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TECHNICAL REPORT

NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND 20670-5304

REPORT NO: SY-62R-91

PHYSIOLOGICAL AND SUBJECTIVE RESPONSES TO WEARING THE A/P22P-9(V) HELICOPTER AIRCREWMAN CHEMICAL, BIOLOGICAL PROTECTION ENSEMBLE

by

Ms. Valerie S. Bjorn
Ms. Ding Huang

21 April 1992

FINAL REPORT

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This Technical Report presents results of the physiological and subjective responses to wearing the A/P22P-9(V) Helicopter Aircrewman Chemical, Biological Protection Ensemble. The evaluation was conducted for NAVAIRWARCENACDIV Warminster, Pennsylvania, under Work Request N62269/88/WX/0029.

This report completes the requirements of the Work Request.

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NAVAIRWARCENACDIV Patuxent River, Maryland, evaluated the physiological and subjective responses of 28 aircrew wearing the A/P22P-9(V) USMC Helicopter Aircrewman Chemical, Biological (CB) Protection Ensemble during warm/hot weather ground and flight testing in four USMC helicopter types. Ground testing evaluated fit, donning and doffing, flight equipment compatibility, mobility, dexterity, ingress, egress, emergency egress, water survivability, crewstation compatibility, and repeated preflight inspections in CH-53, CH-46, UH-1N, and AH-1 helicopters. CH-53 and UH-1N flight testing compared three clothing configurations (the A/P22P-9(V), A/P22P-9(V) above-the-neck respirator assembly only, and standard flight clothing) and two test conditions (4-hr flight profile with daily/turnaround (D/T) and preflight inspections, and 4-hr flight profile without D/T and preflight inspections). During three summers of A/P22P-9(V) testing (1988-1990), aircrew completed 44 test trials and 142 hr wear time. Ambient temperatures ranged from 22°C (72°F) in the ready room to 40°C (104°F) in flight. The following data were statistically analyzed (α=.05): questionnaire responses, wet bulb globe temperature (WBGT), ambient dry bulb temperature (T_a), core

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temperature (T_{core}), mean skin temperature from six body sites (T_{sk}), heart rate, water consumption, urine production, urine specific gravity, and health and medical profiles. The A/P22P-9(V) satisfactorily fit aircrew representing the 1st through 99th percentile for 12 anthropometric dimensions. Aircrew were able to don and doff the A/P22P-9(V), but assisted donning and doffing resulted in fewer errors, a more comfortable fit, and averaged 7 min faster than unassisted donning and doffing. The A/P22P-9(V) did not significantly interfere with SV-2B survival vest equipment use, ingress, egress, emergency egress, water survival procedures, D/T, preflight, or flight mission duties. Three subjects terminated testing early for subjective discomfort. Nearly all subjects reported psychological and performance decrements, which required significant compensation on their part to complete missions safely. No tests were terminated for aircrew exceeding physiological safety limits: T_{core} >38.5°C (>101.3°F), heart rate >70% of estimated maximum for age, or T_{sk} closer than 0.5°C (1.0°F) to T_{core}. Within the scope of these tests, A/P22P-9(V) physiological responses were significantly greater than for standard flight equipment and were affected more by workrate and time duration than by ambient temperature. D/T and preflight activities significantly increased all physiological responses, but, in flight, the lower workrate and windy, open environment allowed physiological responses to level or decrease (though not to resting level). T_{sk} correlated with T_{db}, and not with WBGT (or its components); T_{db} temperature measurement is recommended for mission planning. Cockpit temperatures consistently averaged 3.5°C (6.3°F) hotter than cabin temperatures, and cockpit subjects' physiological data were significantly higher than cabin subjects. A/P22P-9(V) water consumption rates are recommended based on test data. Regardless of water intake, aircrew urinated during testing; the A/P22P-9(V) did not have CB agent-safe urine relief provisions. CH-53, CH-46, and UH-1N aircrew who complete thorough, repetitive A/P22P-9(V) training should be able to complete 4-hr flight missions provided: helicopters are open (unbuttoned); T_{db} is <38°C (<100°F); donning is assisted and in a cool environment (≈ 22°C, 72°F); they are relieved of all preflight duties; drink water as prescribed; and have CB agent-safe urine relief provisions. Recommend same flight testing for closed aircraft with and without environmental control systems (e.g., AH-1, V-22, and OV-10) and for aircrew wearing personal cooling systems.

SUMMARY

NAVAIRWARCENACDIV Patuxent River, Maryland, evaluated the physiological and subjective responses of 28 aircrew wearing the A/P22P-9(V) USMC Helicopter Aircrewman Chemical, Biological (CB) Protection Ensemble during warm/hot weather ground and flight testing in four USMC helicopter types. Ground testing evaluated fit, donning and doffing, flight equipment compatibility, mobility, dexterity, ingress, egress, emergency egress, water survivability, crewstation compatibility, and repeated preflight inspections in CH-53, CH-46, UH-1N, and AH-1 helicopters. CH-53 and UH-1N flight testing compared three clothing configurations (the A/P22P-9(V), A/P22P-9(V) above-the-neck respirator assembly only, and standard flight clothing) and two test conditions (4-hr flight profile with daily/turnaround (D/T) and preflight inspections, and 4-hr flight profile without D/T and preflight inspections). During three summers of A/P22P-9(V) testing (1988-1990), aircrew completed 44 test trials and 142 hr wear time. Ambient temperatures ranged from 22°C (72°F) in the ready room to 40°C (104°F) in flight. The following data were statistically analyzed (α=.05): questionnaire responses, wet bulb globe temperature (WBGT), ambient dry bulb temperature (T_{db}), core temperature (T_{core}), mean skin temperature from six body sites (T_{sk}), heart rate, water consumption, urine production, urine specific gravity, and health and medical profiles. The A/P22P-9(V) satisfactorily fit aircrew representing the 1st through 99th percentile for 12 anthropometric dimensions. Aircrew were able to don and doff the A/P22P-9(V), but assisted donning and doffing resulted in fewer errors, a more comfortable fit, and averaged 7 min faster than unassisted donning and doffing. The A/P22P-9(V) did not significantly interfere with SV-2B survival vest equipment use, ingress, egress, emergency egress, water survival procedures, D/T, preflight, or flight mission duties. Three subjects terminated testing early for subjective discomfort. Nearly all subjects reported psychological and performance decrements, which required significant compensation on their part to complete missions safely. No tests were terminated for aircrew exceeding physiological safety limits: T_{core} >38.5°C (>101.3°F), heart rate >70% of estimated maximum for age, or T_{sk} closer than 0.5°C (1.0°F) to T_{core}. Within the scope of these tests, A/P22P-9(V) physiological responses were significantly greater than for standard flight equipment and were affected more by workrate and time duration than by ambient temperature. D/T and preflight activities significantly increased all physiological responses, but, in flight, the lower workrate and windy, open environment allowed physiological responses to level or decrease (though not to resting level). T_{sk} correlated with T_{db}, and not with WBGT (or its components); T_{db} temperature measurement is recommended for mission planning. Cockpit temperatures consistently averaged 3.5°C (6.3°F) hotter than cabin temperatures, and cockpit subjects' physiological data were significantly higher than cabin subjects. A/P22P-9(V) water consumption rates are recommended based on test data. Regardless of water intake, aircrew urinated during testing; the A/P22P-9(V) did not have CB agent-safe urine relief provisions. CH-53, CH-46, and UH-1N aircrew who complete thorough, repetitive A/P22P-9(V) training should be able to complete 4-hr flight missions provided: helicopters are open (unbuttoned); T_{db} is <38°C (<100°F); donning is assisted and in a cool environment (≈ 22°C, 72°F); they are relieved of all preflight duties; drink water as prescribed; and have CB agent-safe urine relief provisions. Recommend same flight testing for closed aircraft with and without environmental control systems (e.g., AH-1, V-22, and OV-10) and for aircrew wearing personal cooling systems.

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The authors extend their sincerest thanks to the 28 test subjects who endured personal discomfort to benefit their fellow aircrew in the fleet. Their contributions resulted in the creation of a valuable thermal physiology database for USMC helicopter aircrew operating in hot weather while wearing chemical, biological protective clothing. We also thank Peter "Rocky" Woodburn for his continued technical expertise and paramedic skill as an in-flight safety observer, along with LT Roy Helton, HMC Mike Graham, and Greg Kennedy.

INTRODUCTION

BACKGROUND

1. Chemical, biological, and radiological (CBR) warfare is a viable threat to the United States military. USN and USMC airfields, ships, and amphibious assault forces are prime targets for CBR attacks. The A/P22P-9(V) above-the-neck Respirator Assembly (the United Kingdom's [UK] AR-5) was procured for USMC helicopter aircrew in 1987 (reference 1). A Chief of Naval Operations Operational Requirement (reference 2) required USMC helicopter aircrew be provided improved below-the-neck (BTN) protection as well. A NAVAIRWARCENACDIV Warminster, Pennsylvania, Engineering Change Proposal subsequently modified the A/P22P-9(V) with the UK MK-1 undercoverall, gloves, overboots, and accessories (reference 3). The MK-1 was tested previously by U.S. Army, USAF, UK, and Canadian forces and is in service for all except the U.S. Army. Though previous data existed (references 4 through 13), no testing included USMC Aviation Life Support Systems (ALSS); only one test (reference 11) evaluated a USMC helicopter model. NAVAIRWARCENACDIV Warminster tasked NAVAIRWARCENACDIV Patuxent River, Maryland, to evaluate the physiological and subjective responses of USMC helicopter aircrew wearing the full-body A/P22P-9(V) during helicopter operations (reference 14). In 1988, 1989, and 1990, Patuxent River personnel conducted ground and flight testing during hot, summer weather at Patuxent River and NAS New Orleans, Louisiana.

PURPOSE

2. The purpose of this test program was to assess the physiological and subjective responses of USMC helicopter aircrew wearing the full-body A/P22P-9(V) and recommend guidelines for safe operations in AH-1, UH-1N, CH-46, and CH-53 helicopters in warm/hot environments.

DESCRIPTION OF TEST EQUIPMENT

3. The A/P22P-9(V) USMC Helicopter Aircrewman CBR Protection Ensemble (figure 1) is comprised of two major assemblies: a head-eye-respiratory portion and a BTN clothing assembly. Separately, the A/P22P-9(V) weighs approximately 17 lb (weight varies with size); however, as it is worn with a full complement of standard ALSS, the total weight is approximately 47 lb.

Figure 1
A/P22P-9(V) USMC HELICOPTER
AIRCREWMAN CBR PROTECTION ENSEMBLE

RESPIRATOR ASSEMBLY

4. The respirator assembly is described in detail in appendix A and reference 15. The four principal parts are listed below and illustrated in appendix A, figure 1.

MCK-3P Mask

5. The mask consists of a chemically impervious butyl rubber hood, a high optical quality polycarbonate face piece, and an orinasal breathing mask. The mask provides the aircrewman with an adequate flow of clean breathing air and hood ventilation for protection against CBR warfare agents on the head, eyes, and neck.

CQK-2/P Ventilator

6. The ventilator consists of a main housing (containing electrical components), an electrically driven centrifugal fan, a battery compartment, two filter canisters, hose, and support assembly. The ventilator provides a continuous flow of filtered air to the mask.

A/P37S-1 Intercom

7. The intercom is a small, lightweight, man-mounted, battery-powered intercommunication unit. The intercom can be used in several ways: it can be plugged into the helicopter's Internal Communication System (ICS); two aircrew can plug into one intercom to talk; or it can be used as a speaker and receiver to talk to people not wearing an intercom.

Rapid In-line Emergency Disconnect Valve

8. In an emergency situation, the Rapid In-line Emergency Disconnect Valve, or RIED valve, allows the aircrewman to quickly separate the mask hose from the ventilator. When the valve is actuated, it closes to prevent water and CB contaminants from entering the respirator. The aircrewman must depress the valve to allow airflow through the hose.

Additional Items

9. Additional A/P22P-9(V) Respirator Assembly items include compatible spectacles worn by subjects requiring corrective lenses, a drinking straw, a canteen, and a modified SV-2B Survival Vest (reference 16) and a modified helmet (reference 17).

SUPPORT EQUIPMENT

Test Set

10. The A/P22P-9(V) Respirator Assembly portable test set is used by Aircrew Survival Equipmentmen to perform a standardized bench test of the mask assembly and ventilator. It is designed as a portable piece of test equipment. The test airflow circuits and operating controls are fitted to an instrument panel secured inside the lid. It consists of an air pressure and suction system with valves, meters, and test connections.

Helmet Jigs

11. Helmet jigs are provided to mount a helmet fitting kit onto the SPH-3C or HGU-54/P helmets (reference 17). The helmets are then compatible with the respirator's retention system.

VENTILATOR MOUNT ASSEMBLY

12. The USN-designed Ventilator Mount Assembly provides a detachable structural interface between the ventilator and the helicopter while the aircrew is in the aircraft. Detailed design drawings of the bracket are included in reference 18.

BTN ASSEMBLY

13. The BTN assembly is described in detail in appendix A and illustrated in appendix A, figure 2. The assembly consists of eight basic components.

MK-1 Undercoverall

14. The MK-1 is a one-piece coverall constructed of a nonwoven nylon fabric and a small percentage of viscose rayon. The material is treated with a fluorochemical to repel liquid organic chemicals. The undersurface is coated with activated charcoal to adsorb any penetrating vapor agents. The undercoverall is worn under the standard flight suit (CWU-27/P) and over a layer of two-piece cotton long underwear.

Long Underwear

15. The underwear consists of two pieces: an undershirt and drawers. Both are made of a jersey knit cotton and are worn under the MK-1.

Chemical Protective Gloves

16. The 7-mil thick butyl rubber gloves are worn under flight gloves (GSF-2/P).

Glove Inserts

17. The glove inserts are made of jersey knit cotton and are worn under the chemical protective gloves.

Chemical Protective Socks

18. The socks are made of 4-mil thick polyethylene. They are worn over cotton socks and under the standard flight boots.

STANDARD ALSS

19. The remainder of the items to be worn by the test subjects will be standard USN/USMC ALSS (reference 19).

DESCRIPTION OF TEST AIRCRAFT

20. A detailed description of the test aircraft can be found in references 20 through 24. Test aircraft are listed below.

AH-1 HELICOPTER

21. The AH-1 is a single-rotor, twin-engine attack helicopter, manufactured by Bell Helicopter Textron, Incorporated.

UH-1N HELICOPTER

22. The UH-1N is a single-rotor, twin-engine utility helicopter, manufactured by Bell Helicopter Textron, Incorporated.

CH-46 HELICOPTER

23. The CH-46 is a twin-rotor, twin-engine transport helicopter, manufactured by Boeing Helicopters.

CH-53 HELICOPTER

24. The CH-53 is a single-rotor transport helicopter, manufactured by Sikorsky Aircraft. The A and D models have two engines, the E model has three.

SCOPE OF TESTS

25. Table I summarizes the scope of A/P22P-9(V) testing conducted September 1988 through September 1990. All test operations were conducted within applicable NATOPS guidelines (references 20 through 24). The flight test profile is provided in appendix B. Detailed test methods are provided in appendix C. Test termination criteria are provided in appendix D.

Table I

SCOPE OF TESTS

Type	Ground	Flight	
Aircraft	AH-1, UH-1N, CH-53, CH-46	CH-53	UH-1N
Test Aircrew	13	4	11
Location	Patuxent River	Patuxent River	Patuxent River NAS New Orleans
Temp. Range Dry Bulb	22-40°C, 72-104°F		
Condition	Day, dry	Day, dry, visual meteorological	Day, dry, visual meteorological
Profile	N/A	See appendix B	See appendix B
Component Evaluations	- Anthropometry - Fitting - Don/doff - ALSS integration - Mobility - Daily/turnaround (crew chiefs) - Preflight - Cargo load/unload (crew chiefs) - Crewstation compatibility - Ingress/egress/ emergency egress - Water survival	- Daily/turnaround (D/T) & preflight + 2-hr flight - D/T and preflight + 4-hr flight	- Daily/turnaround (D/T) & preflight + 4-hr flight - Respirator only + 4-hr flight - No D/T or preflights + 4-hr flight
	- Physiological Heart rate Mean skin temp. Core temp. Weight change Water intake Urine output Sweat output Specific gravity - Subjective Questionnaire	- Physiological Heart rate Mean skin temp. Core temp. Weight change Water intake Urine output Sweat output Specific gravity - Subjective Questionnaire	- Physiological Heart rate Mean skin temp. Core temp. Weight change Water intake Urine output Sweat output Specific gravity - Subjective Questionnaire

METHOD OF TESTS

26. The Detailed Method of Tests is provided in appendix C. NAVAIRWARCENACDIV Patuxent River evaluated physiological and subjective responses of 28 aircrew wearing the A/P22P-9(V) during warm/hot weather ground and flight testing in four USMC helicopter types. The experimental design was a two-way nested incomplete, unbalanced design. Each test subject served as his own control wearing only standard ALSS. Ground testing evaluated A/P22P-9(V) fit, donning and doffing, flight equipment compatibility, mobility, dexterity, ingress, egress, emergency egress, water survivability, crewstation compatibility, and repeated preflight inspections in CH-53, CH-46, UH-1N, and AH-1 helicopters. (Anthropometric data for 12 body dimensions were measured and used to assess A/P22P-9(V) fit.) CH-53 and UH-1N flight testing compared three clothing configurations:

a. A/P22P-9(V) full-body protection.

b. A/P22P-9(V) above-the-neck respirator assembly only.

c. Standard ALSS.

