# THERMAL STRESS MONITORING IN A RADIOLOGICAL WORK ENVIRONMENT

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## ABSTRACT

Most companies overlook the need to monitor workers for thermal stress, which can be a severe health concern, especially to an unacclimatized worker. When thermal stress monitoring is neglected, adverse health effects in hot and cold environments can increase. With careful considerations and tested guidelines, however, thermal stress can be controlled.

Workers in the Transuranic Waste Inspectable Storage Project (TWISP) at Los Alamos National Laboratory are exposed to heat and cold when retrieving transuranic (TRU) waste containers. Workers in a radiological work environment must wear personal protective equipment (PPE) that increases the physiological heat load. Such PPE as air-purifying respirators, anti-C, or chemical-resistant coveralls all reduce the body’s capability for thermal regulation.

The American Conference of Governmental Industrial Hygienists (ACGIH) and National Institute for Occupational Safety and Health (NIOSH) have established guidelines in the *1999 Threshold Limit Values and Biological Exposure Indices* (TLVs and BEIs) (1), and *Occupational Exposure to Hot Environments, 1986* (2), respectively, for controlling thermal stress. Environmental conditions are monitored using an area heat-stress monitor (wet-bulb globe thermometer [WBGT]) and an onsite electronic weather station. Worker heat load is directly measured using a body-core temperature tympanic thermometer. Another monitoring method of worker response to heat load utilized is pre and post shift weight measurement using a weight scale with ± .25 lb. accuracy. Control measures include ice vests, shade canopies, electrolyte replacement drink (for heat stress), thermal underwear (for cold stress), and limiting time spent under thermal stress.

Documenting such monitoring will provide a reference for protecting personnel from adverse health effects of work under thermal stress. Managers can take appropriate measures to ensure that their workers work in safe conditions. Similarly, the workers can do their work knowing they are protected by a thermal safety protocol.

## INTRODUCTION

The Transuranic Waste Inspectable Storage Project (TWISP) at Los Alamos National Laboratory involves retrieving a variety of containers containing TRU wastes, primarily 55-gallon drums and 85-gallon drums; Fiberglas™-reinforced plywood crates ranging in size from 2 ft x 4 ft x 6 ft to 9 ft x 8 ft x 24 ft; and odd shapes, such as reaction vessels. These containers were stacked four to five layers high in three densely packed arrays, covered with plywood and plastic tarps, and buried with at least three feet of crushed volcanic tuff. The three waste arrays, designated Pad 1, Pad 2, and Pad 4, contained 16,637 drums, 187 FRP crates and 4 "other" containers. As of this writing, 8300 drums, 148 FRP crates, and 3 "other" containers have been removed from Pad 1 and Pad 4.

TRU waste containers are retrieved year-round outside in an unprotected environment, exposing workers to the climatic extremes (Fig. 1).


***Fig. 1.*** **Retrieval of transuranic waste containers from Pad 4.**

Fortunately, the climatic patterns for northern New Mexico are forgiving enough that the number of days that workers are exposed to thermal stress is minimal. For days when conditions warrant, thermal stress monitoring is implemented.

## THERMAL-STRESS MONITORING PROGRAM: HEAT STRESS

The heat-stress-monitoring program at the TWISP is based on the ACGIH TLVs and BEIs (1999). These guidelines have been incorporated into the Johnson Controls Northern New Mexico (JCNNM) Thermal Stress policy to evaluate the workload and specify work–rest regimens for a particular workload for WBGT ranges. Correction factors are specified for different types of clothing or Personal Protective Equipment (PPE). Table 1 shows work–rest regimen vs. WBGT (1). Environmental conditions are monitored with a Questemp 10 WBGT. Table 2 establishes correction factors for clothing types.

**Table 1. Recommended ACGIH Heat Exposure TLVs.**

| | Workload | | |
|---|---|---|---|
| **Work–rest regimen** | **Light $^oC/^oF$** | **Moderate $^oC/^oF$** | **Heavy $^oC/^oF$** |
| continuous work | 30.0(86) | 26.7(80) | 25.0(77) |
| 75% work<br>25% rest each hour | 30.6(87) | 28.0(82) | 25.9(78) |
| 50% work<br>50% rest each hour | 31.4(89) | 29.4(85) | 27.9(82) |
| 25% work<br>75% rest each hour | 32.2(90) | 31.1(88) | 30.0(86) |

***Light work*** is considered to be work in which one is sitting or standing to control machines or to perform light hand or arm work.

