

AL-TP-1992-0033

AD-A255 786



ARMSTRONG

PHYSIOLOGICAL STRESS FROM CHEMICAL
DEFENSE CLOTHING AND EQUIPMENT

Sarah A. Nunneley

CREW SYSTEMS DIRECTORATE
Brooks Air Force Base, TX 78235-5000

August 1992

Final Technical Paper for Period 1 April 1990 - 31 March 1992

Approved for public release; distribution is unlimited.

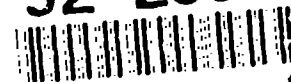
LABORATORY

DTIC
SELECTED
SEP 22 1992

92 9 21 036

422891

92-25544



798

AIR FORCE MATERIEL COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5000

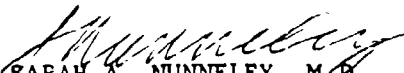
NOTICES


When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.


SARAH A. NUNNELEY, M.D.
Project Scientist


WILLIAM F. STORM, Ph.D.
Chief, Sustained Operations Branch


RICHARD L. MILLER, Ph.D.
Chief, Crew Technology Division

REPORT DOCUMENTATION PAGE			Form Approved OMB No 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing the instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Service, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Project Room (1024-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 1992	3. REPORT TYPE AND DATES COVERED Final 1 Apr 90 - 31 Mar 92		
4. TITLE AND SUBTITLE Physiological Stress from Chemical Defense Clothing and Equipment			5. FUNDING NUMBERS PE - 62202F PR - 2729 TA - 04 WU - 04	
6. AUTHOR(S) Sarah A. Nunneley				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Armstrong Laboratory Crew Systems Directorate Brooks Air Force Base, TX 78235-5000			8. PERFORMING ORGANIZATION REPORT NUMBER AL-TP-1992-0033	
9. SPONSORING MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Topics include groundcrew heat stress in Chemical Defense Ensemble (CDE), validation of the heat-humidity index for work in CDE, evaluation of CDE made with various materials, groundcrew cooling devices, and aircrew guidelines. A bibliography is included.				
14. SUBJECT TERMS Thermal Stress Clothing Heat Stress Chemical Defense Ensemble Physiology			15. NUMBER OF PAGES 10	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

PHYSIOLOGICAL STRESS FROM CHEMICAL DEFENSE CLOTHING AND EQUIPMENT

Groundcrew Heat Stress Caused by Wearing Chemical Defense Clothing

Current U.S. Air Force (USAF) guidance on control of heat stress in chemical defense operations is incorporated into work-rest tables in AFR 355-8, Mission Oriented Protective Postures. The regulation is being revised to make it more useful in the field, but questions remain regarding the efficacy of the prescribed work-rest cycles for control of hyperthermia. Experiments conducted under USAF sponsorship indicated large individual differences in recovery time.

Experience at the Armstrong Laboratory indicated that even thermally acceptable work-rest cycles produced cumulative fatigue which would curtail the duty day. A study was performed to test for possible effects of consecutive daily exposure to work in the chemical defense ensemble (CDE). Subjects wore the current groundcrew CDE and pedaled a cycle ergometer at 38 W in a room at 29 °C. They worked until rectal temperature (T_{re}) reached 38.3 °C, then rested in a room at 21 °C until T_{re} declined to 38.0 °C, repeating work and rest for 4 h or to volitional fatigue. Results showed large intra- and inter-subject variability but no significant effect related to the 4-day repetition.

A related study was designed to evaluate heat stress and fatigue when work-rest cycles are followed for an entire duty day. Subjects wore the current USAF groundcrew CDE. Initial experiments are being conducted at ambient temperatures of 21 and 27 °C (70 and 80 °F) at low and moderate work rates. Work and rest intervals were controlled to produce cyclic changes in T_{re} with peaks at either 38.5 or 39.0 °C and end-rest values of 38.0 or 38.2 °C, respectively. No cumulative effects were found.

Validation of the Heat-Humidity Index for Work in CDE

A study was conducted using a matrix of experiments designed to validate the Texas Model of Human Thermoregulation with respect to the net heat stress on subjects working in CDE in various combinations of dry bulb and wet bulb temperature (T_{db} = 22-40 °C, T_{wb} = 18-30 °C). The model provided satisfactory prediction of human tolerance limits for severe heat stress (tolerance time \leq 60 min). Under milder conditions the model appears to overestimate the evaporation of sweat through the CDE, indicating the need for improved understanding of vapor transport within clothing

systems. The experiments validated the use of "Discomfort Index" as an index of environmental heat load with the current CDE, where $DI=(T_{db}+T_{wb})/2$.

Evaluation of CDE Made with Various Materials

Tests were conducted to compare the heat stress caused in vivo by several different CDEs made of several materials. Subjects walked on a treadmill at 3 mph on a 5% grade to produce a metabolic rate of about 420 W. Environmental conditions were $T_{db}=40\text{ }^{\circ}\text{C}$ and $T_{wb}=24\text{ }^{\circ}\text{C}$ (20% relative humidity (RH)). Measurements included heart rate, T_{re} , skin temperatures, and heat flux. Early indications are that garments made with von Blücher Saratoga technology allow significant evaporative cooling. Suits which fit in that category include the von Blücher PJ-7 (without Goretex), the new USAF flight suit (CWU-66/P), and the US Marines "light-fighter" two-piece suit. Skin temperatures remain lower and tolerance times are much longer in those suits than in the current USAF groundcrew CDE or PJ-7 with a Goretex outer garment.

