



## **THERMAL HEAT STRESS PROTOCOL FOR FIRE FIGHTERS AND HAZMAT RESPONDERS**

In response to several questions from local affiliates about heat stress, the IAFF Division of Health, Safety and Medicine has developed this protocol for the determination of heat stress in both the fire fighting and HAZMAT scenarios. Since the same paramedics may respond to both these types of emergencies, the same criteria for heat stress should be used in both situations to alleviate confusion.

### **I. BACKGROUND**

Body temperature is directly correlated with the onset of heat injuries, but can be difficult to measure and potentially inaccurate at an emergency scene. A paramedic may be overwhelmed with several fire fighters as patients at one time and have difficulty monitoring the core (rectal) body temperature of each one. As each responder removes his protective equipment, cooling will begin. By the time he reaches a paramedic who can begin thermal monitoring, the skin or surface temperature may no longer reflect the body heat burden. Additionally, fire fighters may drink liquids before they are evaluated, thus invalidating any reading on an oral thermometer. Although a large amount of research has been done comparing body temperature to the onset of heat stress, very few studies have been performed evaluating how heart rate (pulse) and blood pressure can be used to predict heat stress and dehydration in workers wearing protective equipment. Elevations of these measurements in healthy individuals reflect the efforts by the cardiovascular system (heart and blood vessels) to cool the overheated body. In one study heart rate was the only significant predictor of exercise-heat tolerance in young soldiers wearing chemical protective clothing (Armstrong). This equipment stresses the body like HAZMAT and turn-out gear and interferes with cooling in the same way. Finally, pulse may be obtained quickly, even by the responder himself, and paramedics should be familiar with the interpretation of these measurements as they relate to dehydration and shock.

As core temperature rises, the body attempts to cool itself by dilating the blood vessels in the skin and releasing perspiration. In normal situations, the sweat evaporates and carries heat away with it. Humans lose heat through their lungs when they breathe, but this has a negligible effect in the emergency response environment. In a HAZMAT suit, no perspiration can evaporate and the cooling mechanism is greatly impaired. Fire fighting protective clothing allows some evaporation, but fire fighters may be unable to cool fast enough. As body temperature then increases, the responder continues to lose liquid through vain efforts to perspire. Consequently he/she becomes both overheated and dehydrated when dressed in this protective equipment. As the body loses fluid, the heart beats harder and faster to maintain blood to the brain and other vital body organs. This effect is seen as an increase in both pulse (first sign) and blood pressure. Of

course, when working in protective clothing and equipment, the responder generates even more heat and eventually reaches a point when he/she can no longer work. Either he/she becomes simply too fatigued to continue, or he/she pushes himself/herself beyond the normal safe limits. In the excitement of the situation he/she may ignore his body's warnings of heat stress, and allow the core body temperature to become so high that brain function is impaired, or get so dehydrated that the heart cannot maintain adequate blood pressure to the brain, resulting in loss of consciousness. Obviously, either of these latter results could be deadly at a fire or HAZMAT scene.

Conforming to prescribed work/rest cycles in a HAZMAT operation is one way of avoiding the complications of heat stress, but this may be impractical while suppressing a fire. By training fire fighters to monitor their own pulse, and paramedics to measure both pulse and blood pressure, responders who are in acute danger of succumbing to the effects of heat and dehydration can be removed from the environment before they become heat casualties. In previous studies, physically fit workers have been able to work harder and longer before reaching a state of fatigue in a hot environment. Consequently, fit emergency responders, who are evaluated as described below, should be able to work at HAZMAT and fire scenes while avoiding heat stress.

## II. DEFINITIONS

A. Age-Adjusted Maximum Heart Rate (AAMHR): The estimated highest heart rate that an individual can achieve based upon their age. As individuals age the maximum heart rate which they can achieve during activity decreases. This decrease in MHR can be attenuated by exercise. AAMHR is an estimate and may not predict MHR for all individuals. AAMHR is calculated using the formula,  $220 - (\text{age}) = \text{AAMHR}$ .

B. Orthostatic: A term to describe significant dehydration based upon a criteria of an abnormal change in pulse or blood pressure after moving from prone to standing position. Compared to the levels when lying down, an increase in pulse of more than ten beats per minute, or a decrease in systolic blood pressure of more than ten mmHg, after standing for two minutes is indicative of orthostatic dehydration.