***Moderate work*** is considered to be walking about with moderate lifting and pushing.

***Heavy work*** is considered to be pick-and-shovel work.

**Table 2. TLV/WBGT Correction Factors in Degrees Celsius for Clothing.**

| Clothing type | Clothing value | WBGT correction (°C) |
|---|---|---|
| summer work uniform | 0.6 | 0 |
| cotton coveralls | 1.0 | -2 |
| winter work uniform | 1.4 | -4 |
| water barrier permeable | 1.2 | -6 |

***Effect of clothing.*** The recommended limits of the ACGIH and NIOSH are for healthy workers who are physically and medically fit for the level of activity required by their job and who are wearing the customary one-layer work-clothing ensemble consisting of not more than long-sleeved work shirts and trousers (or equivalent). The recommended exposure limit (REL) and recommended action limit (RAL) values given by NIOSH may not provide adequate protection if workers wear clothing with lower air and vapor permeability or insulation values greater than those for the customary one-layer work clothing ensemble. According to the ACGIH-TLV reference guide, a WBGT correction for clothing that creates a water barrier is to reduce the WBGT by 6° C.

For an employee wearing a work uniform and cotton coveralls, the WBGT correction will reduce the WBGT TLVs by 2° C (Fig. 1).

An employee wearing two pairs of Tyvek™ coveralls with a full-face air-purifying respirator is considered to be wearing a winter work uniform; a WBGT correction will reduce the WBGT TLVs by 4° C (3) (Fig. 1).

Although not included in the ACGIH guidelines, the use of a professional-grade tympanic thermometer set for rectal temperature equivalence is a key component of the heat-stress monitoring program. Core body temperature is specified by ACGIH as rectal temperature. By taking individual worker temperatures before and after the work shift, worker tolerance to heat stress is uniquely defined (Fig. 2).

***Fig 2.*** **Measuring worker temperature before starting retrieval operations.**

In some cases, workers were not allowed to enter the retrieval operation because of fever that already exceeded the ACGIH action level of 38$^{o}$ C (100.4$^{o}$ F). Without monitoring of individual temperatures, they would have been allowed to enter the retrieval operation at high ambient environmental temperatures with the additional physiological stress of a full-face air purifying respirator (APR) and double layer of anti-C coveralls. Clearly, monitoring individual worker temperatures has definite application in preventing heat-related illness.

Other monitoring includes recording worker weights before and after the work shift with a professional-quality scale, accurate to within ± 0.11 kg (0.25 lb.). An acclimatized worker should lose no more than 1.5% of his or her body weight during the work shift. Body weight loss of more than 1.5% would indicate that the worker was not maintaining sufficient hydration and would be susceptible to heat stress. In addition to monitoring the worker and his or her environment, other options to reduce the risk of heat stress have been implemented.

## MITIGATING OPTIONS: HEAT STRESS

Because the requirement of two layers of anti-C coveralls, skullcap, hood, and full-face APR limits the body's ability for thermal regulation through evaporative cooling, additional options are available to the worker to reduce heat stress. These options include the availability of ice vests to aid in cooling the body's core, providing shade canopies in the work area so the workers can get out of the direct sunlight, and providing electrolyte replacement beverages and water to maintain the proper electrolyte balance during periods of heavy perspiration.

## THERMAL-STRESS MONITORING PROGRAM: COLD STRESS

Environmental monitoring for cold stress is done using an onsite electronic weather monitoring station. Outside temperature, wind velocity, wind chill, relative humidity, barometric pressure and dew point are measured in real time.

## MITIGATING OPTIONS: COLD STRESS

Cold stress is less of an issue for the mild winter climate of northern New Mexico, but the PPE requirements preclude wearing conventional cold-weather gear. Workers are provided with expedition-weight polyester long underwear, including glove liners and balaclavas, which can easily be worn with the required two layers of anti-C coveralls to provide thermal insulation. Cold-weather gear is worn when work is being performed at or below 4°C. If air velocity becomes a concern, shielding is provided to reduce the wind speed. If work is being performed when the temperature is below -7°C, heated warming shelters are provide nearby. The workers are encouraged to use these shelters whenever necessary and at regular intervals.

