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HEAT STRESS PREVENTION PROGRAM FOR WORKERS IN DEMILITARIZATION PROTECTIVE ENSEMBLE AT PUEBLO CHEMICAL AGENT-DESTRUCTION PILOT PLANT TRAINING FACILITY

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by

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Abstract

The Pueblo Chemical Agent-Destruction Pilot Plant (PCAPP) is being constructed to dispose of the entire stockpile of sulfur mustard contained in munitions stored at Pueblo Chemical Depot, Colorado. The PCAPP Training Facility provides courses on protective measures necessary for making entries into areas with hazardous concentrations of chemical warfare agents in air. Students are trained to work in Demilitarization Protective Ensemble (DPE), an encapsulating, impermeable, and positive pressure suit. The course includes wearing the suit and performing tasks to simulate work in PCAPP toxic areas.

Wearing DPE will increase the heat stress load for workers making entries. The PCAPP heat-stress management program includes plans, training, and physiological monitoring such as heart-rate. The heat-stress management program as well, as physiological data from students, was analyzed for effectiveness in managing heat strain.

Results showed a significant correlation between heart-rate and percent loss in body weight, a recognized sign of heat strain. Other parameters under administrative control such as blood pressure, respiratory rate, and pre-entry body temperature did not show significant corresponding relationships with heart-rate monitoring data. Recommendations were also provided for heat-stress management from recognized organizations.

Keywords

Chemical demilitarization, encapsulating PPE, impermeable PPE, heat stress, sulfur mustard

Dedication

I wish to thank Mom and Dad for all their support and instilling the value of continuous education to their children.

Acknowledgements

I would like to thank Daniel Bird, PCAPP Medical Services manager, for compiling and providing information from the PCAPP Medical Clinic. I would also like to thank COL Samuel Jang for coordinating for the site visit with the PCAPP training center and offering educational encouragement.

Table of Contents

List of Tables

List of Figures

List of Equations

Glossary of Terms

Term	Definition
ACGIH	The American Conference of Governmental industrial Hygienists
ACWA	Program Executive Office Assembled Chemical Weapons Alternatives
AIHA	The American Industrial Hygiene Association
Alpha (α) level	The probability of rejecting the null hypothesis when it is true
ATSDR	Agency for Toxic Substances and Disease Registry
BMI	Body-mass index
bmp	Beats per minute
CAA	Clean Air Act
CAS RN	Chemical abstracts service registry number
CBRN	Chemical, biological, radiological, and nuclear
CCTV	Closed-circuit television
CDC	Centers for Disease Control and Prevention
CMA	U.S. Army Chemical Materials Agency
CMA	U.S. Army Chemical Materials Agency
CMO	Competent Medical Authority
CRO	Control room operators
DOD	U.S. Department of Defense
DPE	Demilitarization protective ensemble
EPA	U.S. Environmental Protection Agency
F	Degrees Fahrenheit
GPL	General population limit
Heat strain	The outcomes to the body from heat stress
Heat stress	Heat load put on the body from the environment
Heat stroke	Serious heat-strain condition that can be fatal
Heat syncope	Fainting
HR	Heart rate
HVAC	Heating, ventilation, and air conditioning
IBM	International Business Machines Corporation
IDLH	Immediately dangerous to life or health
lb	pound
LCO	Limiting condition of operations
Level A	Highest level of PPE skin, respiratory, and eye protection is needed
Level B	Highest level of PPE respiratory protection but less skin protection than Level A
mg/dL	Milligrams per deciliter
mg/m^3	Milligrams per cubic meter
mil	Unit of length, typically thickness, equal to a thousandth of an inch
MMI	Medical Monitoring Interface
mmoles	millimoles
MHR	Maximum Heart Rate
MPHR	Maximum permissible heart rate
MPL	Maximum permissible limit

Term	Definition
MWS	Munitions washout system
NIOSH	National Institute for Occupational Safety and Health
NRC	National Research Council
NRC	National Research Council of the National Academies
OSHA	Occupational Safety and Health Administration
P	P value is the calculated probability of obtaining the observed results when the null hypothesis is true
PCAPP	Pueblo Chemical Agent-Destruction Pilot Plant
PCD	Pueblo Chemical Depot, Colorado
pH	Measure of how acidic or basic a substance is
PMC	PCAPP Medical Clinic
PMD	PCAPP Medical Director
PPE	Personal protective equipment
PSM	Plant Shift Manager
RCRA	Resource Conservation Recovery Act
RIR	Recordable incident rate, recordable incidents per 200,000 hours worked
SCBA	Self-contained breathing apparatus
SPSS	IBM® SPSS® Statistics software program
STARRT	Safety Task Analysis and Risk Reduction Talk
STEL	Short-term exposure limit
t distribution	Statistical probability distribution for a given sample size
U.S.	United States of America
VPP	OSHA Voluntary Participation Program
WBGT	Wet bulb globe temperature
WPL	Worker population limit
Y connector	Hose connector allowing two hoses to connect to one receptacle

1. Introduction

The Pueblo Chemical Agent-Destruction Pilot Plant (PCAPP) is being constructed to dispose of the entire stockpile of 2,611 tons of sulfur mustard (bis [2-chloroethyl]sulfide; chemical abstracts service registry number [CAS RN] 505-60-2) contained in munitions stored at Pueblo Chemical Depot (PCD), Colorado. The steps of destruction process, where agent is not contained in munitions, are mechanized; however there will be maintenance activities where workers will be required to wear personal protective equipment (PPE) in order to enter areas with hazardous concentrations of sulfur mustard. The highest level of protection is the Demilitarization Protective Ensemble (DPE)—a sealed, air-tight, positive pressure suit with supplied air. Wearing PPE will increase the heat-stress load for workers making entries.

Detrimental outcomes of heat stress range from fainting (heat syncope) to death (heat stroke). Victims of heat stress would also cause additional risks for workers because the patient may need assistance for removal from a hazardous area in addition to risks of spreading contamination to other workers.

2. Background

The DPE is a specialized suit with a history of use in the U.S. chemical weapons disposal program.

2.1. U.S. Chemical Weapons Disposal Program

In 1990, the chemical weapons stockpile in the United States contained 31,000 tons of chemical agents, lethal nerve and blister agents. These weapons and bulk agents were stored at nine sites: Aberdeen, Maryland; Anniston, Alabama; Newport, Indiana; Pine Bluff, Arkansas;

Pueblo, Colorado; Richmond, Kentucky; Tooele, Utah; Umatilla, Oregon; and Johnston Island, in the Pacific Ocean.

In 1984, the U.S. Congress mandated that the U.S. Army destroy selected items of the chemical weapons stockpile and in 1985 Congress extended the mandate to the entire chemical weapons stockpile (NRC, 2011, p. 7). In addition, the U.S. also joined an international treaty for destruction of chemical weapons. It should be noted that the chemical weapons stockpile does not include research quantities of chemical agents, munitions that are buried, or munitions that had been dumped at sea.

By 2012, the U.S. Army had destroyed 90% (27,000 tons) of the U.S. chemical weapons stockpile at seven sites (CMA, 2012, January 22, p. 6). The two remaining chemical weapons stockpile sites are in Richmond, Kentucky and Pueblo, Colorado.

2.2. Risk Management Goals

The U.S. Army chemical weapons disposal program has an Occupational Safety and Health Administration (OSHA) recordable incident rate (RIR) of less than 1.0 (less than one injury per 200,000 hours worked) (NRC, 2011, p. 8). The Army also has committed to a safety rate equal to or better than the rates of the safest industrial companies, which can have OSHA RIRs as low as 0.5 (NRC, 2011, p. 8). Several chemical weapons disposal facilities have participated in the OSHA Voluntary Participation Program (VPP), an initiative with the goal of reducing workplace injuries. PCAPP achieved the highest level of recognition—VPP Star Status—during construction in 2009, recertified in 2012, and declared intention to recertify for systemization (ACWA, 2014a). Chemical weapons disposal is also conducted under a Resource Conservation Recovery Act (RCRA) permit and Clean Air Act (CAA) requirements issued by the appropriate state or regional Environmental Protection Agency (EPA).

2.3. Pueblo Chemical Depot

PCD is located in Pueblo County, Colorado, roughly ten miles east of Pueblo, Colorado.

2.3.1. Stockpile Description

The PCD stockpile consists of 780,078 mortars and projectiles (NRC, 2011, p. 17). These weapons contain 2,611 tons sulfur mustard, representing 8% of the original U.S. chemical weapons stockpile (ACWA, 2015c).

2.3.2. Sulfur Mustard Toxicity and Exposure Levels

Sulfur mustard is a vesicant or blister agent and a human carcinogen (ATSDR, 2003, p. 4). It is a dermal and inhalation hazard at very low concentrations. Exposure limits recommended by the Centers for Disease Control and Prevention (CDC) are listed in ***Table I***. The maximum permissible limit is based on permeation testing of sulfur mustard for DPE-suit material for a two-hour duration.

Table I: Sulfur mustard exposure levels, concentrations, and averaging times

Level	mg/m^3	Averaging time
General population limit (GPL)*	0.00002	12 hours
Worker population limit (WPL)*	0.0004	8 hours
Short term exposure limit (STEL)*	0.003	≤ 15 minutes
Immediately dangerous to life or health (IDLH)*	0.7	≤ 30 minutes
Maximum permissible limit (MPL)**	100	ceiling

*(CDC, 2004, p. 24167). **(NRC, 2005, p. 21).

2.4. Pueblo Chemical Agent Pilot Plant (PCAPP)

PCAPP, shown in ***Figure 1***, is located within PCD and sited adjacent to the chemical weapons stockpile storage area. At the time of this report, it is being constructed and systemized (commissioned, started, and tested). Chemical-weapons disposal operations are scheduled to begin in January 2016, operations are scheduled to be completed by 2020, and facility closure is

scheduled by to be completed in 2023 (DOD, 2014, p. 10). When disposal operations begin, the plant will run 24-hours a day, 7-days a week.

It should be noted that munitions containing sulfur mustard that cannot be destroyed by the PCAPP facility are planned to be destroyed at another facility on PCD using explosive destruction technology beginning in 2015. Items that cannot be destroyed at PCAPP include identified leaking munitions and munitions otherwise rejected by the PCAPP process described below.

2.4.1. PCAPP Process

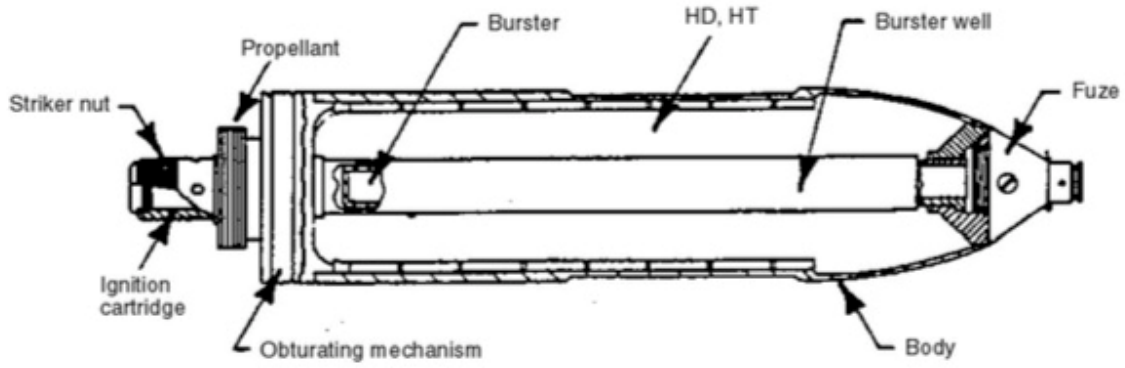
The overall process at PCAPP for destroying munitions containing sulfur mustard is caustic hydrolysis followed by biodegradation. The primary intention of this process is to destroy the sulfur mustard in compliance with criteria defined by international treaty, environmental permits, and Army regulations. Other wastes resulting from this process will be sent to off-site RCRA permitted facilities.