C. Steadman Apparent Temperature Index: An index that expresses the combined effect of environmental temperature and humidity on the body. For example, with an environmental temperature of 90°F (32°C) and a relative humidity of 90%, the Apparent Temperature is 122°F (50°C). Thus, the fire fighter exposed to these conditions will experience discomfort similar to that associated with an environmental temperature of 122°F (50 C) at low humidity. ). Additionally exposure to direct sunlight as well as the use of protective clothing will each increase Apparent Temperature by about 10°F (2°C).

**STEADMAN APPARENT TEMPERATURE INDEX  
APPARENT TEMPERATURE SCALE (Fahrenheit)**

Dry Bulb Temperature (°F)	Relative Humidity (%)										
	0	10	20	30	40	50	60	70	80	90	100
68	61	62	63	64	65	66	67	68	69	70	70
70	63	65	66	67	68	69	70	71	72	72	73
72	66	67	68	69	70	71	72	73	74	75	76
74	68	69	70	71	72	73	74	75	76	77	78
76	71	72	73	74	75	76	77	78	79	80	81
78	74	75	76	77	77	78	79	80	81	83	85
80	76	77	78	79	80	81	82	83	85	87	90
82	78	79	80	81	82	83	85	87	89	92	96
84	79	80	81	83	84	86	88	90	93	97	103
86	81	82	83	85	86	89	91	95	99	105	113
88	82	84	85	86	89	91	95	99	105	114	
90	84	85	87	89	92	95	99	104	112		
92	85	87	89	92	95	99	104	112			
94	87	89	91	95	98	103	110	120			
96	88	91	94	97	102	108	117				
98	90	93	96	100	105	113					
100	92	95	98	103	109	119					
102	93	96	100	106	114						
104	95	98	103	110	120						
106	96	100	106	114							
108	97	102	109	118							
110	99	104	112	122							
112	100	106	115								
114	102	108	118								

NOTE: Add 10°F when protective clothing is worn and add 10°F when in direct sunlight.

D. Vital Signs: The pulse, blood pressure and temperature of an individual.

E. Work/Rest Cycles: The number of minutes each hour designated for work and rest, in order to complete a task without producing undue heat stress. These may be developed empirically ("work as long as it takes to breath one bottle of compressed air") or may be based on established criteria, such as the US Army tables below, which are designed for a specific population and require special temperature determination.

**Fluid Replacement Guidelines for Warm Weather Training**  
(Applies to average acclimated soldier wearing BDU, Hot Weather)

Heat Category	*WBGT Index °F	Easy Work		Moderate Work		Hard Work	
		Work/Rest	Water Intake (qt/hr)	Work/Rest	Water Intake (qt/hr)	Work/Rest	Water Intake (qt/hr)
1	78 - 81.9	NL	½	NL	¾	40/20 min	¾
2 (Green)	82 - 84.9	NL	½	50/10 min	¾	30/30 min	1
3 (Yellow)	85 - 87.9	NL	¾	40/20 min	¾	30/30 min	1
4 (Red)	88 - 89.9	NL	¾	30/30 min	¾	20/40 min	1
5 (Black)	> 90	50/10 min	1	20/40 min	1	10/50 min	

Easy Work	Moderate Work	Hard Work
<ul style="list-style-type: none"> <li>• Walking on Hard Surfaces at 2.5 mph, &lt;= 30 lb. Load</li> <li>• Weapon Maintenance</li> <li>• Manual of Arms</li> <li>• Marksmanship Training</li> <li>• Drill and Ceremony</li> </ul>	<ul style="list-style-type: none"> <li>• Walking on Hard Surfaces at 3.5 mph, &lt; 40 lb. Load</li> <li>• Walking on Loose Sand at 2.5 mph, no Load</li> <li>• Calisthenics</li> <li>• Patrolling</li> <li>• Individual Movement Techniques, i.e. low crawl, high crawl</li> <li>• Defensive Position Construction</li> <li>• Field Assaults</li> </ul>	<ul style="list-style-type: none"> <li>• Walking on Hard Surfaces at 3.5 mph, &gt;= 40 lb. Load</li> <li>• Walking on Loose Sand at 2.5 mph with Load</li> </ul>

### III. PROTOCOL

A. Follow simple **preventive measures** to avoid heat injuries, such as maintaining an adequate state of hydration by remembering to drink fluids frequently throughout the day. No additional salt intake is usually necessary before or after dehydration. Emergency responders may be more comfortable with a single layer of porous cotton under their protective gear since this will trap the least amount of heat near the body.