The three clothing configurations were flight tested during two test conditions:

d. Four-hour flight profile with D/T and preflight inspections.

e. Four-hour flight profile without D/T and preflight inspections.

The flight test profile is provided in appendix B.

27. Three questionnaires were administered to collect baseline medical history, 24-hr pretest health profile, and posttest subjective responses (appendices E, G, and I, respectively). Physiological test termination limits were T_{core} >38.5°C (>101.3°F), heart rate >70% of estimated maximum for age, T_{sk} closer than 0.5°C (1.0°F) to T_{core}; other test termination criteria are provided in appendix D. The following data were statistically analyzed (α=.05): questionnaire responses; wet bulb globe temperature (WBGT); ambient dry bulb temperature (T_{db}); core temperature (T_{core}); mean skin temperature from six body sites (T_{sk}); heart rate; water consumption; urine production; and urine specific gravity. Data reduction, editing, plotting, and analyses were conducted using SAS/STAT, SAS/ETS, and SAS/GRAPHS statistical software on a VAX 11/750.

CHRONOLOGY

28. Table II is a chronology of the A/P22P-9(V) test program.

Table II

TEST CHRONOLOGY

Date	Milestone
8-9 October 1987	Program Management Review
5 May 1988	Order for Work and Service received
20 July 1988	Ground test plan approved
25 July 1988	Ground tests started
6 September 1988	Test equipment received in full
8 September 1988	Flight test plan approved
27 September 1988	Ground tests completed
27 July 1989	Patuxent River flight tests started
6 September 1989	Flight tests completed
27 July 1990	Flight test plan, Amend. I approved
13 August 1990	Patuxent River UH-1N flight tests started
18 August 1990	Patuxent River UH-1N flight tests canceled
11 September 1990	Flight test plan, Amend. II approved
13 September 1990	NAS New Orleans UH-1N tests started
30 September 1990	UH-1N flight tests completed
24 October 1990	Preliminary results (13510 Ser SY71D/648 dtd 24 Oct 1990)

RESULTS AND DISCUSSION

OVERVIEW

29. Table III provides a summary of A/P22P-9(V) ground and flight testing conducted each summer from 1988 through 1990. Within the scope of these tests, aircrew physiological responses to wearing the A/P22P-9(V) were significantly elevated compared to standard ALSS. Both subjective and physiological data indicate significant aircrew compensation was required to complete D/T, preflight, and 4-hr flight mission duties. A/P22P-9(V) deficiencies and recommendations are presented throughout this section. Recommendations should be considered for inclusion in instructions and manuals for survival equipmentmen, aviation medical safety officers, and training and medical commands to improve the training, safety, and performance of aircrew operating in the A/P22P-9(V).

Table III

TEST OVERVIEW

Test Type	Total Hours in A/P22P-9(V)	Maximum Test Duration (hr)	Number of Subjects	Number of Trials
Ground	25	2.5	13	29
CH-53 Flight	39	5.0	4	24
UH-1N Flight	7	2.5	6	6
UH-IN Flight (NAS New Orleans)	71	6.0	6	26
Total	142	-	29	85

ANTHROPOMETRY

30. Anthropometric dimensions were measured on 13 ground test subjects. Measurements included weight, height, acromial shoulder height, functional reach, sitting height, bideltoid breadth, buttock knee length, knee height sitting, chest circumference, waist circumference, hip circumference, and neck circumference. These dimensions were selected to assess the overall fit, mobility, freedom of movement, and ease of donning and doffing the A/P22P-9(V) BTN ensemble. Subject anthropometric data are summarized in table IV.

31. Generally, body dimensions ranged from small (1st percentile) to large (99th percentile). With significant proportionality, three individuals contributed largely to dimensions greater than a 95th percentile. Another two individuals contributed to defining the smaller end limits of 1st to 6th percentile. The remaining eight subject's body dimensions were somewhat average or disproportionate

(body dimensions were not consistently large or small). This well-balanced size range provided excellent correlative information between subjects' size and their subsequent subjective ratings of the ensemble's fit.

Table IV

SUBJECT ANTHROPOMETRY

Variable	$\bar{X}$	SD_x	Maximum	Minimum	Percentile Range
Weight (lb)	176	31.5	215	126	1 - 98
Height (in.)	71	3.3	75	64	1 - 97
Acromial Shoulder Height (in.)	25	1.9	28	24	40 - 99
Functional Reach (in.)	33	1.9	36	29	4 - 99
Sitting Height (in.)	37	1.6	41	34	6 - 99
Bideltoid Breadth (in.)	19	1.2	21	17	6 - 99
Buttock Knee Length (in.)	24	1.5	26	22	1 - 95
Knee Height Sitting (in.)	22	1.6	25	18	1 - 99
Chest Circumference (in.)	39	3.3	43	33	1 - 99
Waist Circumference (in.)	35	3.6	39	28	2 - 98
Hip Circumference (in.)	39	3.0	45	33	1 - 99
Neck Circumference (in.)	15	1.0	17	14	3 - 99

SUBJECTIVE RESPONSES

DONNING AND DOFFING

32. Donning times were recorded for each subject during every test event; these durations included time spent in configuring subjects with physiological sensors. Separate donning and doffing time trials, excluding the physiological sensor configuration, were conducted to provide a specific comparison between unassisted and assisted donning. Without physiological sensors, unassisted donning averaged 25 min and assisted donning averaged 18 min. Assisted donning with physiological sensors averaged 41 min; it is not known whether the additional time, or the sensors themselves, negatively biased the subjects toward the A/P22P-9(V) or affected the physiological condition. Regardless, A/P22P-9(V) and standard ALSS subjects were tested identically, so the donning effect should be relative. Subjectively, there was no significant difference between subjects who felt donning the A/P22P-9(V) was relatively easy and those who felt it was difficult. However, subjects who donned without assistance commonly made errors of omission, and sequence errors. It was nearly impossible for subjects to achieve smooth layering, particularly of the respirator assembly cowl, across the shoulder blades between the undercoverall and the flight suit. Unnecessary bumps and wrinkles equated to hot spots and pressure points hours later. Subjects tended to rush respirator

assembly doffing resulting in sequence errors. The most common mistake was unnecessary pulling and breaking free of the respirator assembly's microphone lead from the helmet communication block. Poor training or unassisted donning and doffing will lead to errors, unnecessary equipment damage, and threaten CB protection integrity. Recommend repetitive, supervised A/P22P-9(V) donning and doffing training to avoid errors of omission and sequence errors. Also recommend donning and doffing assistance by a well-trained survival equipmentman (PR) or fellow aircrew.

33. A/P22P-9(V) items rated most difficult to don were the respirator assembly (especially if the subject was wearing spectacles, a skull cap, or a sweatband), the helmet, CB protective socks and flight boots, and donning with the butyl rubber gloves. Even well-trained subjects with previous CB protective clothing experience quickly frustrated if donning was delayed for one of these items. If aircrew expend undue time and energy in A/P22P-9(V) donning, mental preparedness for their mission may be degraded (see Donning Effect, paragraph 66). The following paragraphs provide aids to help reduce common, aggravating donning and doffing problems:

Hood and Mask

a. Donning the hood/mask portion of the respirator assembly was relatively easy for some wearers and nearly impossible for others. In addition to repetitive training, recommend the respirator assembly air hose be connected to the ventilator and the ventilator turned "ON" to inflate the hood prior to donning. Wearers with spectacles, a skull cap, or a sweatband should not expect initial alignment of these items. Recommend, instead of entirely removing the hood and starting over, an assistant or the wearer himself should work enough slack butyl rubber in the hood to find and align the spectacles, skull cap, or sweatband. It should be noted that some aircrew were able to wear standard issue spectacles (as opposed to the special compatible AR-S spectacles) with the hood/mask assembly.

Helmet

b. The SPH-3C standard helicopter helmet is only available in regular and extra large sizes. Some regular-sized helmet subjects up-sized to an extra large helmet to accommodate the respirator assembly hood. However, extra large helmet wearers were not able to up-size. Regardless of helmet size, many of the subjects' helmet ear cup cushions stuck to the hood's butyl rubber during donning and doffing, causing the ear cup cushions to roll loose. Recommend issuing a larger helmet to aircrew whose current helmet will not fit over the A/P22P-9(V) respirator assembly. Also recommend a talc-powdered cloth be dusted on each side of the donned hood to reduce friction with the helmet during donning and doffing.

CB Protective Socks

c. The thin CB protective polyethylene socks are rectangular bags with a melted seam running horizontally across the toes. On several occasions, subjects pushed their feet through the seams. Donning with the sock seam perpendicular to the toes significantly reduced the incidence of tearing. Reduced CB protection from tearing the sock's toe seam is a Part II deficiency that should be corrected as soon as practicable. Recommend developing more tear-resistant CB protective socks. Also recommend different donning procedures until more tear-resistant CB protective socks are developed.

d. Many subjects felt they needed larger flight boots to accommodate the CB protective socks' bulk. Since larger flight boots were not available, subjects experienced toe and foot cramping and painful hot spots. Careful folding, smoothing, and taping of excess sock plastic reduced the severity (figure 2), but most still experienced some discomfort. Painful hot spots and cramping caused by CB protective sock bulk is a Part III deficiency that should be avoided in future designs. Recommend careful folding and taping of excess sock plastic to reduce sock bulk. Also, if necessary, recommend issuing at least a half size larger flight boot to accommodate sock bulk. Recommend developing a new CB protective sock that better matches the foot's natural shape.

CB Protective Gloves

e. The donning procedures required cotton gloves and then the butyl rubber gloves be donned early in the donning sequence to protect the user's hands from previously contaminated equipment (e.g., a contaminated respirator assembly or flight boots). Subjects had no trouble donning the cotton or butyl rubber glove layers; however, donning the remaining items was significantly more difficult. While this procedure was sound from a protection standpoint, it lacked general feasibility. The thin butyl rubber gloves easily snagged and tore in the flight suit and SV-2B survival vest zippers and snaps. The additional pulling and tugging while donning the remaining ensemble items (worst being flight boots and the respirator assembly) significantly weakened the thin butyl rubber. To avoid snagging the gloves, the wearer had to concentrate during the most common of tasks (e.g., lacing and tieing boot strings, figure 3, or snapping SV-2B leg straps). Recommend aircrew wear snug-fitting butyl rubber gloves, as opposed to loose-fitting, to improve tactility and dexterity and reduce the chance of gloves snagging and tearing. Reduced CB protection from snagging and tearing butyl rubber gloves during donning is a Part II deficiency that should be corrected as soon as practicable. Recommend changing donning procedures so that the butyl rubber gloves are not subjected to snagging or develop stronger, more tear-resistant CB protective gloves.

Figure 2
A/P22P-9(V) CHEMICAL PROTECTIVE SOCK
(Shown folded and taped to improve comfort)

Figure 3
CARE REQUIRED TO NOT SNAG CB PROTECTIVE GLOVES

Ventilator Strap

34. Several subjects reported the ventilator hung too low on its strap and continuously banged their right thigh while walking and especially preflighting. The ventilator strap should be positioned such that the strap/ventilator quick disconnect is just below the lower SV-2B survival vest edge. This will position the ventilator higher and on the outside of the right hip and preclude its interference with thigh movement. Figure 1 shows correct ventilator positioning.

Sequence

35. The current donning procedures required the wearer to don his boots and overboots after the respirator assembly. Subjects were doubly frustrated by the reduced downward field-of-view and the poor gloved-hand dexterity. By rearranging the donning sequence as follows, the wearer can don his socks and overboots before the respirator assembly:

a. Cotton underwear, socks.

b. Spectacles, sweatband, or skull cap.

c. Cotton gloves and CB protective gloves.

d. MK-1 and flight suit to waist.

e. While seated, CB protective socks (carefully folded and taped as shown in figure 2), flight boots, and overboots.

f. Remaining items as currently listed (appendix H).

Intercom

36. The intercom communication lead extended over the subjects' shoulders to connect to the helmet communication pigtail. During D/T and preflight duties, the lead easily fell off their shoulders and snagged objects. Recommend routing the intercom communication lead through one of the life preserver snap retainers on the survival vest to retain the lead from becoming a snag hazard. Many intercom units drew battery power even when in the "OFF" position. This was not a design deficiency but a quality control problem since most units did not draw power when shut "OFF". Recommend removing the intercom battery as part of the doffing procedures. Also recommend that defective switching be investigated and corrected.

Drinking Facility and Canteen

37. A significant number of subjects reported the A/P22P-9(V) drinking facility was too difficult to use and experienced extreme thirst rather than manipulate the drinking straw and canteen. Proper drinking facility use required practice and careful technique (figure 4). The fine straw inside the black rubber bellows was too short and easily kinked when pushed through the entry tube. In some cases, kinking blocked all water flow. Inability of subjects to easily and adequately drink using the drinking straw is a Part III deficiency that should be avoided in future designs. Recommend A/P22P-9(V) drinking facility redesign to be more robust and easier to use.

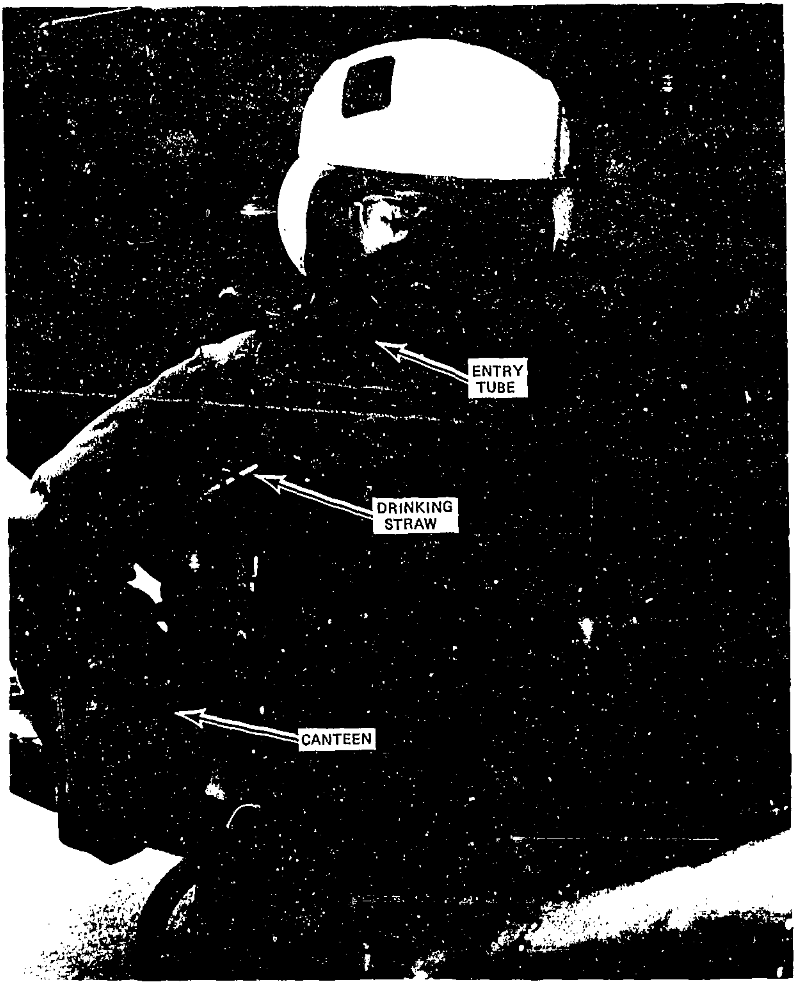

Figure 4
SUBJECT USING DRINKING FACILITY

38. The following procedures are recommended for the current drinking facility. Ideally, two hands should be used to gently compress the black rubber bellows and feed the drinking straw into the entry tube (pilots of dual-piloted aircraft should alternate flying duties and hydration). Finding the straw inside the mask and feeding it into the mouth takes practice. Do not chew on the end of the straw, this will impede water flow. Water cannot be drawn through the straw, it must be pushed through or gravity-fed. In either case, the canteen cap should face down to ensure water (not air) is fed into the straw (be careful not to kink the straw at the canteen cap). To drink, squeeze the canteen hard with both hands, against the chest or under the right arm; hold the canteen upside down overhead; or blow air into the canteen to avoid a vacuum in the canteen. Satiable drinking usually requires a combination of all three drinking methods. Extra water-filled canteens and lower drinking facilities should be carried in flight. Note: when the drinking straw is not in the mouth, water can free-flow into the mask and easily foul the microphone. To avoid this situation, do not allow the canteen to be higher than the facepiece entry tube, e.g., in the case of bending during preflight or stowing equipment. Also, be careful to not unknowingly depress the collapsible canteen, forcing water up the straw.

39. During testing, it was not uncommon for subjects to reduce their cumber by disconnecting their canteens at either the faceplate entry tube or the canteen cap. In a contaminated environment, the only way to avoid contamination at this point would be to close the drinking straw entry tube cap and not reconnect, or drink from the canteen. However, ready access to contaminant-free water is critical and should be readily accessible. Recommend the lower drinking facility top and bottom be connected to the faceplate entry tube and canteen while in a CB contaminant-free ready room and not disconnected until doffing the entire ensemble in a clean or decontamination area. Connecting the lower drinking facility bottom to the canteen cap is eased by wetting both surfaces with water before connecting.

