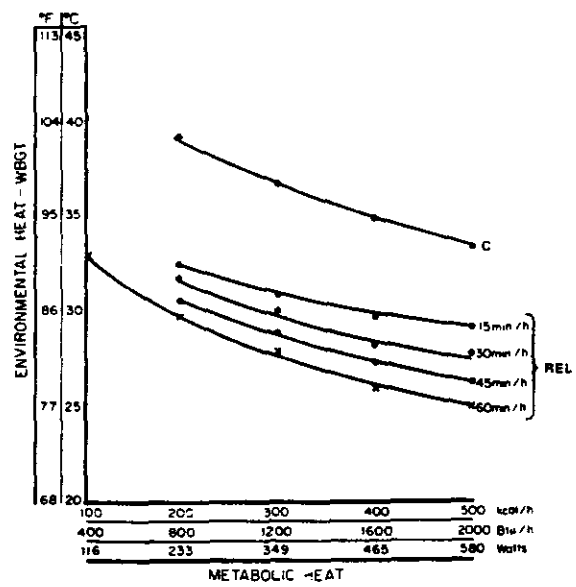


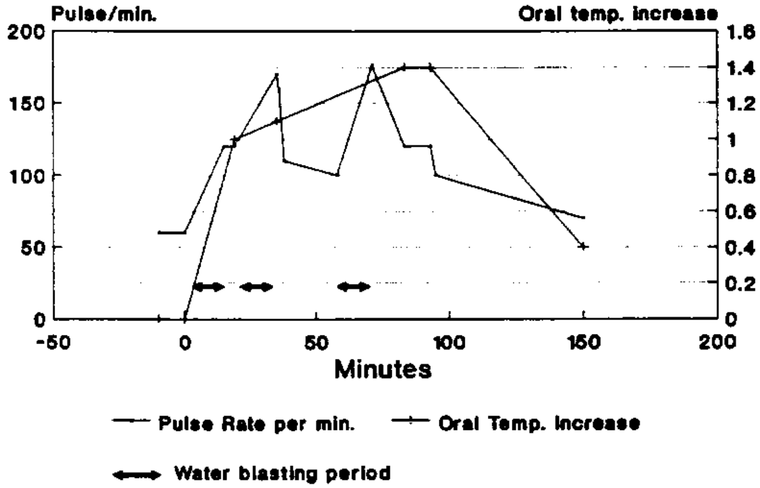
Figure 2. Recommended Heat-Stress Exposure Limits
Heat-Acclimatized Workers

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

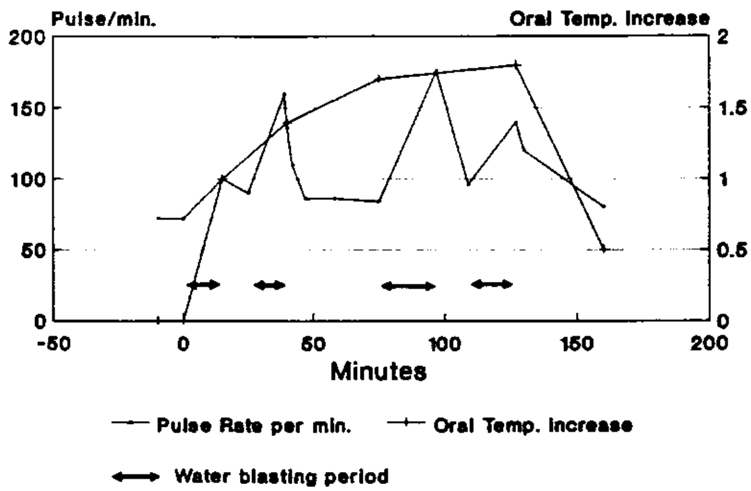
Reference 1

Figure 2
Pulse and Temperature, Water Blasting
Lehigh Portland Cement Company
HETA 89-274

Worker A



Worker B



Appendix A.
Elements of a Comprehensive Heat Stress Management Program.
HETA 89-274

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, and 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 all 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 (50-60°F) 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 95°F or when the daily maximum temperature exceeds 90°F and is at least 9°F 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-induce 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-induce accident or illness is also crucial for correcting program deficiencies.