1. Enhanced Reconfiguration Building	5. Agent Filtration Area
2. Automated Guided Vehicle Corridor	6. Munitions Service Magazine
3. Agent Processing Building	7. Control and Support Building
4. Biotreatment Area	8. Munitions Service Magazine Corridor

(PCAPP, February 2015, p. 9)

Figure 1: PCAPP aerial view

1. Workers will transport munitions from Munitions Storage Magazines at PCD to Munitions Service Magazines at PCAPP, ***item 6*** in ***Figure 1*** (NRC, 2011, p. 13).
2. Workers will transport munitions from the munitions service magazines to the enhanced reconfiguration building, ***item 1*** in ***Figure 1***. The linear projectile and mortar disassembly machine will remove explosive components, bursters, from the munitions in a manner that the agent remains contained in the projectile. The munition cutaway in ***Figure 2*** shows that the burster can be removed from the burster well while the liquid agent remains in steel containment.



Cutaway of 4.2-inch mortar cartridge. Note burster well is steel so that burster can be removed while agent remains contained (NRC, 2011, p. 15).

Figure 2: Cutaway view of 4.2-inch mortar cartridge

3. Reconfigured projectiles will be transported through the Automated Guided Vehicle Corridor, ***item 2*** in ***Figure 1***, to the Agent Processing Building, ***item 3*** in ***Figure 1***. These processes will involve releasing agent from munitions in a mechanized manner in the toxic area. Workers will not be allowed in the toxic area during normal operations. The munitions washout system (MWS) will drain sulfur mustard from the munitions and wash the drained-munition cavities with heated water.
    a. Agent drained from the munitions will be piped to the agent neutralization system. Caustic will be mixed with the agent, mixed, and heated. The hydrolysate will be sampled and sent to the onsite laboratory to verify destruction of agent before the batch is sent out of the toxic area.
    b. Munition bodies will be sent to the munitions treatment unit. This is a conveyer through a muffle furnace where munitions will be heated for thermal destruction of sulfur mustard (1000°F for fifteen minutes) before being conveyed out of the toxic area (NRC, 2011, p. 13).

c. The Agent Processing Building contains a cascade ventilation system so that air is drawn from the least contaminated area of the building to the most contaminated area, the toxic area. Agent vapor will be removed from air in the Agent Filtration Area, ***item 5*** in ***Figure 1***.

4. Hydrolysate will generally consist of thiodiglycol, the caustic degradation product of sulfur mustard. Hydrolysate will be transferred by piping to the Biotreatment Area, ***item 4*** in ***Figure 1***. Nutrients will be added to the hydrolysate and hydrolysate will be pH adjusted for biodegradation by microbes in immobilized-cell bioreactors.

2.4.2. Toxic Area

As described previously, the toxic area contains mechanized equipment to drain munitions, hydrolyze the liquid agent, and thermally decontaminate the munition bodies. Workers will not be allowed in the toxic area during normal operations. During non-normal operations, such as maintenance activities, destruction operations will be shut down for worker entries into the toxic area.

Some equipment in the PCAPP process is first of a kind, entirely new equipment for chemical weapons disposal. This equipment includes the munitions washout system and munitions treatment unit. First of a kind equipment is expected to require more maintenance than equipment previously proven in chemical demilitarization.

An example of a proven technology is the sulfur-mustard hydrolysis system which is similar to the system used for disposal of the sulfur-mustard stockpile in Aberdeen, Maryland.

2.4.3. Demilitarization Protective Ensemble

In the hierarchy of hazard controls for worker protection, personal protective equipment (PPE) is the least desirable from standpoints of effectiveness and reliability. There will be situations where workers will have to enter the toxic area for tasks such as equipment maintenance. The DPE has been test to levels as high as the MPL, ***Table 1***, for up to two hours.

1) Air Supply: Primarily supplied air with backup self-contained breathing apparatus providing 8 to 10 minutes of escape air in case primary supply is disrupted.

2) Inner Clothing: Coveralls provided to the entrant and laundered on site.

3) "Y" Connector: Allows entrant to change hoses without disrupting to air supply.

4) Butyl Gloves

5) Breathing Air System Air Supply Hose

6) Communications Headset: DPE Radio Communications System between entrant, medical personnel, and control room operators supporting entry.

7) Heart Monitor Display: May be read by entrant or buddy.

8) Chemical Resistant Tape: Chemical resistant tape is designed to provide a chemical barrier and seal for interface between protective suits, boots and gloves.

9) Butyl Boots

(PCAPP, 2015, January 27, p. 1)

Figure 3: Worker in demilitarization protective ensemble (DPE)

The demilitarization protective ensemble (DPE), shown in ***Figure 3***, is a unique PPE for the chemical weapons disposal program. It is an OSHA Level A PPE, encapsulating suit, for single use. The DPE is made of 20-30 mil polyvinyl chloride (NRC, 2012, p. 18). Workers can attach to breathing air and also wear a backup self-contained breathing apparatus (SCBA) for emergency egress.

2.4.4. Toxic Area Activities

Tasks performed in the toxic area will vary depending on the task required. Work will be performed by entry teams of two. There will be a third worker in OSHA Level B PPE in case of emergency. Entries will be maximum of two hours.

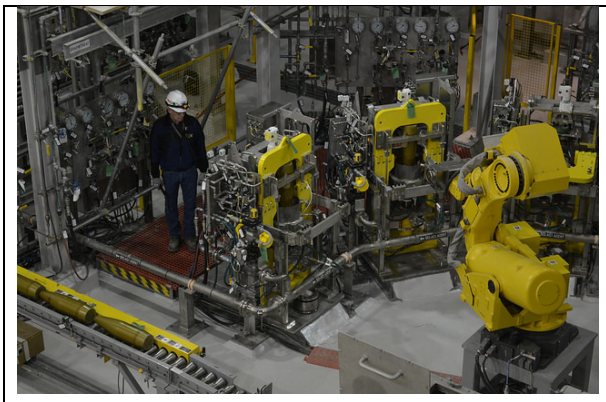
1. Entrants will proceed through two airlocks to enter the toxic area.
2. During the entry:
    - Control room personnel will provide step-by-step instructions for tasks by radio. Control room personnel with advice from medical personnel will provide work rest cycles and may instruct workers to spray process water on suits to cool them.
    - Entrants will be prompted by medical personnel to provide heart rate information every ten minutes by radio. Medical personnel will also monitor breathing rate by radio.
    - Workers must continually manage breathing air hoses.
    - Workers may spray decontamination solution on each other periodically to reduce potential contamination, particularly before ending the entry.

3. Entrants will enter the airlock and rinse off decontamination solution with water. Entrants will use an air monitor to test for agent contamination. The DPE suit, a single-use item, is removed by cutting it open.

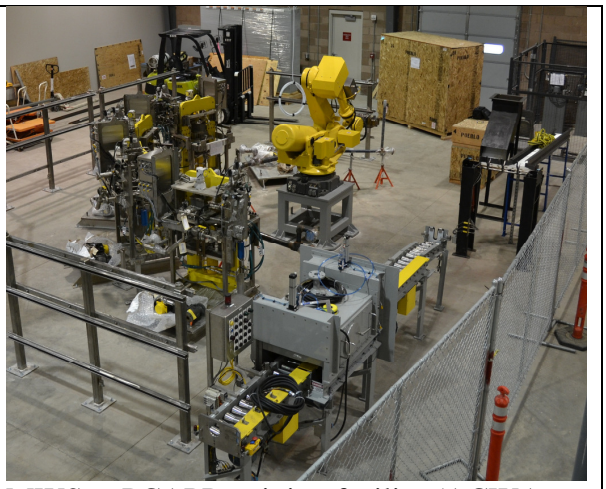
The above activities are for normal operations. Workers have contingency procedures for situations where residual contamination cannot be removed. There are also emergency cutout procedures for situations such as heat stress.

2.4.5. Toxic Area Training Facility

The PCAPP Training Facility is located approximately 10 miles outside of PCD. The facility contains classrooms and a training bay with equipment to support DPE entries, airlocks, and equipment installed at PCAPP such as munitions washout stations (MWS), shown in ***Figure 4***. In the Toxic Area Training course, instructors train workers to properly wear DPE and perform tasks while wearing DPE. Any agent or explosives in the training facility are simulated. Tasks include climbing stairs, managing air hoses, and familiarization with performing tasks with restricted vision and mobility. Simulations include controllers and medics performing physiological monitoring. The PCAPP training facility will also be used for Toxic Area Training for students who will do toxic area entries at the Blue Grass Chemical Agent-destruction Pilot Plant in Richmond, Kentucky.



MWS at PCAPP (ACWA, 2014b)



MWS at PCAPP training facility (ACWA, 2013)

Figure 4: Munitions washout system at PCAPP and at training facility

3. Problem Statement

Is heart-rate monitoring in conjunction with IH controls effective heat-stress management for workers performing tasks in DPE?

Since operations have not yet started at PCAPP, this question will be addressed by examining the PCAPP Training Facility. This examination includes a review of policies and procedures for heat-stress management at PCAPP in comparison with recognized guidelines. In addition, heat stress management during training entries is examined through review and statistical analysis of physiological monitoring, including direct-reading heart-rate monitors, and logsheets recorded by medical personnel.

4. Literature Review

The literature review involved information regarding heat stress and heat strain as applied to workers wearing encapsulating and impermeable PPE. Particular attention was given to recognized recommendations and guidelines for managing heat strain in these environments. Information was also gathered during a visit to the PCAPP Training Facility to witness an entire

entry for students in Toxic Area Training. The site visit complemented information on PCAPP policy for managing heat exposure and information in the Toxic Area Training manual (PCAPP-OTG, 2014, pp. 1-70).

There are limited workplace scenarios where workers are required to wear completely encapsulating and completely impermeable PPE. These scenarios include very hazardous chemical, biological, radiological, and nuclear (CBRN) materials. Consequently there is limited research. One study involved measuring heat strain for law enforcement personnel during CBRN training (Yokota, 2014, p.126). Use of heart-rate data and change in body mass was similar to this paper. However the CBRN trainees were generally under more heat stress due to outdoor conditions and had a wider range of effort in their tasks.

Although there are several recommended guidelines and controls applicable for occupational heat stress, guidelines for encapsulating PPE are limited. The American Conference of Governmental Industrial Hygienists (ACGIH) has a decision tree for evaluating heat stress and strain in their threshold limit values for physical agents. The screening criteria and action limits are based on indoor and outdoor wet bulb globe temperature (WBGT), a measure of temperature, humidity, and solar-radiant heat, and are specifically not recommended for completely encapsulating PPE (ACGIH, 2012, p. 203). For encapsulating PPE, the documentation recommends physiological, signs, and symptoms monitoring. The recommended guidelines are compared with PCAPP policies and training in Appendix B.

The American Industrial Hygiene Association (AIHA) provides conceptual information about how heat stress impacts workers in encapsulating PPE, see ***Figure 5***. AIHA provides a checklist for evaluating heat exposure and applying controls. The recommended guidelines are compared with PCAPP policies and training in Appendix B.

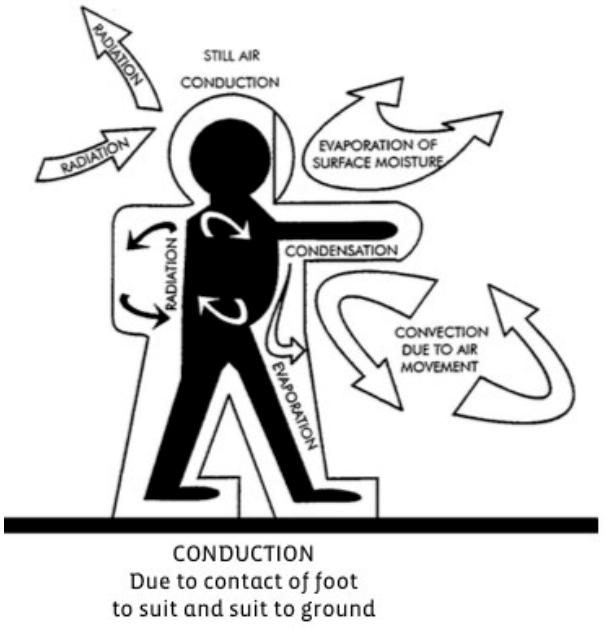


Diagram of heat factors internal to the suit (micro-environment) and external to the suit (macro-environmental) involved in totally encapsulating suit (Larrañaga, 2011a, p. 899).

Figure 5: Heat factors for total encapsulating suit

The U.S. Occupational Safety and Health Administration (OSHA) has no specific regulation for prevention of heat stress and strain. However the general duty clause requires employers to provide a workplace free from hazards recognized to cause death or serious harm. OSHA provides several guidelines for reviewing workplace environments. The recommended guidelines are compared with PCAPP policies and training in Appendix B.

