NIOSH Response to Peer Review Comments on Draft Document

NIOSH Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments

February 19, 2016

GENERAL COMMENTS		
Reviewer	**Comment**	**NIOSH Response**
General (G)-1	I did want to mention very quickly a pair of related terminology issues: the use of the term "healthy" in a way that excludes obese or pregnant people, and the concept of "exclusion" of the medically unfit. An alternative approach may be to describe these individuals as requiring additional accommodations or adapted acclimatization procedures.	The use of the term "healthy" in most places of the document is not intended to exclude any other groups (e.g., pregnant women). Revisions were made where appropriate in the document.
G-2	This is an exceptionally thorough and well referenced review of the impact of heat on human health and strategies to prevent adverse outcomes, with review of military, sports and voluntary occupational standards. This is a particularly challenging topic, since guidelines need to respect the need for workplace accommodations and to avoid unnecessary job loss among those in the workforce who may be obese, pregnant or older, yet at the same time need to reduce the level of illness and injury currently attributed to workplace heat exposure.	Noted; no response needed.
G-3	The recommendations as currently proposed in the document are couched in terms that are more consistent with voluntary standards or best practices, and it is not clear how they could be applied in construction or agriculture or in small bakeries, as examples. A more useful approach for regulatory standard setting may be to begin with one or more of the existing State-plan OSHA regulations for heat illness prevention and improve on it (them).	Information on State-plan regulations was added to the document. Terminology used for the recommendations in this document is consistent with other NIOSH recommendations.
G-4	Glossary: *Acclimatization - The physiological changes which occur in response to a succession of days of exposure to environmental heat stress that reduce the strain caused by the heat stress of the environment.* Recommend adding: This adaptation to heat stress enables a person to work or exercise in heat stress	Revised as suggested.

	exposure with greater effectiveness and with less chance of heat injury than a person new to a hot environment. Why: The definition uses terms ("physiological changes") that may be intimidating or confusing to some of the persons (e.g., supervisors without technical training related to medicine or biology) using this document.	
G-5	Glossary: Deep Core Body Temperature Recommend change to "Core Body Temperature." Why: Adding "deep" is unnecessary and confusing. (Is "deep core" different than "core"?) ALSO, consider adding a discussion of how core temperature may be measured (e.g., rectal thermometer, esophageal thermometer, etc., and strengths, weaknesses, advantages, and disadvantages of each) either in this section or elsewhere. Why: Core temperature is the critical issue in heat exhaustion and heat stroke. However, determining the true core temperature is not as straightforward as taking an oral or even a rectal temperature.	Deep Core Body Temperature was changed to Core Body Temperature as suggested. The other language regarding measurements is discussed in section 9.4 Physiologic Monitoring rather than the Glossary.
G-6	Glossary: *Heat Cramp - A heat-related illness characterized by spastic contractions of the voluntary muscles (mainly arms, hands, legs, and feet) usually associated with restricted salt intake and profuse sweating without significant body dehydration.* Consider replacing "illness" with "injury" or with "illness or injury." Why: Usually occupational illness refers to something sustained after prolonged exposure. While most heat illnesses could be called injuries using that criterion, heat cramps are generally so transient that "injury" may be a preferable term.	Other recent NIOSH documents refer to heat cramps as an illness, so for consistency this document uses "illness".
G-7	Glossary: *Heat Exhaustion - A heat-related illness characterized by muscular weakness, distress, nausea, vomiting, dizziness, pale clammy skin, and fainting; usually associated with lack of heat acclimatization and physical fitness, low health status, and an inadequate water intake.* Recommend changing to:	Revised as the following: ***Heat Exhaustion:*** A heat-related illness characterized by elevation of core body temperature above 38°C (100.4°F) and abnormal performance of one or more organ systems, without injury to the central nervous system. Heat exhaustion may signal impending heat stroke.

	A heat-related illness or injury characterized by elevation of core body temperature above 100.4° F and abnormal performance of one or more organ systems without injury to the central nervous system. Typical symptoms and signs include weakness, nausea, vomiting, reduced or excessive sweating, dehydration, palpitations, confusion, dizziness, headache, and syncope. Heat exhaustion may signal impending heat stroke and is often related to inadequate water intake. Why: More accurate description. Recommend defining heat exhaustion and heat stroke by their pathophysiology, rather than by their symptoms. (For example, a sprained ankle is better defined as "overstretch or tear of the ankle ligaments" than "pain, tenderness, and swelling of the ankle," which also could be caused by arthritis or infection.)	
G-8	Glossary: *Heat Strain - The physiological response to the heat load experienced by a person, which attempts to increase heat loss from the body in order to maintain a stable body temperature.* Recommend: Consider changing the definition, or, better yet, avoid using the term "heat strain" at all. At least add explanation or clarification. It may be worthwhile to point out that the use of "heat strain" in medical literature has several different meanings, but that in this document it refers to the body's response to heat stress. Why: "Heat strain" is confusing, possibly largely due to the various meanings of "strain." Exerting all one's force is to strain; injuring one's self as a result of over-exertion is also to suffer a strain. The use of heat strain in the medical literature varies from meaning the amount of heat stress to which a person is subjected, to the response to heat stress, to abnormalities in physiology due to excessive heat stress, to failure of body responses to overcome heat stress exposure. It is unnecessary to use "heat strain" as NIOSH defines it, and omitting it may prevent	Text has been modified slightly in response to this comment. The authors agree that heat strain in general may be confusing. However, the definition specifies that the strain is a physiological response to heat, not some other kind of response to heat. The authors believe that a reasonable lay person would be able to understand this distinction. This is a term in the Glossary which must be defined in a brief manner. The concept is expanded in the text in Chapter 1. Recommendations for an Occupational Standard for Workers Exposed to Heat and Hot Environments.

	confusion. For example, see the following definitions. Navy and Marine Corps Public Health Center[1] The resulting abnormality or "distortion" of the body's physiology when exposed to more heat stress than the body is prepared to compensate for at that time. The extreme result is the failure of the body to cool itself (thermoregulation failure), and core temperature rises (often precipitously). US Army[2] Heat strain refers to physiological and/or psychological consequence of heat stress. International Labour Organisation[3] The ultimate criterion in terms of heat strain is an oral temperature of 37.5 ºC. International Olympic Committee[4] The exhaustion that develops when persons exercise in environmental conditions specifically chosen to that thermal balance cannot be achieved.	
G-9	Glossary: *Heat Stroke - An acute medical emergency arising during exposure to heat from an excessive rise in body temperature and failure of the temperature regulating mechanism. It is characterized by a sudden and sustained loss of consciousness preceded by vertigo, nausea, headache, cerebral dysfunction, bizarre behavior, and body temperatures usually in excess of 41.1ºC (106ºF).* Recommend changing to: Injury to the central nervous system from excessive heat stress exposure. Heat stroke is an acute and potentially fatal medical emergency arising during exposure to heat, accompanied by failure of the temperature	Revised to the following: ***Heat Stroke:*** An acute medical emergency caused by exposure to heat from an excessive rise in body temperature (above 41.1ºC (106ºF) and failure of the temperature-regulating mechanism. Injury occurs to the central nervous system characterized by a sudden and sustained loss of consciousness preceded by vertigo, nausea, headache, cerebral dysfunction, bizarre behavior, and excessive body temperatures.

[1] US Navy Bureau of Medicine. NEHC-TM-OEM 6260.6A Prevention and Treatment of Heat and Cold Stress Injuries. June 2007.

[2] US Army. TB MED 507 Technical Bulletin Heat Stress Control and Heat Illness Management. March 7, 2003.

[3] Parsons, Kenneth C. Assessment of Heat Stress and Heat Stress Indices. In Heat and Cold, Vogt J, editor. In Encyclopedia of Occupational Health and Safety, Stellman JM, Editor-in-Chief. International Labor Organization, Geneva. 2011.

[4] Shephard RJ, Astrand PO. The Encyclopaedia of Sports Medicine: An IOC Medical Commission Publication, Endurance in Sport. John Wiley & Sons, Apr 30, 2008. P. 595.

	regulating mechanism, an excessive rise in body temperature, and, often, injury to other organ systems, including rhabdomyolysis, renal failure, and coagulopathy. Core body temperature usually is in excess of 41.1ºC (106ºF), but may be lower, especially (but not only) if cooling has taken place prior to temperature measurement. NOTE: Heat injury, especially heat exhaustion and heat stroke, are now often considered as being on a "continuum," rather than being easily distinguished entities. The idea of a heat injury continuum may be worth mentioning somewhere in this document.	
G-10	Glossary: *Hyperthermia - A condition where the core temperature of an individual is higher than one standard deviation above the mean for the species.* Recommend: A condition where the core temperature of an individual is higher than 100.4° F. Why: "One standard deviation above the mean for the species" is enough to scare anyone!	Revised to the following: ***Hyperthermia:*** A condition where the core temperature of an individual is higher than 37.2°C (99°F). Hyperthermia can be classified as mild (37.2–38.5°C; 99–101.3°F), moderate (i.e., heat exhaustion [38.5–39.5°C; 101.3–103.1°F]), profound (>39.5°C; 103.1°F), or profound clinical hyperthermia (i.e., heat stroke [>40.5°C; 104.9°F]), and death can occur without treatment (>45°C; 113°F).
G-11	Glossary: Define REL & RAL.	Added: ***Recommended Alert Limit (RAL):*** The NIOSH recommended heat stress alert limits for unacclimatized workers ***Recommended Exposure Limit (REL):*** The NIOSH recommended heat stress exposure limits for acclimatized workers.
G-12	This is a very complete and detailed document that has developed over the years to become "the authority" for occupational guidance in understanding and avoiding heat-related injuries. The authors are to be commended for a job well-done.	Noted; no response needed.
G-13	1. <u>Is worker acclimatization clearly explained and presented?</u> I would say yes to the understanding of this process; what is it, how it can be obtained, how long it lasts, how it can be recognized. In the basic physiological background, there is new understanding about the molecular changes that occur with heat acclimation that induce increased thermotolerance. However, this new information may be too detailed to include in this document: the up-regulation of the heat shock response and how this might help to prevent cellular damage,	This text is important to include for the professional audience of this technical document. NIOSH has other products, including educational products, with information about heat stress and acclimatization for other audiences.

	enhance immune response, and maintain gut impermeability, all of which may protect against heat stroke.	
G-14	2. <u>Are there additional recommendations that should be made?</u> I would strongly recommend this document add additional guidelines regarding optimal rehydration solutions during and after work (see next section), list hyponatremia as a heat-related illness, and in discussing heat-intolerant individuals include those susceptible to hyponatremia and water intoxication (this may be related to impaired ADH or aldosterone regulation, or the use of certain medications). In the treatment of heat stroke, the most critical issue is immediate reduction of body temperature. Injury and survival are directly related to the rise in core temperature multiplied by the amount of time with elevated temperature. So, my recommendation is to emphasize that if heat stroke is suspected, immediate active cooling is needed—cold water preferred, cold air next. Workers should not wait until help arrives to start the cooling process. More details about the treatment of heat stroke could be provided in an appendix.	Additional information on hyponatremia has been added to the document as suggested. Additional information on the importance of cooling down a heat stroke victim has been added as suggested.
G-15	3. <u>Is there any additional information on hydration that should be considered?</u> I believe that we now have a better understanding of the risks and benefits of varying drinking solutions to optimize hydration. I was trained and believed in the "Adolf" recommendation that water is the best hydration and rehydration solution. However, based on the recent literature (most notably work by Carl Gisolfi and his disciples), I now believe in the added benefits of dilute carbohydrate/electrolyte solutions instead of only water, in two types of work conditions. I recommend that you more forcefully recommend electrolyte drinks in this document, giving specific guidance as to when and why they would be useful. The first condition where an electrolyte solution may be preferred, is for hydration under conditions of extreme heat with	The issue of proper timing and type of hydration (water vs. "sports drinks") is important. Additional language was added to the text to address this issue. NIOSH does not endorse specific brands or products but additional information about electrolyte drinks was added to the document.

	copious sweating over several hours duration. Under these conditions, if only water were ingested, there could be a risk of hyponatremia. A drinking solution containing small amounts (4-8%) of electrolytes would help preserve plasma osmolality and sodium concentration. In addition if heavy work was involved in the long-duration tasks, a small addition of carbohydrate to the drinking solution could help to preserve muscle glycogen, thus reducing fatigue and associated injuries. The second condition where I believe a dilute electrolyte drink would be advantageous is during recovery from an exhaustive day of heavy sweating and dehydration. Such a rehydration solution would allow for a more rapid and possibly more complete restoration of water/electrolyte homeostasis for several reasons. First, drinking large quantities of water results in a transient hemodilution, increased urine flow, and inhibition of drinking. Over time, as plasma osmolality is restored, drinking is again stimulated. This cycle of drinking and urinating continues over several hours until finally fluid/electrolyte homeostasis is restored. A weak electrolyte solution on the other hand, does not result in as deep a fall in plasma osmolality and sodium concentration. There is less diuresis and a greater retention of the fluid ingested. The electrolyte solution results in faster rehydration due to less inhibition of the thirst response and a greater palatability. One might argue that adding extra salt to a meal would serve the same purpose. But this is more of a “hit or miss method” (depending possibly on what’s for supper and what’s available) and would not introduce the optimal concentrations of salt. Key studies that have confirmed the mechanisms for faster rehydration with electrolyte solutions were performed by H. Nose in the laboratory of Ethan Nadel (Nose H. et al., Role of osmolality and plasma volume during rehydration in humans. J Appl Physiol 65:325-331, 1985; Nose H et al., Involvement of sodium retention hormones during	

	rehydration in humans. J Appl. Physiol 65:332-336, 1985). So the new recommendation could be that dilute carbohydrate/electrolyte solutions should be used by workers under conditions of extreme work in heat that continues for 4 hrs or more, to be taken towards the end of the shift. The workers should be encouraged to use dilute electrolyte solutions for rehydration in the evening, especially in conditions that involve frequent repeated heat stress exposures. There could be an appendix listing some of the appropriate hydration and rehydration drinks.	
G-16	4. <u>Are there any additional risk factors for heat-related illness that should be discussed?</u> I didn't see any discussion of the role of increased gut permeability in the etiology of heat stroke. Any sicknesses or diseases in which gut permeability is compromised could result in a greater susceptibility to gut leakage of endotoxin and the cascade of immune reactions and death that occur with heat stroke. Drugs known to alter gut permeability (NSAIDS for example) might increase risk. Recently our lab has done studies showing how certain foods can influence gut permeability during exercise and heat stress (quercetin ingestion during heat acclimation prevented many of the benefits of heat acclimation including a reduced gut permeability, while glutamine ingestion improved gut barrier function and prevented endotoxin absorption and GI distress). See Zuhl MN et al. Effects of oral glutamine supplementation on exercise-induced gastrointesintal permeability and tight junction protein expression. J Appl Physiol 116:183-191, 2014. Kuennen M et al. Thermotolerance and heat acclimation may share a common mechanism in humans. Am J Physiol 301:R524-R533, 2011.	There are additional risk factors to heat-related illness that can contribute to the development of heat injury. A comprehensive review of the literature on this topic is beyond the scope of this document. Some language has been added in 4.1.6.5 Non-heat Disorders to discuss some of the issues of gut permeability and endotoxins in the role of heat injury. Text was added regarding the consumption of certain foods and the use of non-steroidal anti-inflammatory drugs (NSAIDS) in the susceptibility to heat illness. See section 4.1.4.3, Gastrointestinal Factors.
G-17	5. <u>Are there any additional examples of auxiliary body cooling and protective clothing that should be included?</u> In terms of heat acclimation, another approach used in the South African mines to heat acclimate miners, is "microclimate cooling". Kielblock and associates found they	There are many types of auxiliary body cooling systems on the market for both research and practical industry application. These have been discussed in detail in 6.3 Personal Protective Clothing and Auxiliary Body Cooling. These include ice vests, vests with phase change materials, water cooling

	could maximize productivity while heat acclimating their miners by wearing cooling vests to prevent over-heating during the first few days of work. They found that having cooling in contact with approximately 1/3 of the body surface area allowed enough rise in body temperature to obtain acclimation, while preventing overheating. (Kielblock AJ, etal. Development of microcooling acclimation in the South African gold mining industry. Thermal Physiology, Hales JRS Ed., Raven Press, NY, 1984, 483. Schutte PC, et al., Heat acclimation by a method utilizing microclimate cooling. Aviat Space Environ Med 49:710, 1978). One thing to emphasize during rest/break intervals is the benefits of applying cooling during rest breaks. A classical example of this is firefighters, who during their break immerse their arms in cold water or ice water. This rapidly removes stored body heat without requiring removal of protective clothing except their jacket. Immersion of the arms/hands in cold water has been extensively studied by James House in England in military workers wearing protective clothing (eg., House JR et al., Nav Med Serv 89(1):19-26, 1997). Our lab worked as independent evaluators of a commercially available hand cooling device made by AVAcore and developed at Stanford. We found that this device was marginally effective in resting subjects, but not powerful enough to provide sufficient cooling under conditions of high metabolic heat production (exercise). Simple immersion of hands and forearms in cold water was much more effective and less expensive.	systems in which whole or half-body garments in which cool water is circulated through plastic tubing embedded in the garment which conducts heat away from the skin. There are also vapor compression systems (technology similar to a refrigerator) as well as dry air systems. All of these systems to date have significant limitations within an industrial setting. For example, phase change systems are cheap but their temperature cannot be controlled and they often do not stay cool long enough to be practical. Ice vests have the same limitation. Indeed, if the system is too cold, this will result in peripheral vasoconstriction which reduces the heat transfer from the body to the environment. Water cooling systems require that the person be tethered to a system that circulates the cool water which limits the range that the person may operate in. Many of the systems are too heavy or too cumbersome to be practical in a work environment. The authors agree that these systems may be useful in the work-rest cycle. Text has been added to the document to reflect this.
G-18	6. <u>Are there additional research needs that should be mentioned?</u> Treatment of heat stroke is still a pressing issue. A greater understanding of the mechanisms, and appreciation of why, after a certain point it becomes irreversible, could lead to more effective treatments. What types of medications might help prevent the inflammatory cascade that often results in death?	Added to the Research Needs, Chapter 10.