Groundcrew Cooling Devices

The USAF deployed individual groundcrew cooling equipment in the Middle East including contractor-fabricated Air Distribution Units (ADUs) and air vests. The ADU takes chilled air from an avionics cooling cart, passes it through large CD filter canisters and then routes the air to a manifold with ten ports, each delivering filtered air at 566 L/min (20 cfm) and 15-20 °C (59-68 °F). Groundcrew members wear an air distribution vest and tether themselves to the ports during rest breaks; the air is piped to both vest and the face mask. Laboratory experiments show that such a system provides effective cooling and improved comfort. A further advantage is the potential protection offered by positive pressure provided to the face mask and the suit microclimate. The equipment was never used, as the conflict did not extend into hot weather. Meanwhile, it became apparent that the avionics cooling carts to be used with the system were not readily available as expected; in response, in-house personnel developed a Pressurized Air Distribution Unit which would allow use of tent air-conditioners as a cooling source for the ADUs.

Continued progress has been made toward development of a lightweight belt pack to improve groundcrew comfort by ventilating the CDE with filtered air at ambient temperature. The prototype unit weighs 4 kg and delivers 4.5 L/s (10 cfm) to the torso and 1 L/s (2 cfm) to the face mask. Seven subjects performed work-rest experiments while wearing CDE in a chamber at $T_{db}=32\text{ }^{\circ}\text{C}$, RH=40%. They walked on a treadmill at 450 W for 40 min and then rested for 20 min, repeating the cycle four times if possible. Test conditions included control (NC, no cooling), intermittent cooling (IC, chilled air during rest breaks), and continuous cooling (CC, ambient air during work

and chilled air during rest). Both IC and CC produced significant improvements over NC. In addition, CC provided better results than IC with respect to skin temperature, evaporation of sweat, and thermal comfort. Further work is planned to reduce belt pack weight, increase air flow, and optimize work-rest cycles.

Aircrew Guidelines

Experience with a more comprehensive index of heat stress for a wide range of aviation scenarios; the Aircrew Thermal Stress Index is being circulated as draft NATO STANAG 3945, Guidelines for Thermal Limitations Imposed by Aircrew NBC Assemblies.

Bibliography

- Antufano MJ, Nunneley SA. Human tolerance to work in heat with semi-permeable clothing: Validation of predictions. Proceedings of the Fourth International Conference on Environmental Ergonomics, pp. 146-147, 1990.
- Antufano MJ, Nunneley SA. Physiological tolerance to work in a hot, humid environment wearing chemical protective clothing. Aviat. Space Environ. Med. 61:480, 1990.
- Antufano MJ, Nunneley SA. Heat stress in protective clothing: Validation of a computer model and the Heat-Humidity Index. Aviat. Space Environ. Med. (in press), 1992.
- Bishop PA, Nunneley SA, Constable SH. Comparisons of air and liquid personal cooling for intermittent heavy work in moderate temperatures. Amer. Indust. Hygiene J. 52; 393-397, 1991.
- Bomalaski SH, Constable SH. Exercise and in vivo clothing heat transfer. Aviat. Space Environ. Med. 61:481, 1990.
- Bomalaski SH, Constable SH. Gross partitioned thermal balance with protective clothing. Proceedings of the Fourth International Conference on Environmental Ergonomics, pp. 164-165, 1990.
- Bomalaski SH, Kilian JP, Constable SH. In vivo heat flow characteristics of two chemical protective hoods. Aviat. Space Environ. Med. 1991; 62:472 (abstract).
- Constable SH. Alleviation of thermal stress in ground crew supporting air operations during a chemical warfare scenario. Proceedings of Conference on Aeromedical and Performance Aspects of Air Operations in a Chemical Environment. NATO Advisory Group for Aerospace Research and Development, CP 457, pp. 24-1 to 24-8, 1990.

Constable SH, Bishop PA, Nunneley SA, Chen T. Intermittent microclimate cooling during rest increases work capacity and reduces heat stress. Ergonomics (in press), 1992.

Nunneley SA. Heat stress in protective clothing: Interactions among physical and physiological factors. Scand. J. Work, Health, Environ. 15 (Supplement 1):52-57, 1989.

Nunneley SA. Aircrew Thermal Stress Index for Chemical Warfare Operations: Concept and Development. Proceedings of Conference on Aeromedical and Performance Aspects of Air Operations in a Chemical Environment. NATO Advisory Group for Aerospace Research and Development, AGARD-CP-457, pp. 25-1 to 25-7, 1990.

Nunneley SA. Guidelines for Thermal Limitations Imposed by Aircrew NBC Assemblies. NATO Standardization Agreement STANAG 3945, 1991.

Nunneley SA. Guidelines for the assessment of thermal stress in aircraft operations ASCC ADV PUB 61/114G, 1991.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

4

DTIC QUALITY INSPECTED 3