Heat Stress

Presented by: Grant Quiller, OSH Compliance West

NCDOL
N.C. Department of Labor
Cherie Berry, Commissioner
OSH Division
Internal Training

For Public Officials' Use Only

Outline

Part I

I. Introduction
II. Definitions
III. Heat Stress
IV. Heat Strain
V. Prevention of HRI

Part II

I. State of enforcement
II. Investigation guidelines
III. What NC is doing

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Introduction

Why is it important?

- 423 deaths between 1992 and 2006
- 20x higher for crop workers
- 4,190 lost time heat stress cases in 2010

On August 1, 2006, a 44-year-old Hispanic migrant farm worker (the victim) died after succumbing to heat stroke while working in a tobacco field on a farm in North Carolina. The victim arrived on the farm from Mexico on July 21, 2006. On July 24 he was assigned to work in the tobacco fields, where he worked for the next week. On August 1, 2006, he started work at 7 a.m., had a short break between 9 and 10 a.m. that included soda and crackers, and ate lunch between noon and 1 p.m. The weather was hot and humid with a heat index (a measure of the combined effects of high temperatures and high humidity on the body) between 100 and 110. He had been working in a tobacco field when around 3 p.m. he complained to the crew leader that he was not feeling well. The victim drank some water and was driven back to the workers' housing and left alone to rest. At approximately 3:45 p.m. the victim was found unconscious on the steps of the house. Emergency medical service (EMS) personnel were immediately called and responded within five minutes. The victim was transported to the hospital where his core body temperature was recorded at 108º F and he was pronounced dead.

Outdoor occupational heat-related fatalities between 2008-2014

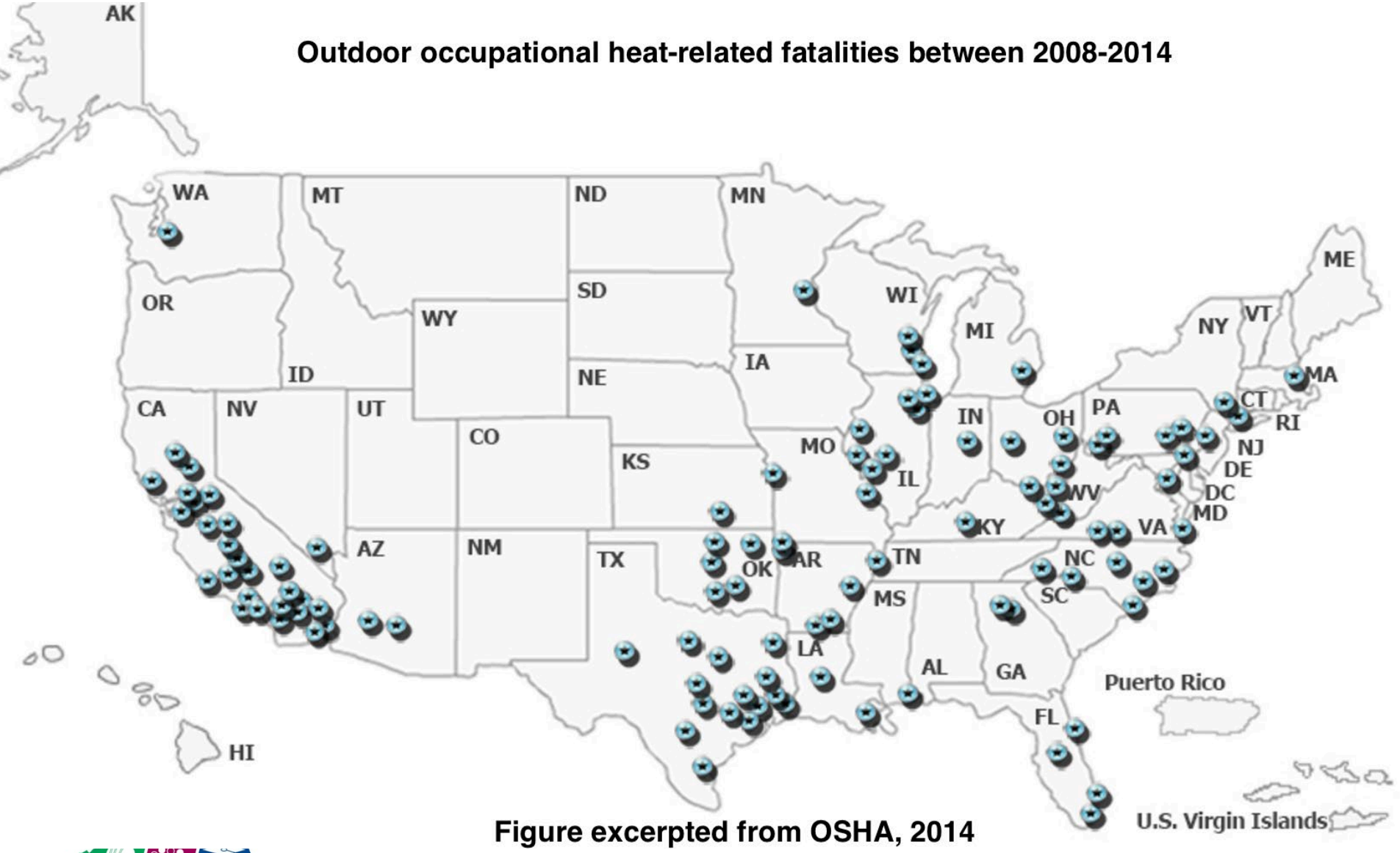


Figure excerpted from OSHA, 2014

Introduction

Why am I teaching today?

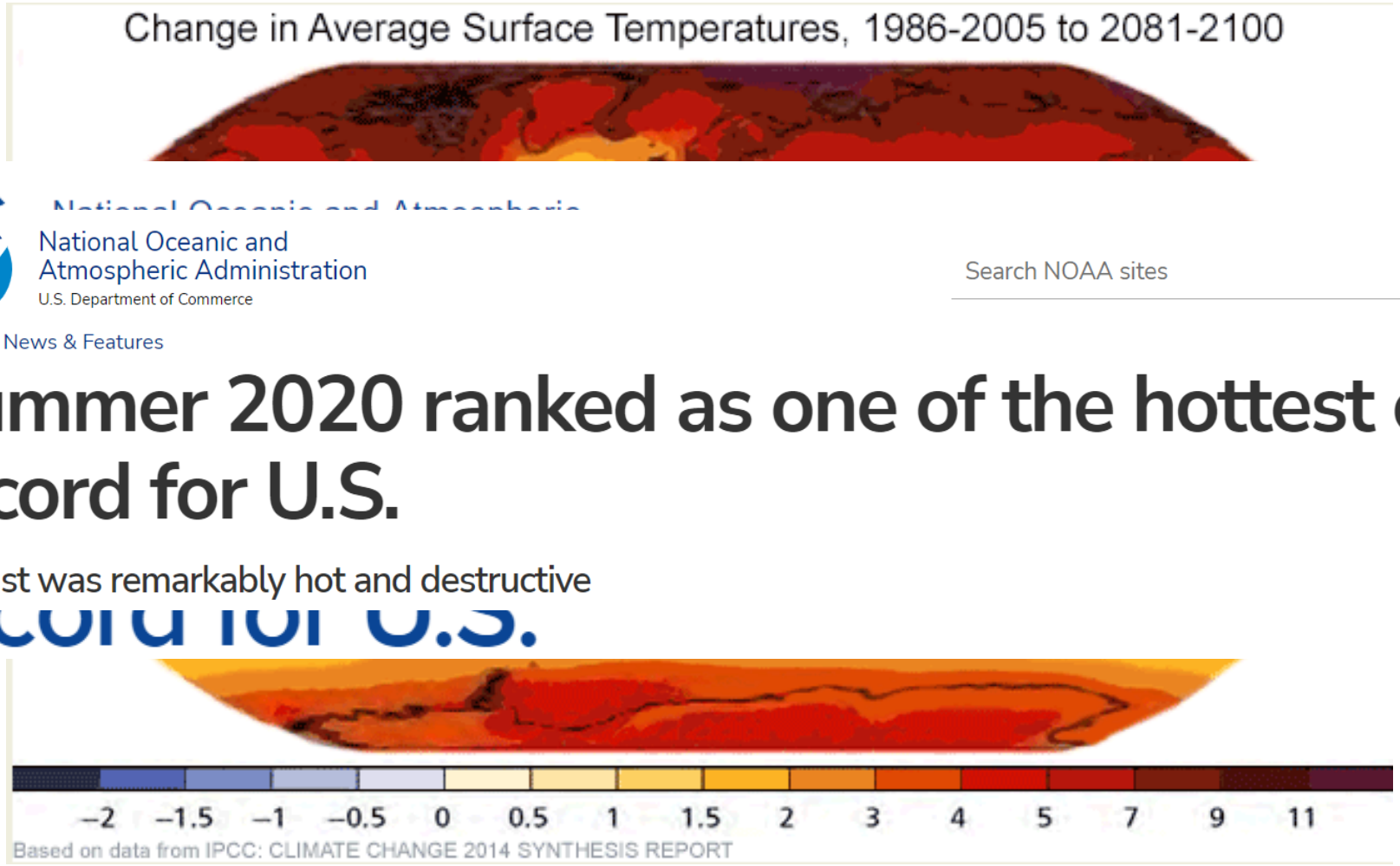
-Hispanic

-Agriculture or ‘un-skilled’ labor

-Climate change

-Master’s thesis

Introduction



Introduction

Archives of Environmental & Occupational Health

ISSN: 1933-8244 (Print) 2154-4700 (Online) Journal homepage: https://www.tandfonline.com/loi/vaeh20

Heat exposure and productivity in orchards: Implications for climate change research

Grant Quiller, Jennifer Krenz, Kristie Ebi, Jeremy J. Hess, Richard A. Fenske, Paul D. Sampson, Mengjie Pan & June T. Spector

Introduction - Objectives

- Definitions of terms associated with Heat Stress
- Heat Stress disorders and health effects
- Prevention and control of Heat Stress
- Heat Stress inspection procedures
- How to write a Heat Stress citation

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Definitions

- **Heat Stress**
  - Sum of environmental and metabolic heat loads on an individual
- **Heat Strain**
  - Overall physiological response resulting from heat stress
- **Heat Related Illness (HRI)**
  - spectrum of disorders due to environmental exposure to **heat**.