	The most effective way to prevent hyperthermia would be personal monitoring of deep body temperature. A cheap, safe, ingestible sensor, similar to a heart watch should be developed for clinical and occupational settings.	
G-19	7. Are there additional references that should be included. Other than those already mentioned in this review, a good compendium of heat stress articles is found in: Medical Aspects of Harsh Environments, Vol 2, Textbooks of Military Medicine, Pub by the Office of the Surgeon General (2001), Ed. By KB Pandolf and RE Burr.	Other more recent physiology texts (McArdle et al. 2010) and articles authored by Pandolf are cited; however this specific reference was not added.
G-20	Glossary: Pg 14, hyperthermia definition. Be specific for humans. What is the threshold temperature for humans?	This is defined in the Glossary as a range of body temperatures depending on the severity of hyperthermia.
G-21	Glossary: Pg 15, mean body temperature definition. Should you add the formulas for mean body temp?	The equation for mean body temperature was added to the text as suggested.
G-22	Glossary: Pg 15, mean skin temperature definition. Should you add some example formulas for mean skin temp?	Mean skin temperature is usually determined by measuring the temperature of several areas of the skin and then applying a "weighting" system which takes into consideration the amount of heat transfer over this area of skin. The areas of skin are typically chest, bicep, forearm, thigh, calf and subscapular. The weighting system used by Ramanathan (1964) is generally considered an accurate manner of determining mean skin temperature from these data. The text in the Glossary has been modified accordingly.
G-23	Glossary: Pg 15, tympanic temperature, definition. I would recommend clearly differentiating between tympanic temperature (where a fine wire sensor rests on the tympanic membrane) and ear canal temperature. Tympanic temperature is difficult and painful to measure. Most ear canal measuring devices add a "fudge factor" to correct ear canal to call it tympanic, but actually it is an estimate. Under some conditions (head and face heating), this measurement can over-estimate core temperature.	The authors agree with this comment. What is commonly termed "tympanic" temperature is not the measurement of the actual tympanic membrane but the temperature obtained from a device inserted into the ear canal and aimed at the tympanic membrane. The temperature is an estimate. However, these devices are in common use due to the ease of operation by people who are unaware of the limitations of the device. Text has been added to the Glossary to reflect these differences.

G-24	Glossary: Pg 16, wettedness definition. Expressed as % of skin that is wet?	Two definitions are in the Glossary, one is general and the other expresses as a percent of skin that is wet. No revisions made.
G-25	Glossary: Pg 19, maximum oxygen consumption definition. Correct the symbol. Differentiate between the absolute VO2max (L/min) and the relative VO2max (ml/kg/min). The later value is the value used as an estimate of fitness.	Revised as suggested.
G-26	It is excellent that an updated NIOSH Criteria document has been prepared on this topic, which is already an important occupational health and productivity risk in the USA, and even more so in a number of other sub-tropical and tropical countries.	Noted; no response needed.
G-27	Climate change is ongoing and will continue according to the global scientific assessments. This change will lead to increasing workplace heat exposures in most parts of the world. The NIOSH document can help provide authorities and enterprises plan for current and future protection of workers against heat. It can guide investments in architectural or technical solutions to indoor work environments, as many recent buildings will still be in use 30-50 years from now. To assume that air conditioning is a simple solution to the indoor heat challenges is simplistic and may be very costly in the future, due to need for retrofitting insulation and other heat reduction approaches.	Noted; no response needed.
G-28	It should also be stressed that air conditioning driven by renewable energy systems (e.g. cooling systems driven by direct solar radiation) can become a major need in the future when requirements for renewable energy systems become more stringent.	Noted; no response needed.
G-29	The workers at highest risk for heat effects are those who have to carry out heavy labor outdoors under the sun without any other protection than their clothing. The need is great to ensure proper and sufficient occupational health and safety management for such workers, whether they are self-employed, employed or working in some other context. The competing factors of the need to get as much income as possible via the daily work on the one hand, and the need to slow down, drink water and take rest to	Noted; no response needed.

	avoid heat effects on the other hand, create potentially serious heat impact risks.	
G-30	The overall impression of the document is that it is well prepared and includes a comprehensive description of the problem and the solutions. However, there is considerable repetition of statements about heat exposure and impact facts. It could be useful to edit the text to avoid repetition	Certain information is repeated in the document in several locations for those users that may not read the entire document.
G-31	Glossary: It would make sense to include WBGT and UTCI (Universal Thermal Climate Index) here with a brief description.	The wet-bulb globe temperature (WBGT) and UTCI definitions have been added to the Glossary and outlined in the text.
G-32	Symbols: Using CO for cardiac output is unfortunate, as CO also means carbon monoxide, a chemical of great importance for the cardiovascular system. I note that CO is also used by Wikipedia for cardiac output, but it would make sense to use some other abbreviation.	No revision was made as carbon monoxide is not discussed in this document, and "CO" is explained in the text and is commonly used to refer to cardiac output in physiology.
G-33	Symbols: Another problem is Twb for psychrometric wet bulb temperature. Why not Tpwb, in line with Tnwb?	Authors agree that the Tpwb is in line with the psychrometric measurement of wet bulb temperature. Revised as suggested.
G-34	Acknowledgements: Will the reviewers be mentioned?	Reviewers will be included in the acknowledgements section of the published document.
G-35	**Is worker acclimatization clearly explained and presented?** It is adequately explained, but the extraneous information that is unnecessary detracts from its utility. We physiologists love this stuff and are happy to wade through pages of it. Many, perhaps most of the users are paid to produce and supervise workers, and likely NOT inherently interested in most of the background and intricacies. Can't we create a Summary of Key points and attach background science as appendices? E.g. Table 3.1 is easily used, but most of the background is NOT vital to safety. Why not put key points in a Summary and move rest to support.	There are summaries of important information in the document, such as Chapter 1, but the more complex technical content is important to provide for the professional audiences of this document.
G-36	Even simple things like the definitions and symbols should be placed in appendices to make a more worker/supervisor -useful document.	There is a glossary and symbols section at the front of the document which is the standard format for NIOSH criteria documents.
G-37	One potential solution is to develop a heat stress "Quick Reference Guide" that would be limited to the essentials. E.g. Worker must read to pg 76 to get to the VERY useful Heat	NIOSH has developed other heat-related products with workers as the intended audience. See the NIOSH heat stress topic page:

	Injury guide. That should be among the FIRST things a reader sees.	http://www.cdc.gov/niosh/topics/heatstress/
G-38	In this text, as is, there is a great need to break very long paragraphs into shorter ones for better readability. The language and writing must be targeted to USERS.	The final draft of the text will be edited, which includes a plain language review.
G-39	**Are there any additional recommendations that should be made?** Yes, to the authors: simplify and think of the user. Extra basic science could be included as appendices. Supervisors KNOWLEDGE of their workers and working conditions is invaluable in protecting them from ALL hazards.	The users of this technical policy document will include safety and health professionals, such as industrial hygienists. The intent is to provide the science behind our recommendations for these professionals, as well as other authoritative agencies. NIOSH has other heat-related products for other audiences.
G-40	**Is there any additional information on hydration that should be considered?** YES, there was NO MENTION of hyponatremia until late in Chap 9. If we get too zealous in pushing water- which is good- going too far precipitates hyponatremia!! This needs to come up earlier and more often.	Text has been added to expand on the important issue of hyponatremia and fluid replacement in several areas of the document.
G-41	**Are there any additional risk factors for heat-related illnesses that should be discussed?** ALL PPE increases the risk.	The use of PPE and the heat-related problems associated with its use are discussed throughout the document. Materials used in PPE and type of PPE are included in section 3.3, Effects of Clothing on Heat Exchange.
G-42	**Are there any additional examples of auxiliary body cooling and protective clothing that should be included?** Yes, the “coolshirt” approach seems viable, as does the palmar cooling system.	There are many types of auxiliary body cooling systems on the market for both research and practical industry application. These have been discussed in detail in Chapter 6. These include ice vests, vests with phase change materials, water cooling systems in which whole or half-body garments in which cool water is circulated through plastic tubing embedded in the garment which conducts heat away from the skin. There are also vapor compression systems (technology similar to a refrigerator) as well as dry air systems. All of these systems to date have significant limitations within an industrial setting. For example, phase change systems are cheap but their temperature cannot be controlled and they often do not stay cool long enough to be practical. Ice vests have the same limitation. Indeed, if the system is too cold, this will

		result in peripheral vasoconstriction which reduces the heat transfer from the body to the environment. Water cooling systems require that the person be tethered to a system that circulates the cool water which limits the range that the person may operate in. Many of the systems are too heavy or too cumbersome to be practical in a work environment. The authors agree that these systems may be useful in the work-rest cycle. Text has been added to the document to reflect this.
G-43	p 14. Line 18- Time to redefine Standard man? Avg worker MUCH HEavier than 70 Kg now. See Pg 38 also where this comes up again. Most crucial is in Figs 8.1, 8.2 where "standard man" is the BASIS for the RALs!!!	We agree that the term "standard man" should be redefined due to the fact that the average worker is much heavier that in the past. However, this definition has not yet been officially changed and revising it is beyond the scope of this document. In addition, the "standard man" has always been simply a reference size against which a larger or smaller person is compared. Thus, "exposures" to heat or drugs or some other challenge can still be determined using this reference size.
G-44	We don't know very much about aging and fatness and their independent contributions to heat strain.	This is true, especially since the general population is suffering from an epidemic of obesity. The subject is touched on in Chapter 4 but the area still requires much research. It is also known that aging is a risk factor in susceptibility to heat stroke probably due to reduced circulatory function. This has also been mentioned in Chapter 4 and also requires more research to establish to a greater extent the effects of heat on the aged.
G-45	**Are there any additional references that should be included?** Yes, in appendices should provide the clothing adjustment factor refs mention on pg 41. Again, this <u>needs to be kept simple</u> for users who are NOT trained in work physiology.	The effects of clothing adjustment factors and other issues are discussed in detail in Chapter 3 including Table 3-1 which provides details on these adjustment factors for commonly worn types of clothing. The appropriate references appear in the text and at the bottom of the table.
G-46	Glossary: Pg 12, line 23- Kcal and BTU must be expressed per unit time to be "rates". Pg 13, lines 2, 4: Kcal and BTU are absolute quantities, W is a rate. Which do you mean?	The authors are referring to a rate. Therefore, the proper notation would be $kcal \cdot h^{-1}$ or Watts. BTU has been eliminated from the text. This has been revised to reflect the rate notation.

G-47	Wouldn't this DOCUMENT be MUCH more useful if the relevant Figures & Tables were close to where first cited?	Figures and tables will be closer to their citation in the final publication.
G-48	There is a mix of units and this is a good time to sort through which units are useful and still widely used. I would recommend using only metric/SI units, but understand the value of presenting data in Imperial (US traditional) units. I do recommend dropping Btu in favor of kcal (and their respective rates).	The text using non-metric/SI units was replaced in favor of the metric/SI units wherever possible. There are certain measurements that are not metric but are retained by tradition (blood pressure in mm Hg, for example).
G-49	The metabolic heat generation is described in various ways. My preference is to describe it as metabolic rate. Metabolic heat rate is okay. Other descriptors like metabolism should be avoided.	The authors agree, however describing it in terms of metabolism may resonate better with some readers.
G-50	Using °C and °F when referring to WBGT can be confusing. There is a discussion within ISO on how to distinguish WBGT from basic temperatures with no resolution yet. In the end, it just may have to be context driven.	The authors used °C (°F) because of the diverse audiences reading this document. By providing both – first Celsius followed by Fahrenheit in parentheses, we can service the greatest number of readers of the document.
G-51	Symbols, p. 17/BTU.This does not belong in the table because other units of measure are not included. Also note that the units are Btu not Btu/h. Recommend deleting	Revised as suggested.
G-52	Symbols, p. 17/H. It is not clear why the two w's are here. Joules (J) should be included.	The extra w's have been deleted and replaced with W. Joules (J) was added.

EXECUTIVE SUMMARY		
Reviewer	**Comment**	**Response**
Executive Summary (ES)-1	p. 4, line 3: recommend inserting "cocaine," before "alcohol"	Revised as suggested.
ES-2	p. 4, consider deleting lines 4 – 8 because caffeine is a minor issue	It may be a minor issue, but it is an issue that tends to come up a lot. In addition, new information is included in the Executive Summary, and this is new information that not everyone is readily aware of.
ES-3	p. 4, consider reworking lines 9 – 15 The important sentence is the last one (lines 13- 15), the need to emphasize that, while "hot and dry" is always an emergency, "hot and wet" can also mean heatstroke and the crucial diagnostic criteria is confusion. The emphasis on exertional vs. classical heatstroke is overstated (both in the document and in the references used), since there is clearly an overlap – some frail elderly die while sedentary in apartments where	Educational training on the differences between heat stroke and heat exhaustion often still erroneously differentiates between the two based on sweating vs. not sweating. Some audiences of this technical document may be interested in the comparison between exertional and classical, and providing this information may result in educational training that no longer emphasizes the *no sweating* rule, and instead

	social isolation means they are afraid to open their windows, while most elderly heat stroke victims have been shopping or doing other modest levels of activity. Similarly, although some young athletes may have had fevers prior to the heatstroke, this is by no means relevant for the vast majority. Finally, the workforce includes a wide range of workers, ranging from the young athletes to older, less fit workers, which further blurs the distinction, although increasing the importance of the "wet can still be heatstroke" message.	focuses on cooling the victim and seeking help earlier. Revisions were not made.
ES-4	In the first paragraph page 3 it could be worth mentioning ongoing climate change as an additional factor in the risk of workplace heat stress.	Climate change is mentioned towards the end of the executive summary, where the research needs are briefly summarized.
ES-5	In the fourth paragraph people working in heavy labor jobs should be added to the list of vulnerable people: it is not just children and elderly.	This issue is discussed throughout the document. The purpose of the 4th paragraph was to highlight some of the newer information that was added.
ES-6	In para 2 on line 9 page 4 it would be good to mention Heat Exhaustion and Heat Syncope as two other effects, less serious than Heat Stroke but still of great importance.	Heat exhaustion and heat syncope are discussed throughout the document and mentioned at the beginning of the executive summary.
ES-7	Page 4, para 3, starting line 16, it would be good to mention the ability with modern computers and mathematical models to calculate any of the available heat stress indexes. Such calculations can also be made from weather station data, which means that future heat stress can be estimated form the weather reports.	Additional phrasing was added.
ES-8	Page 4, para 5, line 32: Not only workers, but certainly also the supervisors and local level managers require training on heat risks and prevention, so that the workers are not seen as the only decision makers.	Additional phrasing was added to include training supervisors as suggested.
ES-9	On page 5, line 19, it mentions just "outdoor workers", but it should be mentioned in a separate sentence that many "indoor workers" are also exposed to serious heat stress from the hot ambient weather conditions (e.g. in open walled workshops and in factories or even offices that have not been fitted with effective air conditioning). It should also be mentioned that workers driving air conditioned trucks, tractors or other equipment with cabs may need special	The word "outdoor" was deleted, so that workers include both indoor and outdoor workers. Indoor work environments are mentioned in section 4.1.6, and examples provided in section 4.1.7 Heat-related illnesses and Work.

	arrangements for cooling down if they work outside the cab from time to time. Recently an argument has developed in Texas about keeping the engines of trucks running in order to keep the cab cool when a worker has to do tasks outside the cab. The employer wanted the engines turned off, but the workers say that then the cabs get too hot ….. so what does NIOSH suggest as a solution?	
ES-10	It looks strange to have references inside an Executive Summary. This is not common practice, and the problem is that all statements cannot be referenced with the limited space available.	The final publication was edited to be consistent with the NIOSH style.
CHAPTER 1. RECOMMENDATIONS FOR AN OCC STD FOR WORKERS EXPOSED TO HEAT & HOT ENVIRO		
Reviewer	**Comment**	**Response**
Chapter 1-Comment 1 (1-1)	Page 22, Lines 16-17. Consider deleting the sentence "The bodily response to total heat stress is called the heat strain." (See previous note about heat strain.)	Revised as suggested.
1-2	**Section 1.1.3 Metabolic heat screening estimates** "For initial screening purposes, metabolic heat rates for each worker should be measured as to determine whether the total heat exposure exceeds the applicable RAL or REL." Exactly what does that mean, and how is that to be done? Is it really feasible? (I cannot imagine every heat-exposed worker having his or her metabolic heat rate measured.) Perhaps the following is more feasible. "For initial screening purposes, whether each worker is performing light, moderate, or heavy work should be determined to estimate the metabolic heat rate (to be used in determining whether the total heat exposure exceeds the applicable RAL or REL)."	Revised to: A screening to estimate metabolic heat load should be calculated for each worker who is performing light, moderate, or heavy work, the metabolic heat rate should be determined in order to determine whether the total heat exposure exceeds the applicable RAL or REL.
1-3	**Section 1.1.3 Metabolic heat measurements** Whenever the combination of measured environmental heat (WBGT) and screening estimate of metabolic heat exceeds the applicable RAL or REL (Figures 8.1 and 8.2), the metabolic heat production should be measured using indirect calorimetry (see Chapter 6) or an equivalent method.	The text has been revised to refer to Chapter 5 per reviewer's comment. Also, text has been added to address the measurement or estimate of the metabolic contribution to the heat load on the worker using the Compendium of Physical Activities 2011. Rest-work cycles are addressed in Chapter 6 under Administrative Controls. All of these strategies should be available to the industrial hygienist or physician in order to assess the

	First, I think the reference should say "see Chapter 5" (section 5.3.1.2 is "Measurements of Metabolic Heat by Indirect Calorimetry"). Second, indirect calorimetry as described by 5.3.1.2 does not seem feasible. Why is that even necessary? Why not use guidelines for rest-work cycles, etc.?	heat load on the worker to prevent heat injury or heat stroke.
1-4	**Section 1.1.2, Lines 24-26** "When air- and vapor-impermeable protective clothing is worn, the dry bulb temperature (ta) or the adjusted dry bulb temperature (tadb) is a more appropriate measurement." Do you have any calculations or explanation or reference substantiating that? What about radiant heat?	Reference cited.
1-5	**Page 26, Line 2** The traditional 70 kg man is being used. According to the CDC,[5] average weight for adults ages 20 years and over is for 195.5 lbs (men) and 166.2 lbs (women). Thus, even women are larger than the 70 kg man. It is recommended that a more representative "average worker" size be used.	We agree that the term "standard man" should be redefined due to the fact that the average worker is much heavier that in the past. However, this definition has not yet been officially changed and revising it is beyond the scope of this document. In addition, the "standard man" has always been simply a reference size against which a larger or smaller person is compared. Thus, "exposures" to heat or drugs or some other challenge can still be determined using this reference size.
1-6	**Page 27, Section 1.2.5, Line 26** Rather than providing the physician with "a copy of this recommended standard," wouldn't it be preferable to provide the physician with a summary document he or she is likely to read, possibly either along with this document or containing a link to this document?	Providing the physician with chapter one of the document would be providing them with a summary document.
1-7	**Section 1.2.6, Line 10** What does "detected material stress" mean?	Text has been rewritten for clarity.
1-8	**Section 1.2.6, Lines 14-15** "An opinion as to whether the worker can perform the work required by the job (i.e., physical fitness for the job)" implies a more complete evaluation than simple heat exposure medical surveillance. Rather, it sounds like a job certification examination.	This is covered fully in chapter 7, Medical Monitoring.