B. Comply with established guidelines for pre-entry **screening** of HAZMAT responders. Any personnel with pulse above 100, blood pressure outside a range from 90/60--150/90 or temperature above 99°F should not be allowed to enter the site. They may enter if these vital signs are normal after a minimum rest period of five minutes. Records must be kept of these measurements on each individual.

C. Allow fire fighters or HAZMAT responders to **work** one work period, for example 30 minutes of a 30-work/30-rest cycle.

D. Measure **heart rate** on each emergency responder (may be measured by worker himself) at the end of the work period, or when he/she voluntarily removes himself/herself early from the work area.

E. If the **pulse exceeds 75%** of the **AAMHR**, the responder worked too long and his next work cycle should be decreased by one third (from 30 minutes to twenty minutes in our example). If the AAMHR is impractical to use, a value of **110** beats-per-minute may be substituted (Skinner). This value is low, but should ensure that all

responders who are at risk of dehydration are adequately followed. Under the AAMHR, a young responder would be "allowed" a much higher pulse, but will suffer no penalty in adhering to this 110 action level, other than being observed during his rest cycle.

1. Remember, the responder must complete his/her 30 minute rest cycle, during which time he/she should **relax** and **rehydrate** under observation by paramedics. His/her pulse should be monitored again after 5 minutes, and if still elevated, he/she should begin aggressive oral rehydration (see G below). Intravenous fluid therapy or other intervention may be instituted during this period if clinically indicated.

2. Before beginning the next cycle, the responder should be evaluated by a paramedic, who will assess his/her condition and measure **vital signs**. If the responder is orthostatic, if his/her vital signs are outside the parameters listed above in part A, or if his/her present blood pressure is below his/her initial blood pressure (taken on HAZMAT responders), then he/she should not return to work until this situation has stabilized. This is evidence of significant dehydration or undue stress imposed by the work environment.

3. Paramedics must be alert for **heat injuries** ranging from heat cramps to heat stroke, and must **record** all of the information on each patient for potential hospitalization of these individuals.

F. If the **pulse** does **not exceed 75% AAMHR** (or 110 as above), the responder can continue to follow prescribed work/rest schedules.

G. **Drink** cool (40°F), dilute fluids at a minimum rate of at least **8 ounces every 15 minutes** or 1 liter( quart)/hour (Skinner). Those who are dehydrated must drink at a rate of 8 ounces every 10 minutes or 1.5 liters/hour. The stomach can absorb fluids no faster than this. Electrolyte replacement solutions, such as Gatorade®, should be diluted first by an equal volume of water. Responders cannot wait until they are thirsty, since they will already be dehydrated by this point.

Local Fire Departments are encouraged to maintain records on this protocol to help IAFF refine it in the future.

#### **IV. TRAINING**

A. Any fire fighting or HAZMAT training drill or exercise should be carefully monitored when Apparent Temperature exceeds 90°F (32°C) and modified or suspended when Apparent Temperature exceeds 105°F (40°C). If protective clothing (fire or HAZMAT) is worn, an adjustment factor of 10°F (2°C) should be added to the environmental temperature before the Apparent Temperature is calculated. Additionally, if the training drill or exercise is being conducted in direct sunlight, an adjustment factor of 10°F (2°C) should be added to the environmental temperature before the Apparent Temperature is calculated.

## V. SOURCES

A. This document was prepared after consultation with LTC Robert Burr, Medical Advisor, US Army Research Institute of Environmental Medicine, Natick, MA 01760, and is based upon the work of Dr. Dave Compton, a former Occupational Medicine physician in the Army, who is now in private practice. He developed a technique based upon his experience and review of the research in this topic.

B. The work/rest tables enclosed are taken from: *Sustaining Health and Performance in the Desert: A Pocket Guide to Environmental Medicine for Operations in Southwest Asia*, Tech. Note 91-2, US Army Research Institute of Environmental Medicine, December 1990.

C. Armstrong, LE, et al., "Prediction of the Exercise-Heat Tolerance of Soldiers Wearing Protective Overgarments", Av Space Env Med, July 1991;62:673-7.

D. Skinner, JS, "Fighting the Fire Within", Firehouse, August 1985;46-8,66.

E. United States Fire Administration, Emergency Incident Rehabilitation, FA-114, July 1992.