Definitions

- **Heat**
  - Measure of energy in terms of quantity.
- **Calorie**
  - Heat required to raise 1 gram of water 1 degree Celsius
- **Metabolic Heat**
  - By-product of the body's activity

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Heat Stress

- **Conduction**
  - Transfer of heat between materials that contact each other.
- **Convection**
  - Transfer of heat in a moving fluid.
- **Evaporative cooling**
  - The cooling effect of sweat evaporating from the skin.
- **Radiation**
  - Transfer of heat through space.
- **Metabolic**
  - Internal production of heat

Heat Stress

- Heat Balance Equation
- S = M ± W ± R ± C ± K − E − RES [W/m2]
  - S – rate of heat storage
  - M – rate of metabolic heat production
  - W – rate of mechanical work accomplished
  - R – rate of heat exchange by radiation
  - C – rate of heat exchange by convection
  - K – rate of heat exchange by conduction
  - E – rate of heat exchange by evaporation
  - RES – rate of heat exchange by respiration

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Heat strain

Body Response to Heat

- **Elimination of heat**
  - 2 step process

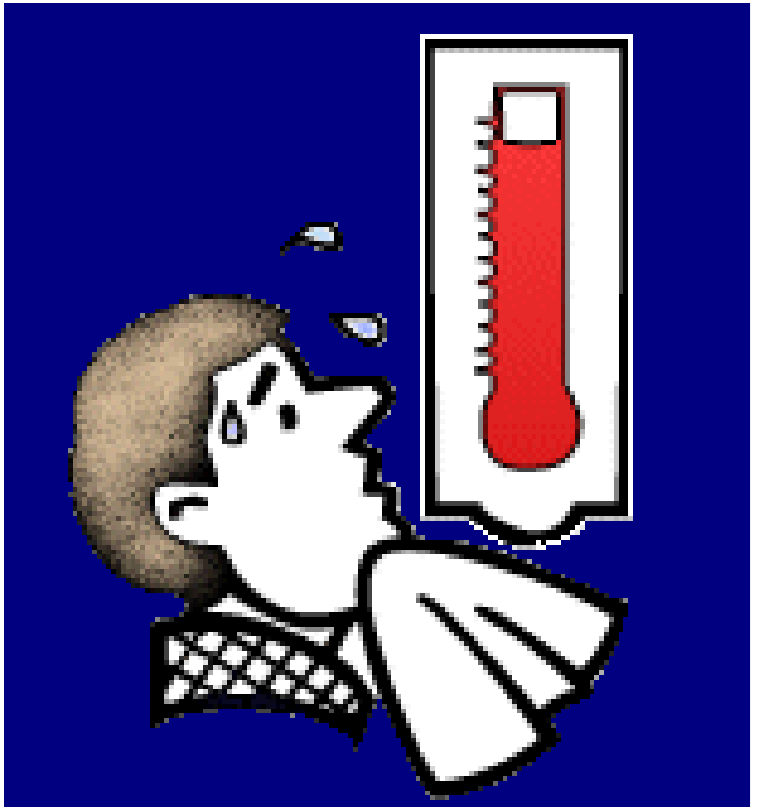
core ----> shell -----> environment

- Blood is the primary vehicle used by the body to transfer heat from the core to the skin.

brain ---> blood ---> heat away from the core

Heat Strain - HRI

- Heat Rash
- Heat Cramps
- Heat Exhaustion
- Heat Stroke



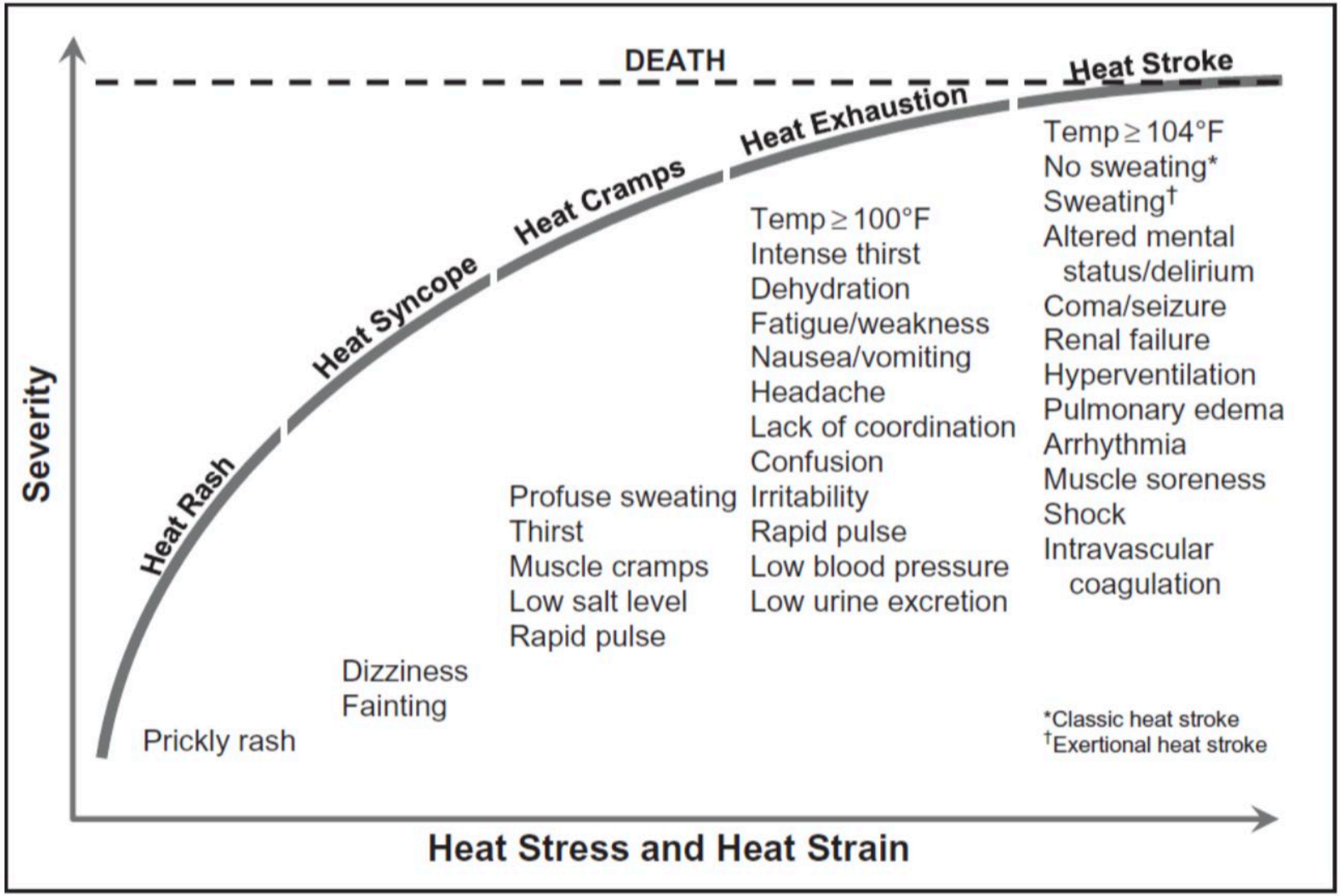


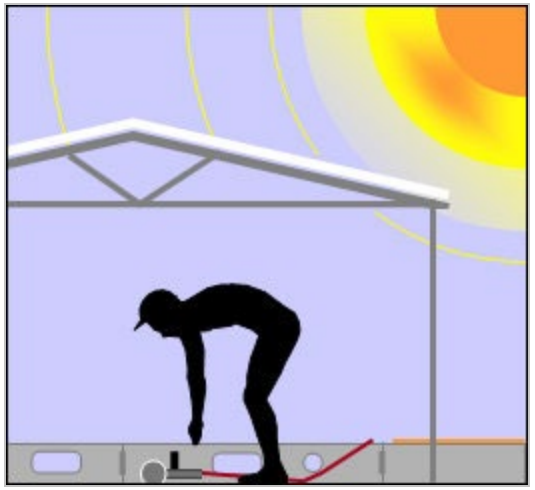
Figure excerpted from Jackson & Rosenberg, 2010

Heat Strain - Heat Rash

- **“Prickly Heat”**
- Sweat cannot freely evaporate from the skin and sweat ducts become plugged.
- **Prevented by**:
  - Breathable clothing
  - Thorough cleansing of the skin
  - Mild drying lotions

Heat Strain - Heat Cramps

- **Cause**
  - Excessive water loss/sweating, dehydration
- **Symptoms**
  - Shriveled skin, dry mouth and tongue, and sunken eyes



Heat Strain - Heat Exhaustion

- Blood supply is not large enough to supply oxygen through the body and remove heat from the core.
- Blood pools in the skin which leaves less for the brain.
- **Symptoms**
  - Fatigue, headache, dizziness, profuse sweating, rapid pulse, thirst, loss of appetite, nausea, vomiting, and fainting.