[5] http://www.cdc.gov/nchs/fastats/bodymeas.htm (last accessed 2-5-2014).

	Medical surveillance is performed to determine whether the worker may work with hazards without increased risk of adverse health effect and whether there has been unexpected or excessive exposure to occupational hazards. Medical surveillance is not done to determine whether a worker can perform the work required for the job.	
1-9	**Section 1.4.1, Lines 10-12** Recommend deleting "HARMFUL IF EXCESSIVE HEAT EXPOSURE OR WORK LOAD OCCUR HEAT-RELATED FAINTING, HEAT RASH, HEAT CRAMP, HEAT EXHAUSTION, OR HEAT STROKE MAY OCCUR." Those 3 additional lines are unnecessary. They contain unnecessary details (which also are incomplete). Most importantly, however, the extra text decreases the likelihood that the posting will actually be read.	Revised and shortened: **DANGEROUS HEAT STRESS AREA** **HEAT STRESS PROTECTIVE CLOTHING OR EQUIPMENT REQUIRED** **HEAT STROKE OR OTHER HEAT-RELATED ILLNESS MAY OCCUR**
1-10	**Section 1.7.2., Lines 20-21** Decreasing hot air flow without mention of humidity does not seem to take into consideration any potential benefit from increased sweat evaporation that may come from more hot, dry air. (I realize the section is addressing convection, specifically, but it seems to be giving a broad recommendation beyond just convection.)	Section 1.7.2(1)(c) addresses the issue of controlling and reducing humidity for the purpose of taking advantage of sweat evaporation. Therefore, no additional language was added to this section.
1-11	**Section 1.7.3, Lines 18** I recommend deleting the temperature range, either entirely or limiting it to "less than 15° C (59° F)." While very cold water may be absorbed more slowly than 59° F water, people exposed to heat stress are better off drinking almost any non-alcoholic beverage at any cool temperature than they are drinking nothing. Providing water at a specific range is more difficult than providing "cool water," and some people may prefer water colder than 50° F. (Admittedly, 55° water may be better for them than 40° water, but people still may not drink unless the water is cold!)	Rephrased as: "Providing adequate amounts of cool (i.e., less than 15°C [59°F], potable water…"
1-12	1.1.1. Pg 24, ln 16. Define C. Also possibly add to the list of abbreviations RAL and REL.	The ceiling limit was removed from the final publication. REL and RAL were added to the glossary as suggested.
1-13	1.2.1. Pg 26, ln 20. Define what would be the requirements for a "qualified health care	Revised text to the following:

	provider". Possibly also add this to the definitions.	The employer should ensure that all medical evaluations and procedures are performed by or under the direction of the responsible healthcare provider (e.g., licensed physician or other licensed and/or credentialed healthcare professional). Added the AMA definition of a "qualified health care professional" to the glossary. A qualified healthcare professional is an individual who is qualified by education, training, and licensure/regulation and/or facility privileges (when applicable) who performs a professional service within his or her scope of practice, and independently reports that professional service. Section 7.2 Program Oversight provides additional information: "The employer should assign responsibility for the medical monitoring program to a responsible healthcare provider. The responsible healthcare provider should be a qualified physician or other qualified health care professional (as determined by appropriate federal and state laws and regulations) who is informed and knowledgeable about the following…"
1-14	1.2.2. Pg 27, ln 7. What is an acceptable method to assess obesity? Are BMI or height/wt tables acceptable, or must it be a method that actually determines body fat? Use caution in using these indirect assessments of body fat.	Using indirect assessments of body fat should be used with caution because they are not always readily available, may be expensive, and trained personnel need to know how to use them. They are also difficult to standardize. [CDC 2014]: "Calculating BMI is one of the best methods for population assessment of overweight and obesity. Because calculation requires only height and weight, it is inexpensive and easy to use for clinicians and for the general public. The use of BMI allows people to compare their own weight status to that of the general population." Measure height and weight to calculate body mass index according to the following formula:

		body mass index = weight (in pounds) × 703 / [height (in inches)]^2 body mass index ≥30, is considered obese. CDC [2014]. Assessing your weight. [http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html#Interpreted]. Date accessed: September 2014.
1-15	1.7.3. Pg 32, ln 18. I understand the need to encourage workers to drink frequently in a hot environment. However, a set guideline to drink an absolute amount of water every 10-15 min could lead to water intoxication. Say 800 ml every hr for 8hrs, if water is being pushed aggressively when the person is not/or cannot sweat profusely, could lead to hyponatremia. Is there some guideline for when water intake becomes too much? Body weight, symptoms of over-hydration?	Text has been added to address this issue. The issue of hyponatremia is more complex than simply over hydration with plain water as is discussed in the additional text. Guidelines are given according to the American College of Sports Medicine as of 2011.
1-16	p. 22, lines 31 – 33: recommend changing to "One occurrence of heat-related illness in a particular worker indicates the need for medical inquiry about appropriate workplace protections." The emphasis should not be on worker fitness, but on workplace requirements.	Revised as suggested.
1-17	Similarly, on p 23, the use of the term "healthy" to imply non-obese, non-pregnant individuals under the age of 40 is problematic, and I would strongly suggest deleting the term "healthy" in this fashion throughout. Similarly, the concept of explicitly excluding workers should be seriously re-thought. In particular, lines 17, 18, 19 and 21 should be re-written, changing "healthy workers are defined as those who are not excluded from placement…" to "when not otherwise qualified, the term "workers" in this document refer to those who do not require additional protection, modifications in acclimatization procedures, or physiologic monitoring". The term "exclusionary " should be deleted in lines 19 and 21. All subsequent discussion of workers, including at the bottom of the same page, should acknowledge the potential need for additional acclimatization or accommodation.	The use of the term "healthy" in most places of the document is relatively loose, and does not specifically exclude any other groups (e.g., pregnant women). Revisions were made to this section and where appropriate in the rest of the document.

1-18	On p. 25, line 18, provide a link or reference to the measurement recommended, but (as noted in comment on chapter 5) please make sure the recommendation is practically applicable first.	Additional information regarding metabolic heat was added throughout the document where appropriate.
1-19	On p. 28, lines 6 through 20 are problematic and should be re-written to address confidentiality concerns and to refocus on the need for potential modifications of the acclimatization schedule or other workplace accommodations rather than the worker's fitness for heat exposure, including the role any physiologic testing may play (and the role the medical professional will play in implementing such follow-up). Lines 27 – 30 should also be rewritten to focus on the need for exposure assessment, remediation, and workplace modifications rather than on "highly susceptible workers".	Sections 1.2.6 and 1.3.2 were revised as suggested.
1-20	On p. 29, line 16, consider adding "as well as emergency response contact information".	Revised as suggested.
1-21	On p. 30, line 3, consider adding "general first aid as well as worksite specific" before "first aid procedures. On line 29, consider adding "including site-specific contact information" before ", and".	Revised as suggested.
1-22	On p. 33, lines 23 to 28, why should these records be retained for 30 years? What are the long-term consequences, who will accept the records if the employer goes out of business? If this is intended to answer questions about chronic effects following heat exposure, NIOSH has elsewhere found retention of company records to be not useful for research purposes, and has furthermore raised concerns about its own storage capacity. Please consider carefully the goals and whether this section can be modified or eliminated.	This was a previous policy that was removed from the final publication.
1-23	Section 1, page 22: It would be better to use the term "heat exposure" for the measured or calculated external heat that the worker is exposed to. This term would then be a pure environmental variable, which is different from "heat stress', which is the combination of heat exposure and metabolic rate and clothing, and "heat strain", which is the changes in human physiology or pathology that heat causes.	The term environmental heat is appropriate, and is described in section 1.1.2.

1-24	Section 1, page 23: The text refers to 1-hour time-weighted averages. This would obscure situations when excessive heat exposure occurs for shorter periods. If a worker is active for 30 minutes in a WBGT of 35 degr. C and then goes to an air conditioned room for 30 minutes, so the average is less than the standard, is this without risks? The issue of short term variations in heat exposure has not been analyzed enough in this document. (same comment for section 1.1.2)	The issue of TWA as regards to heat exposure will always assume that the worker is not continuously exposed to a constant heat load but will be intermittently exposed. Of necessity, this average will underestimate the higher heat load during the time of exposure. However, the TWA is still useful for establishing administrative and engineering controls as well as rest-work cycles to limit the overall heat exposure experienced during an 8 hour work day. Moreover, the worker is also governed by RAL and REL which will limit the exposure to heat levels that are within safe limits. No revisions made.
1-25	Section 1.1.2, page 25, line 9: Environmental measurements should be made at least hourly ….. this is a big task, and the calculation of WBGT is the key to protection. The paper by Lemke and Kjellstrom, 2012, may give some guidance to calculation methods, which can be stored in an App for use in modern phones or Ipads.	The authors agree that this could be a time consuming task. However, one of the authors uses a hand-held WBGT and hand held anemometer to rapidly (seconds) determine WBGT. Therefore, for an industrial hygienist whose job it is to monitor work environments, taking a reading every hour should not be too onerous. However, a reference to the paper was added.
1-26	Section 1.1.3, page 25, line 18: Metabolic heat rates should be measured. This again is a major task. Can one say “estimated” instead of “measured” and have a list of typical jobs and their typical metabolic rates. Later on non-SI units are mentioned. It would be good to promote the use of SI units in the USA via this document.	Revised to: The metabolic contribution to the heat load on the worker must be estimated or measured to ensure a safe working environment. A screening to estimate metabolic heat load should be calculated for each worker who is performing light, moderate, or heavy work, the metabolic heat rate should be determined in order to determine whether the total heat exposure exceeds the applicable RAL or REL.
1-27	Section 1.4, page 29, line 30: Supervisors and local managers also absolutely need information and training. One cannot assume that they are appropriately aware of the heat risks. (same comment, page 30, line 18).	Added text on the need to train supervisors as suggested.
1-28	Section 1.7.3, page 32, line 18: The amount of water appears much less than what people in very heavy labor would sweat (1 L/hour). I also think this preventive action should be listed at the top, as it is so basic and absolutely necessary in all hot workplaces.	Additional information added for clarification.
1-29	Pg 23, lines 17-24—this language is very advanced and probably offers limited benefit to supervisors/workers. Perhaps this accurate info could be placed in the appendix??	This language is for the occupational safety and health professional audience, and other technical experts.

1-30	23:4, 8 What is "total" heat (combination of environ + metabolic??)? This could be shortened considerably with just a little wording change.	In this criteria document, total heat stress is considered to be the sum of heat generated in the body (metabolic heat) plus the heat gained from the environment (environmental heat) minus the heat lost from the body to the environment. Additional phrasing added for clarity.
1-31	24: lines 25-26- What basis for suggesting that Dry Bulb Temp is better than Globe temp for totally encapsulating clothing??? Cite direct refs.	See reference cited above in relation to the same question from another reviewer.
1-32	Pg 26 top—Example is good, though 70 Kg may not be illustrative of today's bigger workers.	We agree that the term "standard man" should be redefined due to the fact that the average worker is much heavier that in the past. However, this definition has not yet been officially changed and revising it is beyond the scope of this document. In addition, the "standard man" has always been simply a reference size against which a larger or smaller person is compared. Thus, "exposures" to heat or drugs or some other challenge can still be determined using this reference size.
1-33	26:12- oral temp may NOT be adequate for worker monitoring under MANY conditions!!! Cite refs.	Revised to "core body temperature".
1-34	28:25 typo	Revised as suggested.
1-35	The concept of "heat stress protective clothing" is a bit misleading from my view. Personal cooling is a great concept, but that should be clearly stated.	The issue of using cooling PPE is addressed in section 1.5, Protective Clothing and Equipment. The warning label simply emphasizes that the work area carries a risk for heat stress and that special clothing and equipment are needed to protect against that heat stress.
1-36	32 part f- other fluids such as electrolytes may help in short run.	The issue of proper timing and type of hydration (water vs. "sports drinks") is important. Additional language was added to the text to address this issue.
1-37	p. 26, line 15. Medical screening is important. I do advocate for the basic elements contained in this section, but allow that some employers may choose an alternative approach that provides a letter for the employee to give to his/her personal health care provider, and the provider counsels the employee.	These recommendations are in place so as to be no additional cost to the worker and to ensure that the healthcare provider is qualified to assess the worker's health in a particularly hot environment. No revisions made.
1-38	P. 28, line 21. For sentinel events, it would be worthwhile to include other seasonally (heat)	It needs to be clear that these are heat-related events. Revision not made.

	related factors like accidents/injuries, absenteeism, and productivity.	
1-39	P. 31, line 5 thru line 21 on p. 32. My preference is to organize controls into general controls that are implemented above the RAL and job-specific controls that are implemented above the REL. (Job-specific controls for unacclimatized workers can also start at the RAL.) See Bernard, T. E. Thermal Stress in Plog, B (ed), *Fundamentals in Industrial Hygiene*, 6th ed. Chicago: National Safety Council, 2012, for my vision of the control scheme. (an out line is appended to the end of thei review.) There is ample room to disagree with acclimatization. Many references place it in work practices or administrative controls.	Controls are organized according to the Hierarchy of Controls and conform to how controls are listed in other NIOSH documents. No revisions made.
1-40	P. 23, line 15-16. It would be worthwhile to re-evaluate the ceiling limit. Originally it represented a limit based on HSI and a few case studies on heat stroke. I am not sure that it would hold up with better models of heat balance and heat strokes can occur below the current recommendation. The ACGIH decided long ago that there was not support for the ceiling limit and others have not picked up on the idea. I suggest dropping it.	After follow-on discussions with NIOSH subject matter experts, the ceiling limit recommendation was removed since many acclimatized workers live and work in environments that exceed the commonly used ceiling limits.
1-41	p. 25, line 16-17, 20. These are examples of the general comment on metabolic rate. The titles should read: Metabolic Heat Rate	Subheadings deleted to improve clarity.
1-42	1.2.4 This section is vague. If it is describing the need for emergency medical care then it should emphasize potential heat stroke and not a more general signs or symptoms of heat illness. With the more general signs/symptoms, then a first aid / emergency response plan is needed.	Rephrased: “If the worker for any reason develops signs or symptoms of heat stroke or heat exhaustion, the employer should provide immediate emergency medical treatment (e.g., call 911 and cool down the worker). Other non-life-threatening heat-related illnesses may be treated with appropriate first aid procedures (see Table 4-3).”
1-43	1.3. Sentinel events should be designed to identify both individuals at risk and similar exposure groups at risk. The individual is clear; the population surveillance is less so.	We make note of “populations at risk to heat injury or illness”. No revisions made.
1-44	1.4.1. Perhaps the following is more focused on the issues	Rephrased and shortened: **DANGEROUS HEAT STRESS AREA** **HEAT STRESS PROTECTIVE CLOTHING OR EQUIPMENT**

	DANGEROUS HEAT STRESS AREA **VERIFY EMERGENCY PLAN PROVISIONS** **HEAT-STRESS PROTECTIVE CLOTHING OR EQUIPMENT MAY BE REQUIRED** **HEAT STROKE MAY OCCUR** Comments: The dangerous warning establishes the excessive heat exposure and the real risk is heat stroke, and fainting, rash and cramps are a distraction. Exhaustion is in the gray area.	**REQUIRED** **HEAT STROKE OR OTHER HEAT-RELATED ILLNESS MAY OCCUR**
1-45	p. 30, lines 1-15. Items 2 and 3 each have two elements that are somewhat independent. Suggest separating them or recombining to be more coherent (e.g., signs and symptoms with first aid; potential health effects with predisposing factors).	Revised as suggested.
1-46	p. 23, line 10. Check with ACGIH to see how they wish to be referenced. (American Conf … has been dropped in favor of ACGIH.) Also include ® as in ACGIH®. They wish to protect their name. Same for Threshold Limit Value® and TLV®.	The final publication was edited.
1-47	p. 24, lines 24-26. It is not clear how these temperatures are to be used. Adjusted dry bulb is not listed in the Glossary	Explanatory text has been added for clarity.
1-48	p. 25, line 10. There is no reason to suggest summer and winter. The real point is that the environment should be characterized in a way that allows the OHS function to know when heat stress management needs to be activated. For instance, the difference might be normal operations and maintenance. Perhaps the transitions will occur in the spring and fall.	Removed “summer and winter” as suggested.
1-49	P. 29, line 4 and 27. C probably means Ceiling limit. Clarify.	This text was not in the final version of the document as the ceiling limit recommendation was removed based on further expert input and analysis.
CHAPTER 2. INTRODUCTION		
Reviewer	**Comment**	**Response**
2-1	p. 1, line 33, consider changing “unsafe acts” to “heat-related reduction in safety performance”.	Rephrased: “The recommended criteria were developed to ensure that adherence to them will (1) protect against the risk of heat-related illnesses and heat-related reduction in safety performance, (2) be achievable by techniques that are valid and reproducible and (3) be attainable using existing techniques.”
2-2	35:33/ 37:7 —need a :	Revised as suggested.