40. The canteen and strap are nearly the last items to be donned, as such, a common error was to route the strap over the air supply tubes, intercom lead, and life preserver lobes. This strap routing has the potential for reducing airflow to the hood and mask, interfering with intercommunication and snagging the life preserver lobes during inflation. Recommend canteen strap routing under the respirator air tubes and intercom communication cord, over the left shoulder but clear of the life preserver lobes. The canteen should be worn on the right side with the cap facing forward.

ALSS COMPATIBILITY

41. Immediately following a test event, subjects were asked to rate A/P22P-9(V) compatibility with their standard personal flight equipment items:

a. SV-2B Survival Vest.

b. SPH-3C Helicopter Helmet.

c. CWU-27/P Flyer's Coverall.

d. GS/FRP-2 Flyer's Glove.

e. Flyer's Boot.

Nearly all subjects felt the A/P22P-9(V) was compatible with their ALSS. A few subjects recommended up-sizing (any combination) their flight suits, helmets, boots, and survival vests. Recommend aircrew be properly fit with standard ALSS and A/P22P-9(V) elements.

42. While wearing the entire A/P22P-9(V), 13 ground test subjects successfully accessed and operated the following:

a. A/P22P-9(V) helmet retention system.

b. A/P22P-9(V) ventilator "ON/OFF".

c. A/P22P-9(V) ventilator battery replacement.

d. Flight suit and survival vest zippers.

e. Boot laces.

f. Strobe light (SDU-5E).

g. Signaling mirror.

h. PRC-90 radio.

i. Pencil-type flare launcher (MK-31).

Subjects complained the three layers of gloves slowed their ability to access and actuate equipment; but with practice, they were able to compensate (figure 5). With adequate training, the CB glove layers should not significantly affect aircrew ability to quickly and effectively access survival equipment. Recommend aircrew practice accessing and using their survival equipment while wearing the entire A/P22P-9(V).

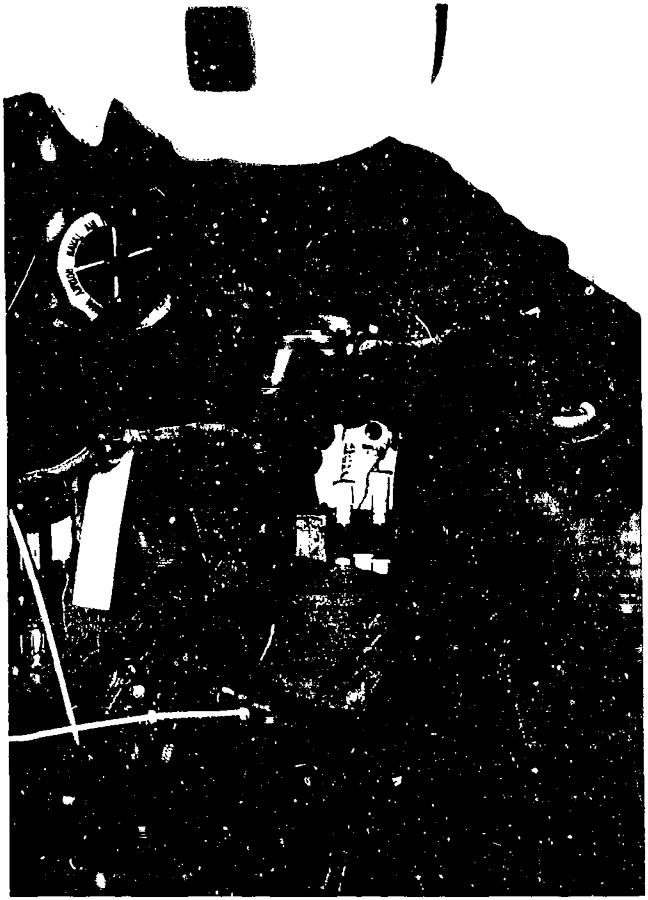

Figure 5
AIRCREWMAN ACCESSING FLARE LAUNCHER WITH
THREE LAYERS OF CB PROTECTIVE GLOVES

MOBILITY EVALUATION

43. During ground testing, subjects wearing the A/P22P-9(V) performed a series of activities to evaluate their freedom of movement for the following: head and neck, shoulders and arms, torso and waist, legs, and dexterity. For example, fine motor dexterity was evaluated by asking subjects to complete the first eight questionnaire questions while wearing the A/P22P-9(V) (including three layers of gloves). Subjects then rated their freedom of movement from very good to very poor

(five-point scale). The remaining test subjects (during flight testing) also completed the same questionnaire but based their freedom of movement on their ability to perform actual aircraft mission duties.

Overall

44. Compared with in-flight duties, D/T and preflight inspections required significantly greater A/P22P-9(V) mobility. The A/P22P-9(V) satisfactorily afforded bending, stretching, and reaching for 1st through 99th percentile aircrew (figure 6).

Figure 6
A/P22P-9(V) MOBILITY DEMONSTRATION
(CH-46 Preflight)

Head and Neck

45. All subjects complained their head and neck mobility was reduced by the respirator assembly, and they had to work much harder to look far left or right. Though no AH-1 attack helicopter flight missions were completed, ground test pilots felt air combat and evasive maneuvers would be degraded by respirator assembly head and neck restriction. These feelings were confirmed during CH-53 and UH-1N flight testing where flight profiles emphasized repetitive landings and confined area work. During these maneuvers, pilots and crew continuously repeated front to back scans of the helicopter's position. Subjects complained of neck muscle fatigue generally on the same side as their helicopter position, e.g., the port seat pilot complained of left-side neck muscle fatigued. However, during NAS New Orleans flight testing, subjects reported that, after wearing the A/P22P-9(V) 12-15 hr over a 2 week period, they noticed a significant reduction in their level of fatigue. Wearing the respirator assembly is a novel, confining experience for aircrew, which initially affects performance. Recommend train aircrew wearing the entire A/P22P-9(V) ensemble a minimum of 3 days, 4 continuous hours per day over a 2 week period several times per year. Each session should encompass D/T inspection, preflight, and flight mission duties.

Shoulders and Arms

46. Nearly all subjects felt the A/P22P-9(V) BTN ensemble (MK-1) afforded ample shoulder and arm movement. A few subjects (acromial shoulder height greater than 97th percentile) noticed their shoulder/arm mobility was reduced when they squatted-down and reached-up with their hands, as is common in preflighting. During this movement, the MK-1 pulled across their shoulders and in their crotch. While this position is common for D/T and preflight procedures, time spent in this position is minimal relative to total mission duration. Considering the small number of aircrew with acromial sitting heights greater than 97th percentile and the limited time they spend in this position, the MK-1 provides suitable shoulder and arm freedom of movement.

Hands and Fingers

47. Subjects were able to complete gross and fine motor dexterity tasks (e.g., writing, using a screw driver, and actuating control panel switches). However, most felt the three glove layers significantly reduced their sense of tactility and dexterity. Several subjects who down-sized to smaller, tighter gloves felt their dexterity improved to the level of standard flight gloves. During actual helicopter testing, pulling circuit breakers and operating maintenance door quick disconnects and screw releases required greater concentration than usual. Despite their frustration over reduced tactility and dexterity, nearly all subjects felt they satisfactorily completed D/T, preflight, and flight duties. With well-fit gloves and adequate training, hand and finger dexterity should be adequate to successfully complete mission duties.

Legs

48. Subjects felt leg movement was not impeded. Only two subjects felt the added bulk was somewhat restrictive; one specifically noted the calves as tight. Within the scope of these tests, the MK-1 provides most aircrew suitable leg freedom of movement.

Waist

49. All but one subject felt they could bend and twist at the waist with no restriction. The restriction felt by the one subject was most likely due to improper MK-1 fit (not all MK-1 sizes were available for testing). Within the scope of these tests, the MK-1 afforded unrestricted waist movement.

AIRCRAFT COMPATIBILITY

50. A significant number of subjects felt the A/P22P-9(V) had no, or a minimal, affect on the following: ability to access and actuate aircraft controls and perform D/T, preflight, and flight duties. Interestingly, CH-53 flight test subjects consistently rated the A/P22P-9(V) as severely affecting their aircraft mission performance while CH-53 ground test subjects did not. Possible explanations for this discrepancy are that ground tests were conducted in relatively cooler temperatures, test durations were shorter, and far less time was actually spent in the cockpit in ground testing than in flight testing. Despite hotter temperatures and longer test missions than CH-53 flight testing, NAS New Orleans UH-1N flight test subjects rated the A/P22P-9(V) significantly better than the CH-53 subjects (discussed further in Helicopter Model Effect, paragraph 88).

D/T and Preflight Inspections

51. Compared to flying the aircraft, D/T and preflight inspections were affected the most by the A/P22P-9(V). All physiological (paragraph 57) and subjective thermal burden indicators increased significantly during D/T's and preflights (aircrew workrate is approximately double the workrate during flight, references 25, 26, and 27). For crew chiefs, D/T procedures required approximately 2 hr checking and maintaining aircraft systems prior to aircraft preflight. Pilot and crew chief preflights then required approximately 20-40 additional minutes to inspect aircraft systems just prior to takeoff. Despite relatively lengthy preflight inspections, a significant number of subjects felt their performance was only minimally affected by the A/P22P-9(V).

52. The overboots had the greatest impact on preflight procedures. Overboots were evaluated during ground testing and, for safety reasons, were not worn during the remaining flight test program. While simply walking from the ready room to the aircraft (approximately 250 yards), most subjects' overboots slid forward on their flight boots until they were walking on the back of the overboot (figure 7).

Figure 7
OVERBOOTS AFTER SLIDING FORWARD ON FLIGHT BOOTS

Eventually, the overboot vinyl dimpled, perforated, and, on some occasions, tore (figure 8).

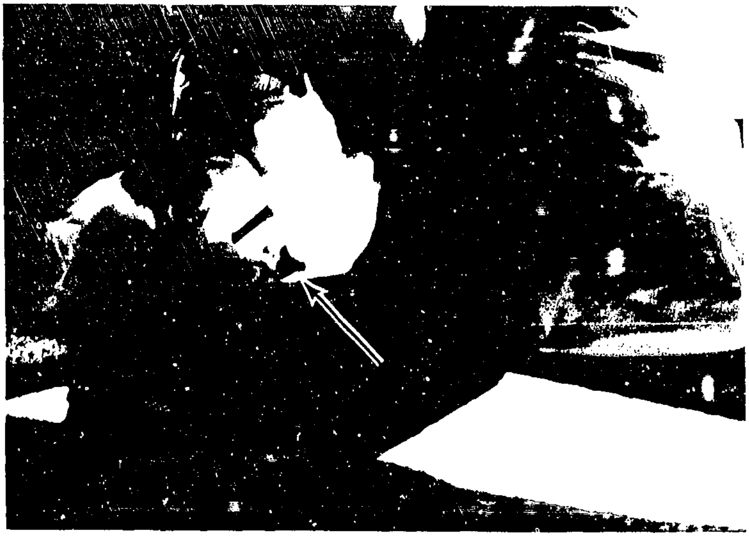

Figure 8
TORN OVERBOOT

The treaded bottom of the overboot did not provide adequate slip protection, and, as the overboot slid forward, the back of the boot had no traction. Subjects felt wary performing even basic helicopter duties (figure 9).

Figure 9
SUBJECT SLIDING DOWN WHEEL SPONSON DURING PREFLIGHT

D/T and preflight inspections required climbing on top of the aircraft. Wearing overboots, subjects often struggled to verify each foothold before progressing up the side of the aircraft. The overboot bulk, coupled with the mask's reduced field-of-view, made it far more difficult to positively locate footholds (figure 10).

Figure 10
OVERBOOT BULK AND POOR TRACTION
(Trouble Locating and Using Helicopter Foothold)

On several occasions, subjects' feet were actively placed in the footholds by safety observers to avoid an accident. Once on top of the aircraft, some subjects crouched and scuffled for fear of slipping. Overboot bulk, poor fit, and poor traction made it unsafe to walk around and climb on the helicopters during D/T and preflight procedures. Unsafe overboot bulk and traction is a Part II deficiency that should be corrected as soon as practicable. Near-term, recommend external overboot lacing or wrapping to provide better fit, reduce bulk, and improve traction. Long-term, recommend improving overboot design.

Ingress, Egress, and Emergency Egress

53. For crew chiefs, ingress and egress were not significantly affected by the A/P22P-9(V). However, with less room to move around in the cockpit, pilot ingress and egress were significantly more cumbersome. Practice was required to become proficient at mounting the ventilator to the aircraft and connecting the aircraft power supply. With its bubble canopy, climb-in, cramped cockpit, the AH-1 presented the most challenging ingress/egress (figure 11).

Figure 11
AH-1 INGRESS

a. Emergency egress was evaluated during ground testing. Subjects successfully egressed with their ventilator or by using the RIED valve. Using the RIED valve, they were able to break free from their aircraft-mounted ventilator using two hands, one hand, or no hands. However, subjects preferred taking their ventilator with them to provide uninterrupted airflow (figure 12). (When the RIED valve is actuated, the snorkel portion must be depressed for air passage.)

Figure 12
EMERGENCY EGRESS FROM CH-53

b. Limited water survival trials (appendix F) were conducted following ground testing. Trained USN Aerospace Physiologists and corpsmen easily and successfully completed multiple underwater egresses from a 9D5A Device (multiplace dunker). The additional weight and bulk of the BTN ensemble did not impact water survival procedures.

OVERALL COMFORT

Heat Tolerance

54. Compared to standard ALSS, all subjects sensed a greater heat buildup caused by wearing the A/P22P-9(V). Despite sensing greater heat, a significant number of subjects felt they tolerated the heat well and it did not significantly hinder their mission performance.

Perspiration

55. Perspiration, more so than heat buildup, caused the greatest discomfort. Subjects reported that, compared to standard ALSS, they experienced excessive perspiration of the head, chest, back, hands, and feet (figures 13 and 14).

Figure 13
PERSPIRATION SOAKED CLOTHING
(The A/P22P-9(V) is not impermeable; perspiration soaked through undergarments, the MK-1 undercoverall, and portions of the flight suit)

Figure 14
CHARCOAL-STAINED AND PERSPIRATION-SOAKED UNDERGARMENTS
(Cotton Undershirt and MK-1 Charcoal Impregnated Undercoverall)

The most debilitating effects were from perspiration in the eyes (one subject terminated a test event for this reason). Subjects were given the option of wearing a cotton skull cap or a medical sweatband to help absorb excess perspiration; however, approximately 50% of the subjects chose not to wear either. Subjects who wore a skull cap or sweatband reported little or no sweat in their eyes. Note that few subjects successfully donned a skull cap under the hood/mask assembly. Any skull cap bumps or wrinkles later lead to severe hot spots under the helmet's pressure. Most success was found with wearing a medical sweatband, which was not like traditional athletic sweatbands. They were lightweight disposables ordered through a medical supply company that consisted of a highly absorbent forehead pad and two thin rubber bands placed around the head to hold the pad in place (figure 15). No hotspots were reported by subjects wearing the medical sweatband. Recommend lightweight, disposable sweatbands (not athletic sweatbands) be worn with the hood/mask assembly to thwart perspiration from entering the eyes.

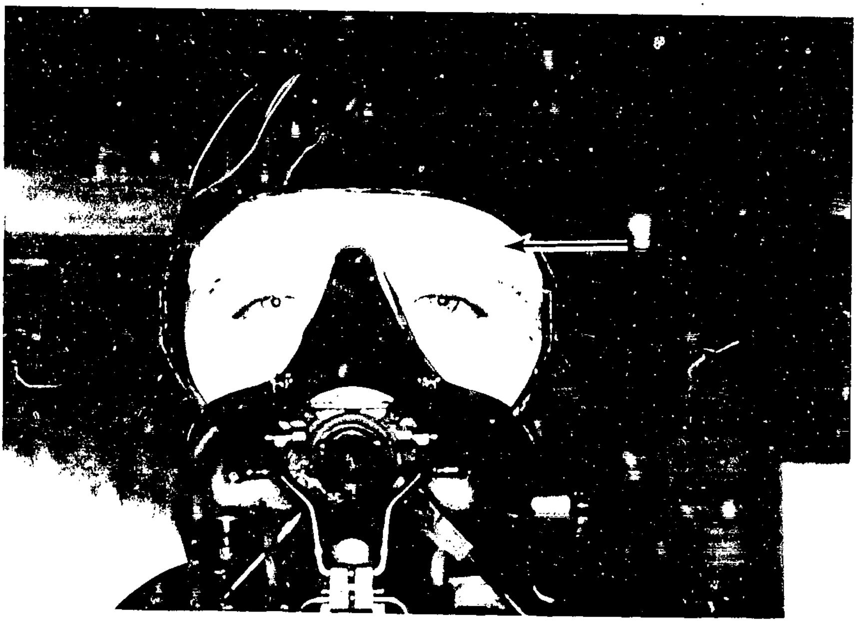

Figure 15
MEDICAL SWEATBAND UNDER HOOD/MASK ASSEMBLY

Other Symptoms

56. Other reported symptoms of discomfort were unusual fatigue, a sense of confinement, pressure points, and headaches. A significant number of subjects reported they were noticeably more tired following missions during which they wore the A/P22P-9(V) than when they wore standard ALSS. Several reported feeling absent-minded and lackadaisical. (On one occasion, a crew chief forgot his toolbox on the aircraft, a notable transgression.) A sense of confinement was reported equally by subjects who had prior CB protective hood/mask assembly experience and those who had none. One subject became claustrophobic and had to be removed from the hood/mask assembly within 1 hr of donning. In most cases, training and experience should decrease the A/P22P-9(V) novelty and claustrophobic effect. Pressure points were reported by different subjects at different body areas. Commonly, pressure points or hot spots were reported by subjects whose helmets did not fit properly. The next most common pressure point was the left shoulder which, in addition to carrying half the weight of the survival vest, also carried the weight of the ventilator and canteen during D/T and preflight inspections. Headaches were not common, but the few subjects who reported them also reported pressure points and/or extreme thirst. As recommended earlier, proper fit and ample training are required to comfortably wear, and operate in, the A/P22P-9(V).