Heat Strain - Heat Stroke

- Core temperature rises so high that the body stops sweating.*classic heat stroke
- Exertional heat stroke can still be sweating

- **Symptoms**
  - Skin is hot and dry, flushed; rapid pulse; confusion; nausea; convulsions; unconsciousness; rectal temperature > 105.8 Fahrenheit.

Heat Strain

Factors Contributing to Heat Disorder Susceptibility

- Age
- Weight
- Physical Fitness
- Acclimatization
- Metabolism
- Alcohol and Drug use
- Medical conditions
  - Hypertension
- Prior heat injury

Heat Strain

TABLE 1. Worker demographic information and job characteristics for 25 outdoor occupational heat-related illnesses — United States, 2011–2016

Characteristic	Fatal illnesses (n = 14)	Nonfatal illnesses (n = 11)	Total sample (n = 25)
Age in years, median (range)	46 (23–64)	17 (15–53)	**36 (15–64)**
Male, no. (%)	14 (100.0)	5 (45.5)	**19 (76.0)**
Unacclimatized to heat, no. (%)	11 (78.6)	1 (9.1)	**12 (48.0)**
Known presence of at least one predisposing personal risk factor, no. (%)*	9 (64.3)	3 (27.3)	**12 (48.0)**
Estimated workload, no. (%)			
Light	1 (7.1)	2 (18.2)	**3 (12.0)**
Moderate	5 (35.7)	3 (27.3)	**8 (32.0)**
Heavy	7 (50.0)	6 (54.5)	**13 (52.0)**
Very heavy	1 (7.1)	0 (0.0)	**1 (4.0)**
Work clothing impeded heat dissipation, no. (%)	2 (14.3)	2 (18.2)	**4 (16.0)**

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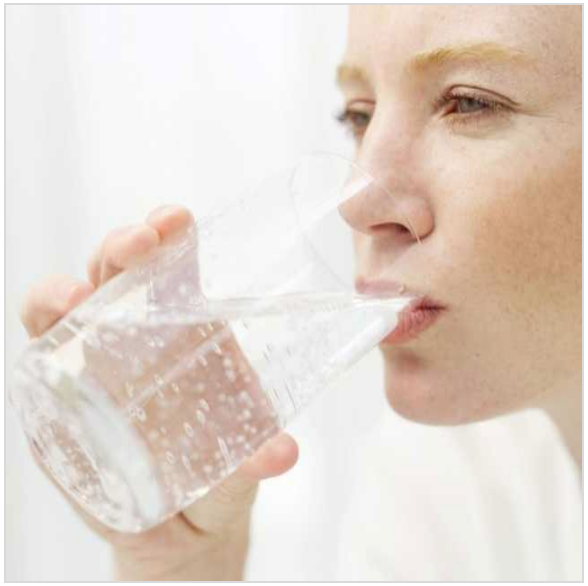
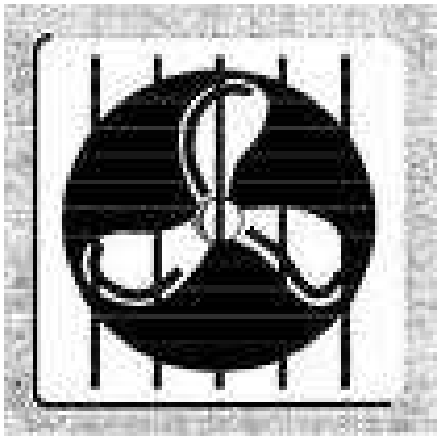
Prevention and Control

- Engineering Controls
- Personal Protective Equipment (PPE)
- Work Practices



Engineering Controls

- General ventilation
- Air treatment/air cooling
  - Air conditioning
- Local air cooling
- Convection
- Heat conduction
- Radiant heat sources
  - Shielding
  - Insulation and surface modification



PPE

- Reflective clothing
- Auxiliary body cooling
  - Ice vests
  - Wetted clothing – low humidity
  - Water-cooled garments – hoods, vests and “long johns”
  - Circulating air – vortex tubes, compressed air

Work Practices

- **Work rate**
  - The fastest way to decrease the rate of heat production is to decrease the work rate.

- **Age** (over 40)
  - The maximum possible output of heat decreases with age. Older people start sweating later and at a lower rate.

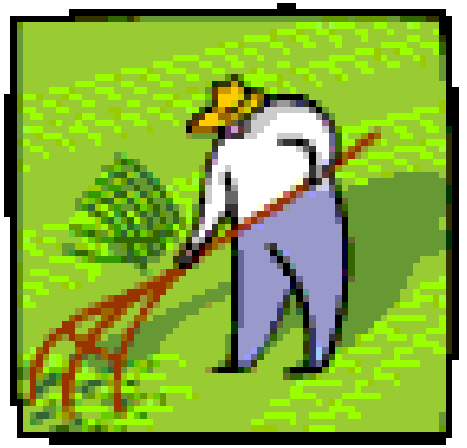
- **Body size**
  - Skin area to weight ratios.

Acclimatization

- **Acclimatization**
  - Successive heat exposures of at least one hour per day
  - Initially, 20% exposure for the first day, followed by 20% per day increase in exposure over the next four days

Re-Acclimating

- **After long absences**
  - 50% exposure on day back
  - 20% per day increase for the next 2 days
  - Final 10% on the 3rd day



Administrative/Work Practice Controls

- **Administrative controls**
  - Perform work activities during cooler periods of the day
  - Minimize activity in hot area
  - Slow down the work pace
  - Reduce the number and duration of exposures
  - Wear proper clothing
  - Provide recovery areas

Work Monitoring Programs

- **Personal monitoring**
  - Heart rate
  - Recovery heart rate
  - Oral temperature
  - Extent of body water loss

Training

- Knowledge of hazards
- Predisposing factors – age, etc.
- Signs and symptoms
- PPE
- First aid
- Health effects of heat stroke

WATER. REST. SHADE.
The work can't get done without them.

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State of Enforcement

- States with heat standards
- Cities in Texas mandating water breaks
- International attention

arab news

Midday work ban comes into force

A common sight at construction sites in the Kingdom at midday.

Investigation Guidelines

- **Employer and Employee Interviews**
  - Review 200/300 logs
  - Discuss steps taken to reduce heat stress problems
  - Identify potential heat sources
  - Assess training
- **Walk-around Inspection**
  - Identify actual heat sources
  - Interview employees
  - Conduct monitoring
- **Work-Load Assessment**
  - Identify activity level and type of clothing

Investigation Guidelines

- **Sampling methods**
  - Body temperature
    - » Instrumentation available not reliable for compliance
  - Environmental
    - » Made at or close to exposed worker
    - » Average for multiple areas