5. Research Design and Methods

The research design was to take a sample of physiological, signs, and symptom data from DPE entries at the PCAPP training facility that was recorded in the Medical Monitoring Interface (MMI). The sampling strategy was to select every fourth student and include every entry that student made at the training center. The entries that were not in DPE were excluded. Additionally, students who did not complete the training were excluded since they would not

make entries at PCAPP when disposal operations begin. The result was a total of 23 students with ages ranging from 24 to 58. Each student made between two and thirteen entries each with a total of 101 entries.

PCAPP medical staff removed all information from the logsheets that was personally identifiable, medical conditions, and medications. As a result, although the students are predominantly male, there is no reliable way to distinguish if each student is male or female. There has been little research on gender and heat stress. Research has shown difference in heat regulation, but no difference in response (Larrañaga, 2011a, p. 902).

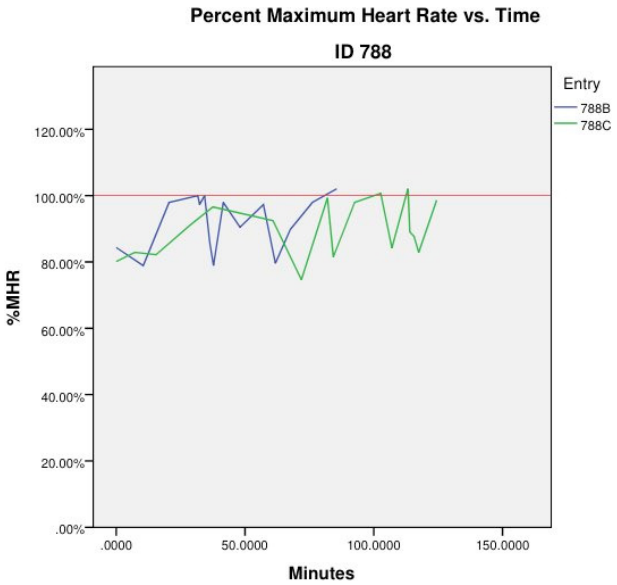
The data obtained prior to entry includes blood pressure, heart rate, respiratory rate, body temperature, weight, body-mass index (BMI), urine specific gravity (an indicator of hydration), age, and maximum permissible heart rate (MPHR). BMI is a function of height and weight, see ***equation (1)*** Appendix A. MPHR is a function of age, see ***equation (2)*** in Appendix A.

There are several disqualifying factors for performing an entry such as lack of sleep, skin wounds, sunburn, medication, illness, non-occupational heat exposure, and emotional stress. The acceptable ranges of vital signs, obtained just prior to the entry, are as follows:

- Blood pressure: systolic/diastolic less than 140/91, respectively
- Resting heart rate: less than 101 beats per minute
- Respiratory rate: less than 22 breaths per minute
- Temperature: greater than 99°F
- Pre-entry weight: greater than 98% of weight from baseline medical screen
- Urine specific gravity: less than or equal to 1.028

The data obtained during entry include time of each data entry, heart rate, and comments by medical staff. The entry data was analyzed for heart rate noting when MPHR was exceeded

and number of times MPHR was exceeded, see ***Figure 6***. The number of times the MPHR was reported exceeded does not directly compare to the duration the MPHR was exceeded since medical staff tended to ask for heart rate more frequently, than the typical ten minutes, during the worker rest period after MPHR was exceeded. However, multiple times exceeding the MPHR suggests sustained exposure.



Percent of maximum heart rate during entries for worker ID 778. Entrant reached the MPHR twice during entry 788B (blue). Entrant reached reached the MPHR three times during entry Entry 788C (green).

Figure 6: Chart of percent maximum heart rate vs. time during entries

The comments from medical staff consisted of activities, signs, and symptoms including the following.

- Activities required for entry included hose change, walking out hoses, walking up or down stairs, and decontamination
- Dexterity exercises including assembling puzzle, toy basketball set, or erector set.

- Exercises similar to PCAPP tasks including changing out a filter, changing out a strainer, draining a tank into a bucket, applying a barrier, equipment inspection, and taking a treaty sample.
- Symptoms included how operator is feeling such as lightheadedness, nausea, numbness, tingling, or burning sensation. Nausea is a particular warning during entries because vomiting while wearing a respirator may lead to asphyxiation.
- Signs included heart rate, respiration rate, speaking in complete sentences ability to perform tasks (such as hose management), and steady gait or difficulty walking. These symptoms show effects of heat on perceptual-performance (Larrañaga, 2011b, p. 941).

The logsheets recorded two medical related termination of entries. However, since both of these events involved the other entrant, it would be inappropriate to include medical-related termination as a variable.

Post-entry data included weight, body temperature, blood pressure, heart rate, and respiratory rate. All variables and descriptions are listed in ***Table II***.

All statistics were calculated using the software program IBM® SPSS® Statistics version 19. Descriptive statistics and frequencies are shown in ***Table VIII*** of Appendix C.

Table II: Variables and descriptions

Name	Description
ID	Identification number assigned to worker
Elapsed min	Duration of the entry, in minutes
Entry Month	Month the entry took place: 1=January, 2=February, etc …
Min HR	Minimum heart rate during an entry, in beats per minute
Max HR	Maximum heart rate during an entry, in beats per minute
Percent MPHR	Maximum heart rate during an entry divided by Maximum permissible heart rate, in percentage
MHR Reached?	Has maximum permissible heart rate been reached or exceeded: 0 = no, 1 = yes
No. Times Exceeded?	Number of recorded exceeding maximum permissible heart rate
C Systolic	Pre-entry systolic (maximum) pressure, in mmHg
C Diastolic	Pre-entry diastolic (minimum) pressure, in mmHg
C Resting HR	Pre-entry resting heart rate, in beats per minute
C Resp Rate	Pre-entry respiratory rate, in breaths per minute
C Temperature	Pre-entry temperature, in Fahrenheit
C PE Weight	Pre-entry weight, in pounds
C Urine SP Grav	Pre-entry urine specific gravity, dimensionless
BMI calc	Body-mass index, dimensionless
MPHR	Maximum permissible heart rate, in beats per minute
Age	Age in years
Post-Entry Weight	Weight, in pounds
Δ Weight	Pre-entry minus post-entry weight, in pounds. Weight loss is expected to be a positive value.
% change	Percent change in weight, in percent
Post Entry Temp	Post-entry temperature, in Fahrenheit
Post Entry Systolic	Post-entry systolic pressure, in mmHg
Post Entry Diastolic	Post-entry diastolic pressure, in mmHg
Post Entry Heart Rate	Post-entry resting heart rate, in beats per minute
Post Entry Resp Rate	Post-entry respiratory rate, in breaths per minute
Δ Systolic	Post-entry minus Pre-entry systolic pressure, in mmHg
Δ Diastolic	Post-entry minus pre-entry diastolic pressure, in mmHg
Δ Heart Rate	Post-entry minus post-entry resting heart rate, in beats per minute
Δ Resp Rate	Post-entry minus post-entry respiratory rate, in breaths per minute

The first statistical method is a comparison of means between two factors from the variable *MHR reached?*.

1. Entrants who had completed the entry without exceeding the MPHR
2. Entrants who had exceeded the MPHR at least once during the entry.

The second statistical method is a correlation and comparison of significance. The metrics of interest were the MHR recorded during the entry and percentage of MPHR.

6. Results

Detailed results of the t-test for equality of means between variables and factors for not exceeding or exceeding MPHR are in ***Table X*** of Appendix C. Detailed results of correlation with MHR and percent MPHR during entries are in ***Tables XI*** and ***XII***, respectively. The significance results of the two statistical tests are summarized in ***Table III***.

Table III: Compiled results of significance tests

	t-test difference in means	**correlation with %MPHR**	**correlation with MHR**
ID		not significant	not significant
Entry Start		not significant	not significant
Entry End		not significant	not significant
Elapsed min	not significant	**significant at 0.01 level**	**significant at 0.01 level**
Entry Month	not significant	not significant	not significant
C Systolic	not significant	not significant	not significant
C Diastolic	not significant	not significant	not significant
C Resting HR	not significant	not significant	**significant at 0.01 level**
C Resp Rate	not significant	not significant	not significant
C Temperature	not significant	not significant	not significant
C PE Weight	**significant**	not significant	**significant at 0.01 level**
C Urine SP Grav	**significant**	**significant at 0.01 level**	**significant at 0.01 level**
BMI calc	**significant**	not significant	not significant
MPHR	not significant	not significant	**significant at 0.01 level**
Age	not significant	not significant	**significant at 0.01 level**
Post-Entry Weight	**significant**	not significant	**significant at 0.01 level**
Δ Weight	**significant**	**significant at 0.05 level**	**significant at 0.05 level**
% change	**significant**	**significant at 0.01 level**	**significant at 0.01 level**
Post Entry Temp	not significant	not significant	not significant
Post Entry Systolioc	not significant	not significant	not significant
Post Entry Diastolic	not significant	not significant	not significant
Post Entry Heart Rate	**significant**	**significant at 0.01 level**	**significant at 0.01 level**
Post Entry Resp Rate	not significant	not significant	not significant
Δ Systolic	not significant	not significant	not significant
Δ Diastolic	not significant	not significant	not significant
Δ Heart Rate	**significant**	**significant at 0.01 level**	**significant at 0.01 level**
Δ Resp Rate	not significant	not significant	not significant

7. Discussion, Conclusion, and Recommendations for Further Research

Since percent MPHR and MHR involve heart rates during the entry, variables also involving heart rate during the entry are not considered independent and are not included in results.

A difference in means between entrants who completed the entry without exceeding the MPHR and those who exceeded the MPHR include (mean for not-exceeding MPHR and mean for exceeding MPHR are in parentheses):

- Pre-entry weight (223 lbs, 195 lbs)
- Pre-entry urine specific gravity (1.011, 1.006)
- BMI (33.94, 28.31)
- Post-entry weight (223 lbs, 196 lbs), change in weight lost (1.27 lbs, 1.93 lbs), and percent weight loss (0.55%, 0.98%)

The means for change in weight lost and percent weight loss was greater for entries that exceeded MPHR than for entries that did not.

Counterintuitively, the means for pre-entry weight, post-entry weight, BMI, and pre-entry urine specific gravity were greater for entries that did not exceed MPHR than entries that did.

The variables for pre-entry weight, post-entry weight, and BMI relate to body size and fatness. Larger body mass should lead to less heat tolerance due to less heat dissipation due to less body surface to mass ratio and greater energy demands of greater weight, yet research has shown substantial individual variability in heat tolerance (Larrañaga, 2011a, p. 908).

Urine specific gravity is an indicator for hydration. Research has shown dehydration as a factor for increased heat-related injury risk (Larrañaga, 2011a, p. 908). Since entrants who would

have signs of dehydration (urine specific gravity greater than 1.028) have been disqualified, entrants may be adequately hydrated and excess hydration may be counterproductive.

The correlation test showed significant correlation for between percent MPHR and the following variables (Pearson correlation coefficients are given in parentheses):

- Pre-entry urine specific gravity (-0.304), see ***Figure 7*** in Appendix C
- Change in weight lost (+0.267) and percent weight loss (+0.344), see ***Figure 8*** in Appendix C

Consistently with the significance in means tests, the correlations for change in weight lost and percent weight lost and percent MPHR were positive. Also consistent with the significance in means tests, correlation for pre-entry urine specific gravity and percent MPHR were negative.

The correlation tests showed significant correlations between MHR and the following variables (Pearson correlation coefficients are given in parentheses):

- Pre-entry urine specific gravity (-0.327)
- Age (-0.554), see ***Figure 9*** in Appendix C
- BMI (-0.182), see ***Figure 10*** in Appendix C
- Pre-entry weight (-0.298), see ***Figure 11*** in Appendix C; post-entry weight (-0.272), change in weight loss (+0.249), and percent weight loss (+0.355)

The correlation for age is negative. Research has shown older workers performing well in hot workplaces when the pace is self-regulated, yet show greater heat strain than younger workers at hotter environments (Larrañaga, 2011a, p. 908).

Variables that show no significant difference in means between exceeding or not exceeding MPHR, correlation with %MPHR, or correlation with MHR include (Pearson correlation coefficients are given in parentheses):

- Entry month
- Pre-entry and post-entry temperature
- Pre-entry, post-entry, and change in blood pressure
- Pre-entry, post-entry, and change in respiratory rate

Month was included to see if there were heat-related effects due to season acclimatization. Warm days in springtime have shown to result in more heat-related incidents than hotter days in summer (Larrañaga, 2011a, p. 892).