## THERMAL STRESS MONITORING DATA

Data collected from the WBGT is recorded and analyzed to ensure that it does not exceed the action level. The action level used at the TWISP project is 30°C with a correction factor of –4°C (for the semi-impermeable clothing used during operations, see Table 2). This correction results in an action level of 26°C. Table 3 is a list of WBGT correlated with the daily time for July 26, 1999. See also Fig. 3.

**Table 3. WBGT vs. Time for July 26, 1999.**

| Time | WBGT (°C) |
|---|---|
| 9:55 | 22.5 |
| 10:11 | 22.4 |
| 10:29 | 23.3 |
| 10:40 | 23.3 |
| 11:06 | 24.7 |
| 11:15 | 23.8 |
| 11:30 | 24.4 |
| 11:45 | 24.2 |
| 11:55 | 25.2 |

This example shows that the action level of 26° C was approached but never reached or exceeded. In this case, operations were not stopped. If the action level were exceeded, a work–rest regimen from Table 1 would have been implemented.

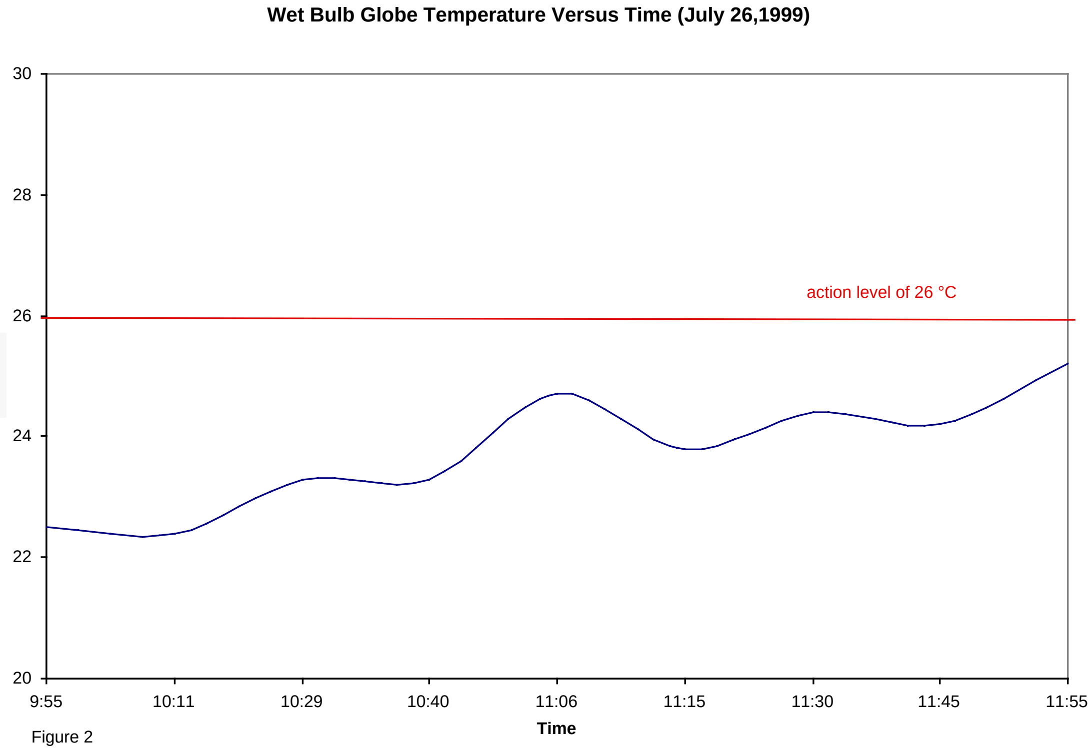


*Figure 3. Wet Bulb Globe Temperature Versus Time (July 26, 1999)*

The following is another example of thermal stress mitigation. The table includes body temperatures of the workers before and after operations on July 30, 1999.

**Table 4. Pre-shift and post-shift worker temperatures on July 30, 1999.**

| Worker | Pre-shift temperature (°C) | Post-shift temperature (°C) |
|---|---|---|
| 1 | 37 | 37.5 |
| 2 | 36.9 | 36.9 |
| 3 | 38.3 | —— |
| 4 | 36.9 | 36.8 |
| 5 | 37.7 | 37.8 |

The action level for an employee's body temperature is 38°C. Because the third worker had a body temperature of 38.3°C before operations, the worker was not allowed to perform operations that day. All of the remaining workers were allowed to conduct operations based on their temperatures remaining below the action level. Variation in pre-operation and post-operation worker temperature is illustrated in Fig. 4 for August 12, 1999.