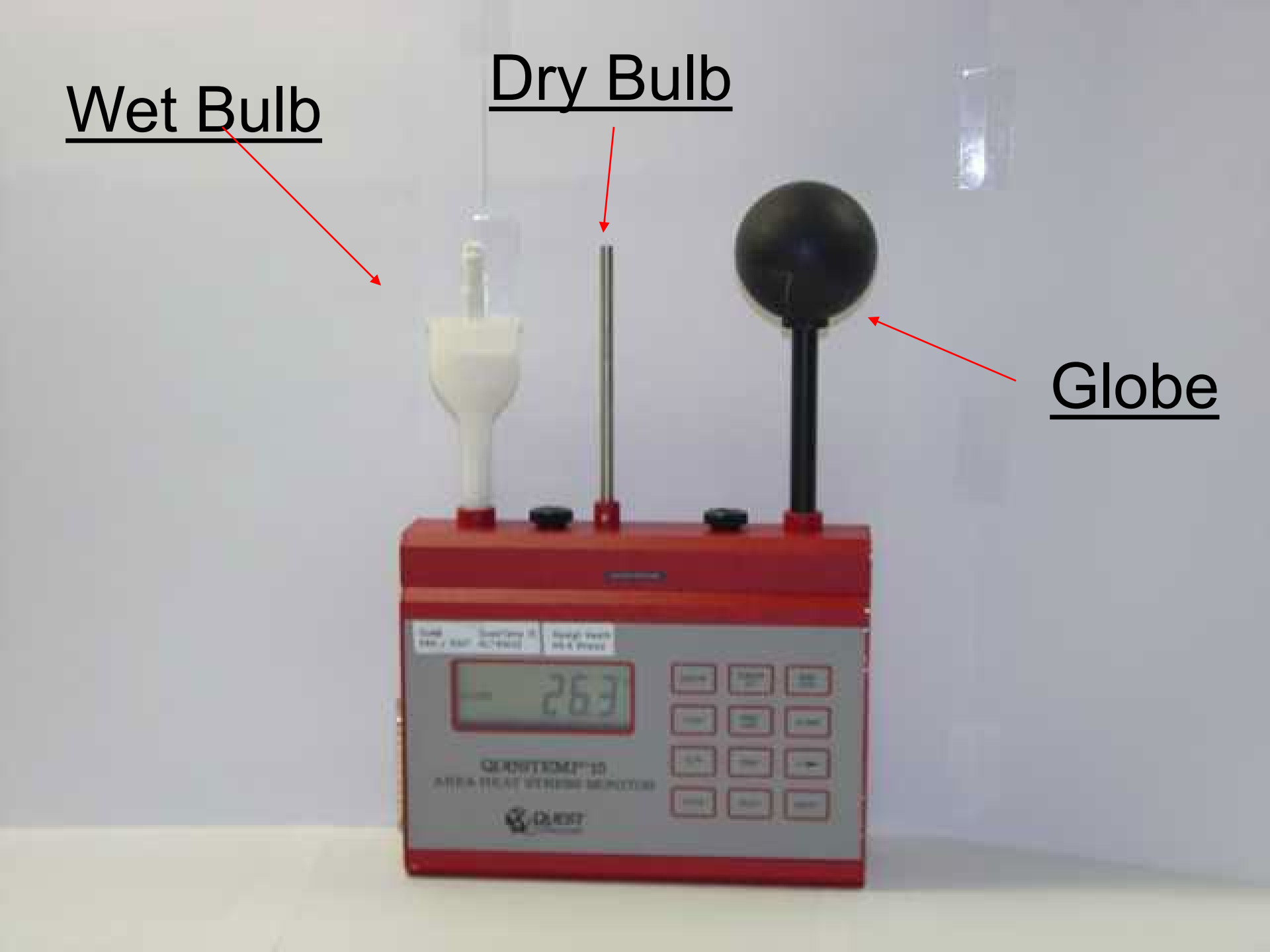
Wet Bulb Globe Temperature

- **WBGT index**
  - Combines air temperature, humidity, air flow, and radiant heat to measure the risk of heat stress disorders

- **QuesTemp 15 and WIBGET**
  - WBGT monitors

Definitions

- **Globe temperature**
  - Temperature inside a blackened, hollow, thin copper globe
- **Natural wet bulb**
  - Measured by exposing a wet sensor to the effects of evaporation and convection.
- **Dry bulb**
  - Measured by a thermal sensor shielded from direct radiant energy sources.


Wet Bulb
Dry Bulb
Globe

WBGT Index

- **For indoor**
  - WBGTin = 0.7WB + 0.3GT
- **For outdoor**
  - WBGTout = 0.7WB + 0.2GT + 0.1DB

Wet Bulb Globe Temperature (WBGT) from Temperature and Relative Humidity

Relative Humidity (%) \ Temperature (°C)	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	15	16	16	17	18	18	19	19	20	20	21	22	22	23	23	24	24	25	25	26	27	27	28	28	29	29	30	31	31	32	32
5	16	16	17	18	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	27	28	29	29	30	31	31	32	33	33	34	35
10	16	17	17	18	19	19	20	21	21	22	23	23	24	25	25	26	27	27	28	29	30	30	31	32	32	33	34	35	36	36	37
15	17	17	18	19	19	20	21	21	22	23	23	24	25	26	26	27	28	29	29	30	31	32	33	33	34	35	36	37	38	39	
20	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	31	32	32	33	34	35	36	37	38	39			
25	18	18	19	20	20	21	22	23	24	24	25	26	27	28	28	29	30	31	32	33	34	35	36	37	38	39					
30	18	19	20	20	21	22	23	23	24	25	26	27	28	29	29	30	31	32	33	34	35	36	37	39							
35	18	19	20	21	22	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39								
40	19	20	21	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39									
45	19	20	21	22	23	24	25	26	27	27	28	29	30	32	33	34	35	36	37	38											
50	20	21	22	23	23	24	25	26	27	28	29	30	31	33	34	35	36	37	39												
55	20	21	22	23	24	25	26	27	28	29	30	31	32	34	35	36	37	38													
60	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38														
65	21	22	23	24	25	26	27	28	29	31	32	33	34	36	37	38															
70	22	23	24	25	26	27	28	29	30	31	33	34	35	36	38	39															
75	22	23	24	25	26	27	29	30	31	32	33	35	36	37	39																
80	23	24	25	26	27	28	29	30	32	33	34	36	37	38																	
85	23	24	25	26	28	29	30	31	32	34	35	37	38	39																	
90	24	25	26	27	28	29	31	32	33	35	36	37	39																		
95	24	25	26	27	29	30	31	33	34	35	37	38																			
100	24	26	27	28	29	31	32	33	35	36	38	39																			

WBGT > 40

Note: This table is compiled from an approximate formula which only depends on temperature and humidity. The formula is valid for full sunshine and a light winds

Table 1
Clothing Adjustment Values

Clothing Type	WBGT Addition Value
Summer Work Uniform	0.0 °C
Cloth Overalls (woven material)	+3.5 °C
Double Cloth Overalls	+5.0 °C

Table 2
Heat Stress TLVs

Acclimatized	Work Load			
Work-Rest Regimen	**Light**	**Moderate**	**Heavy**	**Very Heavy**
Continuous work	29.5 °C	27.5 °C	26.0 °C	
75% work – 25% rest each hour	30.5 °C	28.5 °C	27.5 °C	
50% work – 50% rest each hour	31.5 °C	29.5 °C	28.5 °C	27.5 °C
25% work – 75% rest each hour	32.5 °C	31.0 °C	30.0 °C	29.5 °C

Table 2
Heat Stress TLVs

Un-Acclimatized	Work Load			
Work-Rest Regimen	**Light**	**Moderate**	**Heavy**	**Very Heavy**
Continuous work	27.5 °C	25.0 °C	22.5 °C	
75% work – 25% rest each hour	29.0 °C	26.5 °C	24.5 °C	
50% work – 50% rest each hour	30.0 °C	28.0 °C	26.5 °C	25.0 °C
25% work – 75% rest each hour	31.0 °C	29.0 °C	28.0 °C	26.5 °C

Table 3
Activities within Metabolic Rate Categories

CATEGORY	EXAMPLE ACTIVITIES
Resting	Sitting Quietly
	Sitting with moderate arm movements
Light	Sitting with moderate arm and leg movements
	Standing with light work at machine or bench while using mostly arms
	Using a table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate	Scrubbing in a standing position
	Walking about with moderate lifting or pushing
	Walking on level at 6 Km/hr while carrying 3 Kg weight load
Heavy	Carpenter sawing by hand
	Shoveling dry sand
	Heavy assembly work on a non-continuous basis
	Intermittent heavy lifting with pushing or pulling (e.g. pick and shovel work)
Very Heavy	Shoveling wet sand

Table 3
Activities within Metabolic Rate Categories

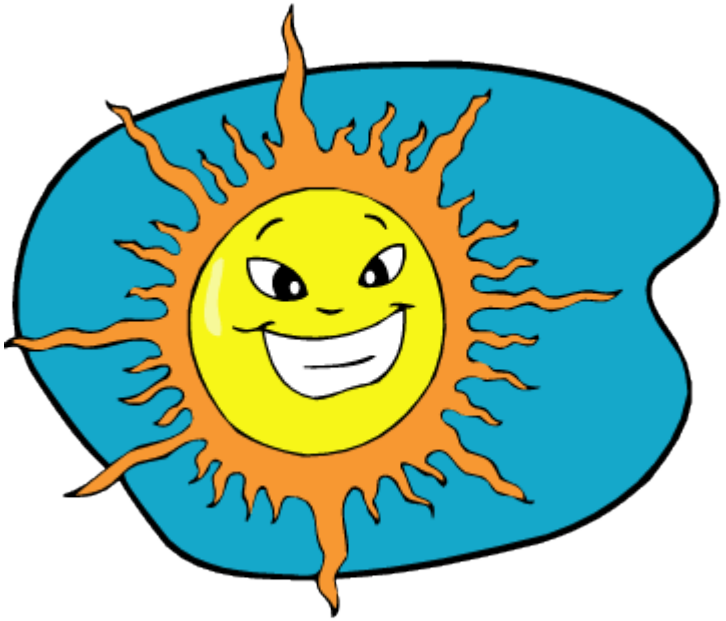
CATEGORY	EXAMPLE ACTIVITIES
Resting	Sitting Quietly
	Sitting with moderate arm movements
Light (<290 Watts)	Sitting with moderate arm and leg movements
	Standing with light work at machine or bench while using mostly arms
	Using a table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate (290-400 Watts)	Scrubbing in a standing position
	Walking about with moderate lifting or pushing
	Walking on level at 6 Km/hr while carrying 3 Kg weight load
Heavy (400-520 Watts)	Carpenter sawing by hand
	Shoveling dry sand
	Heavy assembly work on a non-continuous basis
	Intermittent heavy lifting with pushing or pulling (e.g. pick and shovel work)
Very Heavy (>520 Watts)	Shoveling wet sand