2-3	p. 35, line 33. The RAL and REL will not protect against unsafe acts (see Ramsey J, Buford C, Beshir M, Jensen R: Effects of workplace thermal conditions on safe work behavior. *Journal of Safety Research* 1983, **14:**105-114 and further interpretation of data in the Thermal Stress chapter in FIH mentioned above. With bias, I have unpublished data from an aluminum smelter, municipal waste employer, and from the Deepwater Horizon cleanup to suggest that acute injuries due to heat stress exposure occur well below the REL.	The REL and RAL are just one component of the recommended criteria which this statement refers to.
CHAPTER 3. HEAT BALANCE AND HEAT EXCHANGE		
Reviewer	**Comment**	**Response**
3-1	**Section 3 and Appendix A** There seems to be very much emphasis on calculations. Is it really necessary to have in the third section of this document? What is the actual application to work sites and workers? Would it not be better to put it all in one place, preferably near the end of the document? I suspect the primary target audience would find the document more readable.	This document is used by a variety of audiences from lay persons to industrial hygienists to industrial physicians and research scientists. Having the appropriate calculations in each of the sections allows the various readers who may be interested in different sections of the document to obtain the information they need without having to read the entire document.
3-2	**Section 3.2, Lines 12** Another reference to the 70 kg man (see prior comment using a more representative average worker size).	We agree that the term “standard man” should be redefined due to the fact that the average worker is much heavier that in the past. However, this definition has not yet been officially changed and revising it is beyond the scope of this document. In addition, the “standard man” has always been simply a reference size against which a larger or smaller person is compared. Thus, “exposures” to heat or drugs or some other challenge can still be determined using this reference size.
3-3	**Section 3.3, Page 41, Lines 3 & 5** Those numbers differ from what the Navy uses and may differ from the ACGIH. Note: check for current ACGIH values, as those have changed.	The authors have reviewed the ACGIH values and added Table 3-2 to account for clothing and other factors. However, the original table of numbers has been retained as it represents values from ISO 2007.
3-4	**Section 3.3, Page 41, Lines 8 - 13** Do you have an explanation for using the adjusted air temperature? Also, include an explanation of whether that value should be	The concept of adjusted air temperature is not discussed in this section. This section deals with the issues of clothing insulation and the problem of heat transfer across the clothing layers and the physiological

	considered as the WBGT Index (i.e., used to determine work-rest cycles, etc.). (In other words, if you use t_{adb}, do you also use a special table or reference to determine heat exposure limits?) What about radiant heat? Also, is that feasible? Or is it preferable to simply add a value (e.g., 10° F for light work and 20° F for heavy work) to the measured WBGT?	consequences of this. T_{adb} is part of the definition of the clo. The reason T_{adb} is used is that the clo measurement depends on a thermal gradient between the skin and that of the air. The degree of mass heat transfer depends on the magnitude of the gradient. The clo unit only addresses the radiant and convective heat transfer from the skin to the air – not conduction or sweat evaporation. Convection and radiation are not affected by humidity unlike sweat evaporation and the insulation provided by clothing often limits or prevents heat conduction through direct contact with a colder object. Therefore, in estimating clo, only dry air temperature is used. Adjusted dry bulb temperature will assign a level of radiant heat and a level of humidity as part of the equation rather that use a measurement from WBGT. Those familiar with the clo will understand that T_{adb} is part of the definition of the clo. No revisions made.
3-5	**Section 3.3.3, Page 46, Line 28** Is it reasonable to expect a worker to maintain 160 bpm for 2 hours?	For a young fit worker, 160 $b \cdot min^{-1}$ represents about 80% of the HRmax. Therefore, this person could maintain 80% HR for two hours. This may not be true for the non-fit worker or the older worker with a reduced cardiovascular reserve.
3-6	3.3. Pg 41, ln 13. Due to limitations of oral temperature which are discussed later in this document, perhaps here it would be better to say "core temperature" should be assessed. It should be determined depending on the situation, whether oral temperature is accurate.	Revised as suggested.
3-7	3.3.2. Pg 44, ln 32. Something is missing from this sentence. …the Lewis number is derived from……..	Revised for clarity.
3-8	3.3.3. Pg 45, ln 24. During heat stress there is a need to increase in blood flow to both working muscle and skin, but not all the cardiac output goes to these 2 places. Some cardiac output still perfuses other organs.	The authors agree and text has been added to address this comment.
3-9	3.3.3. Pg 46, ln 26-29. I think it is dangerous to use absolute HR values like this to estimate an individual's cardiovascular strain. A HR of 140 or 160 for example, represents a much greater strain in a 60 yr old than a 25 yr old. Even corrected for age, there is so much variability in maximal HR that it is dangerous	Agreed. The authors prefer using a percent of HR max rather that an absolute HR. Text has been added to address this comment.

	to use a given HR to determine safety. This HR method is commonly done in gyms, but with an age correction.	
3-10	Section 3.1, page 37, line 23: If WBGT has been estimated, already 4 of these variables are gone form the "equation".	WBGT takes into account dry temperature, humidity, and radiant heat. The heat balance equation takes into account the dry environmental temperature and radiant heat (heat load) and evaporative heat losses (determined by level of humidity).
3-11	Section 3.3, page 40: The clo unit is note mentioned in "Symbols" (page 17) and could be given more prominence at the beginning of this section.	The "clo" unit is defined in the Glossary and is given detailed treatment in subsections of Section 3.3.
3-12	Bottom of pg 44 is interesting but likely will never be useful to workers and work supervisors.	This document is broadly used by diverse audiences including employers, supervisors, industrial hygienists, physicians and research scientists. Therefore, while some sections of the document may not be useful specifically to workers or their supervisors, the information may be extremely useful to professionals who will make decisions at the job site that will significantly affect the worker albeit indirectly. NIOSH has other products intended for workers.
3-13	Pg 46 is a great discussion- BUT, is it necessary?? Same for pg 48!! Great physiology, but this is not a physiology text.	This text is important to retain for the technical and professional readership.
3-14	The clothing adjustment factor concept in too flawed to rely upon See pg 41.	The authors addressed the issues of clothing adjustment factors in this section to make it useful to the readership.
3-15	We badly need a means to predict heat stress accurately under common types of protective clothing such as: • Encapsulating suits of all types and levels, e.g. bunker gear, Level A suits, etc. • Partial body coverage equipment such as soft body armor, welding gear.	The authors agree; no revisions made.
3-16	37:19 the "-" symbol needs to be spelled out for clarity. (i.e. is it a dash?)	Revised to "minus" for clarity.
3-17	Pg 37- conductive gain for those lying on hot metal- welders/tank repair etc. See 38: 4-5	The term "conductive" or K was added to the heat balance equation to acknowledge the importance of conductive heat loss under circumstances (physical contact with hot or cold material that affects a significant percent of the body surface area). Section 3.2.4 Conduction (K) added.
3-18	Pg 38 top- conduction IS important in several types of personal cooling!!!	The authors agree that conduction (K) is important in several types of personal cooling and have added the term to the heat balance

		equation as stated above. Elsewhere, we have also written text about the limitations of heat transfer imposed by personal cooling with limited or no thermal control. The authors have also provided the equations for conductive heat loss in Section 3. Section 3.2.4 Conduction (K) added.
3-19	38:17- give some urls!!!	URLs are not provided because they may not be valid over the expected life of the document. NIOSH does not endorse specific companies or products. We refer the readership to the published material in the Reference section of the document.
3-20	Check/reword PG 40 Lines 16-18.	The text has been reviewed and slightly modified per reviewer suggestion.
3-21	PG 41—There are a number of published papers giving "adjustment factors" for clothing. None were cited. This approach is better than nothing- but there are better approaches.	Several articles were cited in the text in addition to Table 3-1 listing the clothing adjustment factors. In addition, at the bottom of the table, the authors refer to a 2007 ISO standard regarding clothing adjustments. This is sufficient information for the readership to use in an industrial setting. No additional text or references were added.
3-22	PG 41— This section in para 2 seems in error. I.e. physiological monitoring suggested in invalid- not oral, not HR.	The point of the text is that one cannot rely on WBGT (external environmental conditions) to completely predict the heat stress imposed on the person wearing impermeable clothing. One can only determine the effects of heat on that person by making physiological measurements such as heart rate and/or core body temperature – both of which are feasible with proper planning and with the right equipment. The text has been revised for clarification.
3-23	Pg 41- Why the Tdb not the Tglobe? Basis?	The authors did not identify any revisions needed on this page.
3-24	This approach is better than nothing- but there are better approaches.>> Area for RSCH!	Research needs are addressed in Chapter 10.
3-25	Pg 46:17- is misleading. Whereas, it is true w increasing Cardiac Output and thermal gradient more heat is removed, the great Metabolic heat production makes homeostasis MORE challenging, as evidenced by the NIOSH work rate tables. This needs reworking for clarity.	The text discusses the basic physiology of the redistribution of CO mostly to skin and muscle to accommodate both the heat transfer to the environment as well as the supply of oxygenated blood to the working muscle. The authors realize that the increase in metabolism increases heat production during exercise. The increase in work results in an integrated physiological response to address both working muscle and increased

		cutaneous blood flow for heat exchange with the environment. Other areas of the document address the limits of this physiological response in the form of cardiovascular failure, thermoregulatory failure resulting in heat injury and heat stroke. The document addresses these issues. No revisions made.
3-26	P. 40, line 15 thru p. 41, line 17. Referring to Fcl is a bit distracting and does not contribute substantially to the points being made. I suggest being more descriptive. The threshold adjustments for REL and RAL based on the 1986 EPRI document are dated and inaccurate based on more recent research. I suggest following the ACGIH® Clothing Adjustment Factors. There are also published studies on a greater variety of clothing ensembles.	The Fcl is only appears twice in this section of text and it is relevant to the topic being discussed in this section. Although NIOSH removed the Ceiling Limits, the RAL and REL were retained since they have proven to be useful guidelines in the field. The Clothing Adjustment Factors were added to this section per reviewer comment.
3-27	**3.1.** It should be made clear to the reader that this a simple model that is useful for illustration but not for evaluation because the model is quite old. It is probably best presented for work clothes only and using one set of units (preference for Watts and discourage Btu/h). kcal/h is acceptable.	Revised as suggested.
3-28	p. 37, lines 16-22. Drop Δ from ΔS. Emphasize that these are rates (w, kcal/h, etc) Introduce Ereq by setting S=0 and rearranging the equation. This will be useful to the reader as Ereq (and Emax) are referred to in later paragraphs in Section 3.	Revised as suggested.
3-29	P. 37, line 27. Add Malchaire J, Piette A, Kampmann B, Mehnert P, Gebhardt H, Havenith G, Den Hartog E, Holmer I, Parsons K, Alfano G, Griefahn B: Development and validation of the predicted heat strain model. *Annals of Occupational Hygiene* 2001, **45:**123-135 to the list. This is also incorporated into ISO 7933 (2004).	This reference has been added as suggested.
3-30	3.2.3. This is the maximum evaporative cooling (Emax) supported by the clothing and environment. It is not the E on pg 37/16 and 22.	In this section, the first set of equations simply show the theoretical rate of evaporative cooling from the skin unencumbered by clothing. In the next set of equations, the rate of evaporative cooling is

	The Glossary does not define these as rates of energy transfer, but rather amounts of sweat. For this purpose SR (or something similar) would be more appropriate to represent sweat loss.	presented for a typical single layer of clothing. The sweat rate does not, strictly speaking, define the rate of evaporation of sweat because sweat evaporation can be defeated by high relative humidity. Therefore, in an environment with high humidity, sweat rate may be very high but energy transfer due to sweat evaporation may be very low. For this reason, we do not address simply the rate of sweat production alone to model heat transfer due to evaporation.
3-31	p. 46, line 28. Bernard and Kenney also suggest HR limits for different time intervals. See Bernard, T. E. and W. L. Kenney. Rationale for a personal monitor for heat strain. *American Industrial Hygiene Association Journal* 55:505-514, 1994.	The authors prefer using a percent of HR max rather that an absolute HR. Text has been added to address this and a previous comment.
3-32	p. 39, line 1. Instead of "English" units, use either Imperial or US traditional.	The original document used non-metric units in many places. In this updated version, all non-metric units have been converted to metric/SI units as appropriate for current scientific literature. However, to make the revision as broadly usable as possible, non-metric units are provided in parentheses after the metric/SI units.
3-33	p. 46, line 15. kcal is missing a time base – it is likely kcal/h	Revised as suggested.
CHAPTER 4. BIOLOGIC EFFECTS OF HEAT		
Reviewer	**Comment**	**Response**
4-1	**Section 4.1.4.1, Page 55, Line 22** See prior comment about water temperature of cool water for drinking. Delete temperatures entirely or change to "59° F or less" (or 60 or less—but it is 60 or less, change the previous use of "59" to "60" as well).	Revised for consistency.
4-2	**Table 4-1** "Advantages of Being Acclimatization" – either delete "being" or change to "acclimatized." Change acclimatization period to 7-21 days.[6] The following table (see original comments in the folder "peer comments" folder) was based on US Navy research on acclimatization	Revised to "Benefits of Acclimatization". As the original data is unavailable and our other resources cite 7-14 days, the acclimatization period timeframe was not revised.

[6] US Navy Bureau of Medicine. NEHC-TM-OEM 6260.6A Prevention and Treatment of Heat and Cold Stress Injuries. June 2007.

	in 1976, contained in a previous edition of NAVMED P-5010 Manual of Naval Preventive Medicine: Chapter 3: Ventilation and Thermal Stress Ashore and Afloat: Section III. Physiological Principles 3-9. Effects of Heat. (Unfortunately, although we are unable to obtain the original data on which that was based, the previous edition of the Navy technical manual showed that acclimatization continues for 21 days.)	
4-3	**Section 4.1.6.4, Page 64, Lines 5-9** Recommend mentioning the adverse behavioral effects of alcohol on taking appropriate action to reduce heat stress exposure (e.g., seeking rest, water, or air conditioning).	The authors agree that alcohol has behavioral effects that can make a worker unsafe. However, this document is focused on how heat affects the worker, and behavioral changes from alcohol are beyond the scope of this document. Revisions not made.
4-4	**Section 4.1.6.4, Page 66, Line 3** Recommend inserting the statement, "However, virtually any non-alcoholic beverage is better than drinking nothing during heat stress exposure." Why: Many people are strongly opposed to drinking plain water or certain other beverages. While it is agreed that cool water is the ideal sweat replacement beverage, if workers refuse to drink water, the result will be heat stress injuries. Therefore, it is preferable not to restrict fluid replacement to plain water. The only restriction should be of alcoholic beverages, possibly also with a warning that replacing large amounts of fluid (e.g., more than 1 liter) with energy drinks may cause caffeine overdose.	Revised as suggested.
4-5	**Table 4-3** The caption of the table says "illness," but "transient heat fatigue" is an effect or, possibly, a "condition," but not an illness. Either change the caption to say "heat-related condition" or omit transient heat fatigue from the table. (Since there is no first aid indicated, there really isn't any reason to include it, so deletion of "transient heat fatigue" from the table is recommended.) The following table (see original comments in the folder "peer comments" folder) contains only suggested changes or additions to the table, not the original text, except for	In the final publication the table was updated and transient heat fatigue was removed.

	"sodium depletion heat exhaustion." As that is a new row, all suggested text is included. The following are additional means of cooling a heat victim, and should be considered for mentioning in this document: Helicopter downdraft Open car windows Immersion in ice water should be done ONLY IF there can be constant attendance (to prevent drowning) AND those attending the victim have gloves to protect them from cold water and from potential blood-borne pathogen exposure.	
4-6	**Section 4.2.1, Page 80, Lines 2-6** Recommend changing text to read: Heat stroke can be described as either classical or exertional. Classical heat stroke includes: (1) a central nervous system injury (transient or permanent); (2) disordered, usually inadequate, sweating; and (3) a high core body (rectal) temperature. Rectal temperatures are arbitrary values for hyperpyrexia because… Why: When defining heat stroke, it is best thought of first as "a stroke caused by heat." Thus, CNS INJURY is the hallmark, regardless of symptoms. The injury may resolve, may be permanent, may progress, or the victim may die, but CNS injury is the issue. Sweating in heat stroke is variable. Sometimes it ceases, sometimes it continues. Practically, considering sweating is of limited value, as it may be difficult to determine if a soaking wet victim is wet from previous sweating that recently ceased or from water that may have been poured on the victim. Rectal temperatures used in the literature to define heat stroke have varied from 103.1° F and above. Because of difficulties in accurately determining true core body temperatures and because some cooling of victims may have been done prior to temperature measurement, using temperature to define heat stroke is also of limited practical value. Sweating and rectal temperatures may also be misleading in the treatment of heat stroke: a medical care provider may note	The authors agree that you do not diagnose heat stroke by measurement of core temperature alone but within the context of neurological symptoms. The first sentence in this section notes that heat stroke is defined by neurological signs and symptoms. In addition, Table 4-4 outlines the characteristics and differences between "classic" and "exertional" heat stroke and also notes that other organ systems are affected by heat stroke in addition to the nervous system. Text was added for clarification.

	sweating and a rectal temperature of 103 and dismiss heat stroke as a possible diagnosis and treat the patient as a victim of heat exhaustion, when the actual situation is far more dire.	
4-7	**Section 4.2.1, Page 80, Lines 20-21** Change: while waiting for professional healthcare personnel To: while waiting for or transporting to medical care Why: Cooling must be started immediately and continued. Also, the wording implies waiting for medical personnel, which may not occur.	Revised to "Placing the affected worker in a shady area, removing outer clothing and wetting or applying ice to the head, neck, armpits, and groin areas, and increasing air movement to enhance evaporative cooling are all important activities to perform while waiting for or transporting to medical care.
4-8	**Section 4.2.1, Page 80, Line 31** Change "ill worker" to "worker experiencing heat exhaustion or heat stroke"	Revised as suggested.
4-9	Table 4-4, row 2, column 2 ("classical") Change "chronic illness common" to "chronic illness or debilitation common"	Revised as suggested.
4-10	**4.2.2, page 82 Lines 10-14** Change to: Failure to replace water predisposes the individual to one or more of the heat disorders, especially heat exhaustion and heat stroke. Data suggest that cases of heat exhaustion can be expected to occur some 10 times more frequently than cases of heat stroke. Why: Existing text is not completely clear.	Revised as suggested.
4-11	**4.2.3, page 82, line 16-17** Change second sentence of paragraph to: The exact cause (or causes) has not been determined, but heat cramps may be attributable to or associated with a continued loss of salt in the sweat, accompanied by a copious intake of water without appropriate replacement of salt. Why: The actual cause of heat cramps is not yet fully understood.	Revised as suggested.
4-12	**4.2.5, page 83, lines 14-16** Change from:	Revised as suggested.