Conclusions:

- Review of PCAPP policies was generally consistent with AIHA and OSHA guidelines. Some outcomes did not meet ACGIH guidelines for limiting heat strain.
    - ACGIH guidelines for limiting heat strain state heart rate in excess of MHR sustained for several minutes for entrants is a measure of excessive heat strain with normal cardiac performance (ACGIH, 2012, p. 209). For several entrants (7%, 7/101) individual's exceeded MPHR for more than three cycles.
    - ACGIH guidelines for limiting heat strain state recovery state heart rate at one minute after a peak work effort is greater than 120 bpm as a measure of excessive heat strain (ACGIH, 2012, p. 209). For several entries (11%, 11/101) individual's heart rates were never below 120 bpm.

    - ACGIH guidelines for limiting heat strain state an individual is at greater risk of heat-related disorders if weight loss is greater than 1.5% during a shift (ACGIH, 2012, p. 209). Several entrants (9%, 9/101) had a weight loss greater than 1.5% during an entry.

- Both significant differences in means and positive correlations were observed for entrants who did not exceed MHR and entrants who exceeded MHR for change and percent weight loss.
- Both significant differences in means and negative correlations were observed for entrants who did not exceed MHR and entrants who did exceed MHR for pre-entry urine specific gravity. Since this result is contrary to scientific literature, this conclusion is that controls implemented result in proper hydration.
- Either significant differences in means or correlations were observed for entrants who did not exceed MHR and entrants who exceeded MHR for age, BMI, and variables involving weight. Since this result is contrary to scientific literature, the conclusion is that controls are properly selected effectively manage factors of age and weight.
- Neither significant differences nor correlations were observed for entrants who did not exceed MHR and entrants who exceeded MHR for variables involving entry month (season), blood pressure, or respiratory rate.

Recommendations for further study include:

- Develop interventions to meet ACGIH guidelines for limiting heat strain with the goals of minimizing exceeding MPHR, recovery heart rate of 120 bpm or less, and weight loss of 1.5% or less.

- Performing a similar study for non-DPE Level A entries. There fewer non-DPE Level A entries than DPE entries for each entrant—generally one each, so this study may require a different sampling method.
- Develop a metric for acclimatization. Worker acclimatization is recognized in PCAPP policies and training, but there is no metric for worker acclimation.
- Develop additional fields for data collection. Some entries were recorded inconsistently in log sheets that may be of interest for heat-stress controls such as use or non-use of ice packs, and ambient temperature of training bay.
- Follow up study for heat-stress management during entries for PCAPP after operations begin.

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Appendix A: Equations

Body Mass Index (CDC, 2015, p. 1)

$$BMI = 703 \times \frac{weight}{height^2} \quad (1)$$

where *weight* is entrant weight in pounds and *height* is entrant height in inches.

The BMI corresponds to weight status using ***Table IV***.

Table IV: BMI and weight status

BMI	Weight Status
Below 18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 and Above	Obese

(CDC, 2015, p. 1)

Maximum Permissible Heart Rate (MPHR) (ACGIH, 2012, p. 209)

$$MPHR = 180 - age \quad (2)$$

where *MPHR* is beats per minute and *age* is age of entrant in years.

Appendix B: Recommendations and Guidelines for Managing Heat Strain

[Tables begin on next page.]

ACGIH

Table V: ACGIH guidelines for limiting heat strain and PCAPP policies and practices

Guidelines for limiting heat strain (ACGIH, 2012, p. 209)

One or more of the following measures may mark excessive heat strain, and an individual's exposure to heat stress should be discontinued when any of the following occur:	
• *Sustained (several minutes) heart rate is in excess of 180 bpm (beats per minute) minus the individual's age in years (e.g., 180 - age), for individuals with assessed normal cardiac performance; or*	"Heart rates will be read back to the paramedic by the entrant or entrant's buddy. These may be evaluated and documented every 10-20 minutes. If at any time the paramedic is concerned about the entrant's heart rate, they may request a heart rate reading" (PCAPP-OTG, 2014, p. 26). "The [Maximum Predicted Heart Rate (MPHR)] can be obtained by one of two ways, but preferably by the first method: • Age-adjusted MPHR is based solely on the worker's age: (180 - age) will be the basis for all entrants unless exclusion is authorized by a CMA • Age-adjusted MPHR: (220 - worker's age) will only be done on a case -by-case basis by a CMA on stress test criteria established by the PCAPP Medical Director" (PCAPP-OTG, 2014, pp. 55-56) "A calculation of (220 BPM - age) x 0.8. This is rarely utilized and will only be authorized by the PMD." (PCAPP, 28 July 2014, p. 10)
• *Body core temperature is greater than 38.5°C (101.3°F) for medically selected and acclimatized personnel; or greater than 38°C (100.4°F) in unselected, unacclimatized workers; or*	"A body temperature, measured by an oral thermometer> 1 01 .3°F for acclimatized individuals and > 100.4°F for non-acclimated individuals." (PCAPP, 28 July 2014, p. 8)
• *Recovery heart rate at one minute after a peak work effort is greater than 120 bpm; or*	

• *There are symptoms of sudden and severe fatigue, dizziness, or lightheadedness.*	"Finally, know and fully understand the signs of heat stress, These include breathing difficulty, chest pain or tightness, cramps, nausea, excessive fatigue, and headaches. Don't ignore these signs. You might feel like you 're invincible or there might be many distracting things taking place, but if anything, no matter how small, doesn't feel right, pay close attention. If you experience any symptoms, you need to notify the CON and medical personnel how you're feeling. They can then put a plan of action together to get you out safely. If you don't speak: up, you put not only yourself but your partner at risk as well" (PCAPP-OTG, 2014, p. 41). "Symptoms of excessive thermal strain always override physiological data. No individual with symptoms of excessive thermal strain (e.g., headache, dizziness, nausea, excessive fatigue, confusion, difficulty with dexterity) should continue work in the thermally stressful area. Physiologic data should never be used to justify continued thermal exposure in individuals developing symptoms of thermal intolerance" (PCAPP, 28 July 2014, p. 17)
An individual may be at greater risk of heat-related disorders if:	
• *Profuse sweating is sustained over hours; or*	"Individuals that might be at greater risk for developing a heat-related illness are those that experience sustained, profuse sweating over a long period of time… (PCAPP, 28 July 2014, p. 8)
• *Weight loss over a shift is greater than 1.5% of body weight; or*	"Individuals that might be at greater risk for developing a heat-related illness are those […] and/or those that experience a weight loss that is > 1.5% of their baseline weight while performing work" (PCAPP, 28 July 2014, p. 8).
• *24-hour urinary sodium excretion is less than 50 mmoles.*	
Elements to Consider in Establishing a Heat Stress Management Program *(ACGIH, 2012, p. 210)*	
General Controls	
• *Provide accurate verbal and written*	"Medical symptoms that may be related to heat strain include but are not

instructions, annual training programs, and other information about heat stress and strain	limited to: • Cramps • Nausea • Excessive fatigue • Headache • Breathing difficulty • Chest pain/tightness" (PCAPP-OTG, 2014, p. 59)
• *Encourage drinking small volumes (approximately 1 cup) of cool, palatable water (or other acceptable fluid replacement drink) about every 20 minutes*	"After temperature has been obtained, the entrant should start rehydration with a chilled, flavored electrolyte replacement drink or water" (PCAPP-OTG, 2014, p. 58). Training bay has refrigerator with three flavors of fluid-replacement drinks and chest with rehydration popsicles.
• *Encourage employees to report symptoms of heat-related disorders to a supervisor*	"Finally, know and fully understand the signs of heat stress, These include breathing difficulty, chest pain or tightness, cramps, nausea, excessive fatigue, and headaches. Don't ignore these signs. You might feel like you 're invincible or there might be many distracting things taking place, but if anything, no matter how small, doesn't feel right, pay close attention. If you experience any symptoms, you need to notify the CON and medical personnel how you're feeling. They can then put a plan of action together to get you out safely. If you don't speak: up, you put not only yourself but your partner at risk as well" (PCAPP-OTG, 2014, p. 41).
• *Encourage self-limitation of exposures when a supervisor is not present*	There will always be control-room supervision during entries. "As far as pacing goes, as you do more entries you will acquire more acclimatization in general and be able to work with more efficiency, However, all entrants know that they need to make sure they've got enough energy to make the return trip. Pacing is extremely important, especially in the beginning when the adrenaline is surging. As it does, you 'll feel invincible and want to move at a quick pace. But if you move too quickly or work too hard, you might expend most of your energy at the forefront and you never want to do that"

	(PCAPP-OTG, 2014, p. 34)
• *Encourage co-worker observation to detect signs and symptoms of heat strain in others*	"Entrant's comments concerning signs and symptoms: An individual will usually feel the onset of symptoms when an illness is developing before it is apparent to others. For this reason, it is paramount that the team leaders, Control Room personnel, and monitoring paramedic give credence to any comments an entrant makes concerning signs and symptoms" (PCAPP-OTG, 2014, p. 25). "If backup personnel on the entry feel that the entrant is straining or showing signs of distress or heat stress of which the monitoring paramedic is not aware, the backup should verbalize their concerns to the paramedic and Control Room operator on the entry" (PCAPP-OTG, 2014, p. 26) "Note any comments or responses by entrants suggesting they do not feel well or that they are becoming symptomatic. This could include exhibiting a significant mood change, stumbling, slowed gait, or difficulty with motor function skills (e.g., pulling hoses, climbing stairs). The CMA will be contacted for additional Recommendations" (PCAPP, 28 July 2014, p. 16).
• *Counsel and monitor those who take medications that may compromise normal cardiovascular, blood pressure, body temperature regulation, renal, or sweat gland functions; and those who abuse or are recovering from the abuse of alcohol or other intoxicants*	"Medications: Prescribed or over-the-counter medication or supplements, previously unreported, require evaluation before proceeding with a pre-entry screen (PCAPP-OTG, 2014, p. 58)
• *Encourage healthy lifestyles, ideal body weight and electrolyte balance*	
• *Adjust expectations of those returning to work after absence from hot exposure situations and encourage consumption of salty foods (with approval of physician if*	"… after seven days off or if you have taken a vacation, that acclimatization will have greatly diminished, meaning you will have to build your tolerances up again" (PCAPP-OTG, 2014, p. 13). " … the entrant should start rehydration with a chilled, flavored electrolyte

on a salt-restricted diet)	replacement drink or water. Workers may be returned to duty if they fall within these parameters: • Resting pulse rate < 110 beats per minute • Weight loss not > 1.5% of pre-entry weight • Temperature ≤ 101.5°F • No symptoms of heat strain • For diabetics, blood glucose > 110 and < 200 mg/dL The CMA will evaluate entrants who experienced heat-related/medical problems during the entry or who are outside the post-screen parameters" (PCAPP-OTG, 2014, p. 28).
• *Consider pre-placement medical screening to identify those susceptible to systemic heat injury*	"All personnel to be screened for thermally stressful work will be required to report to the PMC upon assignment in order to develop baseline vital sign (VS) parameters. Baseline VS data will be obtained using the same types of equipment, measuring techniques, and worker preparation as used during pre-entry heat stress screening. If the ambient temperatures are at the extremes, workers will rest for 15 minutes in a controlled environment (71 - 79° F) to allow for acclimatization before their vital signs are obtained. Baseline vital signs will consist of Blood Pressure (BP), HR, respiratory rate (RR), temperature (T), and weight. The acceptable parameters for baseline vitals are as follows: • Systolic BP of < 140 and a diastolic BP < 90 (maximum acceptable systolic is 139 and maximum acceptable diastolic is 89) • RR < 22 breaths per minute • HR ≤ 100 BPM • Oral temperature ≤ 99.0°F • Weight without shoes rounded to the nearest pound (lb.)" (PCAPP, 28 July 2014, pp. 9-10) "Pre-placement heat tolerance evaluations should include and document the following in the medical record: • Current or previous illnesses or conditions that could reduce heat

	tolerance and increase the risk for heat stress illness • Experience with previous workplace heat stress exposures, episodes of heat-related disorders, and the ability to acclimatize to heat stress • Prescribed and over-the-counter medications with an evaluation of potential effects on heat tolerance • Determination of the degree of heat acclimatization, based on usual job and recreational activities • No reported pregnancy; however, the patient has been counseled regarding the potential hazards of heat stress during the first trimester of pregnancy Workers are required to disclose all medications they are taking, including over-the-counter, prescribed, and herbal remedies. Workers on betablockers, insulin, diuretics, or certain other medications will require special medical attention before authorization to work in heat stressful conditions" (PCAPP-OTG, 2014, p. 55). "Now that you know that there's some work to be done and you've been chosen to do it, the next step is to go to Medical and pre-screen. Before you arrived at this site, you were checked out and cleared by Medical to wear the chemical protective clothing and respirators. Regardless of any past abilities to clear medical every entry, we have to ensure that are you ready and able, this day, to perform an entry" (PCAPP-OTG, 2014, p. 13).
• *Monitor the heat stress conditions and reports of heat-related disorders*	"This desk instruction establishes the roles of the various Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) Medical Clinic (PMC) team members in the monitoring and reporting of thermal-related illness or injury. This document identifies conditions that could present a thermal risk for employees at PCAPP and discusses the requirements for the monitoring of workers who may be at risk for the development of thermally-related illness or injury. Additionally, this instruction addresses methods to evaluate environmental and metabolic heat loading and the guidelines for working in hot or cold environments both inside and outside of toxic areas" (PCAPP, 28 July 2014, p. 5).
Job-Specific Controls	