Calculation of Heat Stress TLV

$$\text{TWA WBGT} = \frac{WBGT_1 * t_1 + WBGT_2 * t_2 + \ldots + WBGT_n * t_n}{t_1 + t_n + \ldots + t_n}$$

Calculation of Heat Stress TLV

$$\text{TWA } M = \frac{M_1 * t_1 + M_2 * t_2 + \ldots + M_n * t_n}{t_1 + t_n + \ldots + t_n}$$



Calculation of Heat Stress TLV

- **Using the TWA WBGT and the TWA M**
  - Decide whether exposed employees are acclimatized or un-acclimatized
  - Determine TLV based on appropriate Figure from the TLV Documentation

Un-Acclimatized

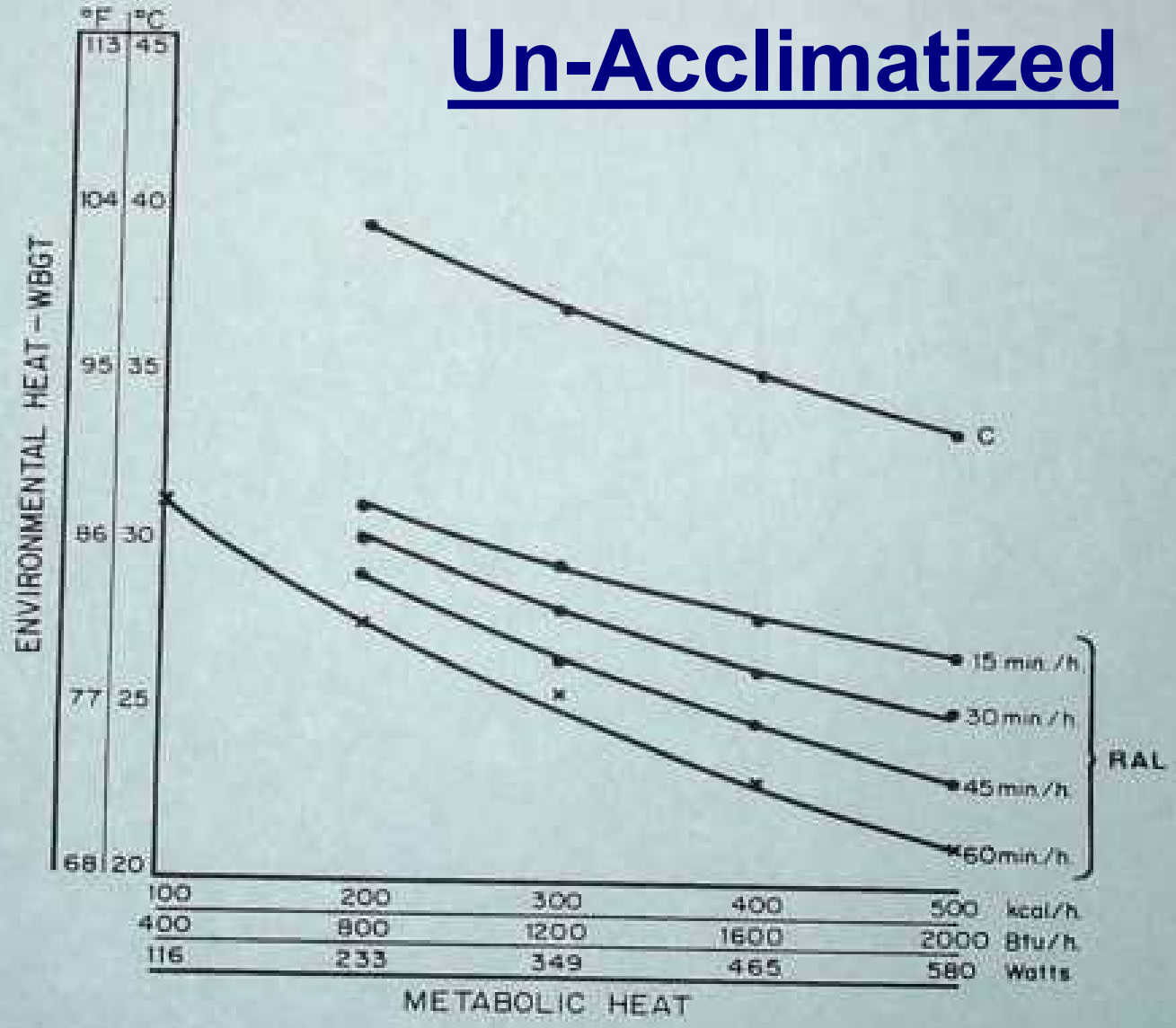


FIGURE 2. Recommended heat-stress Alert Limits (RALs) for heat-unacclimatized standard workers. Standard worker = 70 kg (154 lb) body weight and 1.8 m^2 (19.4 ft^2) body surface; C = Ceiling. From NIOSH.[128]

Acclimatized

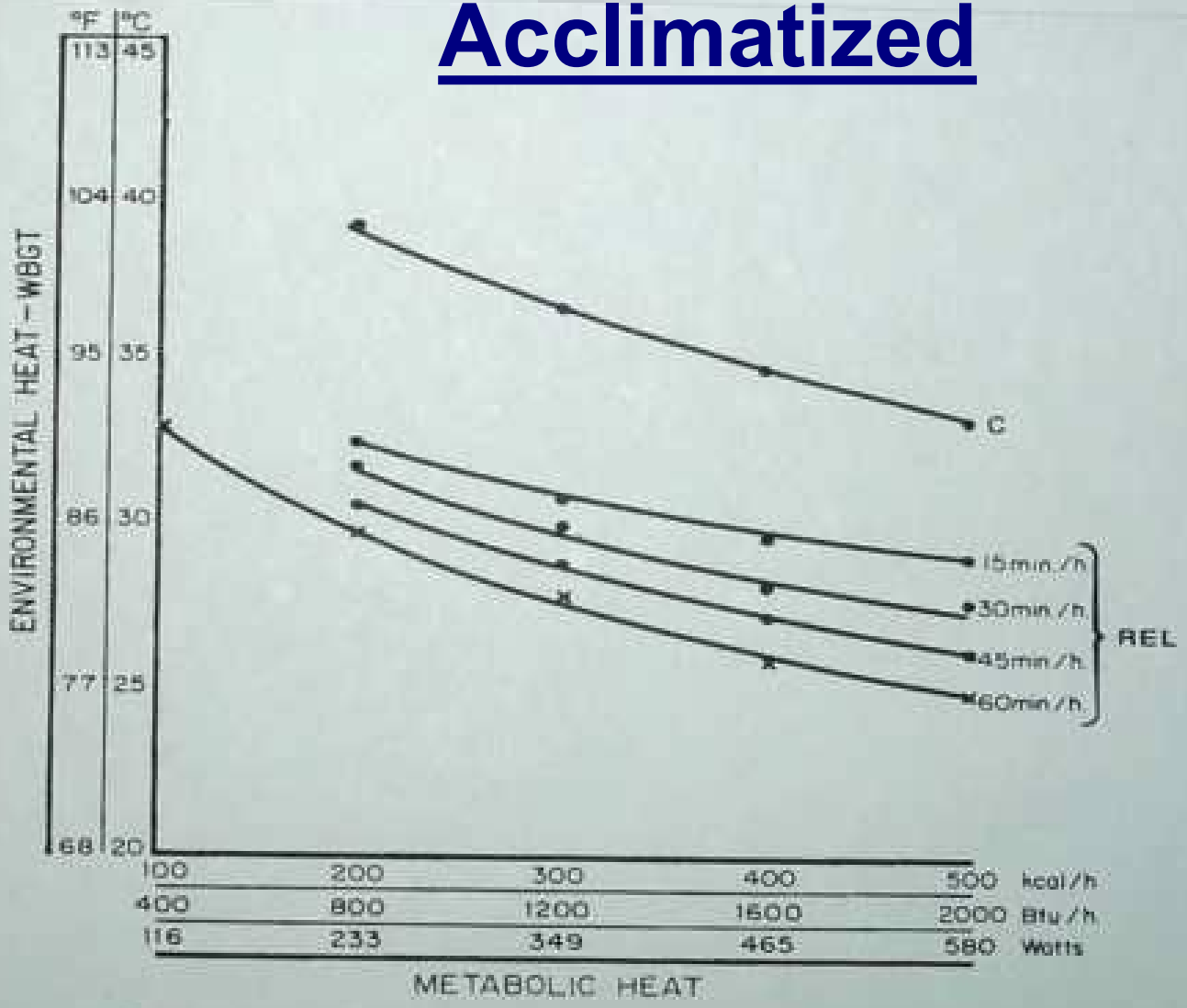
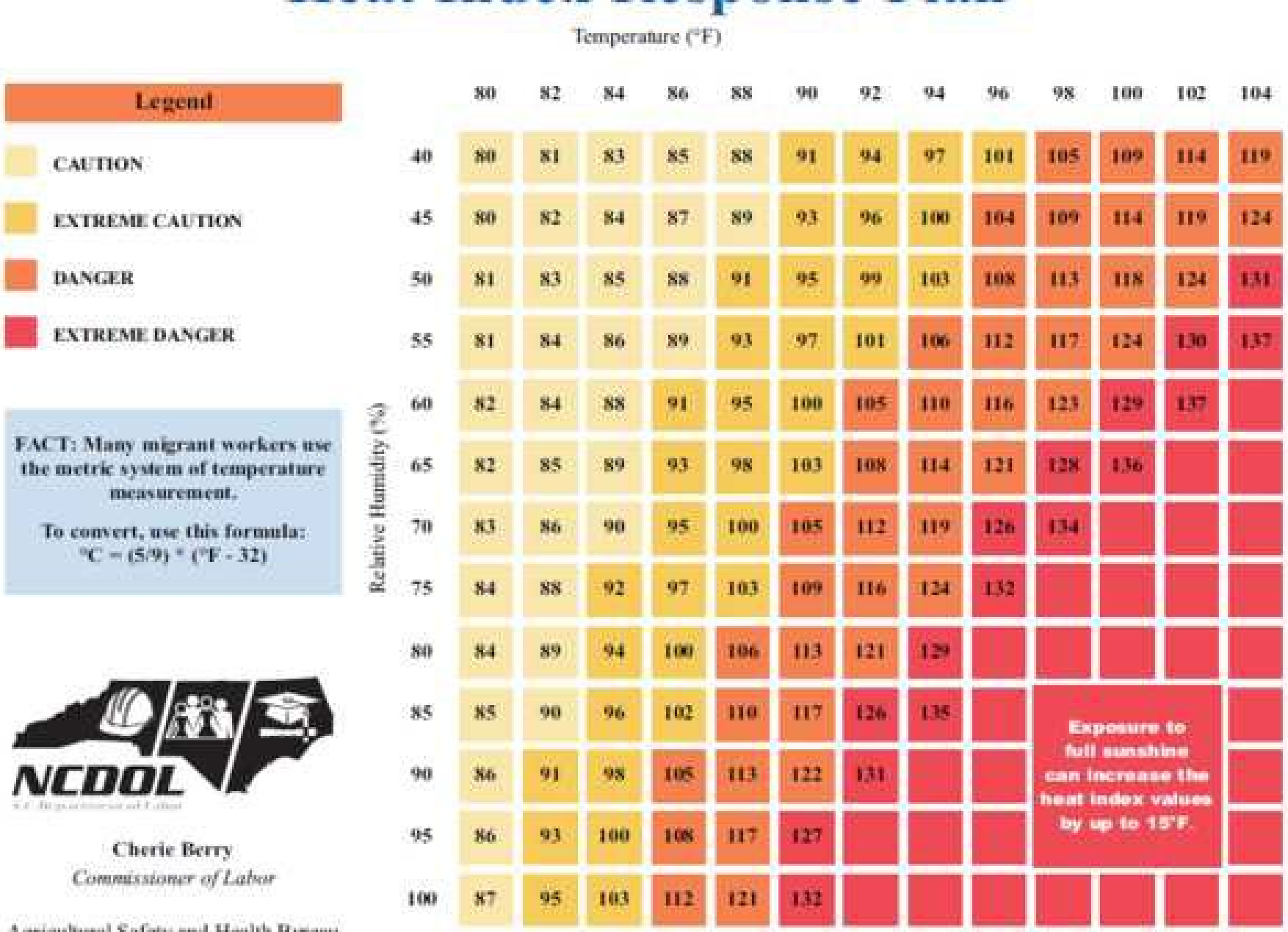