	Although these heat rashes are not dangerous in themselves, each can result in anhidrotic patchy areas which adversely affect evaporative heat loss and thermoregulation. Wet and/or damaged skin could also absorb toxic chemicals more readily than dry, unbroken skin. To (bold text is simply to show what was changed, not for emphasis and should not be kept as bold text): Although these heat rashes are not dangerous in themselves, each can result in **areas of impaired sweating** which adversely affect evaporative heat loss and thermoregulation. Wet and/or damaged skin **can** also absorb toxic chemicals more readily than dry, unbroken skin. Why: "Anhidrotic patchy areas" is not meaningful to most people reading this text, and the significant issue is impaired sweating.	
4-13	**4.3, page 83, lines 20-29** Delete entire paragraph. Why: This is not a widely accepted and established system, and should not be presented here.	Deleted the paragraph as suggested. New text was added to include the fact that, in severe heat stroke with multiple system damage, long-term sequelae can occur.
4-14	**4.3, page 84, line 3** Add, as an area of research need: Heat cramp etiology and prevention.	Added this research need as suggested.
4-15	4.1.1. Pg 48, ln 11. The anterior hypothalamus is influenced by many factors that can alter the balance between heat loss and heat production, such as thyroid and reproductive hormones, CSF ions and osmolality, glucose, and input from other brain regions related to arousal, circadian variation, and menstrual function. This section is greatly over-simplified.	We have added language to acknowledge this fact. However, this section is not intended to be a comprehensive discussion on all of the neuroanatomy or physiology of the hypothalamus. The section is intended to outline the fact that specific regions in the hypothalamus are involved in thermoregulation based on neural inputs from thermoreceptors in the skin as well as from blood temperature and that a failure of thermoregulation can be traced to this area of the central nervous system. However, text has been added to briefly touch on the points made by the reviewer in order to provide this information to the professional audience.
4-16	4.1.2. Pg 50, ln 14. The oxygen debt is generally considered related to both alactate and lactate components.	The authors agree and have added language in response to this comment.
4-17	4.1.2. Pg 51, ln 2. The lower VO_2max in women is due not only to their lower lean	Agreed and revised as suggested.

	body mass but also to differences in their cardiovascular system including lower hemoglobin and a smaller heart.	
4-18	4.1.4. Pg 53, ln 15. When heat loss by radiation and convection are not effective, then evaporation becomes the only means to dissipate body heat.	The authors agree and made that point in the first sentence of this section.
4-19	Pg 55, section 4.1.4.1. I would include in this section some discussion about the possibility of water intoxication and hyponatremia . True, the risk is much, much less than dehydration, but with very prolonged exposure to heavy sweating and water ingestion such as workers often encounter, hyponatremia is a possibility, especially if they are being aggressively encouraged to drink. Some individuals who have impaired ability to concentrate their urine or have altered ADH or aldosterone function are more susceptible to hyponatremia.	Additional information on hyponatremia has been added to the document.
4-20	Pg 56, section 4.1.4.2. A new area of research is how certain dietary supplements may alter gut permeability and therefore susceptibility to heat stroke. Quercetin for example increases gut permeability and may delay the process of heat acclimation (Kuennen M etal. Thermotolerance and heat acclimation may share a common mechanism in humans. Am J Physiol 301:R524-R533, 2011) while glutamine reduces gut permeability (Zuhl MN et al. Effects of oral glutamine supplementation on exercise-induced gastrointesintal permeability and tight junction protein expression. J Appl Physiol 116:183-191, 2014.). Certain drugs such as aspirin and acetaminophen may lead to liver or kidney damage under heat stress conditions and should be avoided (Medical Aspects of Harsh Environments, Vol 2, Textbooks of Military Medicine, Pub by the Office of the Surgeon General (2001), Ed. By KB Pandolf and RE Burr).	Added: “Current research suggests that certain dietary supplements may impair or alter cellular and systemic adaptions associated with both thermotolerance and heat acclimation in exercising humans [Kuennen et al. 2011].” Aspirin and acetaminophen may cause liver or kidney damage in or not in heat stress conditions (and using both increases the risk for damage to both organs in heat stress conditions) and agree should be avoided. Added aspirin and acetaminophen as well as some other drugs/drug classes to the list of drugs and intolerance to heat.
4-21	4.1.5. Pg 58, ln 1. The primary driver for sweating is core temperature. After acclimatization, sweating begins at a lower core or mean body temperature.	Revised as suggested.
3-4-22	Table 4-1. Pg 59, acclimatization plan. Clarify what is mean by the % of exposure. Would it be the same for an 8 hr and a 12 hr shift?	Additional information added for clarification.

3-4-23	4.1.6.1. Pg 61, ln 5. Aging results in a decreased, not increased level of skin blood flow. This is correctly described later in this document (pg 62, ln 13). The impaired ability to vasodilate the skin compromises convective heat loss. This effect may be reduced however, if the person maintains his fitness as he ages.	Revised as suggested.
4-24	4.1.6.4 Pg 64, ln 20. Include drugs that alter intestinal permeability or may injure the kidney during heat exposure. Aspirin and acetaminophen should not be avoided.	Aspirin and acetaminophen may cause liver or kidney damage in or not in heat stress conditions (and using both increases the risk for damage to both organs in heat stress conditions) and should be avoided. Added aspirin and acetaminophen as well as some other drugs/drug classes to the list of drugs and intolerance to heat.
4-25	4.1.6.6. Pg 66, ln 27. Add information that some individuals are heat intolerant or some are susceptible to water/electrolyte disorders.	The authors agree and have added language and a new reference in response to this comment.
4-26	Table 4-3. Pg 76. I would add water intoxication and hyponatremia to this table of heat-related disorders. I would call the section 3 water/electrolyte imbalances.	Hyponatremia has been added to the table.
4-27	4.2.1. Pg 80. I would emphasize in this section that immediate cooling is critical—damage is related to temperature mulitiplied by the time hyperthermic. So workers shouldn't wait for help to arrive but immediately act to reduce body temperature.	Additional emphasis on immediate cooling added.
4-28	4.2.2. Pg 82, ln 8. Emphasize that it is not just core temperature that determines heat stress, but mean body temperature. Thus, a person in encapsulated clothing with a core temperature of only 38^{o}C can suffer heat exhaustion.	Rephrased to specify "mean" body temperature as suggested.
4-29	4.2.3. Pg 82, ln 21. I would argue that someone who has been sweating heavily for many hours, drinking plenty of water, and showing signs of possible electrolyte imbalance, should be given a drink containing dilute electrolytes and sugar rather than water. Dilute electrolyte solutions will empty the stomach and be absorbed as fast as water, will help to maintain thirst and not trigger diuresis, and are more palatable to encourage a more complete hydration.	Information about consuming a sports drink added as suggested.
4-30	pages 54 and 55, please clarify that salt and potassium supplements, if recommended,	On Pg 62

	would only be needed during the acclimatization period (if then) or under extraordinary circumstances. It might be useful to include a comment about the potential (although uncommon) risk of water intoxication with extreme water consumption as well. Other needs, such as diuretic use, should prompt medical supervision.	Revised to address reviewer's comment about diuretic use: "In theory, a prolonged negative salt balance with a large fluid intake may result in a need for moderate supplementation of dietary salt." Added this sentence as a concluding remark to clarify the dietary supplementation: "Salt and potassium supplements, if recommended by a qualified physician or other qualified health care professional, may only be needed during the acclimatization period or under extraordinary circumstances." "Since some diuretics cause potassium loss, workers taking such medication while working in a hot environment should prompt medical supervision." Water intoxication was addressed with following added information: "During these events or work periods, hyponatremia develops when the athlete or worker consumes too much plain water in an attempt to rehydrate after copious sweating. The excess water results in a dilution of plasma Na^+ which, in turn, causes an osmotic disequilibrium which can lead to cerebral edema (brain swelling) and pulmonary edema. These conditions can be fatal in a small number of patients (Rosner and Kirven, 2007)."
4-31	As noted in the comments on the Executive Summary, care should be taken to clarify that, while age, obesity, pregnancy and other conditions can impact heat tolerance, most jobs can be structured to accommodate such workers safely. Given that they in fact reflect the majority of the workforce, they should be excluded only from jobs, like emergency services or fire safety, for which actual performance criteria have been developed and implemented.	This chapter presents evidence regarding factors that may increase susceptibility to heat stress. Other areas of the document provide recommendations for modifying or better preparing workers at additional risk.
4-32	For pages 67 to 72, the HHE descriptions are interesting and additional detail may be helpful to the reader. However, unless you can add follow-back confirmation of	The HHEs have been summarized and key points have been added for the purpose of this document, however as some readers

	implementation and effectiveness, the somewhat arbitrary lists of NIOSH recommendations at the end of each HHE seem not to add to the value of the overall discussion, and you may want to delete them. Additional detail about acclimatization or other factors from the FACE evaluations would be of interest.	might want more information, links to each HHE have been added.
4-33	The table on p. 76 – 79 could be simplified by deleting the middle two columns, which are already addressed in the body of the text. Transient heat fatigue could be deleted altogether. Since the critical distinction between heat stroke and everything else is CNS dysfunction (hard to convey, but "confusion" may be closest), this should be clarified and repeated at various points.	The middle 2 columns were retained as they provide a useful summary at a glance. Transient heat fatigue was removed as suggested. "Confusion" and "loss of consciousness" were moved higher on the list, and throughout the document are described as key indicators of heat stroke.
4-34	As noted, the distinction between exertional and classical heat stroke is of limited utility and may have been oversold; the importance of distinguishing between a sweating person with heat illness and a still-sweating person with heat stroke is the life and death issue, so clarity on the central importance of confusion is more helpful. I would suggest deleting the table on p. 81.	First aid talks on the differences between heat stroke and heat exhaustion often still erroneously differentiate between the two based on sweating vs. not sweating. Some audiences of this technical document may be interested in the comparison between exertional and classical, and providing this information may result in first aid training that no longer emphasizes the *no sweating* rule, and instead focuses on cooling the victim and seeking help earlier.
4-35	Section 4.1.2, page 51: The work capacity reduction and its relationship to heat and heart rate is described in the recent paper by Sahu et al., 2013.	This phenomenon has been well described in many papers over the years. This information is from a previously published revision of this document.
4-36	Section 4.1.4, page 53: Here suddenly the "heat index" is included. Why not use WBGT as the key heat exposure and heat stress index?	The NOAA heat index chart is readily available and can be read by nearly everyone. A WBGT device is not always available and the reading may not be readily understandable to some people. The authors added some language using the WBGT for completeness.
4-37	Section 4.1.4, page 54, line 14: Why start using mEq as an amount unit? Maybe once, but it would seem more useful to talk about grams. It also says 10-70 mEq = 0.23 – 1.62 g, and later on it says that 23 mEq = 0.23 g. Something is wrong. This whole para is a bit confusing.	The units of grams were added for clarity.
4-38	Section 4.1.5, page 57, line 31: It looks like more water is only needed during the period of acclimatization, but in fact it is needed for	Rephrased for clarification.

	ever after acclimatization has taken place, as the sweat rate stays higher.	
4-39	Section 4.1.6.2 and 4.1.6.3: The lack of details about heat effects during pregnancy, and particularly on pregnant women in jobs that require physical effort, is surprising. Please make a new separate section about this risk group.	Additional information regarding pregnancy was added as suggested.
4-40	Section 4.1.6.6, page 66, line 35. "variability" being an "unexplained problem" sounds a bit vague. There is in fact a lot of thermal ergonomics research data which could be analyzed from the point of view of individual variability, but the published reports usually just report averages. Some of these reports include detailed graphics that show the great individual variation, but this is often overlooked. Some sponsored research by NIOSH could provide variability estimates in the not too distant future.	Noted; no response needed.
4-41	Section 4.1.7.1, page 67 onwards: This is where some more published examples could be included, such as the specific analysis by Cachon et al, 2012, and Dell et al., 2013.	This section provides some NIOSH-related examples with previously reviewed and agreed upon recommendations for the workplaces presented; therefore suggested publications were not added.
4-42	Same section, page 72: The ongoing work by Prof Marc Schenker and colleagues at UC Davis could be referred to here.	This section provides some NIOSH-related examples with previously reviewed and agreed upon recommendations for the workplaces presented; therefore suggested publications were not added.
4-43	Page 76: move the practical immediate actions to the top. Same comment for page 77.	Table has been updated as suggested.
4-44	Page 82: Section 4.2.4 should come before Section 4.2.2 in order to create a systematic trend from most serious (heat stroke) via syncope and exhaustion down to the less serious effects. Should be the same order here as in Table 4-3.	Ordered as: heat stroke, rhabdomyolysis, heat exhaustion, heat cramps, heat syncope, heat rashes.
4-45	top of pg 56 is a great discourse on endocrinology of fluid regulation—but what direct use to workers/supervisors??	This is a technical document with professionals and other technical experts as one of the target audiences; no revisions made.
4-46	The HHEs and recommendations starting on pg 68 were very good; however they should be in the appendices rather than the middle of the reference, and should be conveyed in simpler language.	This is standard format for these documents to include HHEs and other case studies within the body of the document.

4-47	50:11 Association of fatigue w lactic acid accumulation seems incorrect, especially for most workers, and of no practical benefit here. I rec. you eliminate this section.	There are alactate factors that contribute to fatigue and we have added language to the text to address those factors. However, we disagree that lactic acid build up is not a factor in people performing very hard work.
4-48	50:18- suggesting it takes more than 24 hours for lactic acid clearance is not based on science and also unusual even for fluid restoration in healthy humans w access to palatable fluids.	This was part of the original 1986 document. What was meant was that some physiological factors may take up to 24 hour to achieve equilibrium. However, if after a long day of hot work, the person indulges in alcoholic beverages, the diuretic nature of the beverage may leave the person dehydrated for a day or so. Language has been added for clarification.
4-49	Pg 51 :10- do you have refs to support than reductions in PV secondary to dehydration do NOT reduce VO2max? Need those listed here. Contradicted by pg 52, lines 21-27, and pg 53 line 11.	The authors do not claim that reductions in PV do not result in a reduction in VO_{2max}. The authors explain how the cardiovascular system initially responds to the demand for both an increase in blood supply to both the skin and working muscle that, as dehydration continues via the sweating mechanism as well as sequestration of blood in the cutaneous vasculature, this cannot be indefinitely sustained. We also note that decreases in VO_{2max} are not always due to dehydration and may be due to other factors as well. However, we have added text to the section for clarity.
4-50	53: 26-27- ERROR!! Incompensable heat stress does occur often. Whereas this is explained in next para., but it is confusing here without the necessary qualifications.	The authors do not maintain that uncompensable heat stress does not occur fairly frequently. This section of the text is simply to illustrate the physiological adjustments that the body attempts to make in a hot, humid, and physically demanding environment. Then the authors address the issue, in the following paragraph of what happens when those physiological mechanisms fail to dissipate the heat due to the fact that the worker is exposed to an uncompensable heat stress. No revisions made.
4-51	53:35 Bottom- this appears wrong. Even at 100% rh (Wet-bulb =23 C, HI= 26 C) it would take a pretty high metabolic rate prolonged to put someone in serious risk of heat injury—wouldn't it?	That metabolic rate can be achieved by many unacclimatized, dehydrated, obese, or poorly fit workers taking certain medications during the course of the work day under certain conditions. The information is provided to prevent industrial hygienist or occupational physician from being complacent regarding metabolic heat stress (McArdle et al., Exercise and thermal stress. In: Exercise Physiology: Energy, Nutrition, and Human Performance.