• *Consider engineering controls that reduce the metabolic rate, provide general air movement, reduce process heat and water vapor release, and shield radiant heat sources, among others*	"Entrant may be asked to be cooled down with water" (PCAPP-OTG, 2014, p. 56). "You may be the person who needs to find a process water hose to help cool off him or her (PCAPP-OTG, 2014, p. 37). "We try to control the effects of our protective gear through the use of air supply tubes that push air across your body to help keep you cool, using ice vests to help keep you cool" (PCAPP-OTG, 2014, p. 13). "ESA operator will be able to place up to four cooling tubes on your person. As you may recall, air will be chilled (possibly purged ahead of time by the CRO) to a nominal 40°F (PCAPP-OTG, 2014, p. 17)". Breathing-air tank is located indoors and supplied air is maintained at 60°F.
• *Consider administrative controls that set acceptable exposure times, allow sufficient recovery, and limit physiological strain*	"… a two-hour rest, rehydration, and cooling-off period is required between post-screen and pre-screen for the second entry" (PCAPP-OTG, 2014, p. 57). "There will be at least three rest cycles to be followed per the paramedic's direction. Circumstances surrounding the heart rate elevations are relayed to the CMA, so that the CMA can determine whether this entry can continue based on the worker's response to the work" (PCAPP-OTG, 2014, p. 26). "… 'Limit the potential exposure to a minimum number of personnel, for a minimum period of time, and to a minimum amount of hazardous material, consistent with sale and efficient operations.' This includes prohibiting concurrent, unrelated work within the same area" (PCAPP-OTG, 2014, 53).
• *Consider personal protection that is demonstrated effective for the specific work practices and conditions at the location*	" … PPE is the last line of defense between you and the agent in the building. The demilitarization industry has developed specialized gear that can protect you head to toe and provide you with a source of clean air. You will be introduced to the Demilitarization Protective Ensemble (DPE) and what limitations it can create for you when you wear it" (PCAPP-OTG, 2014, p. 8). "In [pre-entry meeting] process, you'll discuss the work scope and the Safety Task Analysis and Risk Reduction Talk. (STARRT) form, discussing current conditions (such as temperature, air levels, state of equipment), what problems people have encountered in the past, and how things may have changed over

	time. Abort levels will be discussed. There are different abort criteria depending upon what type of entry you are performing. These will be reviewed" (PCAPP-OTG, 2014, p. 15).

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AIHA

Table VI: AIHA guidelines for limiting heat strain and PCAPP policies and practices

Checklist for Heat Exposures (Larrañaga, 2011a, p. 913-914)

1. *Are adequate supplies of a variety of appealing cool drinks available*	"It is vitally important to make sure that you have enough fluids in your system because the protective gear you'll be wearing and the dry air you'll be breathing will dehydrate you significantly during your entry" (PCAPP-OTG, 2014, p. 13). Training bay has refrigerator with three flavors of fluid-replacement drinks and chest with rehydration popsicles.
2. *What is the major source of heat stress and how can it be mitigated (e.g., protective clothing requires particular strategies)?*	"Unfortunately, these fully encapsulating ensembles trap the heat your body generates inside and only lets it out slowly" (PCAPP-OTG, 2014, p. 40). Microclimate cooling.
3. *If radiant shielding (including shade) is possible, is it in the most strategic location?*	Not applicable
4. *Is temperature-monitoring equipment available at the work site?*	"[Pre-entry meeting] current conditions (such as temperature, air levels, state of equipment)" (PCAPP-OTG, 2014, p. 15). "Pre-entry medical screening includes testing for blood pressure, heart rate, temperature and urine specific gravity (USO)" (PCAPP-OTG, 2014, p. 57). "DPE entrants will have their heart rate and temperature recorded immediately upon exiting the C airlock by a paramedic" (PCAPP-OTG, 2014, p. 28). "DPE/OSHA A has been approved for use at temperatures above 90°F, with the following stipulations …" (PCAPP-OTG, 2014, p. 49) There are seven thermometers in the training bay.
5. *Are work guidelines that are appropriate to the situation available to workers and supervisors?*	"In [pre-entry meeting] process, you'll discuss the work scope and the Safety Task Analysis and Risk Reduction Talk. (STARRT) form, discussing current conditions (such as temperature, air levels, state of equipment), what problems people have encountered in the past, and how things may have changed over time. Abort levels will be discussed. There are different abort criteria depending upon what type of entry you are performing. These will be reviewed" (PCAPP-OTG, 2014, p. 15).
6. *Are first aid supplies available that are appropriate to heat/cold emergencies?*	Information for agent emergencies, not for heat stress emergencies.

7. *Has an appropriate work rate and work-rate schedule been determined, and is there sufficient manpower to stay on schedule despite a slower work pace?*	"There will be at least three rest cycles to be followed per the paramedic's direction. Circumstances surrounding the heart rate elevations are relayed to the CMA, so that the CMA can determine whether this entry can continue based on the worker's response to the work" (PCAPP-OTG, 2014, p. 26).
8. *Have supervisors been instructed to remove workers at the first sign of problems?*	Willingness to Stop: Act conservatively. One of the basic attitudes we want you to employ is to consider the consequences of your actions, and to take a thoughtful approach to your work. We don't take risks or gamble with our lives or the lives of others. We pause as necessary and think things through. Remember the tortoise, not the hare, won the race" (PCAPP-OTG, 2014, p. 11). "In any emergency, the monitoring paramedic may contact the CMA for guidance and advise the Control Room to abort the DPE entry as soon as safe practices allow" (PCAPP-OTG, 2014, p. 57).
9. *Have workers been properly and thoroughly acclimatized (or reacclimatized after time away from the stressing environment)?*	"… a two-hour rest, rehydration, and cooling-off period is required between post-screen and pre-screen for the second entry" (PCAPP-OTG, 2014, p. 57).
10. *Is a cool recovery/rest area available?*	"Workers will rest for 15 minutes in the cooled environment (<80°F) before their vital signs are obtained" (PCAPP-OTG, 2014, p. 55).
11. *Are workers and supervisors trained in recognizing the symptoms of, and providing first-aid treatment for heat injury?*	"… know and fully understand the signs of heat stress, These include breathing difficulty, chest pain or tightness, cramps, nausea, excessive fatigue, and headaches" (PCAPP-OTG, 2014, p. 41, p. 59).
12. *Is there a means of calling emergency medical support? Do workers know how and where to call emergency medical support?*	"Medical monitoring of entrants includes maintaining radio contact throughout the entire process. Failure of the radios or heart rate monitors may result in abortion of the entry until proper function is restored" (PCAPP-OTG, 2014, p. 25). "A dedicated, limited range, secure radio system which provides a means of communication between personnel wearing OPE in Category A and B areas and observers, support personnel, maintenance, medical, and Control Room operators (CROs). This system is wireless, allowing hands-free operation for DPE wearers. The system is comprised of a radio strapped onto the wearer's waist or shoulders, a microphone strapped around the throat and a handset. Each team will have dedicated portable radios. The radios and batteries are waterproof to prevent damage. Team members can communicate among themselves and support personnel Conversations are recorded with CCTV video" (PCAPP-OTG, 2014, p.

	49).
13. Is the clothing appropriate (minimal obstruction of sweat evaporation and maximal protection from radiant heat; i.e., use the lightest, most permeable clothing that provides adequate safety)?	"Unfortunately, these fully encapsulating ensembles trap the heat your body generates inside and only lets it out slowly" (PCAPP-OTG, 2014, p. 40).
14. Is air velocity as high as practical?	"ESA operator will be able to place up to four cooling tubes on your person. As you may recall, air will be chilled (possibly purged ahead of time by the CRO) to a nominal 40°F" (PCAPP-OTG, 2014, p. 17)
15. Are workers well hydrated at the beginning of work?	"The paramedic who screens you will ask for your urine specific gravity. You'll provide a sample and based on that, medical can determine how well hydrated you are, a process that begins the previous day (if not earlier). It is vitally important to make sure that you have enough fluids in your system because the protective gear you'll be wearing and the dry air you'll be breathing will dehydrate you significantly during your entry. Based on that reading, you'll either be cleared for continued screening or you may have to rehydrate. If you are very dehydrated, you may not be able to perform the entry at all" (PCAPP-OTG, 2014, p. 13). "A [Urine Specific Gravity (USG)] of < 1.027 g/mL indicates hydration is normal and entry may proceed" (PCAPP-OTG, 2014, p. 57)
16. Is spot cooling available?	"Entrant may be asked to be cooled down with water" (PCAPP-OTG, 2014, p. 56). "You may be the person who needs to find a process water hose to help cool off him or her (PCAPP-OTG, 2014, p. 37).
17. Is microclimate cooling available as needed?	"We try to control the effects of our protective gear through the use of air supply tubes that push air across your body to help keep you cool, using ice vests to help keep you cool" (PCAPP-OTG, 2014, p. 13). "ESA operator will be able to place up to four cooling tubes on your person. As you may recall, air will be chilled (possibly purged ahead of time by the CRO) to a nominal 40°F (PCAPP-OTG, 2014, p. 17)".
18. Have workers who might be pregnant, or those with cardiovascular problems, previous heat injuries, on problematic medications, and who have fever, been	If you were recently ill or taking medication or were heat stressed at home, you need to speak up because those kinds of things can have an effect on your body's preparation" (PCAPP-OTG, 2014, p. 13). "Pre-placement heat tolerance evaluations should include and document the

protected from elevated deep body temperatures?	following in the medical record: • Current or previous illnesses or conditions that could reduce heat tolerance and increase the risk for heat stress illness • Experience with previous workplace heat stress exposures, episodes of heat-related disorders, and the ability to acclimatize to heat stress • Prescribed and over-the-counter medications with an evaluation of potential effects on heat tolerance • Determination of the degree of heat acclimatization, based on usual job and recreational activities • No reported pregnancy; however, the patient has been counseled regarding the potential hazards of heat stress during the first trimester of pregnancy Workers are required to disclose all medications they are taking, including over-the-counter, prescribed, and herbal remedies. Workers on betablockers, insulin, diuretics, or certain other medications will require special medical attention before authorization to work in heat stressful conditions" (PCAPP-OTG, 2014, p. 55). "Disqualifying Factors include: … Temperature: Oral/temporal or tympanic temperature that is >99.0°F or >0.4°F [?]" (PCAPP-OTG, 2014, p. 57)
19. Have workers been reminded of appropriate safety precautions?	"[Pre-job meeting] is part of our safety planning process. Your team knows what they want to work on, but you'll want to break this up into more detail. What are the steps in your process and who's going 10 participate? What do we need to do first, what happens if that doesn't work? What equipment, parts, tools and support do you need? Who's got experience, who do we need to train? Asking questions is crucial at this stage" (PCAPP-OTG, 2014, 14) "In [pre-entry meeting] process, you'll discuss the work scope and the Safety Task Analysis and Risk Reduction Talk (STARRT) form, discussing current conditions (such as temperature, air levels, state of equipment), what problems people have encountered in the past, and how things may have changed over time. Abort levels will be discussed. There are different abort criteria depending upon what type of entry you are performing. These will be reviewed. Your entry routes, what breathing air stations you'll connect to, and what emergency routes you'll use will also be discussed. Good entry practices will be reviewed" (PCAPP-OTG, 2014, 15).