FIGURE 3. Recommended heat-stress Exposure Limits (RELs) for heat-acclimatized standard workers. Standard worker = 70 kg (154 lb) body weight and 1.8 m^2 (19.4 ft^2) body surface. From NIOSH.[128]

Heat Index Response Plan



Legend

- CAUTION
- EXTREME CAUTION
- DANGER
- EXTREME DANGER

FACT: Many migrant workers use the metric system of temperature measurement.

To convert, use this formula:
°C = (5/9) * (°F - 32)

NCDOL

Cherie Berry
Commissioner of Labor

Agricultural Safety and Health Bureau

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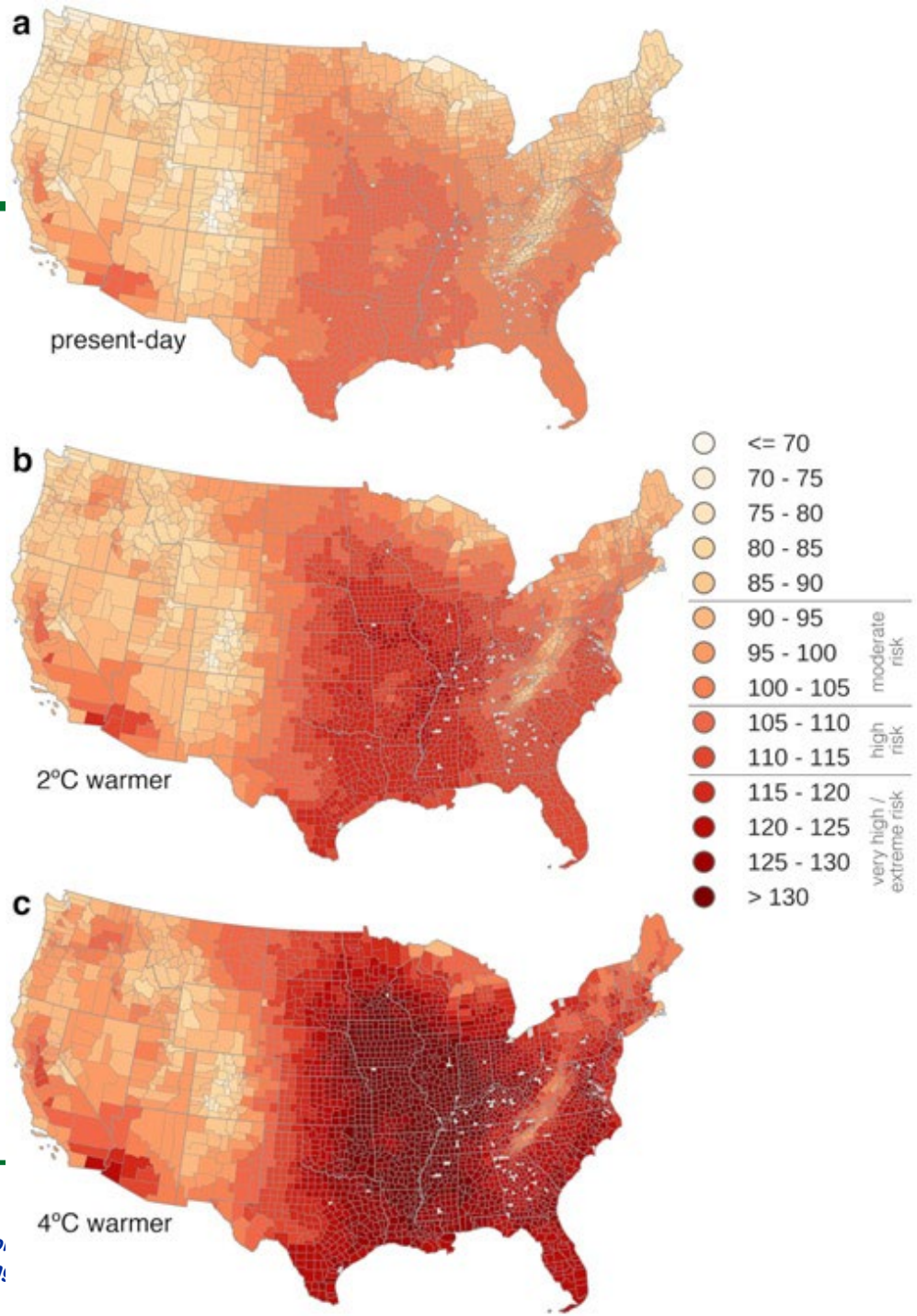
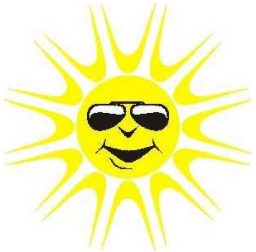

a
present-day
b
2°C warmer
c
4°C warmer
<= 70
70 - 75
75 - 80
80 - 85
85 - 90
90 - 95
95 - 100
100 - 105
105 - 110
110 - 115
115 - 120
120 - 125
125 - 130
> 130
moderate risk
high risk
very high / extreme risk

Example

- **Indoor facility**
  - Full shift WBGT measurements taken
  - Employee works in 3 areas during the day
  - 4 hours in location one, soldering parts while sitting
    - » 3 hours in location two, assembling parts while standing
    - » 1 hour in location three, loading a truck with boxes of finished product