PHYSIOLOGICAL RESPONSES

57. Recall, three clothing configurations and two test conditions were evaluated:

a. A/P22P-9(V) full-body ensemble.

b. A/P22P-9(V) above-the-neck respirator assembly only.

c. Standard ALSS.

e. Four-hour flight profile with D/T and preflight inspections.

f. Four-hour flight profile without D/T and preflight inspections.

Test data from the four test programs (ground testing, CH-53 flight testing, and UH-1N flight testing conducted at Patuxent River and NAS New Orleans) were analyzed and tabulated separately, since each program had different test conditions. Within the scope of these tests, A/P22P-9(V) physiological responses were significantly elevated compared to standard ALSS; notable compensation was necessary for A/P22P-9(V) aircrew to complete D/T, preflight, and 4-hr flight mission duties. A/P22P-9(V) deficiencies are documented and modified operational guidelines are recommended.

SUBJECT AMBIENT TEMPERATURE

58. There were two types of ambient temperature measurements: WBGT from Wibget Heat Stress Monitors and dry bulb from individual SQ32 units (T_{db}) (appendix C, paragraphs 28 and 29). Current Navy and Marine Corps instructions and training handbooks do not address ambient temperature criteria for aircrew in CB protective clothing; they generically cover all troops in conventional and CB protective clothing (references 28 through 31). WBGT is the prevailing temperature index in these doctrines, and the only mention of CB personal protection is to add 10°F to the current WBGT to account for the protective clothing. Both T_{db} and WBGT were

included in this evaluation to determine the most applicable mode of temperature measurement and to tailor operational temperature guidelines specifically for helicopter aircrew wearing the A/P22P-9(V).

59. The correlative and predictive capabilities of T_{db} and WBGT for T_{core}, T_{sk}, and heart rate responses were evaluated. T_{sk} was correlated with SQ32 T_{db}, correlation coefficient $(\rho) \approx .75$, and not at all correlated with WBGT. Neither T_{core} nor heart rate showed strong correlations with T_{db} or WBGT. The strong T_{sk} correlation with T_{db} was anticipated since the near-impermeable A/P22P-9(V) negates the effect of ambient humidity, greatly reducing the importance of the wet bulb component of WBGT and leaving dry bulb as the predominant indicator (references 32, 33, and 34). An additional factor may have been the better man-mounted SQ32 location compared with the helicopter-mounted Wibgets. Subsequently, SQ32 T_{db} was selected for all later statistical analyses. WBGT data will be presented to provide relative comparisons of preflight and in-flight ambient temperature conditions.

60. In table V, the maximums, least-squares mean estimates ($\overline{X}$), and their standard deviations ($SD_{\overline{X}}$) are provided for T_{db} and WBGT test data. The maximums presented are the overall highest values recorded for each test condition and do not necessarily relate to each other; for example, a maximum preflight temperature and a maximum flight temperature may not have occurred on the same day. The overall test environment T_{db} ranged from room temperature 22°C (72°F) up to the maximum temperature of 40°C (104°F).

Table V

SUBJECT AMBIENT TEMPERATURE

Test Type		Maximum °C (°F)		Least-squares Mean $\overline{X}$ °C (°F)		$SD_{\overline{X}}$ °C
		Dry Bulb Man-mounted	WBGT	Dry Bulb Man-mounted	WBGT	
Ground	Preflight	38.0 (100.4)	33.0 (91.4)	25.6 (78.1)	24.0 (75.2)	.15
CH-53	Preflight	35.0 (95.0)	30.5 (86.9)	27.2 (81.0)	30.0 (86.0)	.22
	Flight	39.0 (102.2)	35.0 (95.0)	32.2 (90.0)	27.1 (80.8)	.09
UH-1N	Preflight	37.7 (99.9)	29.0 (84.2)	31.0 (87.8)	28.0 (82.4)	.5
	Flight	38.6 (101.5)	30.0 (86.0)	32.0 (89.6)	26.4 (79.5)	.23
UH-1N New Orleans	Preflight	38.0 (100.4)	30.0 (86.0)	29.7 (85.5)	28.8 (83.8)	.23
	Flight	40.0 (104.0)	31.0 (87.8)	32.0 (89.6)	25.6 (78.1)	.07

a. Preflight/flight testing was scheduled to span the hottest part of each day. T_{db} data collected on the tarmac were consistent with such scheduling; tarmac temperatures did increase throughout preflight and flight testing. From table V, flight T_{db} means, collected in the aircraft, were hotter than preflight T_{db} means, collected on the tarmac. A hot cockpit environment contributed greatly to the overall higher T_{db} in-flight means (refer to Cabin and Cockpit Environment Differences, paragraph 94). Therefore, in figure 16, T_{db} means of the cockpit supersede those of the cabin and tarmac. The tarmac temperature is a reasonable indicator of cabin temperature but is not an adequate indicator for cockpit temperature. From overall test temperature data, cockpit temperatures averaged 3.5°C (6.3°F) and were up to a maximum of 6.0°C (10.8°F) hotter than cabin temperatures. To safely approximate cockpit temperature, add 6.0°C (10.8°F) to the tarmac temperature.

b. As shown in table V, the mean preflight (tarmac) WBGT is higher than mean flight WBGT; this trend is opposite of the mean T_{db}. Generally speaking, in flight, ventilation reduced WBGT reading, but there were days when humidity rose so rapidly that WBGT continued to increase and the maximum in-flight WBGT's were higher than preflight as indicated in the table. The lower in-flight mean WBGT was likely due to Wibget monitor locations in shaded, breezy areas; as such, WBGT more closely estimated cabin temperatures while underestimating the sunnier, low airflow cockpit environment.

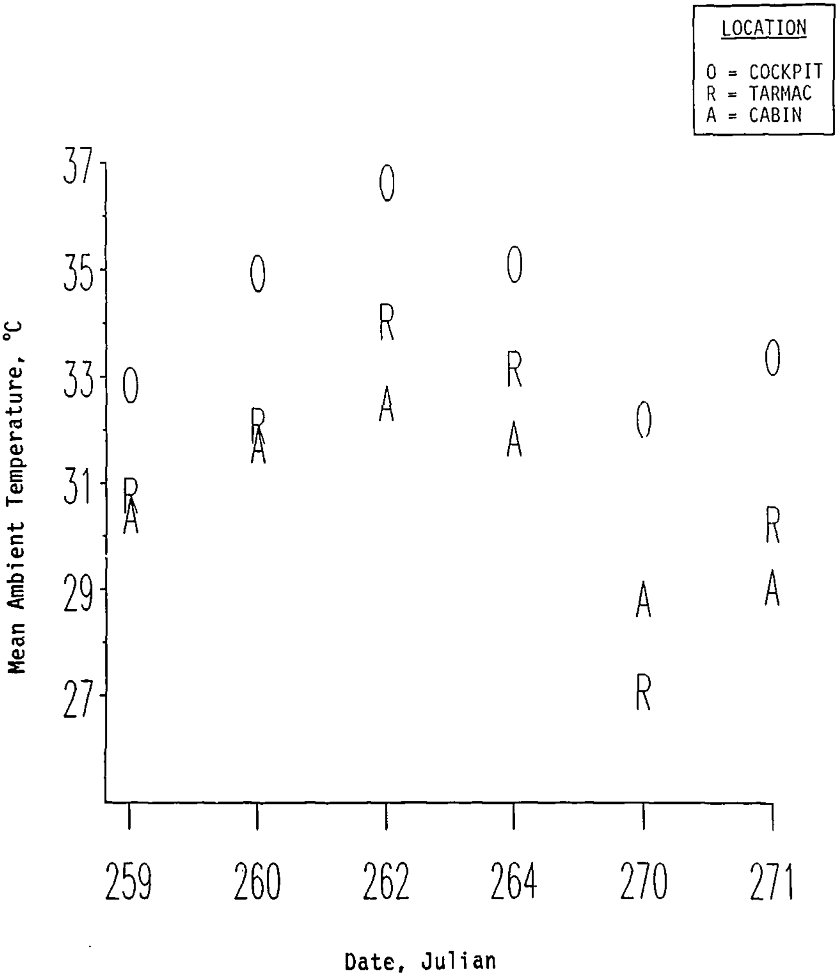

Figure 16
SUBJECT AMBIENT TEMPERATURE (DRY BULB)
(Cockpit, Tarmac, and Cabin Comparison)

61. As mentioned earlier, Navy and Marine Corps instructions (references 28 through 31) do not provide adequate GO, NO-GO ambient temperature criteria for helicopter aircrew wearing the A/P22P-9(V). Either no mention is made of preventing heat stress, guidance is for standard military clothing and not CB protective clothing, or the guidance provided is geared toward troops and not aircrew.

a. For example, Marine Corps Order (MCO) 6200.1D (reference 31) provides good, general heat stress prevention guidance for troops, including the widely used WBGT-based Heat Condition Flag Warning System. For troops wearing CB protective clothing, it recommends adding 10°F to the recorded WBGT. Applying the Flag Warning System to helicopter aircrew wearing the A/P22P-9(V) is not applicable since "troops" and "aircrew" duties and work environments are generally different. Like troops, crewchiefs too sustain moderate to high workrates for long periods of time, but the low in-flight workrates in a shady and airy cabin made long helicopter missions possible. Pilots may maintain low workrates for long periods of time, but the cockpit is higher in temperature and their mental acuity is essential to aircraft, aircrew, and cargo safety (Cabin and Cockpit Environment Differences, paragraph 94). In addition to the warnings not pertaining to aircrew, results of this test program indicate WBGT does not correlate with any physiological response, while simple dry bulb ambient temperature correlated well with subjects' T_{sk}.

b. The Marine Corps Institute course on Nuclear, Biological, and Chemical Warfare (reference 28) does provide dry bulb ambient temperature criteria, but it too is geared toward troops. Paradoxically, it also recommends reducing CB protection levels in temperatures ranging from 85-100°F: apparently, the heat stress threat surpasses the CB contamination threat.

62. Based on the results of this test program, several conclusions can be made regarding ambient temperature and helicopter aircrew wearing the A/P22P-9(V). Throughout the test temperature range, 22-40°C (72-104°F), T_{sk} and T_{db} correlated well, $\rho = .75$. T_{core} and heart rate responses were not correlated with ambient temperature, i.e., cooler temperatures did not guarantee lower physiological responses. The implication is there's an equal chance of thermal stress throughout the temperature range tested, and workrate and time in the CB ensemble are bigger physiological drivers than ambient temperature. Dry bulb temperature (from a common mercury thermometer), and not WBGT, will more accurately indicate aircrew ambient temperature than WBGT.

63. Recommend medical safety officers be thoroughly familiar with the prevention and treatment of heat stress, provide squadron members heat stress prevention briefs, and conduct and monitor aircrew acclimatization programs (at least 2 weeks working in the operational environment wearing the A/P22P-9(V) for several hours per day). To estimate preflight and in-flight cabin temperature, simply use the tarmac dry bulb temperature. This may overestimate in-flight cabin temperature on occasion, but it will allow a buffer for more stressful flight scenarios such as combat and live fire combat. To estimate the in-flight cockpit temperature, add 6.0°C (10.8°F) to the tarmac dry bulb. Also recommend shielding the dry bulb sensing element as described in Dry Bulb, appendix C, paragraph 29. Since physiological responses were not correlated with the ambient temperature, there is no reason for A/P22P-9(V) operational guidelines to have small temperature gradations, e.g.,

70-75°F, 75-80°F, etc. For all dry bulb temperatures <38°C (<100°F), USMC helicopter aircrew wearing the A/P22P-9(V) should be able to complete 4-hr flight missions in UH-1N, CH-46, and CH-53 helicopters operating within the following guidelines:

a. Donning is assisted and in a cool environment (≈ 22°C, 72°F).

b. All preflight duties are transitioned to nonflying crew.

c. Helicopter doors, windows, hatches, and ramp are open.

d. Water intake is as prescribed (page 60).

(These items will be discussed in detail throughout the remainder of Results and Discussion.)

A/P22P-9(V) EFFECT

64. The T_{core}, T_{sk}, and heart rate for all subjects' A/P22P-9(V) and standard ALSS data sets were compared. Despite varying ambient conditions, different activities, and different test durations and individuals, there was a significant elevation (α=.05) in T_{core}, T_{sk}, and heart rate for subjects wearing the A/P22P-9(V) over the same subjects wearing standard protective clothing. Figure 17 compares the A/P22P-9(V) and the matching standard ALSS WBGT, T_{db}, T_{core}, T_{sk}, and heart rate data from one CH-53 subject and will be referred to during subsequent T_{core}, T_{sk}, and heart rate discussions. This particular subject's data are presented for several reasons: (1) the data collection period spanned 5 consecutive hours, which was one of the longest test periods; (2) during flight testing, the CH-53 cockpit had the hottest ambient temperature of all crewstations tested; and (3) the subject's response was consistent with the statistical findings of all 28 test subjects. In figure 17, the top ambient temperature plot consists of SQ32 T_{db} and WBGT from two similar test days. Notice that T_{sk} more closely tracks T_{db} changes as compared with WBGT; also, WBGT is much lower than T_{sk} and T_{db}. Since ambient temperatures were similar between the test days, the plot of A/P22P-9(V) T_{sk} was not consistently higher than standard ALSS. In the T_{core} and heart rate plots, A/P22P-9(V) measurements were higher throughout the entire testing; this was typical for most subjects. Observing the plots, preflight and flight operations produced characteristically different physiological responses and were subsequently analyzed as two separate operations. A/P22P-9(V) physiological curves during testing, in general, increased sharply during D/T and preflight procedures, continued increasing after takeoff, then leveled or even decreased during flight. Comparatively, standard ALSS physiological curves showed a similar pattern, but the overall trace was nearly always flatter and lower in magnitude than its corresponding A/P22P-9(V) trace.

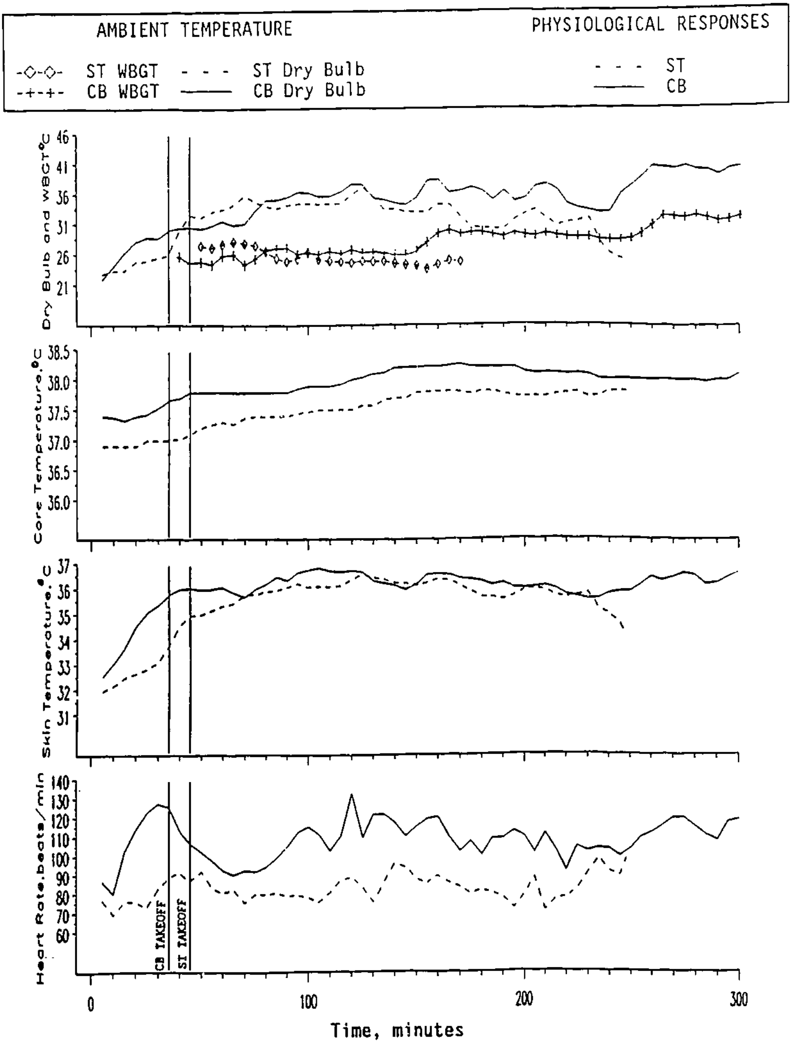

Figure 17
A/P22P-9(V) (CB) AND STANDARD ALSS (ST) COMPARISON
(Ambient Temperature and Physiological Response)

65. The T_{core}, T_{sk}, and heart rate maximums, least-squares mean estimates ($\bar{X}$), and their associated standard deviations ($SD_{\bar{X}}$) for each subject and each test program are provided in tables VI, VII, and VIII. The least-squares estimates are from analyses of covariance with time as a covariate. In addition to reading these tables horizontally to compare A/P22P-9(V) and standard ALSS data differences, reading these tables vertically will provide a comparison of the ensembles with respect to preflight and in-flight activities. The maximums presented are the overall highest values recorded for each test condition and do not necessarily relate to each other. For example, a maximum preflight T_{core} temperature and a maximum in-flight T_{core} temperature may not have occurred on the same day or have been produced by the same subject. Mean differences between A/P22P-9(V) and standard ALSS are the product of 28 subjects in 44 test events; therefore, even the slightest differences are significant. Also, when reviewing the mean data, consider the worst case individual mean differences between the A/P22P-9(V) and standard ALSS: T_{core} 0.9°C (1.6°F), T_{sk} 3.0°C (5.4°F), and heart rate 40 beats/min (where A/P22P-9(V) was always higher). A/P22P-9(V) donning alone elevated physiological condition compared to donning standard ALSS. T_{core}, T_{sk}, and heart rate for donning, ground/preflight, and flight testing are discussed further.