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OSHA

Table VII: OSHA guidelines for limiting heat strain and PCAPP policies and practices

Heat Stress: General Workplace Review (OSHA, 1999, App. IIII)

Workplace Description	
A. Type of business	Chemical weapons destruction
B. Heat-producing equipment or processes used	Electric autoclave, heated vessels. Operations stopped during entries.
C. Previous history (if any) of heat-related problems	"Pre-placement heat tolerance evaluations should include and document the following in the medical record: • Current or previous illnesses or conditions that could reduce heat tolerance and increase the risk for heat stress illness • Experience with previous workplace heat stress exposures, episodes of heat-related disorders, and the ability to acclimatize to heat stress • Prescribed and over-the-counter medications with an evaluation of potential effects on heat tolerance • Determination of the degree of heat acclimatization, based on usual job and recreational activities • No reported pregnancy; however, the patient has been counseled regarding the potential hazards of heat stress during the first trimester of pregnancy Workers are required to disclose all medications they are taking, including over-the-counter, prescribed, and herbal remedies. Workers on betablockers, insulin, diuretics, or certain other medications will require special medical attention before authorization to work in heat stressful conditions" (PCAPP-OTG, 2014, p. 55).
D. At "hot" spots:	
• *Is the heat steady or intermittent?*	Not applicable. Heat generated by worker in encapsulating PPE. "Unfortunately, these fully encapsulating ensembles trap the heat your body generates inside and only lets it out slowly" (PCAPP-OTG, 2014, p. 40).
• *Number of employees exposed?*	2 per entry "To maintain the maximum level of safety for personnel in agent areas and to ensure compliance with surety requirements, the two-person rule is employed. Under no circumstances will one person enter a chemical exclusion area without a second employee, knowledgeable of the work to be performed, accompanying them at all times. Visual contact must be maintained at all times" (PCAPP-OTG, 2014, p.

	53).
• *For how many hours per day?*	2-hours each entry "During mustard operations, personnel are authorized to perform no more than two two-hour entries per shift into chemical hazard areas identified as A, A/B or B, regardless of the level of dress" (PCAPP-OTG, 2014, p. 53).
• *Is potable water available?*	"It is vitally important to make sure that you have enough fluids in your system because the protective gear you'll be wearing and the dry air you'll be breathing will dehydrate you significantly during your entry." (PCAPP-OTG, 2014, p. 13)
• *Are supervisors trained to detect/evaluate heat stress symptoms?*	Medical personnel
Are Exposures Typical For A Workplace In This Industry?	
A. Weather at Time of Review	
B. Temperature	
C. Humidity	Not applicable. Heat generated by worker in encapsulating PPE.
D. Air velocity	Not applicable. Heat generated by worker in encapsulating PPE.
E. Is Day Typical of Recent Weather Conditions? *(Get information from the Weather Bureau)*	Not applicable. Indoors.
F. Heat-Reducing Engineering Controls	Operations stopped during entries. "… 'Limit the potential exposure to a minimum number of personnel, for a minimum period of time, and to a minimum amount of hazardous material, consistent with sale and efficient operations.' This includes prohibiting concurrent, unrelated work within the same area" (PCAPP-OTG, 2014, 53).
G. Ventilation in place?	Functional Heating ventilation and air conditioning (HVAC) is a limiting condition of operations (LCO) "Your control room operator will be verifying that the utilities systems you will need to support your entry are up and running. Breathing air, electrical, communications, etc. There are circumstances that would prevent an entry from

	happening; these are known as limiting conditions of operations. The plant has to make sure that the situation is right and safe before letting people into the toxic areas" (PCAPP-OTG, 2014, p. 14).
H. Ventilation operating?	Functional HVAC is an LCO
I. Air conditioning in place?	Functional HVAC is an LCO
J. Air conditioning operating?	Functional HVAC is an LCO
K. Fans in place?	Not applicable. Heat generated by worker in encapsulating PPE.
L. Fans operating?	Not applicable. Heat generated by worker in encapsulating PPE.
M. Shields or insulation between sources and employees?	Not applicable. Heat generated by worker in encapsulating PPE.
N. Are reflective faces of shields clean?	Not applicable. Heat generated by worker in encapsulating PPE.
Work Practices To Detect, Evaluate, And Prevent Or Reduce Heat Stress	
A. Training program?	Toxic Area Training
B. Content?	**"TAT Objectives** **Terminal Objective** At the end of this course, PCAPP personnel will have the basic knowledge and skills necessary to perform toxic area operations safely, efficiently and compliantly. Successful completion of this course means passing performance exercises for Level C, A and DPE gear. **Enabling Objectives** **Introduction** Explain the rules of entries. Evaluate the hazards of working in agent contaminated environments in protective gear. Apply good conduct of operations to toxic area entries. **How to Perform a Toxic Entry in Nine Easy Stages** Reconstruct the sequence for performing a toxic entry. **Stage 1** Discuss the purpose for performing a visual survey. Distinguish the requirements for chemical hazard areas A through E. Define the cardinal principle, **Stage 2** Identify pre-entry screening medical criteria. **Stage 3** Express the purpose of the pre-job meeting as part of the safety planning process.

	Stage 4 Express the purpose of the pre-entry meeting as part of the safety planning process. **Stage 5** Recognize the components of toxicological agent protective gear. Differentiate between levels A through C gear. **Stage 6** Recall the repeat back communication process. Define the two-man rule. Identify features of the airlocks relevant to the ingress process. **Stage 7** Explain the communication requirements between entrants, medical, control, and emergency response backups. Paraphrase the habits of highly effective entries. Interpret PCAPP's protocol for chemical agent hygiene. **Stage 8** Relate the egress process to chemical agent hygiene. **Stage 9** Identify post-entry requirements" (PCAPP-OTG, 2014, p. 65).
C. Where given?	PCAPP Training Facility
D. For whom?	DPE entrants and support personnel
E. Liquid replacement program?	"It is vitally important to make sure that you have enough fluids in your system because the protective gear you'll be wearing and the dry air you'll be breathing will dehydrate you significantly during your entry." (PCAPP-OTG, 2014, p. 13) "After temperature has been obtained, the entrant should start rehydration with a chilled, flavored electrolyte replacement drink or water. Workers may be returned to duty if they fall within these parameters: • Resting pulse rate < 110 beats per minute • Weight loss not > 1.5% of pre-entry weight • Temperature ≤ 101.5°F • No symptoms of heat strain • For diabetics, blood glucose > 110 and < 200 mg/dL" (PCAPP-OTG, 2014, p. 28).
F. Acclimatization program?	Pre-placement heat tolerance evaluations should include and document the following in the medical record: • Current or previous illnesses or conditions that could reduce heat tolerance and increase the risk for heat stress illness • Experience with previous workplace heat stress exposures, episodes of heat-related disorders, and the ability to acclimatize to heat stress

	• Prescribed and over-the-counter medications with an evaluation of potential effects on heat tolerance • Determination of the degree of heat acclimatization, based on usual job and recreational activities • No reported pregnancy; however, the patient has been counseled regarding the potential hazards of heat stress during the first trimester of pregnancy Workers are required to disclose all medications they are taking, including over-the-counter, prescribed, and herbal remedies. Workers on betablockers, insulin, diuretics, or certain other medications will require special medical attention before authorization to work in heat stressful conditions" (PCAPP-OTG, 2014, p. 55).
G. Work/rest schedule?	"Depending on the heart rate, an entrant may be asked to rest or be cooled down with water. There will be at least three rest cycles to be followed per the paramedic's direction. Circumstances surrounding the heart rate elevations are relayed to the CMA, so that the CMA can determine whether this entry can continue based on the worker's response to the work" (PCAPP-OTG, 2014, p. 26).
H. Scheduling of work (during cooler parts of shift, cleaning and maintenance during shut-downs, etc.)	Operations shut down during entries. "… 'Limit the potential exposure to a minimum number of personnel, for a minimum period of time, and to a minimum amount of hazardous material, consistent with sale and efficient operations.' This includes prohibiting concurrent, unrelated work within the same area" (PCAPP-OTG, 2014, 53).
I. Cool rest areas (including shelter at outdoor work sites)?	"Workers will rest for 15 minutes in the cooled environment (<80°F) before their vital signs are obtained" (PCAPP-OTG, 2014, p. 55).
J. Heat monitoring program?	"In [pre-entry meeting] process, you'll discuss the work scope and the Safety Task Analysis and Risk Reduction Talk (STARRT) form, discussing current conditions (such as temperature, air levels, state of equipment), what problems people have encountered in the past, and how things may have changed over time. Abort levels will be discussed. There are different abort criteria depending upon what type of entry you are performing. These will be reviewed" (PCAPP-OTG, 2014, p. 15).
K. Personal Protective Equipment	Encapsulating PPE
L. Reflective clothing in use?	Not applicable. Heat generated by worker in encapsulating PPE.
M. Ice and/or water-cooled garments in use?	"We try to control the effects of our protective gear through the use of air supply

	tubes that push air across your body to help keep you cool, using ice vests to help keep you cool" (PCAPP-OTG, 2014, p. 13). "ESA operator will be able to place up to four cooling tubes on your person. As you may recall, air will be chilled (possibly purged ahead of time by the CRO) to a nominal 40°F (PCAPP-OTG, 2014, p. 17)". "Entrant may be asked to be cooled down with water" (PCAPP-OTG, 2014, p. 56). "you may be the person who needs to find a process water hose to help cool off him or her (PCAPP-OTG, 2014, p. 37).
N. Wetted undergarments (used with reflective or impermeable clothing) in use?	Not applicable. Heat generated by worker in encapsulating PPE.
O. Circulating air systems in use?	"We try to control the effects of our protective gear through the use of air supply tubes that push air across your body to help keep you cool, using ice vests to help keep you cool" (PCAPP-OTG, 2014, p. 13). "ESA operator will be able to place up to four cooling tubes on your person. As you may recall, air will be chilled (possibly purged ahead of time by the CRO) to a nominal 40°F (PCAPP-OTG, 2014, p. 17)".
P. First Aid Program	"Paramedics … Provide appropriate emergency medical care as per protocol and/or with direction of the CMA to any thermally stressed workers or compromised workers" (PCAPP, 28 July 2014, p. 6). Medics are trained to use advanced life support (ALS) located in training bay. Non-medics are trained to use automated external defibrillator (AED) located in administrative area of training facility.
Q. Trained personnel?	"Ensure that designated PMC staff members are trained and qualified to perform medical screening, real-time biological monitoring, and data entry." (PCAPP, 28 July 2014, p. 8).
R. Provision for rapid cool-down?	"Paramedics … Provide appropriate emergency medical care as per protocol and/or with direction of the CMA to any thermally stressed workers or compromised workers" (PCAPP, 28 July 2014, p. 6). Medics are trained to use fans, ice packs, and intravenous cooling.
S. Procedures for getting medical attention?	"Medical monitoring of entrants includes maintaining radio contact throughout the

	entire process. Failure of the radios or heart rate monitors may result in abortion of the entry until proper function is restored" (PCAPP-OTG, 2014, p. 25). "A dedicated, limited range, secure radio system which provides a means of communication between personnel wearing PPE in Category A and B areas and observers, support personnel, maintenance, medical, and Control Room operators (CROs). This system is wireless, allowing hands-free operation for DPE wearers. The system is comprised of a radio strapped onto the wearer's waist or shoulders, a microphone strapped around the throat and a handset. Each team will have dedicated portable radios. The radios and batteries are waterproof to prevent damage. Team members can communicate among themselves and support personnel Conversations are recorded with CCTV video" (PCAPP-OTG, 2014, p. 49).
T. Transportation to medical facilities readily available for heat stroke victims?	"The entrant will be taken to the PMC for evaluation by the CMA if decontamination or monitoring is indicated. Otherwise, the entrant will be transported to the most appropriate medical facility for treatment" (PCAPP, 28 July 2014, p. 8).
U. Medical Screening and Surveillance Program	"This desk instruction establishes the roles of the various Pueblo Chemical Agent Destruction Pilot Plant (PCAPP) Medical Clinic (PMC) team members in the monitoring and reporting of thermal-related illness or injury. This document identifies conditions that could present a thermal risk for employees at PCAPP and discusses the requirements for the monitoring of workers who may be at risk for the development of thermally-related illness or injury. Additionally, this instruction addresses methods to evaluate environmental and metabolic heat loading and the guidelines for working in hot or cold environments both inside and outside of toxic areas" (PCAPP, 28 July 2014, p. 5).
V. Content?	"Pre-entry medical screening includes testing for blood pressure, heart rate, temperature and urine specific gravity (USG)" (PCAPP-OTG, 2014, p. 57). "**Respiratory Rate** Respiratory rate is monitored over the audio monitor. Any acute distress or severe shortness of breath will be noted. If there are any concerns for the medical well-being of the entrants, they will be questioned by the paramedic. Any comments or responses by entrants suggesting they do not feel well or that they are becoming symptomatic, exhibiting a significant mood change,