		Seventh Edition (McArdle WD, Katch FI, Katch VL, eds) Wolters Kluwer Lippincott Williams & Wilkins, Philadelphia, pp. 634-635, 2010).
4-52	54:7 450 ml= 15.1 Fl Oz NOT 16. Make sure to differentiate between oz weight and ounce volume	Corrected to 15.2 oz.
4-53	54:8 My understanding is that the water loss is pretty evenly distributed over all water compartments. In the old days they even said plasma "sparing" but that is not correct.	This is correct although the authors were attempting to emphasize that the loss of fluid in the intravascular compartment was of great importance to cardiovascular function which is, in turn, significantly involved in thermoregulation. The text has been corrected for clarification.
4-54	Pg 54, line 8 is also contradictory to earlier claims and seems to exaggerate PV losses. If the Hct is 50 and there are 5 liters of blood and if a person sweats at 2L/hr, and if the sweat chiefly comes from plasma… you see the problem, I hope.	This is a follow-on to the previous comment and has been corrected.
4-55	54: 13-18 At least one of these MEq to g conversions is wrong. Check the math here-something is wrong.	Corrected as suggested.
4-56	Pg 55:24 - needs Documentation. Check Jones et al., metered vs bolus drinking.	Text revised per reviewer request and reference added.
4-57	53:35 Bottom- this appears wrong. Even at 100% rh (Wet-bulb =23 C, HI= 26 C) it would take a pretty high metabolic rate prolonged to put someone in serious risk of heat injury—wouldn't it?	That metabolic rate can be achieved by many unacclimatized, dehydrated, obese, or poorly fit workers taking certain medications during the course of the work day under certain conditions.
4-58	Pg 55—Suggest you delete refs to sports and exercise and refer to WORK instead.	Many of the best physiological studies available are focused in sports and exercise. There are relatively few studies involving workers. Sports and exercise references are included for completeness.
4-59	Pg 59: What is 20% exposure? 50%? 80%	Additional information added for clarification.
4-60	61: Fig 4—What is "advanced age" ? Over 40? So state.	Advanced age is discussed in 4.1.6.1, where various references provide differing definitions for when advanced age becomes a risk factor.
4-61	Pg 61:4- document this comment on aging and sweat glands.	Reference added as suggested.
4-62	61:5 Wouldn't INCREASED SBF be advantageous- text must be mis-worded.	Corrected as suggested.
4-63	61:14-62:1>>> if VO2s were lower, how would we know that THIS wasn't the key independent variable??	This would be one contributing factor. The decreased VO2 would result in a greater relative workload which would in turn result in a greater metabolic heat generation which in turn increases body heat that is more difficult to dissipate in the older individual.

4-64	62:8 Pls document this statement. "Total body water decreases with age, which may be a factor in the observed higher incidence of fatal and nonfatal heat stroke in the older group."	Text has been added and reference provided per reviewer comment.
4-65	64; Beta Blockers- shouldn't these common drugs be on list as impacting CV function?	Beta-blockers are included in Table 4-2 (atenolol). Added other examples of beta blockers in text and table as suggested.
4-66	65: 11- Latest research says caffeine has minimal diuretic effects.>> even stronger than line 16 says it. You hit it in the next section—but why confuse the manual users?	Rephrased.
4-67	66:3 Basis for saying water is optimal when you previously recommended electrolyte beverages in high heat?? Water is fine, but so are lots of others- water is not "optimal".	Cool water is preferred over sports drinks for those working hard in a hot environment for less than 1-2 hours. Sweat is hypotonic to plasma and you do not lose that much salt in that period of time. We recommend electrolyte/carbohydrate drinks when exercising in the heat for more than 2 hours.
4-68	65:24- Convert the caffeine dosage to cups of coffee, tea or pop to make it relevant.	Caffeine dosage can vary by brand, so attempting to list cups may be misleading.
4-69	66: 9 Recheck this toxic dose—and it should be expressed as mg/kg!! Give ref.	Revised: "The lethal oral dose for caffeine in humans has been reported to range between 18-50 grams [HSDB 2011]."
4-70	66:34 fix the terminal preposition.	Rephrased as suggested.
4-71	Pg 81, what is DIC?? Claudication?	DIC is disseminated intravascular coagulation. Revised to write this out in the document.
4-72	Pg 83 line 27- language level??	Removed from final publication.
4-73	Table 4-3. First Aid for Heat Stroke There is a reasonable literature to suggest that cold water/ice bath is the most effective immediate (first aid) treatment for heat stroke. For a review, see Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. McDermott BP, Casa DJ, Ganio MS, Lopez RM, Yeargin SW, Armstrong LE, Maresh CM. J Athl Train. 2009 Jan-Feb;44(1):84-93. doi: 10.4085/1062-6050-44.1.84. Strongly recommend that this be encouraged as appropriate in the criteria document and included in discussions of emergency response plans. There are at least 4 other papers to come to the same conclusion.	Information regarding usage of an ice bath added as suggested.
4-74	4.3. Consider including Redmond CK, Emes JJ, Mazumdar S, Magee PC, Kamon E. Mortality of steelworkers employed in hot jobs.	Reference added to discussion in section 10.4 Effects of Chronic Heat Exposure.

	J Environ Pathol Toxicol. 1979 May-Jun;2(5):75-96.	
CHAPTER 5. MEASUREMENT OF HEAT STRESS		
Reviewer	**Comment**	**Response**
5-1	**5, page 85, line 5** Delete "(heat strain)" Why: Use of the term is confusing, as there are several definitions in use outside this document; also, use in this document does not add anything. (See glossary section discussion about heat strain.)	The authors appreciate the comment. However, heat strain is an extremely common term used in the literature to describe the physiological responses to heat exposure (heat stress). Although there may be other descriptors for the physiological responses to heat exposure, heat strain seems to be the most commonly used and understood by the broadest readership. Therefore, the authors retained the use of heat strain to describe the physiological response to heat exposure regardless of the source (metabolic or environmental) in this as well as other sections of the document.
5-2	**5.1, page 85, line 18** Change "industrial" to "occupational" Why: Not all occupational exposure is in "industry."	Revised as suggested.
5-3	**5.1, page 85, line 18 & 5.1.1 line 21** Change "(1) dry bulb (air) temperature" to "(1) air (dry bulb) temperature." Why: **The environmental factor is the air temperature (as measured by the dry bulb), not the dry bulb temperature.**	Revised as suggested.
5-4	**5.1.1, page 86, line 3** Delete "in contact with or" Why: The discussion is addressing air temperature, not the temperature of anything else the thermometer may be touching.	Revised as suggested.
5-5	**5.1.4.2, page 91, line 25** Consider changing "Direct solar radiation comes from the solid angle of the sun's disc" to "Direct solar radiation implies no barrier exists between the sun and the worker." Why: "The solid angle of the sun's disc" may be the correct term, but it is not familiar to me.	Revised as suggested.
5-6	**5.2, page 94 AND ELSEWHERE (e.g., page 95, lines 1-4)** Virtually all heat stress research and work-rest cycles have been based on the WBGT	We agree that the traditional means of measuring environmental heat stress is through the use of a WBGT device. However, not all organizations have, or have access to,

	Index. No other measurement has been established as a reliable substitute. The WBGT Index should be emphasized, and every discussion of other measurements should mention that those measurements must not be relied on or substituted for the WBGT Index. The current document seems to indicate that worksites can rely on weather reports and heat indices, when they can only be helpful guidelines indicating when WBGT Index readings must be carefully followed.	a WBGT. Moreover, some people may not understand what the WBGT temperature is and how it differs from a combination of heat and humidity. Nearly everyone understands that humidity in combination with heat is harder to endure that dry heat alone.
5-7	**5.3.2.1, page 97, line 5** Note that using recent CDC measurements (as referred to previously), male surface area is approximately 2.08 and female surface area is approximately 1.84.	This will no doubt change with time as the population becomes more obese. The calculations for body surface area will take into account the persons anthropometric measurements.
5-8	5.3.1.2. Pg 96, ln 20. Open circuit methodology has come a long way and there are now several portable and even wearable, open circuit oxygen consumption systems commercially available.	Added text to reflect this as suggested.
5-9	the table on p. 93 should be enlarged (perhaps through landscape printing) to be readable.	Desktop publishing will address these changes in the final publication.
5-10	On pp. 95 through 97, it would be helpful to clarify what is background scientific information and how it informs practical recommendations. Additional guidance on whether available apps might help or other references for employers would be useful. Is NIOSH recommending specific approaches to measuring metabolic heat, are they intended for all employers, or are there specific sub groups who should consider using them? More useful guidance would allow readers to factor in protective factors or range of error margins for the ISO “standard man” and “standard woman”.	The document is clear about what is background scientific information. Not all users will have a scientific background and will not care about or use this information. The user with a scientific background will use this information. Other reviewers have mentioned “apps” for this document. We have to assume that this criteria document is the only source available to the user. Therefore, we have not referred to any “apps” that might be available because this is intended to be a “stand-alone” document that does not rely on other information to be useful. We do refer to NIOSH websites where appropriate but the document itself is intended to be a stand-alone. Not all users have access to, or use computers or other hand-held computer systems and yet have a need for this document to be a “stand-alone” tool for their use. NIOSH is not making any recommendations as to how to measure metabolic heat since not all readers of this document have access to all equipment needed. We provide the

		information so that the user can estimate the metabolic heat based on the resources available to that person. This is the best way to reach the broadest audience. The ISO standard man or women is for reference only. The calculations should take into account the individuals height, weight, body surface area, etc. which will give useful numbers for that situation. The difference between those numbers and that of the "standard" man or women will be the adjustment factor needed for estimating protection factors.
5-11	Section 5: Make a clear distinction between measuring: 1. Heat exposure, 2. Heat stress, 3 heat strain.	Text added for clarification as suggested.
5-12	Page 90: call section 5.1.4 "Heat radiation"	Revised as suggested.
5-13	Page 93: this type of diagram is 1950s technology. Why not refer people to Apps and calculation programs available on the NIOSH website, without need for this old-fashioned looking at nomograms.	We cannot make the assumption that "apps" are available to everyone on every job site. Therefore, it is our intent to make this document self-contained and not rely on accessing an "app" to make it work. We refer to NIOSH websites in the document but the document must be able to stand alone to be most useful.
5-14	Section 5.2, page 94, line 26: Heat exposure not "heat stress", as the latter requires more than the environmental data. The ancient methods for measurements referred to in this section should also be updated. See: Lemke and Kjellstrom, 2012, and consider using datalogger climate recording equipment (very user friendly and can be bought for < $100.	Heat stress has been changed to heat exposure. Lemke and Kjellstrom 2012 are mentioned in Ch. 1.
5-15	Table 5-1: Not certain what NIOSH new recommendations are. Is the column to the right the new numbers? What about individual variability and exposure-response relationships?	This is a table for comparison, which has been updated since the last revision of the document.
5-16	Beginning of Chap 5 (and again in Chap 9), around 90+ page which explain in detail ALL options could be in the appendices, since workers need to know only the most common means for measuring WBGT- i.e. an intro to manual and mechanized measurement devices.	Each chapter may be used by different people for different reasons. The details found in each chapter are there for a reason and are to be used by industrial hygienists, occupational physicians, scientists, factory workers, first line supervisors. No revisions made.

5-17	96: The out-of-date Max Planc info might should be replaced with a description of the Cosmed and similar portable spirometry.	We have added language to this section to reflect this.
5-18	97 top- surface areas WRONG (reversed for gender) for humans.	Revised as suggested.
5-19	Table 5.1 is not very useful without considerably MORE explanation.	This is a comparison table, it is of use to industrial hygienists.
5-20	Section 5.2, P. 94, line 25 thru p. 95, line 4. There are more recent models of predicting workplace measurements from ambient conditions than the cited reference. To start, see • Bernard, T. E and M. Pourmoghani. Prediction of workplace wet bulb global temperature. *Applied Occupational and Environmental Hygiene* 14:126-134, 1999. • Bernard, T. E and R. R. Cross. Heat stress management: Case study in an aluminum smelter. *International Journal of Industrial Ergonomics* 23:609-620, 1999. • Logan, P. W. and T. E. Bernard. Heat stress and strain in an aluminum smelter. *American Industrial Hygiene Association Journal* 60:659-665, 1999. (see Fig 6) • Bernard, T. E., C. A. Barrow. Empirical approach to outdoor WBGT from meteorological data and performance of two different instrument designs. *Industrial Health* 51:79-85, 2013 There are others from other investigators.	Relevant references updated as suggested.
5-21	In Chapter 5, care should be given to the case for the symbol for temperature. The glossary uses lower case t and that is respected in the earlier sections. In this section, there appears to be a reversion to T (upper case)	Revisions made for continuity.
5-22	5.1.1.1. Due to environmental hazards, Hg thermometers are seldom used and may be difficult to purchase.	These are readily purchased for research use. However, the reviewer is correct in that the mercury thermometer may not be available for the general public. Text was added in this section.
5-23	p. 87, line 25. The SI units for water vapor pressure is Pascal (kiloPascal)	Corrected with explanatory text.
5-24	p. 91, lines 3-12. MRT was already designated in the glossary as bar-t-sub r.	Glossary updated to reflect the equation in the text.

5-25	p. 94, lines 15-24. This paragraph does not seem relevant to the criteria document	This paragraph provides additional information on heat waves and extreme heat events which some readers may be interested in.
5-26	5.3.1. There are new references. For instance, see GP Kenny	Revised as suggested.
5-27	p. 95, line 5 and p. 97, lines 1-7. It might be worthwhile to cite ISO 8996:2004 Ergonomics of the thermal environment -- Determination of metabolic rate It is a nice layout of the different methods available and applicability.	Reference added as suggested.
CHAPTER 6. CONTROL OF HEAT STRESS		
Reviewer	**Comment**	**Response**
6-1	**6., page 99, line 10** Delete "and strain" Why: See previous comments about heat strain.	The authors disagree because reducing the heat stress will usually reduce the heat strain. No revision made.
6-2	**Table 6-1, page 99, first bullet to the right of "convective load (C)":** The text is somewhat confusing. While blowing more hot air across a worker's skin will warm the worker's skin, if the worker is sweating, there may be a net cooling because the negative heat of vaporization is likely to exceed any convective heating, depending on the actual temperature, wind velocity, and humidity. It is suggested that this be mentioned, either parenthetically or by footnote.	This is a point well taken since the heat of vaporization may overcome the heating effects of the air alone on the skin. However, the recommendation is still a good one since you cannot be sure that, in a humid environment, the heat of vaporization will effectively cool the surface of the skin. No revision made.
6-3	**6.2.1, page 103, line 16** Add: "Scheduling hot work on alternate, rather than successive, days." Why: **Exposure to excessive heat stress on previous days has been associated with heat injuries.[7]** (This—i.e., working in the heat yesterday, rather than having had a heat injury months or years ago—is an additional heat injury predisposing factor that may not have been mentioned.)	Revised to: "When possible, schedule hot jobs for the cooler part of the day (early morning, late afternoon, or night shift) and/or schedule hot jobs on alternate rather than successive days."

[7] Kark JA, Burr PQ, Wenger CB, Gastaldo E, Gardner JW. Exertional heat illness in Marine Corps recruit training. Aviat Space Environ Med. 1996 Apr;67(4):354-60.

6-4	**Tables 6-2 and 6-3, column 1** Is “adjusted temperature” the WBGT Index? (WBGT usually is taken to mean the “Wet Bulb Globe Temperature Index” rather than a F or C value.)	The WBGT is a °F or °C value but it takes into consideration radiant heat, dry heat and humidity in coming up with a temperature called the WBGT. The adjusted temperature for the tables takes a larger number of factors into consideration and adds or subtracts a number of °C or °F to the measured temperature to account for the following factors: Full sun (no clouds): Add 13° Partly cloudy/overcast: Add 7° No shadows visible/work is in the shade or at night: no adjustment For relative humidity of: 10%: Subtract 8° 20%: Subtract 4° 30%: No adjustment 40%: Add 3° 50%: Add 6° 60%: Add 9°
6-5	**6.2.3, page 106, line 20** Change “7 to 14” to “7 to 21” Why: Acclimatization may take 21 days (see prior comments on US Navy research).	Revised as suggested.
6-6	**6.2.4, page 107, line 10** Insert “and first aid” after “prevention” Why: Although first aid is addressed in line 18, it seems it would be best to be complete in line 10.	Revised as suggested.
6-7	**6.3, page 109, line 30** Change “industrial” to “occupational.”	Revised as suggested.
6-8	**6.3, page 110, line 25** Delete. Why: Oral temperatures will be time consuming, will be done inconsistently (improperly), and can be very misleading (as is pointed out elsewhere in the document).	Revised to “core”.
6-9	**6.4.1, page 112, line 8-15** The paragraph is confusing. Does it refer to a specific model?	The text does not refer to a certain model. The text is referring to water cooled garments in general and their characteristics.
6-10	6.2.5. Pg 109, lns 10-16. This Israeli heat tolerance test was used in subjects of a narrow range of age (young army recruits).	Added a note of caution in the text regarding the use of heart rate in determining heat tolerance.

	These absolute HR values should not be used in a population with a wide age range.	
6-11	6.3. Pg 110, ln 25. I would say core temperature, rather than oral.	Revised as suggested.
6-12	Pg 111, section 6.4. I would add another approach to artificial cooling to reduce heat stress, similar to firefighters—to enhance cooling and rehydration during short frequent rest breaks. During the rest breaks (of the work/rest schedules), apply active or passive cooling. For firefighters who don't have time to disrobe, they take off their coats and immerse both arms in cold water. This rapidly lowers body temp, before they have to work again. Another approach to enhance rehydration would be to encourage use of dilute (4-8%) sugar/electrolyte solutions.	Language has been added to reflect the reviewer's comments.
6-13	p. 102, line 23 should be preceded by a discussion of the hierarchy of controls and engineering out heat stress as the primary means of prevention. I would strongly recommend deleting lines 29 through 35, which suggest alternatives to primary prevention. On lines 34 and 35, the phrase " medical screening of workers to eliminate individuals with low heat tolerance and/or low physical fitness" is particularly unfortunate in its Orwellian implications.	Additional information added as suggested along with rephrasing.
6-14	The information on p. 103 is very useful, but would be enhanced if placed in the context of the hierarchy of controls.	Section revised to "Administrative Controls". Other sections revised to better reflect the hierarchy of controls.
6-15	The tables on pp. 104 and 105 are both extremely important and very problematic, since they explicitly provide work/rest guidance for persons "…under the age of 40, physically fit"… Given that the average age for construction workers in the U.S. exceeds 40, what are employers to do?	Additional adjustments may need to be made if the worker has additional risk factors. The tables represent examples of work/rest schedules.
6-16	From p. 106, line 14, through line 6 on page 107, consider re-writing so that the level and speed of acclimatization required for workers is based on specific needs (rather than focusing on the fit and eliminating everyone else). One approach could be to start with the 50% slower approach described on p. 106, lines 28 – 29, and use it as the default, with exceptionally fit workers (as determined by medical screening) able to proceed more quickly.	While it is mentioned that heat tolerance is often enhanced in fit workers, the focus is on how to acclimatize all types of workers, including those new to the job and those with previous work experience. The recommendations for acclimatizing these workers do state "no more than" before the percentages, and the time requirement for the less physically fit workers is mentioned. No revision made.