$WBGT_1$ of 29.0 ^{O}C, $WBGT_2$ of 26.5 ^{O}C, & $WBGT_3$ of 31.5 ^{O}C



Example

$$\text{TWA WBGT} = \frac{29.0*240 + 26.5*180 + 31.5*60}{240 + 180 + 60}$$

TWA WBGT = 28.0 ^{O}C

Table 3
Activities within Metabolic Rate Categories

CATEGORY	EXAMPLE ACTIVITIES
Resting to Light (<290 Watts)	Sitting Quietly
	Sitting with moderate arm movements
	Sitting with moderate arm and leg movements
	Standing with light work at machine or bench while using mostly arms
	Using a table saw
	Standing with light or moderate work at machine or bench and some walking about
Moderate (290-400 Watts)	Scrubbing in a standing position
	Walking about with moderate lifting or pushing
	Walking on level at 6 Km/hr while carrying 3 Kg weight load
Heavy (400-520 Watts)	Carpenter sawing by hand
	Shoveling dry sand
	Heavy assembly work on a non-continuous basis
	Intermittent heavy lifting with pushing or pulling (e.g. pick and shovel work)
Very Heavy (>520 Watts)	Shoveling wet sand

Example

$$\text{TWA M} = \frac{145*240 + 218*180 + 500*60}{240 + 180 + 60}$$

TWA M = 208 Watts

Example

- **TWA WBGT** = 28.0 ^{O}C
- **TWA M** = 208 Watts

Un-Acclimatized

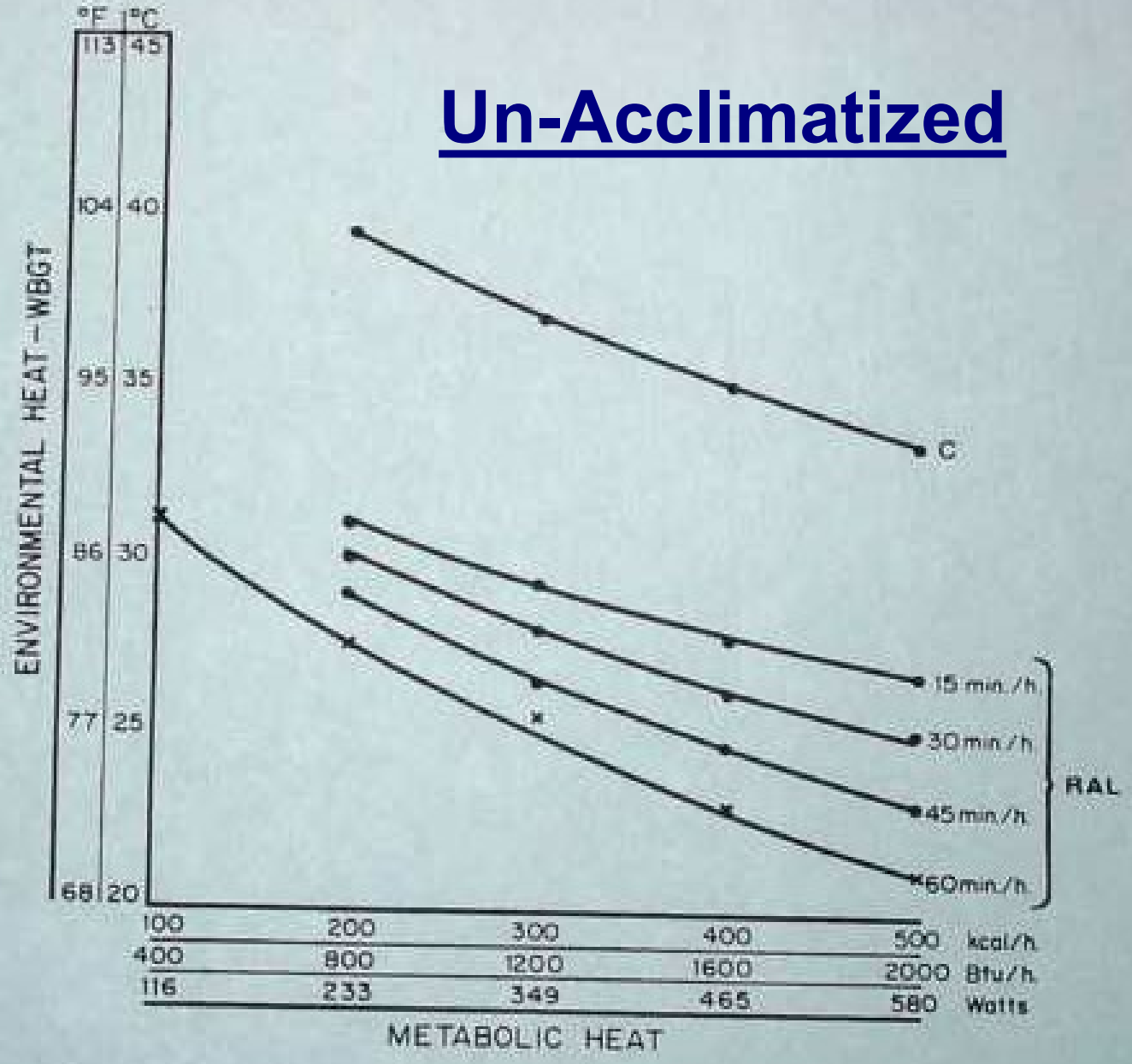


FIGURE 2. Recommended heat-stress Alert Limits (RALs) for heat-unacclimatized standard workers. Standard worker = 70 kg (154 lb) body weight and 1.8 m^2 (19.4 ft^2) body surface; C = Ceiling . From NIOSH [128]

Acclimatized

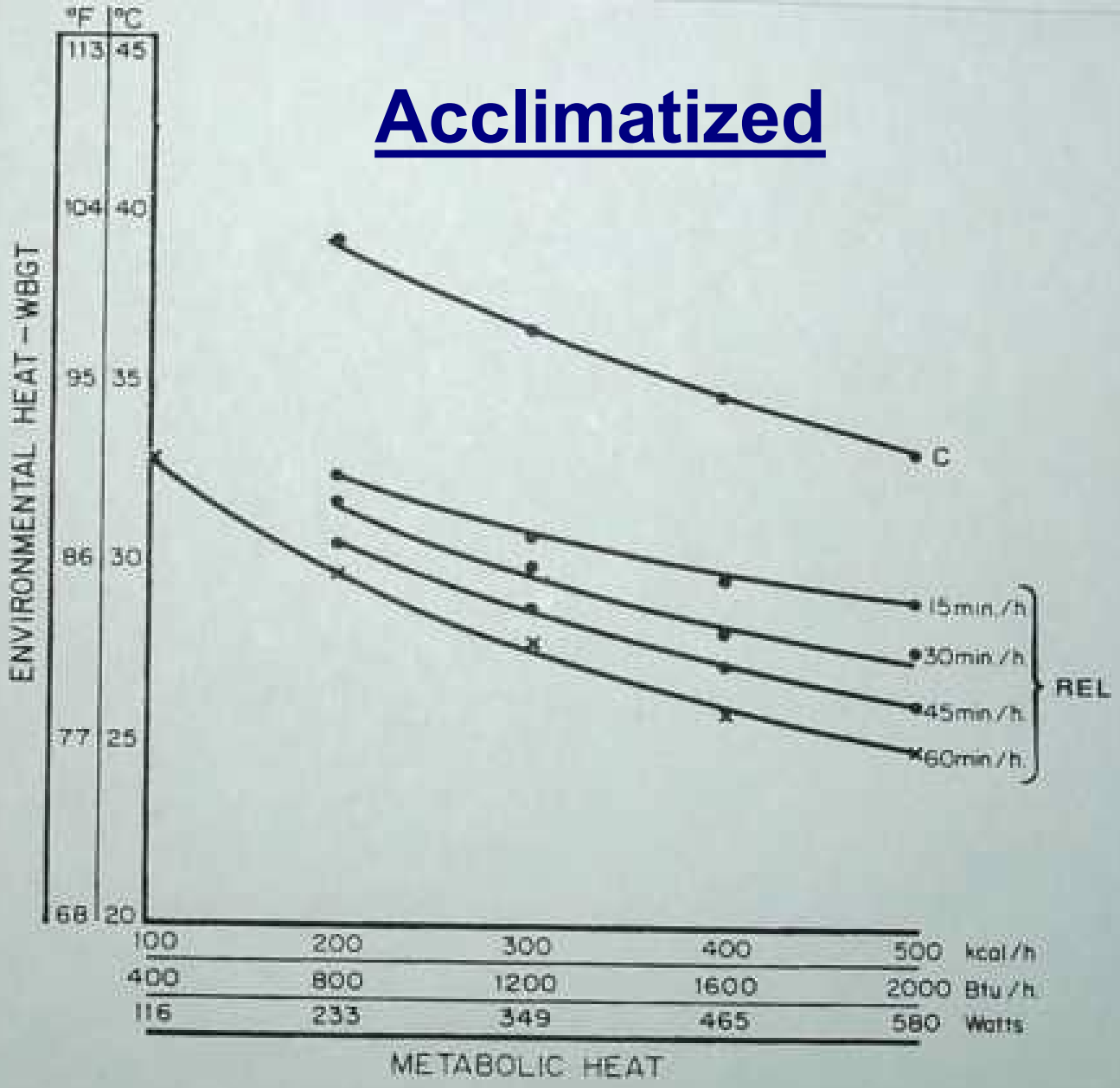


FIGURE 3. Recommended heat-stress Exposure Limits (RELs) for heat-acclimatized standard workers. Standard worker = 70 kg (154 lb) body weight and 1.8 m^2 (19.4 ft^2) body surface. From NIOSH.[128]