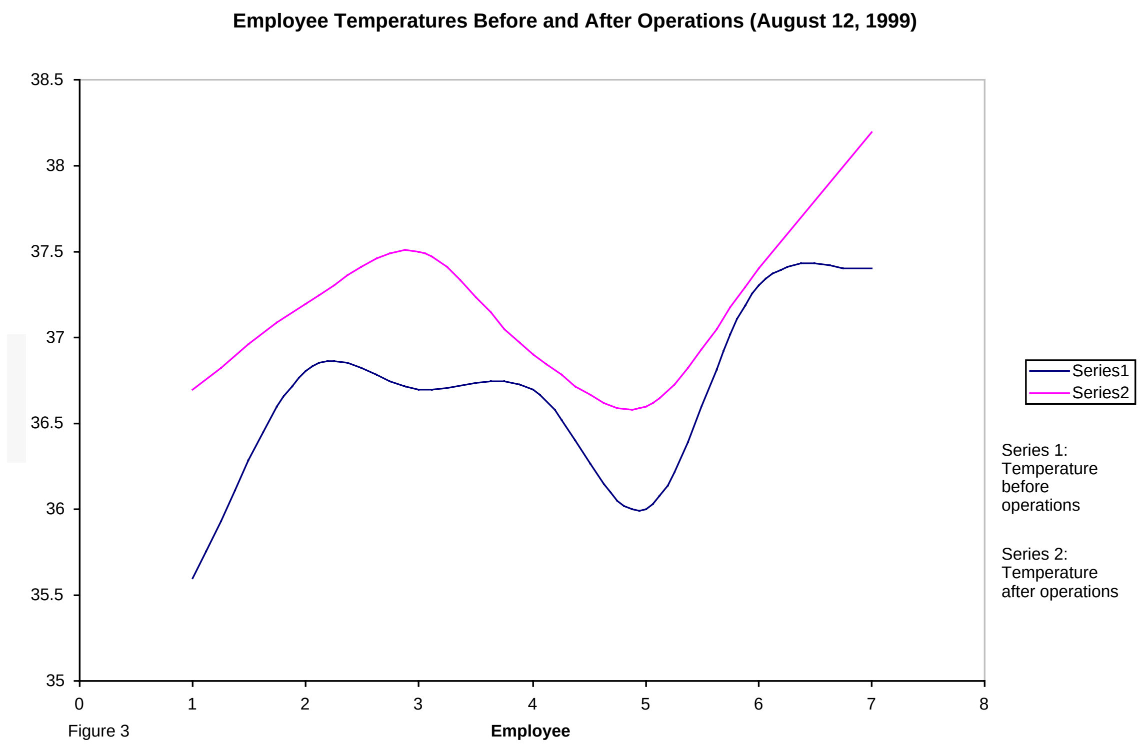


***Figure 4: Employee Temperatures Before and After Operations (Augut 12, 1999)***

## MONITORING EQUIPMENT

Questemp 10–wet-bulb globe thermometer, area heat stress monitor, Quest Technologies

First Temp Genius Model 3000A, infrared tympanic thermometer, Sherwood Medical Company

Fisher Weather System 02-402, Fisher Scientific

Tanita electronic scale, Model BWB-800, Tanita Corporation

## CONCLUSION

Thermal stress monitoring is an integral part of maintaining a healthy work force. The heat-stress monitoring program recommended by the ACGIH is based on environmental monitoring with a WBGT area heat-stress monitor. We recommend that an additional monitoring component, direct measurement of worker temperatures, be added. Based on our measurement of worker temperatures before and after the workers performed retrieval operations of transuranic waste, some workers were prevented from entering the retrieval operation because of elevated temperature. If only the environmental conditions are monitored, these workers would have been subjected to the increased physiological heat load of elevated ambient temperature and the required anti-C PPE, potentially resulting in heat induced illness.

## REFERENCES

1. 1999 TLVs and BEIs Threshold Limit Values for Chemical Substances and Physical Agents, Biological Exposure Indices, American Conference of Governmental Industrial Hygienists (1999).
2. Occupational Exposure to Hot Environments, National Institute for Occupational Safety and Health (1986).
3. Health, Safety and Environment Manual, Industrial Hygiene, Section 13. Heat and Cold Stress, Johnson Controls Northern New Mexico (1998).

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