Donning Effect

66. The donning effect for the A/P22P-9(V) and standard ALSS was compared. After donning, A/P22P-9(V) physiological conditions were higher than standard ALSS conditions: T_{core} mean was 0.2°C (0.36°F) higher, T_{sk} mean was 0.4°C (0.72°F) higher, and heart rate mean was 9 beats/min faster. Undue time donning will inevitably result in a premature and unnecessary elevated physiological condition. As reported earlier (paragraphs 32 and 33), assisted donning reduced time and alleviated common agitating problems. Recommend donning be assisted and be conducted at room temperature (≈ 22°C, 72°F) or cooler.

Core Temperature Response

67. Core temperature is an important indicator of body thermoregulation, or heat balance. Compared with skin temperature, core temperature is less affected by ambient temperature and, under normal conditions, it remains remarkably constant at a mean of 37.0°C (98.6°F). Since core temperature is so stable, very slight changes result in overt corrective action by the body. For example, with core temperature rises of just 0.3°C (0.5°F), sweating begins (reference 35). There is some debate over the safest core temperature maximum for effective performance, but the most agreed upon values are between 38.0°C and 39.0°C (100.4°F and 102.2°F) (reference 33). The World Health Organization recommends (in reference 33) stated that "it is considered inadvisable for deep body temperature to exceed 38°C (100.4°F) for prolonged daily exposures (to heat) in heavy work", and that the heat exposure should be terminated if deep body temperature reaches 39°C (102.2°F). The core temperature limit for this test program was 38.5°C (101.3°F); this provided a margin for in-flight safety and mental acuity. At this 38-39°C core temperature range, the area of debate centers to a lesser degree on actual physiological safety and to a greater degree on cognitive performance. Some popular questions amongst scientists include, "Does the rate of core temperature rise affect performance?" "Does duration of elevated core temperature affect performance more?" and "Does core temperature rise effect newly learned skills more than old, repetitive skills?" These issues will be discussed relative to the findings of this test program.

68. In figure 17, A/P22P-9(V) T_{core} was higher than standard ALSS T_{core} throughout the entire test event, indicating A/P22P-9(V) mission performance was more difficult than mission performance in standard ALSS. (This T_{core} pattern was typical of most aircrew wearing the A/P22P-9(V).) Notice T_{core} increased quickly during preflight testing, then slowed in flight, and eventually decreased: all despite this subject was exposed to the hottest crewstation environment (CH-53 cockpit) and one of the longest test durations (5 hr). Notice A/P22P-9(V) T_{core} begins approximately 0.4°C (0.5°F) higher than standard ALSS T_{core}: recall donning (paragraph 66) alone can result in a T_{core} rise, establishing an elevated physiological condition even before leaving the ready room.

69. A/P22P-9(V) T_{core} was significantly higher (α=.05) than standard ALSS T_{core}. Table VI provides preflight and flight T_{core} maximums and the least-squares means ($\overline{X}$) from all data (least-squares estimates are from analyses of covariance). The maximums presented are the overall highest values recorded for a particular test condition; for example, a maximum preflight T_{core} and a maximum flight T_{core} may not have been produced by the same subject but by different subjects under similar conditions. Comparing T_{core} means in table VI, even a 0.1°C (0.18°F) difference is significant since each mean was computed from an entire test season, in all totaling 28 subjects, 44 events, and 142 hr wear time. As was expected, preflight responses generally indicated a greater difference between the two ensembles than in-flight data. The higher preflight work rate produced more heat buildup in the A/P22P-9(V) than the more permeable standard ALSS. Reading downward through the mean T_{core} columns, in-flight A/P22P-9(V) mean T_{core} was not greater than preflight mean T_{core}. This is reflective of the T_{core} tendency to level and eventually decrease as aircrew transitioned from preflight to flight operations. The greatest individual mean difference was 0.9°C (1.6°F), which is not only much hotter than the standard ALSS but extremely hotter than normal core temperature (consider additional temperature rise delta between resting core and standard ALSS core temperature). The highest maximum T_{core} was 38.5°C (101.3°F), which occurred during repeated preflight ground testing.

Table VI

CORE TEMPERATURE

Test Type		Maximum °C (°F)		Least-squares Mean $\bar{X}$ °C (°F)		$SD_{\bar{X}}$ °C	
CB = A/P22P-9(V) ST = Stand. ALSS		CB	ST	CB	ST	CB	ST
Ground	Preflight	38.5 (101.3)	38.2 (100.8)	37.8 (100.0)	37.4 (99.3)	.01	.01
CH-53	Preflight	38.1 (100.6)	38.0 (100.4)	37.6 (99.7)	37.5 (99.5)	.01	.01
	Flight	38.3 (100.9)	37.9 (100.2)	37.6 (99.7)	37.5 (99.5)	.01	.01
UH-1N	Preflight	37.8 (100.0)	37.4 (99.3)	37.4 (99.3)	37.2 (99.0)	.02	.02
	Flight	37.7 (99.9)	37.6 (99.7)	-	-	-	-
UH-1N New Orleans	Preflight	38.0 (100.4)	38.2 (100.8)	37.4 (99.3)	37.3 (99.1)	.01	.01
	Flight	38.0 (100.4)	38.2 (100.8)	37.1 (98.8)	37.1 (98.8)	.01	.01

70. Linear regression analyses were conducted on all preflight and flight data, and models were used to describe and compare data sets. A/P22P-9(V) T_{core} and time were positively correlated (ρ=.90) during preflight and negatively correlated (ρ=-.75) during flight, i.e., T_{core} increased with time during preflight and decreased with time during flight. The T_{core} and T_{db} correlation in either operation was not detected. T_{db} was not controlled in this test program, and it was correlated with time (ambient temperature increased with time throughout the day). Consequently, the validity of using a linear model with both T_{db} and time as multiple regressors in the regression analyses was infeasible, so time was selected as the only regressor. Since T_{db} was not included in the regression analyses, application of the model below is set for conditions similar to this test scope, <38°C (<100°F). T_{core} was modeled with time as follows:

$$T_{core} = \beta_0 + \beta_1 \times \text{time} + \epsilon \qquad (1)$$

where: β_0 = T_{core} intercept at time = 0, and denotes its estimate as $\hat{\beta}_0$
β_1 = $\Delta T_{core}/\Delta$time, and denotes its estimate as $\hat{\beta}_1$
ϵ = error

As anticipated, T_{core} had a high autocorrelation (.90) indicating T_{core} was stable and dependent on its own previous state. Since T_{core} was autocorrelated, the model was analyzed by the SAS/ETS autoregression procedure (AUTOREG) to give a better fit than SAS/STAT regression procedure (REG). Specific examples of this linear model applied to two subjects are provided in appendix L, paragraph 1.

a. Observing the models, preflight operations consistently resulted in rapid T_{core} rise and appeared to be a mission limiting factor. Medical safety officers are encouraged to apply the preflight model estimates to predict preflight T_{core} rises for their squadron A/P22P-9(V) wearers. During preflight testing, for all A/P22P-9(V) subjects, β_1 was always positive and ranged from 0.005-0.02°C/min (0.009-0.036°F/min). T_{core} increased with time even in decreasing ambient temperatures (albeit a slower rate). Standard ALSS T_{core} was more subject to T_{db} changes, so its β_1 varied between positive, zero, and negative. The implication of this β_1 preflight range is that, if D/T's or preflights last more than 50 min in the 22-38°C (72-100°F) temperature range, some aircrewmember's T_{core} will have already increased to the safety limit (1.0°C) and should not be allowed to fly; this is particularly true for pilots. Review the following:

β_1 x time = the rise in core temperature

0.02°C/min x 50 min = 1.0°C rise in core temperature

In the case of a hotter environment, or where aircrew have much higher than normal work rates, this β_1 may grossly underestimate true T_{core} rise.

b. During flight testing, for all A/P22P-9(V) subjects, β_1 typically continued to increase, but with a slower rate than preflight, and leveled off or even decreased before reaching the safety limit. Maximum T_{core} values generally occurred within the first 50 min of flight.

71. The discovery that aircrew T_{core} actually decreased in flight and that the A/P22P-9(V) did not preclude 4 hr flight missions was encouraging. In fact, despite rising ambient temperatures (paragraph 58), in-flight T_{core} still decreased. Apparently, the increased in-flight airflow provided a significant amount of convective cooling. This cooling, coupled with the lower in-flight workrates, stabilized T_{core}. These data contradicted other research that concluded core temperature would climb to an unsafe level within 4 hr of flight and, in some studies, within 45 min (reference 36). Noted earlier, only one previous U.S. Army helicopter flight test program evaluated the A/P22P-9(V) (reference 11). The primary conclusion of that program was that well acclimated aircrew who did not preflight their aircraft and hydrated hourly could fly safely for only 2 hr. Beyond 2 hr, older (>29 years) and heavier aircrew were at a greater risk of thermal stress. Comparing the Army test methods to those of this test program, the one difference that probably impacted results the most occurred at the Army 2 hr mark. At this time, their aviators returned to base and sat outside in a shaded area to drink water while their aircraft was refueled. Whereas, throughout this (Navy) test program, aircrew remained with their helicopters, rotors turning, for the entire test period. Reviewing the Army T_{core} plots, there was always a T_{core} rise immediately following the refueling and water break. During this exact timeframe in this (Navy) test program, aircrew T_{core} had already begun its decreasing slope. This observation strongly suggests that convective cooling offered by the turning helicopter rotor blades and flying is a powerful thermal stress deterrent for aircrew wearing the A/P22P-9(V).

72. Within this test program, no tests were canceled for exceeding the safety limit of T_{core} 38.5°C (101.3°F). This is not to say aircrew were not at risk. On the contrary, sustained elevated T_{core} is known to affect cognitive capabilities (references 37 through 41 reported in reference 42) more so than short intervals. Hancock concluded as cognitive tasks become more complex, performance will decrease with exposure to a heat load. Generally, simple task performance is affected with a T_{core} rise of 1.3°C (2.3°F), tracking task performance after a T_{core} rise of 0.8°C (1.4°F), and complex task performance (two tasks simultaneously) after a T_{core} rise

of just 0.2°C (0.4°F). As such, the more automated or skilled a person becomes at a task, the less he will be affected by a thermal load. Since the safety of the aircrew, aircraft, and cargo depends on pilot performance, it is critical for commanding officers to consider pilot experience level and ambient conditions when figuring mission duration. Novice pilots exposed to heat and the novelty of wearing the A/P22P-9(V) have double jeopardy; pilots with over ≈ 2,000 hr in type can be expected to tolerate this situation <u>relatively</u> better. An equally important point is that aircrew willingness to perform, i.e., highly motivated, does not guarantee better performance. Research indicates that aircrew ability to assess their own heat stress level is unreliable (reference 43).

73. To summarize, despite the ambient temperature range, T_{core} increased significantly with time during ground and preflight activities such that the aircrew effective time flying would be decreased. The in-flight environment, however, provided some relief relative to preflight activities: lower workrate and windy, open environment. Recommend commanding officers substitute flight crew with a qualified ground crew to perform D/T, preflight, and nonflying duties (refueling, loading, etc.); this will significantly reduce flight crew heat buildup in the A/P22P-9(V) and increase their effective performance time flying (as a minimum, relieve pilots from preflight activities). Also recommend aircrew remain with their aircraft rotor blades turning throughout the mission to benefit from convective cooling.

<u>Skin Temperature Response</u>

74. In body thermoregulation, skin serves as the medium for heat exchange between the body's core and the ambient environment. Normally, skin temperature is maintained around 33.0°C (91.4°F), about 4.0°C (7.2°F) cooler than T_{core}; this temperature gradient allows heat produced during body metabolism to pass to the environment and not build up in the body. If skin temperature rises to 33.9-34.4°C (93.0-94.0°F), there is a feeling of heat, which is tolerable but uncomfortable. At skin temperatures above 34.4°C (94.0°F), sweating begins, and, above 35.0°C (95.0°F), there is a distinct hot feeling (reference 35). Though T_{sk} itself is not generally used as a thermal limit, T_{sk} convergence (<1.0°C difference) with T_{core} has gained support as a thermal limit for personnel in near-impermeable and impermeable clothing (reference 44). As skin temperature converges with core temperature, the reduced temperature gradient between the two no longer provides ample cooling and heat stress is imminent.

75. During preflight testing, A/P22P-9(V) T_{sk} was significantly higher than the standard ALSS T_{sk} (α=.05), but in-flight T_{sk} for both clothing configurations were so close, they were not significantly different. Table VII provides preflight and flight T_{sk} maximums and the least-squares means ($\overline{X}$) from all data, which were the estimates from the analysis of covariance. The maximums presented are the overall highest values recorded for a particular test condition; for example, a maximum preflight T_{sk} and a maximum flight T_{sk} may not have been produced by the same subject but by different subjects under similar conditions. All T_{sk} data indicated subjects were experiencing uncomfortable levels of heat in both the A/P22P-9(V) and standard ALSS: the highest T_{sk} recorded in testing was 37.5°C (99.3°F), and generally, T_{sk} means were 34.0-35.0°C (93.2-95.0°F). Reading downward through the mean T_{sk} columns, in-flight A/P22P-9(V) mean T_{sk} was not greater than preflight mean T_{sk}. This is reflective of the T_{sk} tendency to level and eventually decrease as aircrew transitioned from preflight to flight operations.

Table VII

MEAN WEIGHTED SKIN TEMPERATURE

Test Type		Maximum °C (°F)		Least-squares Mean $\overline{X}$ °C (°F)		$SD_{\bar{x}}$ °C	
CB = A/P22P-9(V) ST = Stand. ALSS		CB	ST	CB	ST	CB	ST
Ground	Preflight	36.9 (98.4)	35.8 (96.4)	34.0 (93.2)	33.2 (91.8)	.02	.02
CH-53	Preflight	36.2 (97.2)	36.1 (97.0)	35.0 (95.0)	34.5 (94.1)	.02	.02
	Flight	37.5 (99.3)	36.7 (98.1)	35.0 (95.0)	35.0 (95.0)	.01	.01
UH-1N	Preflight	36.5 (97.7)	35.8 (96.4)	35.1 (95.2)	34.7 (97.5)	.08	.08
	Flight	36.5 (97.7)	36.0 (96.8)	35.0 (95.0)	34.5 (94.1)	.05	.05
UH-1N New Orleans	Preflight	36.3 (97.3)	36.6 (97.9)	34.5 (94.1)	34.0 (93.2)	.02	.02
	Flight	36.2 (97.2)	36.2 (97.2)	34.1 (93.4)	34.2 (93.6)	.01	.01

76. Viewing figure 17, T_{sk} shows preflighting was more difficult in the A/P22P-9(V) than in the standard ALSS, but once in flight, both skin temperatures were very similar. Notice T_{sk} increased quickly during preflight testing, slowed its rate of climb soon after takeoff, and then maintained a slow, gradual decline in flight.

77. Linear regression analyses were conducted on all preflight and flight data, and models were used to describe and compare data sets. During preflight, A/P22P-9(V) T_{sk} was correlated with both time (ρ=.75) and T_{db} (ρ=.85). Unlike T_{core}, T_{sk} more readily responded to heat buildup in the A/P22P-9(V) and to external ambient changes. As such, T_{sk} more quickly responded than T_{core} to the cooling effects of the in-flight environment: T_{sk} generally started decreasing within 30 min of flight while T_{core} was generally within 50 min. In flight, T_{sk} and time generally had a negative correlation (T_{sk} decreased with time), but the T_{sk} and T_{db} correlation was more complex and lacked consistency for all subjects. Observing the models, preflight operations consistently resulted in rapid T_{sk} rise. Medical safety officers are encouraged to apply the preflight model estimates to predict preflight T_{sk} rises for their squadron A/P22P-9(V) wearers. Comparing calculated T_{core} and T_{sk} predictions will be useful in estimating the cooling temperature gradient between the two as well as estimate effective aircrew performance time wearing the A/P22P-9(V). Since T_{db} was not included in the regression analyses, application of the model below is set for conditions similar to this test scope, <38°C (<100°F). As with T_{core}, T_{sk} was modeled with time:

$$T_{sk} = \beta_0 + \beta_1 \times \text{time} + \epsilon \tag{2}$$

where: β_0 = T_{sk} intercept at time = 0, and denotes its estimate as β_0
β_1 = $\Delta T_{sk}/\Delta$time, and denotes its estimate as β_1
ϵ = error

This model is only applicable under conditions similar to this test scope. T_{sk} had a high autocorrelation (.90), i.e., T_{sk} was stable and dependent on its own previous state. Since T_{sk} was autocorrelated, the model was analyzed by the SAS/ETS autoregression procedure (AUTOREG) to give a better fit than the SAS/STAT regression procedure (REG). Both A/P22P-9(V) and standard ALSS T_{sk} responded to ambient temperature and workrate changes more quickly than T_{core}. Specific example of this linear model applied to one subject is provided in appendix L, paragraph 2.