6-17	On p. 107, consider inserting a new item, "h. First aid response procedures to implement while waiting for emergency medical services to arrive."	"a." includes recognition of heat-related illnesses and first aid. No revision made.
6-18	On p. 108, suggest a new "a", "how to implement appropriate acclimatization" (line 3) and a new "d" "how to monitor and encourage adequate fluid intake and rest breaks". On line 16, change the title to "Medical Surveillance" and consider deleting this entire section (which continues through line 16 on p. 109) or reworking it so that it provides suggestions for physiologic monitoring of potentially at-risk workers, and moving it to the medical surveillance chapter (chapter 7).	Additional points added as suggested. Section 6.2.5 remains in this location as it provides information on screening for heat intolerance which may be of interest to some audiences.
6-19	The question of physiologic monitoring of heart rate and tympanic membrane temperature measurement is discussed in varying places throughout the document, but is essentially dismissed as "intrusive". It is likely to be much less intrusive than job loss, and should be discussed at greater length, particularly as part of a medical monitoring program.	Table 9-1 provides a summary of various examples of physiological monitoring and provides factual and practical information on each.
6-20	On the top of p. 111, insert new item "k. Suspend piece-rate payment mechanisms".	Revised as suggested.
6-21	P. 111 Delete the sentence that begins on line 5 with "To do…"	The sentence was revised to make it more practical to those responsible for improving the safety of those working in a hot environment.
6-22	Section 6.1.1, page 101: Confusing text about 0.6 root function. Why not give clearer examples.	0.6 root was deleted from the sentence for clarity.
6-23	Section 6: It would be useful to include some estimates of costs as well, and to guide the reader on solar driven cooling systems for factories and workshops.	Any estimate of the cost will be outdated by the time of publication of this document. NIOSH cannot endorse any specific products.
6-24	Section 6.2.4, page 107: supervisors and managers also need training.	Additional wording added to emphasize training workers and supervisors as suggested.
6-25	Section 6.5, page 113: Performance degradation due to heat at work is a very important issue for productivity and economic output. Some references have already been supplied (nrs 2-4) and the following ones describe further research on this topic. The only assessment available with economic loss calculations for 2030 of increasing workplace	Noted; no response needed.

	heat is the Climate Vulnerability Monitor, 2012 (DARA, 2012). This report calculates the losses in the USA to US$ 50 billion annually by 2030.	
6-26	Pg 112- the discussion of inlet temps for water cooling is probably FAR beyond the control of the users of this doc. Good Appendix material	The audience is mixed and includes technical experts. This information was retained in the body of the document.
6-27	108--2 hours in an environmental chamber does NOT seem practical for 99% of workforce as a means to identify heat intolerance practically.	The authors agree that this may not be a practical test for everyone. The chamber test is one of several means for detecting heat intolerance in potential workers. The entire section deals with this topic. However, there are facilities where this type of testing can be conducted and, if necessary, the organization can send their workers to be tested in an environmental chamber in the manner described. This text was retained for completeness.
6-28	110 line 25 g—I do NOT believe oral temp will work validly here. Pls provide direct research reports to support this.	The term “core” temperature has been substituted for “oral”.
6-29	111 The prescriptions of cooling required seem to assume NONE of the cooling produced is lost to the environment- which rarely is accurate.	The authors agree that some of the cooling will be lost to the environment. However, the concern is not about how much of the cooling is lost to the environment but how effective the cooling provided is in reducing the thermal burden on the person. Therefore, the authors did not calculate the percent of cooling loss to the environment.
6-30	111, line 28, “cooling vests” tells us almost nothing. Do you mean “phase change” cooling systems??	The text describes several types of cooling vests including those mentioned by the reviewer, i.e., phase change and ice cooling vests. No revision made.
6-31	112 The info on W delivered needs a ref.	This text is from the 1986 NIOSH document. The primary reference was not documented.
6-32	The whole section on Personal cooling might better be replaced or supplemented by a table that shares the benefits and liabilities of the current options. (See #1 above).	The text provides a general description of personal cooling technologies, their advantages and disadvantages of using them. Each cooling system would be expected to share in these advantages and disadvantages. No revision made.
6-33	Table 6-2. I have not reviewed this table to confirm that it is consistent with the REL. The reference to ACGIH (1993) does not provide enough detail to locate the source. The origin may be the US Army because it refers to under 40.	Table 6-2 is provided as an example of a work/rest schedule. Reference information corrected.

	Overall, this is an important table that may not be based on the same protective limits as the REL.	
6-34	6.4. A good review of studies performed by USARIEM is available and helpful. It will help frame the importance of heat transfer rate from skin to heat sink or transfer fluid (and from transfer fluid to sink), the capacity of the heat sink, the surface area covered, etc. (See Speckman KL, Allan AE, Sawka MN, Young AJ, Muza SR, Pandolf KB. Perspectives in microclimate cooling involving protective clothing in hot environments. International Journal of Industrial Ergonomics. 1988; 3:121-147.) There are many papers available on cooling systems. Some caution should be offered that bandanas and head coolers are not very effective (small surface area) although they may offer some comfort.	The authors considered the reference but the document describes the heat transfer concepts adequately for the purposes of informing the IH or physician and contains more recent references than the one offered by the reviewer. There is also much text about auxiliary cooling systems and bandanas and head coolers were not emphasized. The reviewer correctly asserts that bandanas and head coolers may offer comfort but probably inadequate cooling.
6-35	p. 106, line 2. The major source of heat gain is the metabolic heat generation and the major loss is evaporative cooling. Reconsider this statement. There is value to reduce the work demands (e.g., metabolic rate).	A major source of heat gain is metabolic and heat loss is evaporative. But this holds true only for the given environment. A person can be sitting in a hot environment with a low metabolic contribution to the heat and have a significant heat gain. In addition, a person may be sweating profusely in an environment with high humidity and receive no benefit from sweat evaporation. The issue of the metabolic contribution to the heat load and heat transfer due to sweat evaporation in several sections of the document. The authors believe that those interested readers would be able to find that information readily in the other sections of the document. In addition, the document discusses in several sections the strategy of reduction in workload as a means to reduce the metabolic heat production and, therefore, the heat strain experienced by the person.
6-36	p. 99, line 2. The heat balance equations are different between here and Section 3.	Corrected.
6-37	Table 6-1 I. Controls should be Engineering Controls II. Consider calling work practices Administrative Controls	Revised as suggested.

	Work practices (in my mind) tend more toward work rules and practices.	
6-38	6.1.1. Here and elsewhere, a caution about air speed above an air temperature of 35 °C / 95 F is offered. While it is true, it seems to ignore the continuing benefit of air speed in enhancing Emax above skin temperature. The break-even point is in the vicinity of 105 °F for work clothes.	The comment is well taken. This section seeks to provide a balance between the environment (ambient temperature, humidity, etc) and the human skin temperature in order to maintain effective heat transfer to maintain comfort. These are engineering controls that are used for this purpose. The authors are not ignoring the benefit of wind speed in removing heat from the skin. However, the point is made that a convective heat transfer can occur such that the person gains heat rather that loses heat if the air temperature is above a certain point. If this is understood, then the IH or occupational physician will not attempt to use only wind speed (i.e., fans) to control heat loss from the worker when the air temperature is above a certain level. No revisions made.
CHAPTER 7. MEDICAL MONITORING AND SURVEILLANCE		
Reviewer	**Comment**	**Response**
7-1	**7.1, page 114, lines 12-15** Suggest changing to the following: Workers exposed to a hot environment above the RAL. Workers with personal risk factors, including medical conditions and/or a prior history of heat-related illness, that put them at higher risk of heat-related illness. Why: Those are “personal risk factors,” not entities distinct from personal risk factors.	Revised as suggested.
7-2	**7.3 Medical Screening Elements, page 115, line 1 (and others)** Suggest changing “screening” to “surveillance” in many places in this section. Why: Screening is generally used to identify who is exposed to a stressor (e.g., heat), or to identify those with a condition. Surveillance is used to follow those known to have occupational exposure to a stressor.	The section above this 7. Medical Monitoring, was modified and terminology was made clearer. See also 7.3 Medical Monitoring Program Elements and 7.4 Medical Surveillance – Periodic Evaluation of Data.
7-3	**7.3, lines 5-8** Change that sentence to:	See modified Section 7.3 Medical Monitoring Program Elements.

	The purpose of initial and periodic medical examinations of persons working at a particular hot job (i.e., a Heat Stress Medical Surveillance Program) is to determine if the person is at increased risk of, or has already suffered, an adverse health effect from heat stress exposure. Why: The current sentence describes the purpose of a certification exam, not of surveillance (see prior discussion of this). Surveillance is focused on the specific stressor(s) of the job, looking for increased risk from exposure. It does not seek to establish a worker's ability to safely perform a job. For example, a forklift operator may receive a certification exam to be sure he can safely drive a forklift, an exam which may include visual acuity, depth perception, etc. If he is exposed to heat while on the job, he will be enrolled in the heat stress surveillance program to see whether he has experienced or is at increased risk of experiencing adverse health effects from heat stress; that exam (i.e., the Heat Stress Medical Surveillance Program exam) is unlikely to cover all the elements necessary to drive a forklift (e.g., visual acuity).	
7-4	**7.3.2.1.a., page 116, lines 10-11** Modify or remove the reference to diabetes, as it seems to imply that diabetics are heat intolerant, which they may or may not be.	Deleted as suggested.
7-5	**7.3.2.1.b.(2), page 116, lines 21-24** Change this to only a urinalysis. Why: Those laboratory values are far beyond what is necessary for screening or surveillance of workers exposed to heat stress (although they may be appropriate tests for evaluating heat stress injuries). Doing those tests on all heat exposed workers would add a lot of unnecessary expense and incur additional costs from following up on positive results, most of which would be unrelated to heat stress exposure.	Revised as suggested.
7-6	**7.3.2.1.b.(5), page 117, lines 1-3** Change the first sentence to: For workers who must wear respiratory protection or other personal protective	Added as suggested.

	equipment, appropriate medical surveillance, such as enrollment in a respiratory protection program, should be provided. Why: Deciding whether PFTs and stress EKGs are necessary should be left to the medical provider, and should be part of the respiratory protection program, not the heat stress program.	
7-7	**7.3.2.2., page 117, line 30** Why not change "periodic" to annual (or whatever is thought to be appropriate)? 7.4, page 119, lines 2-4 Change to: Standardized individual medical surveillance data should be periodically aggregated and evaluated to identify patterns of worker health that may be linked to work activities and practices that require additional primary prevention efforts. Why: The use of screening and surveillance as currently in the document are confusing.	Section 7.4 Medical Surveillance – Periodic Evaluation of Data has been revised with clearer terminology.
7-8	**7.6.3, page 121, lines 3-5** Recommend deleting this paragraph. Why: Performing such monitoring will be problematic and may not be permissible (considering worker discrimination regulations, including the Americans with Disabilities Act and privacy regulations). (Can you imagine the embarrassment of a woman, who may not even want her co-workers to know she is pregnant, being called out hourly to be checked?)	"It is important to monitor the body temperature of a pregnant worker exposed to total heat loads above the REL every hour or so to ensure that the body temperature does not exceed 39°-39.5°C (102°-103°F) during the first trimester of pregnancy." The heart rate and "core" body temperature of pregnant workers in a known heat stress environment should be monitored frequently. Nonintrusive methods exist for doing this in a prompt manner.
7-9	Pg 121 (7.6.3) and 126 (8.1), concerns for effect of heat on a fetus. These observations of fetal injury with only a 10 min exposure to an elevated Tcore are alarming. Perhaps a stronger recommendation is needed for women to be aware of such possible danger. This is somewhat surprising considering the exercise literature encourages women to continue to exercise all the way through pregnancy (as long as they are not unusually fatigued).	Pg. 72, Section 4.1.6.2 Sex: a paragraph was added in response to another reviewer comment that discusses pregnancy and the risk to the fetus (e.g., teratogenic effects).
7-10	p. 114, line 1, insert "Prevention," before "Screening". On line 4, insert "prevention of adverse outcomes and the" before "early".	Ch. 7 Medical Monitoring had major revisions clarifying the terminology.

7-11	p. 115, consider inserting “prevention and” on line 2 before “screening”. On line 8, consider inserting “and to work with management to modify the job as necessary”. On line 15, consider adding “and trained in first aid”.	Ch. 7 Medical Monitoring had major revisions clarifying the terminology.
7-12	p. 116, delete the sentence in lines 10 and 11 that begins “The use of insulin”, and instead make sure diabetes is mentioned in the next page among conditions placing workers at greater risk.	Sentence removed as suggested. Added “diabetes insipidus and diabetes mellitus.”
7-13	p. 118, line 15, add “or for accommodation” at the end of the sentence. Delete the bullet on lines 20 – 22. First aid logs and episodes of heat related illness should be reported on the OSHA 300 Illness and Injury log. The employer should not need clinical information, but rather what modifications to make. The second bullet, on lines 23 – 25, might also include medical recommendations for worksite medical or physiologic monitoring.	“or for accommodation” added as suggested. Deleted the bullet in regards to the employer needing clinical info as suggested. Added: “medical recommendations for worksite medical or physiologic monitoring” to the other bullet.
7-14	p. 119, I would recommend deleting lines 2 – 8, and instead use first aid logs for heat-related surveillance.	Deleted as suggested. Text revised to: “Incidents of heat-related illness should be reported on first aid logs and the OSHA Form 300-A and OSHA Form 301 Incident Report, if required to keep these forms, while following OSHA recordkeeping regulations. For sites under MSHA jurisdiction, MSHA Form 7000-1 may be required. The responsible healthcare provider should evaluate data from incident reporting systems to look for trends in type of injury or illness (e.g., heat-related illness) or job title to target interventions.”
7-15	p. 120 – 121, I would suggest tempering the discussion of the potential teratogenicity of heat exposure to include a statement that core temperatures of 102 – 103 ^{o} should be avoided, period, regardless of gender.	This information was added as suggested.
7-16	Pg 115- It would seem that ONLY Occupational Physicians would be qualified for medical screenings for heat exposure. I oppose suggesting any M.D. can do this.	Ch. 7 Medical Monitoring had major revisions clarifying the terminology.
CHAPTER 8. BASIS FOR THE RECOMMENDED STANDARD		
Reviewer	**Comment**	**Response**
8-1	**Figures 8.1 and 8.2, pages 123-124** Recommend adding exertion levels (for example, as mentioned in the following pages	The REL/RAL reflect variables considered in their original determination. No revisions made.