	stumbled or slowed gait, or difficulty with motor function skills (i.e. pulling hoses, climbing stairs) will be documented, **Heart Rates** Heart rates will be read back to the paramedic by the entrant or entrant's buddy. These may be evaluated and documented every 10-20 minutes. If at any time the paramedic is concerned about the entrant's heart rate, they may request a heart rate reading. Also, if an entrant does not comply with reasonable requests to confirm the heart rate visually, the monitoring paramedic shall advise the Competent Medical Authority (CMA) and Plant Shift Manager (PSM). The CMA will determine if the entry will be aborted, as this may be a sign of heat injury. If the rate is approaching or exceeds the Maximum Predicted Heart Rate (MPHR), a heart rate reading may be requested and documented more frequently. If any worker demonstrates difficulty with duties or any adverse symptoms, they will be instructed to restrict duties such as pulling hoses and climbing stairs. Depending on the heart rate, an entrant may be asked to rest or be cooled down with water. There will be at least three rest cycles to be followed per the paramedic's direction. Circumstances surrounding the heart rate elevations are relayed to the CMA, so that the CMA can determine whether this entry can continue based on the worker's response to the work" (PCAPP-OTG, 2014, p. 26).
W. Who manages program?	"PCAPP Medical Director (PMD) Ensure that designated PMC staff members are trained and qualified to perform medical screening, real-time biological monitoring, and data entry. Provide medical oversight for PMC staff performing thermal stress screening and biological monitoring" (PCAPP, 28 July 2014, p. 8).
X. Additional Comments: (Use additional pages as needed.)	

Appendix C: Results of Statistical Calculations

Descriptive statistics using SPSS
Analyze > Descriptive Statistics > Frequencies

Table VIII: Description and frequencies

	N		Mean	Median	Std. Deviation	Variance	Range	Minimum	Maximum
	Valid	Missing							
Elapsed min	101	0	108	125	43	1813	208	5	213
Entry Month	101	0	5	5	3	7	11	1	12
Min HR	101	0	102	99	15	238	89	74	163
Max HR	101	0	132	131	19	367	86	87	173
Percent MPHR	101	0	93%	93%	0	132	1	1	1
MHR Reached?	101	0	0	0	0	0	1	0	1
No. Times Exceeded?	101	0	1	0	1	2	7	0	7
C Systolic	97	4	122	122	11	123	44	98	142
C Diastolic	97	4	78	78	6	42	30	60	90
C Resting HR	97	4	81	80	9	81	40	60	100
C Resp Rate	97	4	16	16	1	1	4	14	18
C Temperature	97	4	98	98	0	0	2	97	99
C PE Weight	97	4	215	208	51	2615	226	119	345
C Urine SP Grav	97	4	1	1	0	0	0	1	1
BMI calc	55	46	32	31	7	50	28	23	52
MPHR	101	0	142	144	9	83	34	122	156
Age	101	0	38	36	9	83	34	24	58
Post-Entry Weight	93	8	215	207	51	2589	224	119	343
? Weight	92	9	1	1	1	2	6	-1	5
% change	92	9	1%	1%	1%	40%	3%	0%	2%
Post Entry Temp	95	6	98	98	1	0	3	97	99
Post Entry Systolioc	95	6	121	120	10	99	43	99	142
Post Entry Diastolic	95	6	77	78	8	57	34	60	94
Post Entry Heart Rate	95	6	93	93	12	143	53	69	122

Post Entry Resp Rate	95	6	16	16	1	1	8	12	20
Δ Systolic	94	7	-2	-2	11	116	50	-26	24
Δ Diastolic	94	7	0	0	7	50	40	-22	18
Δ Heart Rate	95	6	13	12	12	136	61	-18	43
Δ Resp Rate	95	6	0	0	1	1	7	-3	4

T-test for equality of means

Procedure:

Comparison of means t-test

1. Develop statistical hypotheses (null and alternative).

Null Hypothesis H_o: xbar (mean) Exceeded = xbar (mean) not exceeded

Alternate Hypothesis H_A: xbar (mean) Exceeded 1 ≠ xbar (mean) not exceeded

2. Choose the appropriate select test or procedure.

Choose the *t* test.

3. Determine the distribution.

Use the *t* distribution.

4. Determine comparison significance level.

Will use α level of P = 0.05 or (95% confidence limits).

5. Formulate decision rule.

We will reject the null hypothesis and accept the alternative if the P value is less than 0.05.

6. Run the test.

SPSS Analyze > Compare means > Independent samples T test

Define Groups > Use specified values Group 1 = 0; Group 2 = 1

Confidence Interval Percentage 95%

7. Conclusion

- Accept the null hypothesis (the correlation coefficient is not significant) for variables where P ≥ 0.05.
- Reject the null hypothesis and accept the alternative hypothesis (the correlation coefficient is significant) for variables where P < 0.05.

Table IX: Group statistics for listed variable and MPHR reached

Group Statistics

	MHR Reached?	N	Mean	Std. Deviation	Std. Error Mean
Elapsed min	0	71	104.94	43.59	5.17
	1	30	116.17	39.68	7.24
Entry Month	0	71	5.13	2.55	.30
	1	30	5.83	2.85	.52
Min HR	0	71	97.93	12.08	1.43
	1	30	111.37	18.33	3.35
Max HR	0	71	123.76	14.79	1.75
	1	30	151.83	12.78	2.33
Percent MPHR	0	71	.87	.09	.01
	1	30	1.06	.05	.01
No. Times Exceeded?	0	71	.00	.00	.00
	1	30	2.47	1.70	.31
C Systolic	0	68	122.13	11.36	1.38
	1	29	123.10	10.63	1.97
C Diastolic	0	68	77.47	6.53	.79
	1	29	77.93	6.39	1.19
C Resting HR	0	68	80.22	7.91	.96
	1	29	81.72	11.24	2.09
C Resp Rate	0	68	15.51	.86	.10
	1	29	15.72	.84	.16
C Temperature	0	68	98.09	.42	.05
	1	29	98.24	.40	.07
C PE Weight	0	68	222.79	48.53	5.89
	1	29	195.48	52.80	9.80
C Urine SP Grav	0	68	1.011	.01	.00
	1	29	1.006	.00	.00
BMI calc	0	35	33.94	7.64	1.29
	1	20	28.31	4.03	.90
MPHR	0	71	141.42	8.11	.96
	1	30	143.53	11.19	2.04
Age	0	71	38.58	8.11	.96
	1	30	36.47	11.19	2.04
Post-Entry Weight	0	65	222.82	48.82	6.06
	1	28	196.07	51.50	9.73
Δ Weight	0	64	1.27	1.36	.17
	1	28	1.93	1.41	.27
% change	0	64	0.55%	0.58%	0.07%
	1	28	0.98%	0.67%	0.13%
Post Entry Temp	0	67	98.28	.61	.07

Group Statistics

	MHR Reached?	N	Mean	Std. Deviation	Std. Error Mean
	1	28	98.36	.48	.09
Post Entry Systolioc	0	67	120.70	8.16	1.00
	1	28	122.54	13.45	2.54
Post Entry Diastolic	0	67	77.15	7.05	.86
	1	28	78.14	8.63	1.63
Post Entry Heart Rate	0	67	90.46	12.24	1.50
	1	28	99.50	8.47	1.60
Post Entry Resp Rate	0	67	15.85	1.12	.14
	1	28	15.79	.63	.12
Δ Systolic	0	66	-1.64	10.77	1.33
	1	28	-1.21	11.04	2.09
Δ Diastolic	0	66	-.52	6.32	.78
	1	28	-.04	8.80	1.66
Δ Heart Rate	0	67	10.24	10.79	1.32
	1	28	18.04	11.95	2.26
Δ Resp Rate	0	67	.34	1.14	.14
	1	28	.07	.98	.18

Table X: Results of t-test for equality of means between listed variable and MPHR

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Elapsed min	-1.21	99.00	.23	-11.24	9.25	-29.59	7.12
Entry Month	-1.23	99.00	.22	-.71	.57	-1.85	.43
Min HR	-3.69	40.06	.00	-13.44	3.64	-20.80	-6.08
Max HR	-9.06	99.00	.00	-28.07	3.10	-34.22	-21.93
Percent MPHR	-13.09	85.99	.00	-.18	.01	-.21	-.16
No. Times Exceeded?	-7.96	29.00	.00	-2.47	.31	-3.10	-1.83
C Systolic	-.39	95.00	.70	-.97	2.47	-5.88	3.94
C Diastolic	-.32	95.00	.75	-.46	1.44	-3.32	2.40
C Resting HR	-.65	40.32	.52	-1.50	2.30	-6.15	3.14
C Resp Rate	-1.11	95.00	.27	-.21	.19	-.58	.17
C Temperature	-1.56	95.00	.12	-.14	.09	-.33	.04
C PE Weight	2.47	95.00	.02	27.31	11.05	5.37	49.25
C Urine SP G	4.08	85.21	.00	.00	.00	.00	.01
BMI calc	3.05	53.00	.00	5.63	1.84	1.93	9.33
MPHR	-.93	42.45	.36	-2.11	2.26	-6.67	2.44
Age	.93	42.45	.36	2.11	2.26	-2.44	6.67
Post-Entry Weight	2.38	91.00	.02	26.74	11.22	4.46	49.03
Δ Weight	-2.13	90.00	.04	-.66	.31	-1.28	-.04
% change	-3.12	90.00	.00	.00	.00	-.01	.00
Post Entry Temp	-.62	93.00	.54	-.08	.13	-.34	.18
Post Entry Systolic	-.67	35.61	.51	-1.83	2.73	-7.37	3.71
Post Entry Diastolic	-.59	93.00	.56	-.99	1.70	-4.37	2.38
Post Entry Heart Rate	-4.13	72.23	.00	-9.04	2.19	-13.40	-4.67

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post Entry Resp Rate	.29	93.00	.77	.07	.23	-.38	.51
Δ Systolic	-.17	92.00	.86	-.42	2.45	-5.28	4.44
Δ Diastolic	-.30	92.00	.77	-.48	1.61	-3.68	2.72
Δ Heart Rate	-3.11	93.00	.00	-7.80	2.51	-12.77	-2.82
Δ Resp Rate	1.11	93.00	.27	.27	.25	-.22	.76

Correlation t-test

Procedure

1. Develop statistical hypotheses (null and alternative).

Null Hypothesis; The correlation coefficient equals 0.

Alternative Hypothesis: The correlation coefficient is not equal to 0.

2. Choose the appropriate select test or procedure.

Choose the *t* test for correlations.

3. Determine the distribution.

Use the *t* distribution.

4. Determine comparison significance level.

Will use α level of P = 0.05 or (95% confidence limits). SPSS also notes where α level of P = 0.01 or (95% confidence limits).

5. Formulate decision rule.

We will reject the null hypothesis and accept the alternative if the P value is less than 0.05.

6. Run the test.

Analyze > Correlate > Bivariate

Correlations Coefficients: Pearson

7. Conclusion

- Accept the null hypothesis (the correlation coefficient is not significant) for variables where $P \geq 0.05$.
- Reject the null hypothesis and accept the alternative hypothesis (the correlation coefficient is significant) for variables where $P < 0.05$.