78. During preflight testing, summarizing from each subject, β_1 ranged from 0.03-0.08°C/min (0.05-0.14°F/min), and increased slightly faster than the matching standard ALSS, 0.02-0.05°C/min (0.04-0.09°F/min). The implication of this A/P22P-9(V) β_1 is that, within 25 min of preflighting, some aircrew will be feeling skin temperatures as hot as 35.0°C (95.0°F).

β_1 x time = the rise in skin temperature

0.08°C/min x 25 min = 2.0°C rise in skin temperature

Considering the previous preflight T_{core} prediction (paragraph 70.a), T_{core} will have risen 1.0°C and T_{sk} 4.0°C in just 50 min of preflight or D/T procedures. For the average aircrewmember, this equates to a T_{core} of 38.0°C and T_{sk} of 37.0°C, which indicates core and mean skin temperature are converging within 1.0°C of each other and, if conditions persist, thermal stress is likely.

79. In flight, both A/P22P-9(V) and standard ALSS T_{sk} typically continued to rise with the rate established during preflight, then leveled-off shortly after takeoff, and eventually decreased. In flight, A/P22P-9(V) β_1 ranged from -0.002 to -0.008°C/min (-0.004 to -0.14°F/min), and standard ALSS β_1 ranged from -0.004 to -0.008°C/min (-0.007 to -0.14°F/min). These β_1 values confirm how T_{sk} moved with time; in flight, T_{sk} decreased with time for both A/P22P-9(V) and standard ALSS with a similar rate, but the decreasing speeds were not as fast as the increasing rate during preflight testing.

Heart Rate Response

80. In considering human thermoregulation, heart rate response is somewhat tertiary, but no less important than core or skin temperature. In relative terms, body temperature increases as ambient, core, or skin temperatures rise. The body counterbalances the increase and maintains a normal body temperature. Heart rate increases to send more blood to the skin surface for cooling. The cooled blood returns to cool the core temperature. If core or skin temperature rises further, the heart rate increases proportionately. In essence, the heart rate serves to mediate temperature between the core and surface; in this regard, it is a good indication of the body's thermal condition.

81. Reviewing figure 17, heart rate, even more so than T_{core} and T_{sk}, distinctly showed mission performance in the A/P22P-9(V) was more difficult than in the standard ALSS; A/P22P-9(V) was higher during the entire test. Notice that A/P22P-9(V) heart rate increased much faster than standard ALSS during preflight testing. During flight, in contrast to core and skin temperatures continuing to rise after takeoff, heart rate decreased immediately after takeoff, though A/P22P-9(V) heart rate still remained higher than standard ALSS.

82. Table VIII presents heart rate maximums and the least-squares means ($\bar{X}$) from all data, which were the estimates from the analysis of covariance, a general linear model. The maximums presented are the overall highest values recorded for a particular test condition; for example, a maximum preflight heart rate and a maximum flight heart rate may not have been produced by the same subject but by different subjects under similar conditions. Comparing heart rate means in table VIII, even a 6 beats/min difference is significant since each heart rate mean was computed from an entire test season, in all totaling 28 subjects, 44 events, and 142 hr wear time. A/P22P-9(V) heart rate was significantly higher than standard ALSS heart rate for both preflight and flight procedures at a significant level (α=.05).

a. As was expected, preflight responses generally indicated a greater difference between the two ensembles than shown in the in-flight data, due to a higher preflight workrate than in flight. Despite relatively constant preflight workrates, the very smooth five-minute-smoothed-data revealed heart rate had an increasing trend with time, a positive correlation ρ=.75. Reading downward through the mean heart rate columns, the CH-53 in-flight heart rate means were lower than preflight heart rate means. This reflects the tendency of heart rate to decrease as aircrew transitioned from preflight to flight operations. The greatest <u>individual</u> mean difference is another important mark as the worst case. In the case of heart rate, the greatest individual difference between one subject's A/P22P-9(V) and standard ALSS mean heart rates was 40 beats/min faster. That means this subject's heart rate was 40 beats/min faster for nearly the entire 4 hr of testing.

b. "Normal" resting (seated) heart rate is 72 beats/min; more aerobically fit individual's may have resting heart rates as low as 40 beats/min, while less fit people may have resting heart rates in the low 100's. The average resting heart rate of the 28 subjects who participated in this test program was 69 beats/min, with a standard deviation of 10.3 beats/min. Without a treadmill test and electrocardiograph, an individual's maximum heart rate can be estimated (reference 45) and percentages of that maximum can be used to determine the exertion level of the person. In this test, 70% of each subject's estimated maximum heart rate was used as a test termination criterion. The average maximum heart rate for this subject pool was 188 beats/min and 70% was 152 beats/min (formula in appendix D, paragraph 1). Reviewing the test heart rate means and maximums, none came close to the estimated maximum, though several people were approximately at 60-70% of their maximum capacity.

Table VIII

HEART RATE

Test Type		Maximum (beats/min)		Least-squares Mean $\overline{X}$ (beats/min)		$SD_{\bar{x}}$ (beats/min)	
CB = A/P22P-9(V) ST = Stand. ALSS		CB	ST	CB	ST	CB	ST
Ground	Preflight	163	144	110	84	.4	.4
CH-53	Preflight	154	125	101	90	.5	.5
	Flight	148	135	97	85	.3	.3
UH-1N	Preflight	114	106	-	-	-	1
	Flight	120	111	-	-	-	-
UH-1N New Orleans	Preflight	137	122	88	82	1	.5
	Flight	134	124	-	-	-	-

83. In addition to the previously presented heart rate means and maximums used to compare the two ensembles, each subject's heart rate distribution was studied further as bar chart histograms (for bar chart construction, refer to appendix C, paragraph 39). Heart rate is so sensitive to workrate, body temperature, and stress that a heart rate curve is not smooth, and one instantaneous heart rate alone is not a good thermal stress indicator. However, if heart rate is considered over time, it can be an excellent heat stress indicator. In a bar chart, each bar represents the duration for a given heart rate interval, and the tallest bar on a graph represents the most frequent heart rate, or the mode. By summing all durations, a cumulative duration above a certain threshold can be calculated. In reference 32, Goldman recommends heart rate during work should not exceed 160 beats/min for 2 hr, 140 beats/min for 4 hr, or 110-120 beats/min for an 8 hr day. Combining this heart rate duration information with mean and maximum heart rates, core and skin temperatures assess a subject's overall condition.

a. Figure 18 provides one subject's A/P22P-9(V) and standard ALSS heart rate plots and corresponding bar chart histograms. A/P22P-9(V) preflight and flight operations lasted 32 and 281 min, respectively, and standard ALSS preflight and flight operations lasted 42 and 206 min, respectively, in mid-30's°C range. Notice the A/P22P-9(V) distribution shifts right to a higher heart rate area relative to the standard ALSS. (For specific heart rate frequency information, refer to appendix L, paragraph 3, figures 4 and 5.) A/P22P-9(V) heart rate tested significantly higher (α=.05) than standard ALSS with a two-way contingency table CHI-squared result.

b. In the A/P22P-9(V), the preflight heart rate mode was 125 beats/min and remained 110 beats/min or greater for 18 min. During flight, the mode was 115 beats/min and remained 110 beats/min or greater for 285 min. For this entire A/P22P-9(V) mission, this subject's heart rate remained 110 beats/min or greater for 303 min. Comparatively, this subject's standard ALSS preflight heart rate mode was 75 beats/min and did not exceed 110 beats/min. In flight, his standard ALSS mode was 85 beats/min and exceeded 110 beats/min for 2 min.

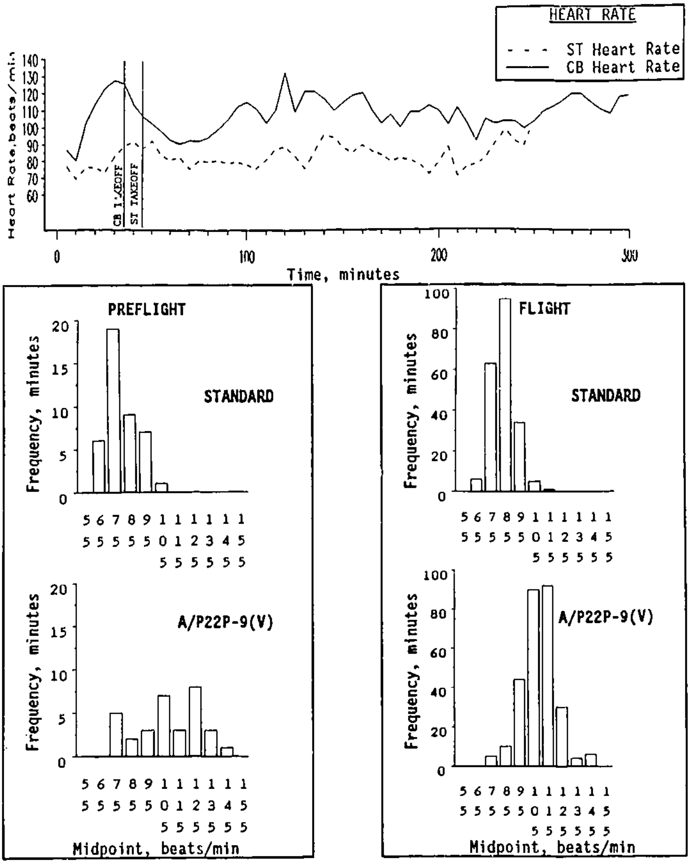

Figure 18
A/P22P-9(V) (CB) AND STANDARD ALSS (ST) HEART RATE COMPARISON
(Heart Rate Time Plot Data Presented as Bar Chart Histograms)

84. To summarize heart rate distributions from all subjects:

a. The entire A/P22P-9(V) heart rate distribution had a right shift to a higher heart rate area relative to standard ALSS; this was unanimously true for each subject.

b. The most frequent rate, the mode, of A/P22P-9(V) and standard ALSS from the four test programs were as follows: 95 versus 65, 115 versus 85, 115 versus 75, and 115 versus 95 beats/min. A/P22P-9(V) heart rate mode was 20 to 40 beats/min faster than standard ALSS.

c. Judging from the distribution shape, standard ALSS heart rate was a tight cluster around the mode, while A/P22P-9(V) heart rate spread out and changed its pace often; this could be seen from its larger range and higher standard deviation. A/P22P-9(V) standard deviation was often twice the standard ALSS one.

85. In reference 32, Goldman recommends heart rate during work should not exceed an increase of 30 beats/min for any exposure, 160 beats/min for 2 hr, 140 beats/min for 4 hr, or 110-120 beats/min for an 8-hr day. The subject's heart rate, in figure 18, remained 110 beats/min or above for nearly 5 hr during a total 6 hr test mission. This did not exceed the referenced recommendation, yet considering overall conditions (maximum T_{core} 38.3°C (101°F) and maximum T_{sk} 37°C (98.6°F)), this subject was unquestionably experiencing a thermal stress. Again, since heart rate generally rose the highest during preflight, it is recommended that A/P22P-9(V) aircrew be relieved of D/T and preflight duties to maximize their effective time flying.

PREFLIGHT AND FLIGHT DIFFERENCES

86. Despite the ambient temperature range, T_{core}, T_{sk}, and heart rate increased significantly with time during D/T and preflight activities such that the aircrew effective time flying would be decreased. The in-flight environment provided some relief relative to preflight activities (lower workrate and windy, open environment) and made it possible to complete 4-hr flight missions. Recommend commanding officers substitute flightcrew with a qualified ground crew to perform D/T, preflight, and nonflying duties (refueling, loading, etc.); this will significantly reduce flightcrew heat buildup in the A/P22P-9(V) and increase their effective flying time performance (as a minimum, relieve pilots from preflight activities).

NO PREFLIGHT OR RESPIRATOR ASSEMBLY ONLY

87. During ground testing and CH-53 flight testing, it was observed that A/P22P-9(V) preflight was hard on aircrew. So, in the 1990 New Orleans testing, two alternatives were tested and compared against the earlier A/P22P-9(V) testing, which included preflight activities: (1) A/P22P-9(V) above-the-neck respirator assembly only with preflight and (2) A/P22P-9(V) full ensemble with no preflight. Table IX summarizes the test results.

Table IX

TEST TYPE COMPARISONS

Test Type[1]	Operation	T_{core} °C (°F)		T_{sk} °C (°F)		Heart Rate (beats/min)	
		Maximum	Mean	Maximum	Mean	Maximum	Mean
A	Preflight	37.7 (99.9)	37.5 (99.5)	35.8 (96.4)	34.8 (94.6)	110	89
	Flight	37.7 (99.9)	37.2 (99.0)	35.5 (95.9)	34.2 (93.6)	102	77
B	Flight	37.3 (99.1)	37.0 (98.6)	34.9 (94.8)	33.7 (92.7)	106	77
C	Preflight	37.6 (99.7)	37.4 (99.3)	35.9 (96.6)	34.7 (94.5)	114	90
	Flight	37.5 (99.5)	37.2 (99.0)	35.6 (96.1)	34.5 (94.1)	123	79

NOTE: (1) Test Type A = A/P22P-9(V) above-the-neck respirator assembly only with preflight
B = A/P22P-9(V) full ensemble without preflight
C = A/P22P-9(V) full ensemble with preflight

Viewing table IX, type B T_{sk} and T_{core} responses were significantly lower than types A and C. Type A was not a significant improvement over type C. Physiological data agreed with subjective responses well. Subjects complained of fatigue, malaise, and absent-mindedness after type A and type C testings but performed type B with normalcy. Again, it is recommended to relieve A/P22P-9(V) aircrew from preflight duties.

EFFECT OF HELICOPTER TYPE

88. Physiological data collected during ground and flight testing were analyzed to determine differences attributable to helicopter model differences. Helicopter model effect on physiological responses was found significant (α=.05); however, within this test design, individual subject and activity variations could not be entirely stripped from the helicopter effect.

A/P22P-9(V) Ground and Preflight Testing

89. Physiological response data were collected and analyzed for repeated preflight and D/T inspections on the CH-53, UH-1N, CH-46, and AH-1 helicopters. The anticipated response was that the larger CH-53 and CH-46 helicopters would require more demanding workrates than the smaller UH-1N and AH-1 helicopters and thus result in significantly higher physiological responses. Surprisingly, CH-53 and UH-1N physiological responses were nearly identical. As anticipated, the CH-46 presented the greatest and AH-1 the least preflight situation for T_{core} and heart rate responses. However, AH-1 T_{sk} was the highest, more so than the CH-46 T_{sk}. While the high CH-46 T_{sk} is likely caused by high workrate, the higher AH-1 T_{sk} is likely caused by the high radiant load passing through the canopy during the prestart

procedures (as noted previously, T_{sk} was susceptible to the T_{db} changes). The relative effect of the four helicopter's preflights from the analysis of covariance appeared as follows:

Physiological Response Rank Order

anticipated:		CH-46 ≈ CH-53 > UH-1N > AH-1
actual:	T_{core}	CH-46 > CH-53 ≈ UH-1N > AH-1
	heart rate	CH-46 > CH-53 ≈ UH-1N > AH-1
	T_{sk}	AH-1 > CH-46 > UH-1N > CH-53

90. The AH-1's placement in the rank order was further confirmed. One A/P22P-9(V) subject, who participated in both AH-1 and UH-1N testing, provided an opportunity to compare the two helicopters directly. The subject's T_{core}, T_{sk}, and heart rates were significantly higher in the AH-1 than the UH-1N, despite the AH-1 test day averaged 3°C (5.4°F) cooler than the UH-1N test day (with up to a maximum of 8.5°C (15.3°F)).

<u>A/P22P-9(V) Flight Testing</u>

91. Though, from the first year ground test results, the CH-46 was the worst-case, this helicopter was not available for subsequent testing; therefore, CH-53 and UH-1N helicopters were selected for later flight testing. Based on ground test results, there was little or no difference in these two helicopters. But from flight testing results, CH-53 physiological responses were significantly higher than the UH-1N and indicated a significant helicopter effect. Recall in Aircraft Compatibility, paragraph 50, CH-53 subjects rated A/P22P-9(V) far worse than UH-1N subjects, such a drastic difference could be explained by the helicopter effect. Two additional investigations further explored CH-53 and UH-1N differences.