	in the document) to the horizontal axis, as they will make the graphs more meaningful to most readers. Also, the "standard worker" is still the 70 kg man (much smaller than today's average American worker).	
8-2	**8.1, page 125, line 3** Delete "level of strain and the". Why: Recommend removing all possible references to "heat strain," as use of the term can be confusing.	Heat strain is defined in the document and its usage is appropriate.
8-3	**8.2, page 127, lines 21-23** Delete "The regression of heat strain on heat stress is applicable to population groups, and, with the use of a 95% confidence interval, it can be applied as a modified form of risk prediction." Why: I have no idea what that means.	The language is part of a description of the capabilities of a model to determine or predict heat strain on populations of people with a high degree of confidence. It is intended for those readers interested in modeling of the potential of heat strain resulting from hot environments.
8-4	**8.3, page 129, lines 3-20** Is it acceptable to refer to specific products and proprietary names in this document? It appears as an endorsement.	When a specific product is referred to, it is usually either the only one on the market or a commonly used product. There is a standard disclaimer on all NIOSH documents that states that mention of any product does not imply endorsement.
8-5	Figures 8-1 and 8-2: Anything new in these? Are they just copies of the 1986 report?	The REL and RAL remain the same.
8-6	Too much text seems repetitive ….. after these pages. The previous comments will influence the writing in this part of the report as well. I will not repeat them here.	Noted.
8-7	Page 136: Are Canada and Japan the only countries of interest??? What about Australia, China, India, EU, etc ??	They are not the only countries of interest, but it has been difficult to find countries with heat stress standards that differ and provide other insights. Most either do not have a standard or their standards are based on ISO or ACGIH TLVs, which is already provided elsewhere in section 8.4 Recommendations of U.S. Organizations and Agencies.
8-8	128, line 5: suggesting that oral temp is accurate in working humans seems DANGEROUS without some substantial direct data to this as a valid measure in THIS application.	Revised to "core".
8-9	129: the descriptions of wearable measurement devices seems of little use until research shows valid heat strain applications. Seems more apropos for appendices.	Research is beginning to validate many of the new systems on the market. We have received many inquiries regarding wearable measurement systems so we want to make

		this information immediately useful to the reader in the body of the document.
8-10	P. 132, line 25-31. These temperature limits were based on prevalent dew point temperatures across Washington State, which were lower than many other locations in the US. It would serve the readers well to alert them to the risk of generalizing the dry bulb/air temperatures.	Additional information added.
8-11	8.1. The European BIOMED II project also examined the risk of serious heat-related disorders. It would be worthwhile to include a discussion of their findings. See J. Malchaire, B. Kampmann, G. Havenith, P. Mehnert, H. J. Gebhardt. (2000) Criteria for estimating acceptable exposure times in hot working environments: a review. International Archives of Occupational and Environmental Health, 73:215-220	The authors realize that there are many studies in the literature that discuss the risk of heat related disorders. In fact, the list is so comprehensive that there is simply not space in this document to discuss all of them. The authors have cited several works more recent than the BIOMED II project. That seems adequate for the purpose of this document.
8-12	p. 127, lines 9-11. The two references cited are too old and not reflective of current models. The general statements of the paragraph hold but newer references to newer models is necessary. The PHS model is a good example and perhaps a currently used military model might help to demonstrate the point.	The following more recent references are cited in the text in Section 8.2: Kenny GP, Yardley JE, Martineau L, Jay O. [2008] Physical work capacity in older adults: implications for the aging worker. Am J Ind Med. Aug;51(8):610-25. Bernard TE, Pourmoghani M. [1999] Prediction of Workplace Wet Bulb Global Temperature. Appl Occup Environ Hyg14: 126-134.
8-13	P. 128, line 5 thru p. 129, line 31. While there is technology to measure physiological strain, and more coming, it would be helpful to provide criteria values.	Measurement of physiological strain is the "holy grail" in experimental physiology and, while it is true that physiological monitoring systems are under development, the problem is daunting – especially for measurements in the field. One of the authors has served on a national committee that has attempted to address the issue of what should be measured and how. This discussion continues. One of the authors has published articles on two different physiological monitoring systems and their limitations. From this, this author is reluctant to offer criterial values because there is often no current means of obtaining the physiological variable in the field. Thus, based on the above, the authors decline to offer criteria

		values that cannot and may never be able to be obtained in the field.
CHAPTER 9. INDICES FOR ASSESSING HEAT STRESS AND STRAIN		
Reviewer	**Comment**	**Response**
9-1	**9.4.3, page 147, lines 25-27** Change sentence to: As the skin temperature rises and approaches the core temperature, this temperature gradient is decreased; without a compensatory increase in cardiac output and cutaneous shunting, the rate (and amount) of heat moved from the core to the shell is decreased and the rate of core heat loss is reduced. Why: The current sentence is correct, but may be a little misleading as other variables are involved.	The rest of the section discusses other physiological variables and their importance and contribution to physiological strain. Revision not made.
9-2	9.3.2. Pg 143, ln 9. Spelling. Squirrel data system.	Revised as suggested.
9-3	9.4.2. Pg 147, ln 19. This paragraph discusses Tre. Should this line refer to the fall in Tre rather than HR?	Revised as suggested.
9-4	9.4.4. Pg 148, ln 21. To measure skin temperature accurately, the thermistor head should be firmly attached to the skin without covering the thermistor head with tape, etc. It is a common mistake to cover the thermister, creating a microclimate not indicative of the true temperature of the surface of the skin. This is a very common mistake, promoted by even the thermistor companies. Once the tape (or other cover) becomes saturated with sweat, it no longer “breathes”.	The authors appreciate the problem of taping the skin thermistors to the skin and creating a microenvironment that may not be the actual skin temperature. The difficulty is that there may not be any other way to attach the skin thermistor. All the person can do is follow the manufacturer’s instructions on how to attach the skin thermistors. The authors did not discuss the methods of attaching the thermistors for that reason. Section 9.4.4 deals with dehydration, not skin temperature.
9-5	9.4.4. Pg 148, ln 18. Finally, a sugar/electrolyte solution is recommended—but not very obviously in this document. I believe stronger and clearer guidelines should be included in this document. With copious sweating for > 2 hrs, consider electrolyte drinks. (including sugar depends on the work level). Different concentrations should be considered during recovery (many sport s drinks now have separate solutions for before, during, or after exercise).	See author responses to a similar set of questions in the context of hyponatremia in a section 4.1.4.1.
9-6	p. 147, I would suggest deleting lines 15 – 20 as irrelevant.	As there are not always examples from the research related to workers, examples involving athletes or those involved in athletic

		activities are the closest available and relevant.
9-7	On p. 148, would delete the chapter on dehydration as duplicative and instead focus some attention on the use of episodic aural temperatures. These are elsewhere lumped in with oral and rectal thermometers as being unacceptable, which is hard to understand and begs better data. Note the table on p. 149 clearly describes use of aural temperatures as well-tolerated examples of recommended physiologic monitoring.	Information about tympanic temperature monitoring has been added to the chapter.
9-8	141 line 10: do authors really mean "reliability" or do they mean validity?	Within the context of the writing, the authors mean reliability. The measurement is not to validate anything but to obtain a measure of the physical environment, in this case wind velocity, in a reliable manner. In other words, can we rely on the measurement as being accurate? No revision made.
9-9	142, 21: brackets not needed.	The final document will go through editorial review prior to publication.
9-10	143, 10: Several commercial devices can do this, so recommend against endorsing only one vendor.	There are other commercial devices on the market. NIOSH does not endorse any of them. We used e.g. (for example) in the sentence to give the reader an example of a commonly used device.
9-11	143, 19: The Tnwb temp reflects air movement, not the Tg temp. Check me pls.	The authors agree and that was stated correctly in the original text.
9-12	144, 5: I suggest the Tg is the BEST temp in this situation. Provide refs for your rec.	The authors agree and that was correctly stated in the original text. This statement was from the previously published revision of the document.
9-13	145, 14; 146, 26; 147, 8: oral temp suggested again. Basis for valid use during work conditions?? Must cite definitive refs.	Changed to "core" and text revised to reflect that regarding oral temperature. References cited.
9-14	145, 19: NOT a catheter!!	Authors agree and have revised the word "catheter" to "thermistor".
9-15	145, 19: "Thermoscan" < this is a proprietary name I think, cite properly) and ear temps are NOT valid measures of deep body temp in the work situation. Provide supporting refs.	The authors understand that the Thermoscan is proprietary and have only provided the name as it is a very commonly used device. The authors are also aware that ear temps are not a good measure of deep body temperature. The worksite is not a research setting and the workers almost never have access to the more sophisticated equipment to measure deep body core temperature. The Thermoscan and similar devices are a easy to use and relatively inexpensive device to get an estimate of a change in body core

		temperature that can at least give the IH an indication that the person is getting too hot. Oral thermometers may not be appropriate if the person is nauseated or vomiting. Therefore, the authors suggest the use of the Thermoscan and have given a detailed explanation as to why the Thermoscan is the better device to use in most work settings.
9-16	148,18: What basis for recommending against drinking COLD water?? Some evidence for some cooling effects has been published.	Revised.
9-17	p. 145, line 11. Suggest also Bernard, T. E. and W. L. Kenney. Rationale for a personal monitor for heat strain. *American Industrial Hygiene Association Journal* 55:505-514, 1994 and Logan, P. W. and T. E. Bernard. Heat stress and strain in an aluminum smelter. *American Industrial Hygiene Association Journal* 60:659-665, 1999	Added as suggested.
9-18	9.2.2. The HSI is not current. If just one example of a rational model is presented, the PHS (ISO7933) is likely the best candidate.	The text mentions the HSI to place the remaining rationale indices in a historical context. The remaining text goes on to discuss the many other means of measuring the heat stress experienced by the worker.
9-19	9.2.2. Malchaire, especially, would take issue with the difficulty of using rational models. He has made available an Excel package that use semi-quantitative data to do an assessment, where PHS runs in the background. Further, he would argue that it is no more difficult to gather the data for empirical indices than it is for PHS. (Just channeling him after years of discussion about the merits of PHS- versus WBGT-based evaluations.)	The authors do not claim that it is difficult to use rational models to determine the potential influence of heat on the person. However, there are many models and which to choose in the particular setting. In addition, the authors are providing information on the different methods. It may be easy for researchers interested in heat stress to use a particular model that happens to be their personal favorite, but that model may not be available to the IH with limited resources who needs to determine the level of influence of heat on their workers. This is a stand-alone document that can be used by the greatest number and variety of audiences.
9-20	p. 145, line 11. Add the BIOMED II review of the literature: See J. Malchaire, B. Kampmann, G. Havenith, P. Mehnert, H. J. Gebhardt. (2000) Criteria for estimating acceptable exposure times in hot working environments: a review. International Archives of Occupational and Environmental Health, 73:215-220	Added as suggested.

9-21	p. 148, line 7-8. It is not clear that Lenhardt and Sessier 2006 make the case that skin temperature can predict core temperature and that it is relevant to occupational settings. They are looking at surgical cases and trying to predict mean body temperature from skin and core temperatrures. Other literature suggests that HR and skin temperature together may be helpful but not skin temperature alone.	Skin temperature cannot be used to predict core temperature – only estimate it. The idea of skin and core temperature are used as concepts for convenience as the temperature varies over various parts of the body (both skin and internal). One only gives averages of skin or internal temperature. Several authors have attempted to use HR and skin temperature to estimate core temperature with varying degrees of success. In practice, skin or internal temperatures should be measured directly using techniques discussed elsewhere in the document. Language has been added to indicate this.
9-22	9.4.4. There should be some further discussion on the progressively increased voluntary fluid intake moving from water to flavored drinks to electrolyte replacement drinks. A clearer case for the need for electrolyte drinks as a preferred drink based on the electrolyte replacement for occupational exposures (versus high performance athletics) should be made. Elsewhere in the document, it is suggested that water needs may reach 8 to 12 liters. The BIOMED II project found that workers do not tend to hydrate well about 6 L/day.	The issue of proper timing and type of hydration (water vs. “sports drinks”) is important. Additional language was added to the text to address this issue.
9-23	Table 9-1. Heart Rate/Additional Info: The HR will remain elevated with high cardiovascular strain in the absence of experiencing a heat-related illness. It may be predictive of a current or imminent illness.	Major changes made to table to address concerns and provide additional information.
9-24	Table 9-1. Tympanic Temperature/Additional Info: Measuring with an IR sensor should not be confused with data that places a sensor on the tympanum. Recommendation is to cite literature that has used the IR sensor method and compared it to core before making this statement.	Major changes made to table to address concerns and provide additional information.
9-25	Table 9-1. Continuous/color-changing and skin patches: Before adding these to the list, a literature that supports their use should be confirmed.	Major changes made to table to address concerns and provide additional information.
9-26	Table 9-1. Body Weight: Some thought should be given to the measurement sought. Is it gross change in BW over the day or a modestly accurate measure of water loss that requires a total mass balance. Sometimes for mass	Major changes made to table to address concerns and provide additional information.

	balance, the process is easier for a shorter time interval.	
9-27	Table 9-1. Respiratory Rate/ Additional Info: Does the rate stay high due to physiological strain or heat illness? Suspect that it is the strain with or without illness.	Major changes made to table to address concerns and provide additional information.
9-28	Table 9-1. Alertness: If there is cognitive dysfunction, suggest that it is a suspected heat stroke rather than some vague illness.	Major changes made to table to address concerns and provide additional information.
9-29	p. 141, line 20 and 26. ET probably fell out of use by the 1970s, which is not recent. A similar comment about when ET* was proposed – not recent.	The text mentions the HSI to place the remaining rationale indices in a historical context. The remaining text goes on to discuss the many other means of measuring the heat stress experienced by the worker. This is only part of the overall information given on rational indices.
9-30	p. 143, line 9. Most WBGT instruments have a data-logging feature. Mentioning one type (i.e., Squirril) is not relevant.	The author uses a hand held WBGT that does not have a data logger. Mention of the Squirrel system is only to illustrate an example of a commonly used data logging system available for the WBGT for reference to the reader.
9-31	p. 146, line 34. Oral temperature thermometers should be calibrated. For disposable thermometers, several in one batch should be calibrated.	Oral temperatures are not a reliable measure of core temperature regardless of whether or not they are calibrated. They only give the IH or occupational physician an indication of whether the person is becoming hyperthermic. Thus, it is not only impractical to "calibrate" the commonly used oral thermometers, but probably unnecessary. Calibration is only practical and needed in a research setting.
9-32	p. 147, lines 15-18. Not sure why a discussion of elite (self-selected for heat tolerance) athletes should be mentioned here. The purpose is to discuss limits for the normal population of heat-exposed workers.	The point of using results of "elite" and "non-elite" athletes is to illustrate that thermal tolerance varies widely among people. The authors were using extreme core temperatures to make the point that in some people (even normal heat exposed workers) higher core temperature can be tolerated without harm while heat injury can occur in other people at much lower temperatures.
9-33	p. 147, lines 18-20. Not sure that this sentence clearly follows from the preceding.	The authors were making the point that in highly heat tolerant people, the elevated core temperature will continue during recovery compared to non-heat tolerant people.
CHAPTER 10. RESEARCH NEEDS		
Reviewer	**Comment**	**Response**
10-1	Suggest adding:	Added as suggested.

	Discovering means of quickly and accurately identifying individuals experiencing or about to experience adverse effects of heat stress exposure, specifically, mechanisms and methods that are inexpensive and that can screen groups of workers quickly (e.g., migrant harvesters). Add, as an area of research need: Heat cramp etiology and prevention.	
10-2	**Figure 10.1, page 155** Recommend changing "Increased ambient temperature" to "Ambient temperature variation." Why: Despite some outspoken researchers and confusion in the popular press, there is still considerable controversy over whether "climate change" specifically means "global warming." Rather than get into that unnecessary debate, leave "climate change" as "temperature variation."	Increased temperatures would be included in temperature variation, and more specifically this would include the potential for more hot days as well as increased temperatures.
10-3	**10.8, page 156** It may be worth mentioning, either in this section or elsewhere, that the Navy Physiological Heat Exposure Limits (PHEL curves), which identify the maximal allowable exposure time or "stay time" for all U.S. Navy shipboard personnel when working in the heat, have different curves for work in the presence of fuel vapors or combustion gases.[8] **NMCPHC – TM - OEM 6260.6A Prevention and Treatment of Heat and Cold Stress Injuries, June 2007. Pp 16-17. http://www.med.navy.mil/sites/nmcphc/Documents/oem/Heat_and_Cold_final_June07.pdf**	The reasoning behind the adjusted curves is unclear. This is supported by the statement, that "The presence of fuel vapors or combustion gases greatly reduces the safe exposure times…" The toxicity of combustion gases may not increase with increased temperature, but the risk of explosion/combustion does increase with temperatures.
10-4	10.5. Pg 153, ln 21. Should there be a similar consideration for the variations in basal body temperature with the menstrual cycle—0.5°C higher temperatures during the post-ovulatory phase?	The authors agree and have added language to indicate this fact.
10-5	Some of the questions, such as whether there is a differential impact if core body temperature is raised quickly or more slowly, seem less than relevant if the goal is	The authors agree that prevention of heat injury/illness is the primary goal. However, prevention is not taking place in all workplace settings. The issue of how the body responds

[8] NMCPHC – TM - OEM 6260.6A Prevention and Treatment of Heat and Cold Stress Injuries, June 2007. Pp 16-17. http://www.med.navy.mil/sites/nmcphc/Documents/oem/Heat_and_Cold_final_June07.pdf

	prevention. Along those lines, please consider adding in questions about research into better/cheaper/easier PPE or engineering controls, as well as any research that might be needed to update the existing work/rest cycles for obese individuals or those over 40, as well at the role physiologic monitoring may play in safely allowing less-than-fit workers continue to perform baking, laundry, landscaping, agricultural, or construction tasks.	to heat under a variety of conditions remains extremely relevant. In fact, without that knowledge, one cannot design engineering controls, PPE, work/rest cycles and so forth. Additional language has been added to address this specific comment.
10-6	Section 10.7: Nice to see this included, but for future investment planning by enterprises in the USA I would have expected much more text and references and comments on workplace building designs.	This topic is beyond the scope of this document.
10-7	Chapt 10- Research has LITTLE interest or application for users of this information. Those who do research know already what is in the manual.	There are various audiences for this document, including researchers.
10-8	To the list offered in the criteria document, the following might be considered (See Bernard, T (2014) Editorial: Occupational Heat Stress In USA: Whither We Go? Industrial Health 52:1-4) • Validity / sensitivity and specificity of personal monitoring methods • Effective management methods (e.g., value and content of training) • Epidemiological studies to evaluate the REL and RAL. Outcomes can be heat-related disorders and other outcomes like productivity and injury Practical methods to include clothing in the evaluation	Added as suggested.
10-9	10.4. See also Redmond CK, Emes JJ, Mazumdar S, Magee PC, Kamon E. Mortality of steelworkers employed in hot jobs. J Environ Pathol Toxicol. 1979 May-Jun;2(5):75-96	Added.
APPENDICES		
Reviewer	**Comment**	**Response**
A-1	Appendix B: Based on our data, I am VERY skeptical of urine color as an index of hydration for workers who are hypohydrating to various degrees through the day.	Evidence demonstrating the usefulness in training is presented. It is noted that the urine chart does have weaknesses and colors may be affected by other factors.

A-2	Appendix C: The Heat Index is a widely known metric for the environment but that does not make is useful of and in itself. Two comments: (1) in the absence of radiant heat HI and WBGT follow a non-linear relationship that is reasonably good, but this breaks down substantially in the presence of radiant heat; (2) in a paper to be published by others, there is good evidence that the NOAA classification of likelihood of disorders may underestimate the risk. The adjustment of HI for radiant heat should be described and justified.	Added: "*Note: The presence of a radiant heat source may decrease the accuracy and usefulness of the above heat index."*
A-3	Appendix A: Not sure that this is needed. HSI provides some insight to engineering control measures but it is fundamentally an old method that could be over-interpreted (used in ways that it is not valid). PHS is complicated for the usual reader of the criteria document.	This appendix provides a good set of easy to use tools that can help the worker, IH or occupational physician determine if the person is well hydrated by examining urine color, provides some calculations to determine rate of heat exchange given the environmental conditions, and provides a heat stress index used by NOAA as a quick guide to determine if the environment is dangerously hot for continued work. These tools do not rely upon sophisticated computer programs or expensive tools. They can be used essentially anywhere and that is their value.