Table XII: Correlation results between listed variable and MHR

	Pearson Correlation	Sig. (2-tailed)	N	Significance level
Elapsed min	.286	.004	101	significant at 0.01 level
Entry Month	-.011	.917	101	not significant
Min HR	.622	.000	101	significant at 0.01 level
Max HR	1.000	.000	101	significant at 0.01 level
Percent MPHR	.885	.000	101	significant at 0.01 level
MHR Reached?	.673	.000	101	significant at 0.01 level
No. Times Exceeded?	.574	.000	101	significant at 0.01 level
C Systolic	.043	.676	97	not significant
C Diastolic	.097	.347	97	not significant
C Resting HR	.291	.004	97	significant at 0.01 level
C Resp Rate	.141	.168	97	not significant
C Temperature	-.024	.813	97	not significant
C PE Weight	-.280	.005	97	significant at 0.01 level
C Urine SP Grav	-.327	.001	97	significant at 0.01 level
BMI calc	-.182	.183	55	not significant
MPHR	.554	.000	101	significant at 0.01 level
Age	-.554	.000	101	significant at 0.01 level
Post-Entry Weight	-.272	.008	93	significant at 0.01 level
Δ Weight	.249	.017	92	significant at 0.05 level
% change	.355	.001	92	significant at 0.01 level
Post Entry Temp	-.004	.972	95	not significant
Post Entry Systolic	.058	.577	95	not significant
Post Entry Diastolic	.157	.129	95	not significant
Post Entry Heart Rate	.579	.000	95	significant at 0.01 level
Post Entry Resp Rate	.018	.862	95	not significant
Δ Systolic	-.014	.895	94	not significant
Δ Diastolic	.084	.420	94	not significant
Δ Heart Rate	.374	.000	95	significant at 0.01 level
Δ Resp Rate	-.098	.344	95	not significant

Table XII: Correlation results with listed variable and %MPHR

	Pearson Correlation	Sig. (2-tailed)	N	Significance level
Elapsed min	.316	.001	101	significant at 0.01 level
Entry Month	.068	.499	101	not significant
Min HR	.437	.000	101	significant at 0.01 level
Max HR	.885	.000	101	significant at 0.01 level
Percent MPHR	1.000	.000	101	significant at 0.01 level
MHR Reached?	.737	.000	101	significant at 0.01 level
No. Times Exceeded?	.646	.000	101	significant at 0.01 level
C Systolic	.093	.364	97	not significant
C Diastolic	.190	.062	97	not significant
C Resting HR	.129	.208	97	not significant
C Resp Rate	.156	.126	97	not significant
C Temperature	.067	.512	97	not significant
C PE Weight	-.173	.090	97	not significant
C Urine SP Grav	-.304	.002	97	significant at 0.01 level
BMI calc	-.217	.111	55	not significant
MPHR	.105	.294	101	not significant
Age	-.105	.294	101	not significant
Post-Entry Weight	-.175	.094	93	not significant
Δ Weight	.267	.010	92	significant at 0.05 level
% change	.344	.001	92	significant at 0.01 level
Post Entry Temp	.027	.793	95	not significant
Post Entry Systolic	.176	.089	95	not significant
Post Entry Diastolic	.200	.052	95	not significant
Post Entry Heart Rate	.521	.000	95	significant at 0.01 level
Post Entry Resp Rate	.019	.857	95	not significant
Δ Systolic	.045	.664	94	not significant
Δ Diastolic	.045	.670	94	not significant
Δ Heart Rate	.441	.000	95	significant at 0.01 level
Δ Resp Rate	-.112	.282	95	not significant

Plots

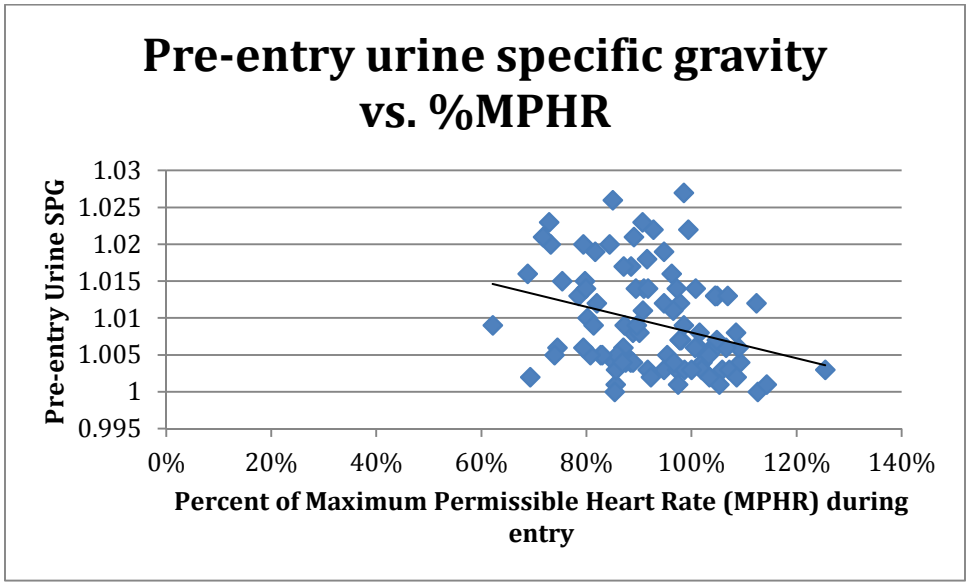

Figure 7: Plot of pre-entry USG vs. % MPHR

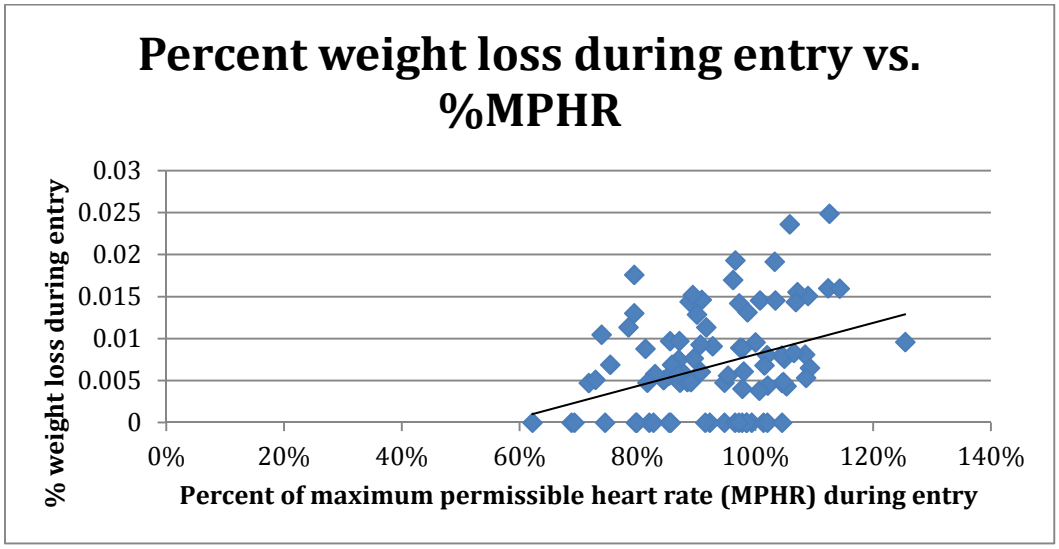

Figure 8: Plot of % weight loss vs. % MPHR

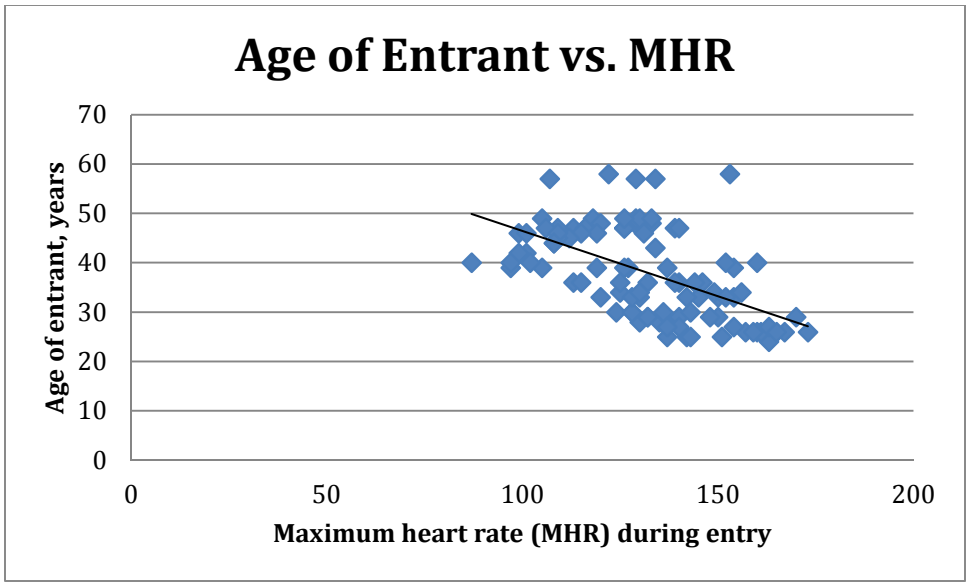

Figure 9: Plot of age of entrant vs. MHR

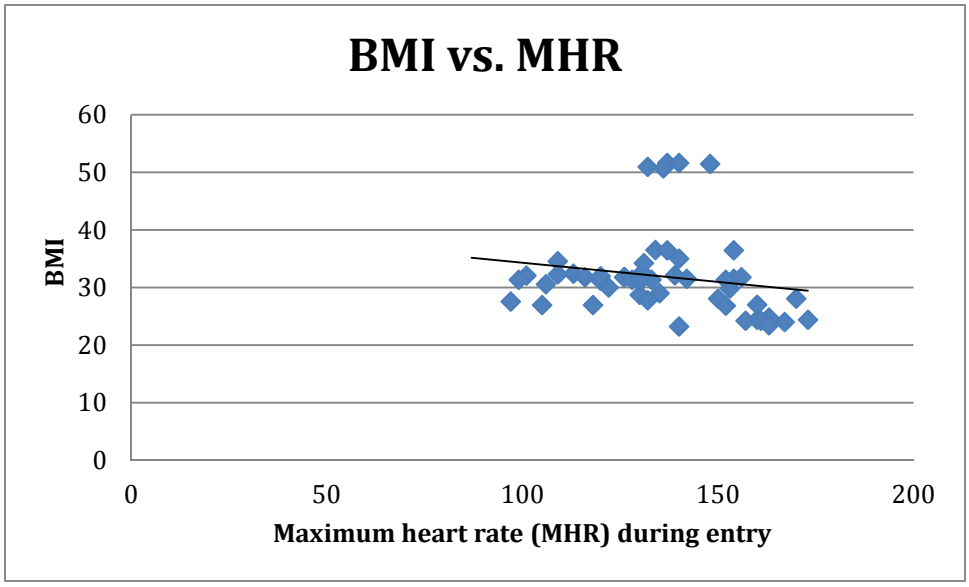

Figure 10: Plot of BMI vs. MHR

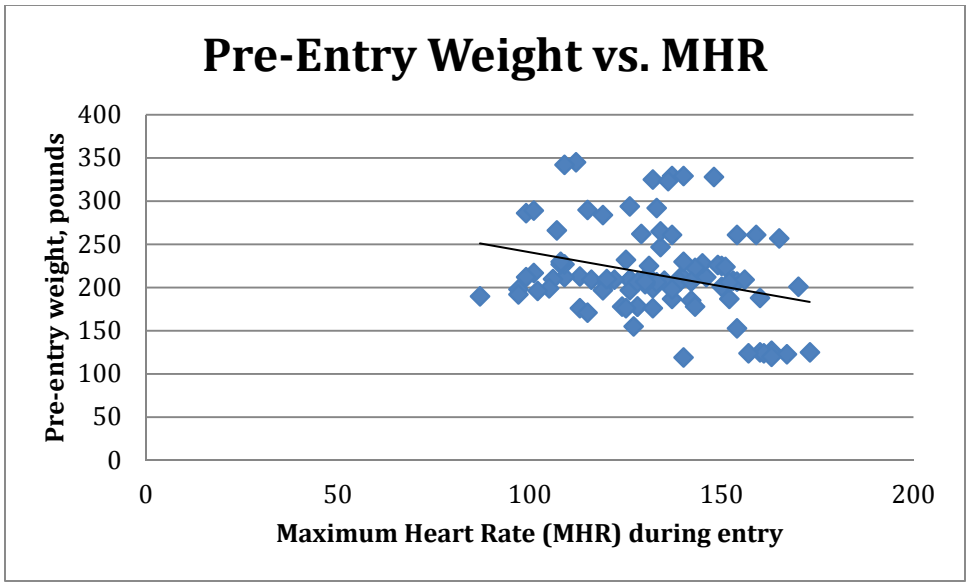

Figure 11: Plot of pre-entry weight vs. MHR