Same Subjects, Different Helicopters

92. Three subjects participated in both the CH-53 and UH-1N flight testing; therefore, the two helicopters were able to be compared without biases from subject differences. Comparing physiological response data, CH-53 missions were significantly harder than UH-1N missions. Table X compares one cockpit subject's physiological responses from the two helicopters. In table X, despite the CH-53 test day was a cooler day, the CH-53 was significantly harder for the subject than the UH-1N; for both preflight and flight, the CH-53 mean T_{core} and heart rate were higher than for the UH-1N. But, the mean T_{sk} presented an opposite effect; this was likely caused by the higher T_{db} in the UH-1N test day.

Table X

A/P22P-9(V) SUBJECT PHYSIOLOGICAL DIFFERENCES BETWEEN THE UH-1N AND CH-53 (CH-53 Minus UH-1N)

Operation	Subject Ambient Dry Bulb Temperature °C (°F)	Core Temperature °C (°F)	Skin Temperature °C (°F)	Heart Rate (beats/min)
Preflight	-5.5 (9.9)	0.4 (0.7)	-0.8 (1.4)	16
Flight	-2.5 (4.5)	0.6 (1.1)	-0.5 (0.9)	14

Different Subjects, Different Helicopters

93. In this second example, the effect from CH-53 and UH-1N was illustrated by using entire CH-53 and UH-1N test year data from different subjects. First, T_{db} and WBGT were similar throughout the entire test mission sequence, and the mean T_{db} was 32°C (90°F). Also, the initial core temperatures of the two groups were similar. By the end of preflights, the physiological responses from CH-53 were greater than UH-1N. Once in flight, the CH-53 data continued increasing for approximately 50 min before starting a decreasing trend, while UH-1N data showed a decreasing trend shortly after takeoff. Apparently, as originally anticipated, preflighting larger helicopters will adversely affect crew performance once in flight.

CABIN AND COCKPIT ENVIRONMENT DIFFERENCES

94. Comparing cockpit and cabin differences within each helicopter during flight, both CH-53 and UH-1N showed cockpit T_{db} averaged 3.5°C (6.3°F) hotter than cabin T_{db} and up to a maximum difference of 6.0°C (10.8°F). Despite open vents and windows, the cockpit did not receive nearly the same airflow as the cabin; coupled with a greater radiant heat load (greenhouse effect), the cockpit was significantly hotter. Figure 19 compares mean T_{db} of cabin, cockpit, and tarmac from six test days in UH-1N testing; the T_{db} order was cockpit > tarmac > cabin for nearly every test day.

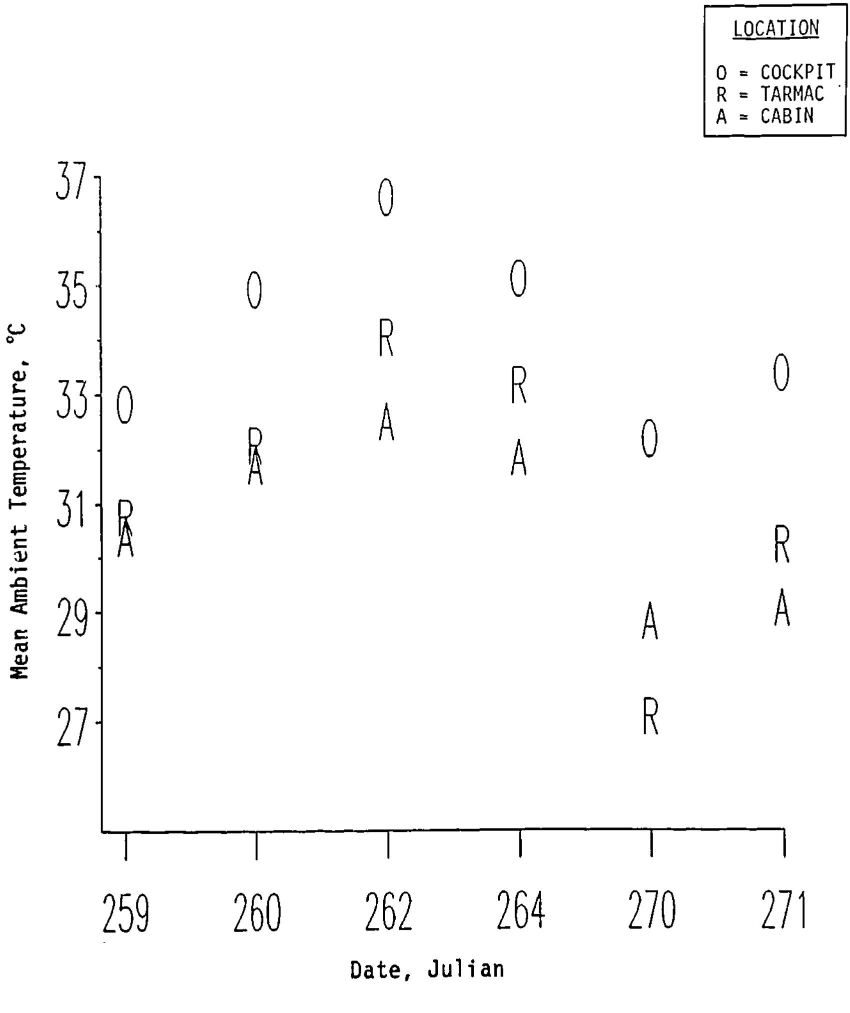

Figure 19
SUBJECT AMBIENT TEMPERATURE (DRY BULB)
(Cockpit, Tarmac, and Cabin Comparison)

Figure 20 includes cabin, cockpit, and tarmac T_{db}. For the same day, figure 21 includes cabin and cockpit subjects' T_{sk}. Notice the following: (1) cockpit T_{db} was greater than tarmac T_{db} which was greater than cabin T_{db}, and (2) the cockpit subject had a higher T_{sk} than the cabin subject T_{sk}.

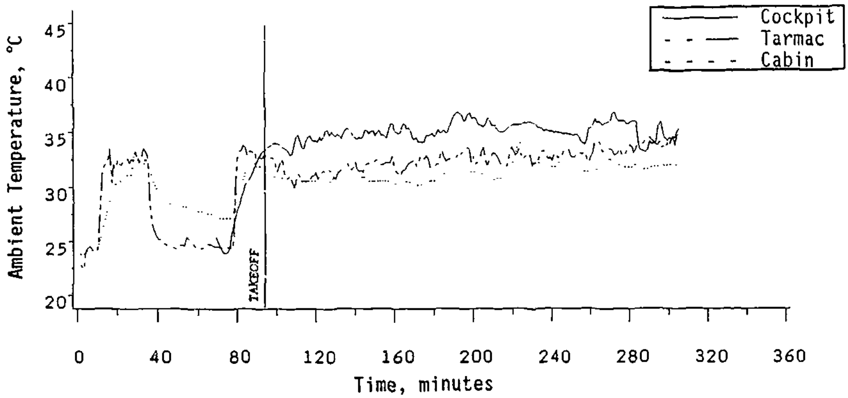

Figure 20
SUBJECT AMBIENT TEMPERATURE COMPARISON (DRY BULB)
(Cockpit, Cabin, and Tarmac Locations)

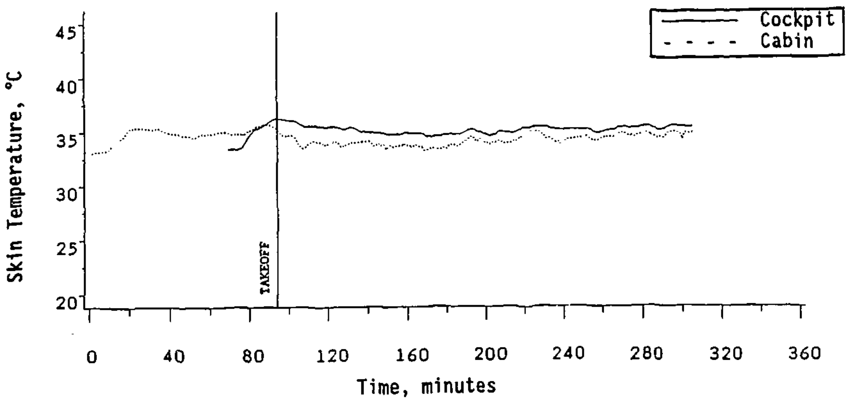

Figure 21
SUBJECT SKIN TEMPERATURE COMPARISON
(Cockpit and Cabin Locations)

Observing cockpit and cabin differences, the next investigation compared the physiological responses of subjects in these two locations. Table XI summarizes the cockpit and cabin environments and physiological response differences from both CH-53 and UH-1N.

Table XI

COCKPIT AND CABIN DIFFERENCES

Aircraft	Location	Mean T_{db} °C (°F)	Mean T_{core} °C (°F)	Mean T_{sk} °C (°F)	Mean HR (beats/min)
CH-53	Cabin	30.3 (86.5)	37.4 (99.3)	34.6 (94.3)	91
	Cockpit	34.0 (93.2)	37.7 (99.9)	35.4 (95.7)	92
UH-1N	Cabin	30.4 (86.7)	36.9 (98.4)	33.5 (92.3)	77
	Cockpit	33.6 (92.5)	37.3 (99.1)	34.8 (94.6)	78

Cockpit T_{db} was significantly hotter than cabin T_{db} in flight, and cockpit T_{core}, T_{sk}, and heart rates were also significantly higher than the cabin. The physiological differences could have been caused by the following: (1) ambient temperature differences; (2) piloting the aircraft was more stressful than cabin duties during this test scope; or (3) without rotating subjects between the two locations, individual subject differences. To investigate this situation further, it would be necessary to interchange cockpit and cabin subjects to eliminate individual differences, but this was not completed within this test program. Further study is necessary to determine which of the three factors provided was the major factor.

95. Using the entire NAS New Orleans UH-1N test data to demonstrate the environmental difference further, the cabin remained 32°C (90°F) or hotter for 441 min, while the cockpit remained 32°C (90°F) or hotter for 1,055 min. Based on these observations, if manpower limitations preclude substituting an entire preflight crew, recommend pilots be relieved of the hardest preflight mission duties (paragraph 86) to compensate for the later in-flight hotter cockpit environment.

HYDRATION EFFECT

96. Initially, correlative analyses were conducted to determine whether water intake affected physiological responses. Surprisingly, T_{core}, T_{sk}, and heart rate were not strongly correlated with water intake. In other words, subjects who drank the most water did not perform significantly better than subjects who drank little or no water. It is important to <u>not</u> draw the wrong conclusion from these results. The critical elements to study further are water intake balanced with water loss and eventually to estimate a successful hydration schedule for aircrew wearing the A/P22P-9(V).

97. Interestingly, research indicates the body has 1-2 liters extra water, which can be lost with no real performance decrement (reference 32). In fact, 1-2% dehydration may produce little or no performance decrement; 5% dehydration being the feasible limit. Beyond this, every additional percent dehydration appears to increase the rate of T_{core} by roughly 6% (reference 32). Upon reviewing table XII, 1.4% average body weight loss was the worst degree of dehydration produced during testing. It is conceivable now that no correlation could be found between water intake and physiological responses. Subjects generally maintained their hydration levels within the 2% dehydration limit, not producing any gross physiological response. In fact, there was a slight tendency for subjects to lose more body weight wearing standard ALSS than wearing the A/P22P-9(V). Subjects were likely sensitized to the importance of drinking water while wearing the A/P22P-9(V) and made a more conscious effort to drink. This is particularly evidenced in the slight 75 gram weight loss seen in NAS New Orleans UH-1N flight testing.

Table XII

MEAN BODY WEIGHT LOSS

CB = A/P22P-9(V) ST = Stand. ALSS	CB			$SD_{\bar{x}}$			ST			$SD_{\bar{x}}$		
	%	gm	lb	%	gm	lb	%	gm	lb	%	gm	lb
Ground	0.6	426	0.94	0.4	250	0.56	0.9	725	1.6	0.7	590	1.3
CH-53 Flight	1.4	1180	2.6	0.6	450	1.0	1.2	1040	2.3	1.0	820	1.8
UH-1N Flight	0.8	770	1.7	1.1	1000	2.2	0.2	230	0.5	-	-	-
UH-1N Flight (NAS New Orleans)	0.1	75	0.16	0.9	100	2.2	1.0	730	1.6	0.6	500	1.1

Water Balance

98. The next logical step was to explore the balance between water intake and water losses necessary to remain within a 2% dehydration limit. Normal body water balance is outlined below (reference 46):

Normal routes of water:

Intake	ml/day
Drunk	1200
In food	1000
Metabolically produced	350
TOTAL	2550
Output	
Insensible loss (skin and lungs)	900
Sweat	50
Feces	100
Urine	1500
TOTAL	2550

Applying test data to the outline above gave a solid frame of reference. Considering the "intake" side of the equation, water drunk during testing was critical since no food was administered and metabolic production remained somewhat constant and unmeasurable. On the "output" side, urine was easily accounted, but insensible losses and sweat production were impossible to separate (there were no feces).

Water Intake and Urine

99. Water intake and urine production are easy gauges for studying body water balance. Normally, approximately 60% (1500 ml + 2550 ml, paragraph 98) of all water intake (drinking, food, metabolic) leaves the body as urine. Considering subjects who drank the most, the ratio of water drunk to urine produced was 10% for A/P22P-9(V) subjects and 30% for standard ALSS. Data were ranked by total water intake and compared to urine output. Interestingly, A/P22P-9(V) subjects drinking 0-600 ml did not urinate at all. A/P22P-9(V) subjects drinking between 600 and 1500 ml had a drinking-to-urine ratio of only 0.14%. Not until subjects drank more than 1500 ml for an average 5.5 hr mission did urination become a consistent variable with a drinking-to-urine ratio of 10%. A similar water volume breaking point was found for standard ALSS subjects. Urination was not consistent until drinking more than 750 ml for a 5.5 hr mission with a drinking-to-urine ratio of 30%. Rank ordering also made it clear to see that the NAS New Orleans subjects were solely responsible for water consumptions greater than 1500 ml (A/P22P-9(V)) and 750 ml (standard ALSS): average New Orleans water consumptions were 2100 and 1400 ml, respectively. As a loose gauge, A/P22P-9(V) subjects drank twice the water volume of standard ALSS subjects, yet their drinking-to-urine ratio was far lower suggesting the need to drink even more water.

100. Table XIII provides average water intake and urine values for each of the four test programs. Values are reported in hourly rates to account for varied test durations. For example, subjects may drink 200 ml during a 2-hr mission and 600 ml during a 6-hr mission, but the drinking rates are identical, 100 ml per hour. Recalling from table XII, the average NAS New Orleans subject lost only 75 grams of body weight during testing. As might be expected, NAS New Orleans drinking rate exceeded all other drinking rates. Conversely, CH-53 flight test subjects averaged the smallest drinking rate and the highest total weight loss. Note also in table XIII that, despite greater water intake by subjects wearing the A/P22P-9(V), urine output is less than while wearing standard ALSS. Again, this suggests the difference was lost in sweat and moisture from the lungs.

Table XIII

WATER INTAKE AND URINE OUTPUT

Test Type	$\bar{X}$				$SD_{\bar{x}}$	
CB = A/P22P-9(V) ST = Stand. ALSS	CB ml/hr (qt/hr)		ST ml/hr (qt/hr)		CB	ST
	Water	Urine	Water	Urine	Water Only	
Ground	340 (.36)	0	45 (.05)	0	245 (.26)	90 (.09)
CH-53 Flight	180 (.20)	0	70 (.07)	0	80 (.08)	100 (.1)
UH-1N Flight	190 (.20)	0	30 (.03)	155 (.16)	285 (.30)	51 (.05)
UH-1N Flight (NAS New Orleans)	411 (.43)	82 (.09)	284 (.30)	100 (.11)	221 (.23)	135 (.14)

Crew Relief Provisions

101. No closed, contaminant-free system existed for aircrew to urinate wearing the A/P22P-9(V). During NAS New Orleans testing, subjects urinated in 21 out of 24 test events. Table XIV lists water intake and urine for NAS New Orleans A/P22P-9(V) test events. One subject urinated four times during a 6-hr mission for a total volume of 1815 ml. The A/P22P-9(V) does not provide a closed system for urination in a contaminated environment. This leaves the wearer with three poor options: limit water intake to limit urine output (risk dehydration); open the BTN protection to urinate (risk contamination); or wet himself. None of these options are viable. Recommend developing a CB protective retention or expulsion system for safe urination during CB threat missions. Crew performance wearing the A/P22P-9(V) requires excessive operator compensation or compromise to accomplish CB contaminated helicopter missions. Inability to drink ad libitum and safely urinate without risk of contamination is a Part II deficiency that should be corrected as soon as practicable.

Hydration Schedule

102. Reviewing NAS New Orleans water intake and urine output data (table XIV), it is clear that reducing water intake does not preclude urination during a mission. One subject consuming only 600 ml over 6 hr still urinated. Paradoxically, a subject who drank 3600 ml (six times more) did not urinate. The point is, water should not be restricted to check urine production. If fact, the correlation between water intake and urine volume was very low, r=.30 for A/P22P-9(V) and r=.55 for standard ALSS. Aircrew wearing the A/P22P-9(V) should follow a hydration schedule to ensure adequate amounts of water are being consumed.