Outline

Part I

I. Introduction
II. Definitions
III. Heat Stress
IV. Heat Strain
V. Prevention of HRI
VI. State of enforcement
VII. What NC is doing

Investigation Guidelines

- If the TLV for heat stress is exceeded…
- And the employer has not implemented some heat stress prevention tactics…
  - A **General Duty Clause** citation may be appropriate

Citations

- 95-129 (l) - **General Duty Clause** support criteria:
  - 4 Things:
    - » Serious
    - » Recognized hazard
    - » Abatement available
    - » Likely to cause death or serious physical harm

What NC is doing

- Inspection 318077690
  - CSHO Curt Hobson
- Charlotte Mecklenburg Police Department

What NC is doing

North Carolina Department of Labor

Occupational Safety and Health Division

Fatality/Catastrophe Report

Wednesday 2/27/2019 15:01:31

Reporting ID	0453730	Previous Activity			Event Number	102986049		
Establishment Information	Establishment Name	Charlotte Mecklenburg Police Department Tra			Employer ID			
	Site Address	1770 Shopton Road Charlotte, NC 28217						
		Site Phone	- -	Site FAX	- -	City Code	0870	County Code	119

Classification	A Fatality					
Event Description	Event Date	Event Time	Number of Fatalities	Number of Hospitalized Injuries	Number of Non-Hospitalized Injuries	Number Unaccounted
	07/05/2016	08:30 am	1	0	0	0
	Type of Event	Cardio-vascular; respiratory system failure				
Preliminary Description	The decedent collapsed after conducting physical exercise as part of the Charlotte Mecklenburg Police Department Training Academy physical training program.					

What NC is doing

- Inspection 318077690
  - CSHO Curt Hobson
- Charlotte Mecklenburg Police Department

What NC is doing

- Opening conference
  - two heat injuries recorded in 2015
  - stated that no water was provided at the physical training area.
  - heat stress prevention program that had been established in the Basic Law Enforcement Training Student Handbook

What NC is doing

- Walk-through
  - students need to be aware of the Flag conditions

150+ - Black flag warning! Outdoor exertion is unsafe. Use extreme caution.

140-149 – Red flag warning! Exercise indoors if possible, but if no other choice, work at a lower in and use great caution.

130-139 – Yellow flag warning! Humidity is somewhat elevated. Use some caution.

120-129 – Green flag! Weather conditions are safe for outdoor exercise.

What NC is doing

- none of the recruits interviewed knew what the Flag Warning conditions were for the morning of the fatality.
- From CLT Douglas airport –
  - @ 6:52 AM T= 80.1°F and Humidity = 76% => 156.1 Black Flag Warning,
  - @ 7:52 AM T= 82.9°F and Humidity =70% => 152.9 Black Flag Warning
  - @ 8:52 AM T=86°F and Humidity = 65% => 151 Black Flag Warning

What NC is doing

- majority of work-related emergency department visits for heat-related illness in NC are among 19-45 year old males, on occasion the temperature was below 85 degrees Fahrenheit

What NC is doing

- some of the students came from different parts of the country but did not have any specific procedures for acclimatization
- encouraged to not t[illegible] during PT
- On the[illegible] fatality the students were [illegible] wear bullet proof vest

EE core body temp was 105.9F

What NC is doing

Standard Number: 95.129(01)

a) At the Charlotte-Mecklenburg Police Department Training Academy, on or about July 5th, 2016, a heat stress awareness and prevention program was not implemented for employees/recruits while performing strenuous physical training. Employees/recruits were required to complete the physical training session in a high temperature, high humidity environment with no water provided, breaks not encouraged while wearing bullet proof vest.

What NC and Fed OSHA doing

- Scott is asking questions
- “On October 27, 2021, OSHA published an Advance Notice of Proposed Rulemaking (ANPRM) for Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings in the Federal Register.”
- Comment period closed January 26,2022.

Resources

- **Technical Manual – Chapter 4**
  - www.osha.gov
- **NIOSH**
  - http://www.cdc.gov/niosh/homepage.html
- **ACGIH – TLV book**
- **Weather Underground**
  - http://www.wunderground.com/

Summary

- Defined terms associated with Heat Stress
- Heat Stress disorders and health effects
- Prevention and control of Heat Stress
- Heat Stress inspection procedures
- How to write a Heat Stress citation

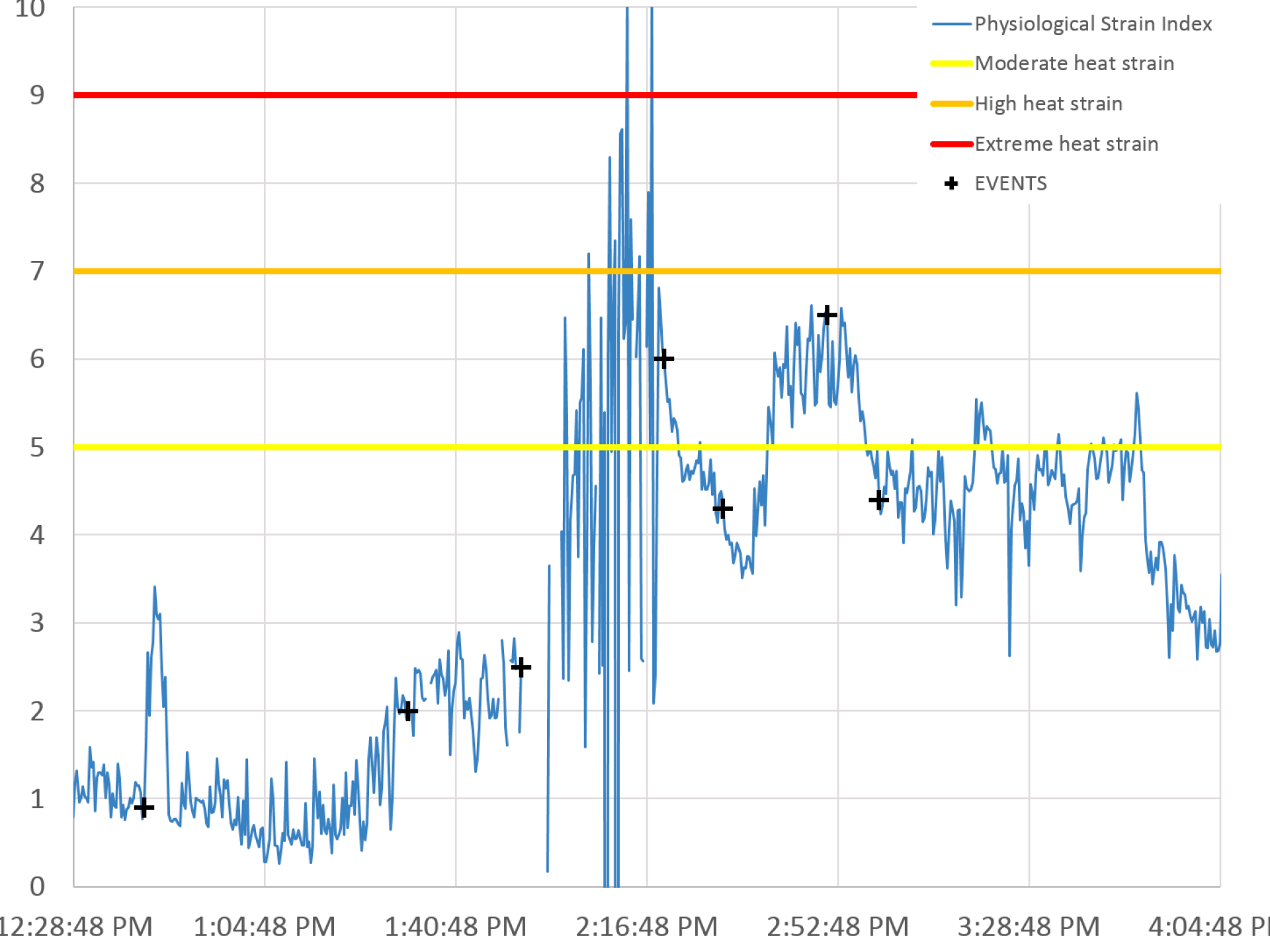
Thank You For Attending!

Final Questions?

1-800-NC-LABOR

(1-800-625-2267)

www.nclabor.com


10
9
8
7
6
5
4
3
2
1
0
Physiological Strain Index
Moderate heat strain
High heat strain
Extreme heat strain
EVENTS
12:28:48 PM
1:04:48 PM
1:40:48 PM
2:16:48 PM
2:52:48 PM
3:28:48 PM
4:04:48 PM