Table XIV

NAS NEW ORLEANS A/P22P-9(V) TEST EVENTS

Test Event	Water Intake (ml)	Urine (ml)
1	2500	1815
2	4400	675
3	2300	725
4	1680	200
5	2110	0
6	1900	80
7	830	405
8	750	375
9	2535	150
10	3600	0
11	600	260
12	2210	500

103. Various hydration schedules have been specified for industrial workers and other military agencies. Within the scope of this test program, most water schedules would have been overkills. As noted in table XIII, the average water intake of A/P22P-9(V) subjects during testing ranged from 0.20-0.43 qt/hr (180-410 ml/hr). Compare with the following hydration schedules noted in the literature:

a. 150-200 ml every 15-20 min as opposed to 750 ml or more an hour (reference 33).

b. Since the body has sustainable sweat capacity of about 1 L per hour, the recommendation for a minimum of 8 qt (per 8 hr) of cool potable water should receive as much emphasis as possible (reference 32).

c. Temperature (°F) qt/hr

< 70	0.5 - 1.0	
70-79	1.0 - 1.5	
80-89	1.15 - 2.0	
> 90	< 2.0	(reference 47)

d. WBGT (°F) qt/hr

< 82	up to 0.5	
82-85	0.5 - 1.0	
85-88	1.0 - 1.5	
88-90	1.5 - 2.0	
> 90	2 or more	(reference 48)

Based on test results, the following hydration schedule (table XV) is recommended for USMC helicopter aircrew wearing the A/P22P-9(V). Nearly halving some other hydration schedules above still produced drinking rates higher than actually maintained ad libitum by subjects during this testing. If weight loss is noted after a mission, a general rule of thumb is to drink two 8 oz glasses of water for every pound lost.

Table XV

HYDRATION SCHEDULE FOR A/P22P-9(V) USE

Temperature Ranges	qt/hr	qt/6 hr	ml/hr	l/6 hr
< 21°C (70°F)	0.25	1.5	250	1.5
21° - 26°C (70° - 79°F)	0.50	3.0	500	3.0
27° - 32°C (80° - 89°F)	0.75	4.5	750	4.5
33° - 43°C (90° - 109°F)	1.00	6.0	1000	6.0

Other Water Losses

104. Pretest and posttest nude and clothed weights, water intake, and urine output values were used to calculate the following (refer to appendix C, paragraph 41):

a. Water loss (recall, this equals water lost in sweat and respiration).

b. Sweat absorbed in clothing.

c. Water evaporated (insensible loss from lungs and sweat evaporated).

Reviewing table XVI, total water loss rate for A/P22P-9(V) subjects was significantly greater than the water loss rate for standard ALSS subjects. Ranking the highest to lowest water loss rates, A/P22P-9(V) ground testing (880 gm/hr) produced the highest and UH-1N flight testing the lowest (390 gm/hr). These findings are consistent with what was anticipated: ground testing required subjects to repeat their preflight inspections several times without rest; their workrates were higher for longer periods of time compared with flight test subjects. UH-1N flight testing required only one preflight on a relatively small helicopter and low, flying workrates in a well-ventilated helicopter.

Table XVI

MEAN WATER LOSS RATE

CB = A/P22P-9(V) ST = Stand. ALSS	CB gm/hr (lb/hr)	$SD_{\bar{x}}$ gm/hr (lb/hr)	ST gm/hr (lb/hr)	$SD_{\bar{x}}$ gm/hr (lb/hr)
Ground	880 (1.94)	210 (0.47)	460 (1.00)	290 (0.65)
CH-53 Flight	700 (1.54)	350 (0.78)	415 (0.92)	315 (0.70)
UH-1N Flight	560 (1.20)	270 (0.60)	110 (0.25)	-
UH-1N Flight (NAS New Orleans)	390 (0.86)	130 (0.28)	310 (3.69)	80 (0.17)

Reference 33 provides a standard for comparison:

	Unacclimated		Acclimated	
	Alert	Danger	Alert	Danger
Resting sweat rate (gm/hr)	260	390	520	780
Max work sweat rate (gm/hr)	520	650	780	1040

A true comparison is difficult since test subjects' workrate and acclimatization varied. Workrates varied from low to moderate, rarely maximum. No subjects were formerly acclimated, but some did exercise a couple of hours a day during the hottest part of the day. With these ranges in mind, A/P22P-9(V) subjects' water loss rates could be classified at the "alert" or event the "danger" level considering the standard deviation. (Keep in mind, no tests were terminated for having reached a safety criterion.)

Sweat Absorbed and Water Evaporated

105. Theoretically, of sweat produced, a portion remains on the skin, a portion is absorbed in clothing, and a portion of that evaporated. The difference between sweat absorbed and sweat evaporated indicates clothing permeability. As described earlier (paragraph 98), sweat evaporation and insensible water loss from the lungs are difficult to separate, but together, they total an average water loss of 950 ml water loss per day under normal conditions. Such measurements, even in a laboratory, require sensitive measuring equipment and strict control; both are impossible during field testing. CH-53 and UH-1N flight testing indicate that, of the total water lost, the following breakout for sweat absorbed and water evaporated was observed:

	A/P22P-9(V)	Standard ALSS
Sweat absorbed	40%	60%
Water evaporated	60%	40%

The data suggest the A/P22P-9(V) absorbed less sweat than standard ALSS and evaporated more, which is opposite of what might be expected. These percentages might be interpreted as the result of greater insensible loss, or loss of moisture from the lungs, while wearing the A/P22P-9(V). The CB gear weighed approximately 17 lb more than standard ALSS, and A/P22P-9(V) orinasal mask presented a greater breathing resistance. The additional labor associated with carrying the extra weight and the rigors of inhalation and exhalation may have contributed greater losses from the lungs than evaporated from clothing.

Specific Gravity

106. Each subject's urine specific gravity was measured before and after each test and used as an indicator of hydration level. Specific gravity values were analyzed to determine whether A/P22P-9(V) subjects were significantly more dehydrated than standard ALSS subjects following test missions. No significant difference or trend was found. Specific gravity values relative to water intake were also analyzed. No correlation was found: water intake did not ensure lower posttest specific gravities. Though no difference existed between A/P22P-9(V) and standard ALSS specific gravities, the trend for both was to increase (refer to table XVII).

Table XVII

URINE SPECIFIC GRAVITY MEAN DIFFERENCES
(Posttest Minus Pretest)

Test Type	$\bar{X}$	
CB = A/P22P-9(V) ST = Stand. ALSS	CB	ST
Ground	0.009	0.007
CH-53 Flight	0.003	0.003
UH-1N Flight	0.004	0.009
UH-1N Flight (NAS New Orleans)	0.004	0.002

107. Though these results are disconcerting, they must be reviewed within the context of this test's design. Subjects' water, food, and exercise were not controlled prior to testing. Some subjects hydrated immediately before arriving to the ready room but drank nothing during testing. The effect was to decrease specific gravity (hydrate) while seemingly drinking no water. Many such combinations perturbed a clear view of specific gravity differences and their attributable causes.

108. Normal 24-hr specific gravities range from 1.015 to 1.025 (references 49 and 50). In states of dehydration, during periods of excessive sweating and reduced water intake, specific gravity will approach 1.035. Reviewing ground and flight data results, some general observations can be reported. Most subjects arrived at testing with high-end normal specific gravities (≈ 1.023) and left testing with slightly higher specific gravities (≈ 1.026). The remaining subjects ranged from hyper-hydrated (specific gravity ≈ 1.005) to dehydrated (specific gravity > 1.040).

AGE EFFECT

109. To assess the age effect, physiological data were divided into three age groups: 25-30 years, 30-35 years, and 35-40 years. In both the A/P22P-9(V) and standard ALSS, the 35-40 year group resting heart rates and heart rates throughout testing were significantly lower than the other two groups. Other physiological responses for the 35-40 year group were not significantly different from the other groups. Within the scope of these tests, subjects in the 35-40 year age group had more experience in their particular helicopter type than did younger subjects. Research literature also substantiates this finding: highly skilled subjects perform better in thermal stress situations than less skilled counterparts (Mackworth as reported in reference 39). One rationale for this conclusion is that skilled responses tend to be more automatic requiring less active information processing than someone still learning. As such, skilled responses are less susceptible to thermal stress decrements. Based on these test data, there are no age restrictions for wearing the A/P22P-9(V) up to age 40.

RESTING HEART RATE

110. The correlation between resting heart rate and overall physiological performance during A/P22P-9(V) testing was also evaluated. The premise being lower resting heart rates indicate better physical conditioning. All resting heart rates were divided in the three groups: <60 beats/min, 60-76 beats/min, and >76 beats/min. As expected, the >76 beats/min group had significantly greater physiological responses to the A/P22P-9(V). Combining age and resting heart rate, the 35-40 year group average resting heart rate was 55 beats/min; 30-35 years was 67 beats/min; and surprisingly, the youngest 25-30 year group was 80 beats/min. It would be speculative to say exactly what attributed to these significant heart rate differences: exercise, stress tolerance, skill level. The important point is the lower the resting heart rate, the better.

CONCLUSIONS

GENERAL

111. Within the scope of this ground and flight test program, the A/P22P-9(V) contributed significantly to subjective and physiological thermal stress symptoms in USMC helicopter aircrew conducting AH-1, UH-1N, CH-46, and CH-53 helicopter missions in warm/hot environments (dry bulb range 22-40°C, 72-104°F). USMC helicopter aircrew wearing the A/P22P-9(V) should be able to complete 4-hr flight missions in UH-1N, CH-46, and CH-53 helicopters operating within the following guidelines:

a. Donning is assisted and conducted in a cool environment (≈ 22°C, 72°F) (paragraphs 32 and 66).

b. All preflight duties are transitioned to nonflying crew (paragraphs 73 and 86).

c. Helicopter doors, windows, hatches, and ramp are open (paragraph 71).

d. Dry bulb temperature <38°C (<100°F) (paragraph 63).

e. Water intake is as prescribed (paragraph 103.d).

f. Aircrew are well-rested, well-nourished, and acclimated (paragraph 63).

g. Urine relief provisions are CB protective (paragraph 101).

h. Aircrew are aerobically fit (preferably resting heart rates lower than 76 beats/min) (paragraph 110).

112. With properly fitted A/P22P-9(V) clothing and thorough training, A/P22P-9(V) aircrew can successfully perform the following:

a. Assist other aircrew in A/P22P-9(V) donning and doffing (paragraph 32).

b. Access and use survival equipment (paragraph 42).

and in CH-53, CH-46, UH-1N, and AH-1 helicopters:

c. Ingress and egress (paragraph 53).

d. Emergency egress (paragraph 53.a).

e. Water survival procedures (paragraph 53.b).

f. D/T and preflight duties (paragraph 51).

PART II DEFICIENCIES

113. Reduced CB protection from tearing the sock's toe seam (paragraph 33.c).

114. Reduced CB protection from snagging and tearing butyl rubber gloves during donning (paragraph 33.e).

115. Unsafe overboot bulk and traction (paragraph 52).

116. Inability to drink ad libitum and safely urinate without risk of contamination (paragraph 101).

PART III DEFICIENCIES

117. Painful hot spots and cramping caused by CB protective sock bulk (paragraph 33.d).

118. Inability of subjects to easily and adequately drink using the drinking straw (paragraph 37).

SPECIFIC

119. Poor training or unassisted donning and doffing lead to errors and unnecessary equipment damage and threatened CB protection integrity (paragraph 32).

120. Standard-issue spectacles were comfortable for some aircrew, as opposed to the A/P22P-9(V) compatible AR-S spectacles (paragraph 33.a).

121. Some aircrew needed larger helmets to comfortably accommodate the hood/mask assembly (paragraph 33.b).

122. The ventilator continuously struck aircrew right thighs while walking and preflighting (paragraph 34).

123. Aircrew tended to disconnect canteens to reduce weight and cumber; in a contaminated environment, they could not safely reattach to the water supply without risking contamination (paragraph 39).

124. In general, the A/P22P-9(V) was compatible with standard ALSS; occasionally, some larger ALSS equipment was needed to achieve a comfortable fit (paragraph 41).

125. With thorough training, aircrew could access and use survival equipment and perform mission duties with the three-layer gloves effectively (paragraphs 42 and 47).

126. Nearly all 1st through 99th percentile A/P22P-9(V) aircrew could bend, stretch, and reach satisfactorily (paragraph 44).

127. The respirator assembly reduced head and neck mobility and lead to neck muscle fatigue; with training, wearing the gear 12-15 hr over a 2 week period, aircrew overcame both problems (paragraph 45).

128. The MK-1 undercoverall afforded ample shoulder and arm mobility for aircrew smaller than a 97th percentile acromial shoulder height (paragraph 46).

129. The MK-1 undercoverall afforded suitable leg freedom of movement (paragraph 48).

130. The MK-1 undercoverall did not restrict waist bending or twisting (paragraph 49).

131. With and without the ventilator, the A/P22P-9(V) did not impede ingress, egress, or emergency egress in the CH-53, CH-46, UH-1N, and AH-1 helicopters (paragraph 53).

132. During emergency egress, aircrew were able to actuate the RIED valve by using one hand, two hands, and no hands (paragraph 53.a).

133. The additional weight and bulk of the MK-1 undercoverall did not impact water survival procedures (paragraph 53.b).

134. Perspiration, more so than heat buildup, caused the greatest subjective discomfort (paragraph 55).

135. Dry bulb ambient temperature is a better thermal indicator than WBGT for personnel wearing the near-impermeable A/P22P-9(V) protective clothing, particularly when activities are involved, such as during D/T's and preflights (paragraph 62).

136. Undue time donning will inevitably result in a premature and unnecessary elevated physiological condition (paragraph 66).

137. Even in cool temperatures, D/T and preflight inspections wearing the A/P22P-9(V) can cause T_{core} to rise 1.0°C (1.8°F) in 50 min, which is already too high for pilots to fly safely, particularly when considering T_{core} may continue to increase in flight (paragraph 70).

138. Relative to preflight activities, the in-flight environment provided relief: lower workrate (paragraphs 73 and 86) and windy, open aircraft flying offered cooling to A/P22P-9(V) aircrew (paragraph 71).

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RECOMMENDATIONS

GENERAL

139. Correct the deficiencies in paragraphs 113 through 116 as soon as practicable.

140. Avoid the deficiencies in paragraphs 117 and 118 in future designs.

SPECIFIC

141. Consider including reported recommendations in instructions and manuals to improve the training, safety, and performance of aircrew operating in the A/P22P-9(V) (paragraph 29).

142. Provide survival equipmentmen and aircrew repetitive, supervised A/P22P-9(V) donning and doffing training to avoid errors and equipment damage (paragraph 32).

143. Don and doff the A/P22P-9(V) with the assistance of a well-trained survival equipmentman or fellow aircrew and also conduct donning at room temperature (≈ 22°C, 72°F) or cooler (paragraphs 32 and 66).

144. Don the A/P22P-9(V) with the air hose connected and ventilator turned "ON" (paragraph 33.a).

145. Do not remove the hood/mask assembly to adjust a skull cap, sweat band, or eye glasses; it is simpler to make corrections through the butyl rubber (paragraph 33.a).

146. Dust a talc-powdered cloth on each side of the donned hood to reduce friction with the helmet during donning and doffing (paragraph 33.b).

147. Develop more tear-resistant CB protective socks and provide better donning procedures until a better CB protective sock is developed (paragraph 33.c).

148. To reduce foot cramping and hot spots, carefully fold and tape excess sock bulk, issue larger flight boots when needed, and develop a new sock that better matches the shape of the foot (paragraph 33.d).

149. Develop more tear-resistant CB protective gloves or change donning procedures so the butyl rubber gloves are not subjected to snagging and wear snug-fitting CB protective gloves to avoid snagging and tearing (paragraph 33.e).

150. Position ventilator strap quick-disconnect slightly below the survival vest (SV-2) lower edge, placing the ventilator high and on the outside of the right hip (paragraph 34).

151. Don the CB protective socks, flight boots, and overboots before donning the hood/mask assembly (paragraph 35).

152. Route the intercom communication lead through a survival vest snap retainer to avoid a snag hazard (paragraph 36).

153. Remove the intercom battery after doffing is completed (paragraph 36).

154. Connect top and bottom of drinking facility to faceplate entry tube and canteen while in a CB contaminant-free ready room and do not disconnect until back in a clean environment (paragraph 39).

155. Route canteen strap under respirator air tubes and intercom communication lead, and over the left shoulder clear of the life preserver lobes, and wear the canteen on the right side with the cap facing forward (paragraph 40).

156. Ensure aircrew are properly fit with standard ALSS and A/P22P-9(V) elements (paragraph 41).

157. Practice accessing and using survival equipment while wearing the entire A/P22P-9(V) (paragraph 42).

158. Train aircrew wearing the entire A/P22P-9(V) ensemble a minimum of 3 days, 4 continuous hours per day over a 2 week period several times per year; each session should encompass D/T inspection, preflight, and flight mission duties (paragraph 45).

159. Make certain gloves fit properly and aircrew practice fine motor dexterity tasks (paragraph 47).

160. Modify or redesign overboots to reduce bulk and increase traction (paragraph 52).

161. Lightweight, disposable sweatbands should be worn to absorb sweat and help prevent perspiration from entering the eyes (paragraph 55).

162. Redesign drinking straw and facility for easier use (paragraph 37).

163. Use developed procedures to better use the current drinking facility and straw (paragraph 38).

164. Pilots and copilots should switch helicopter control every 15-20 min so the nonflying pilot can drink water safely (paragraphs 38 and 102).

165. Ensure standard and CB protective clothing fit properly; this will reduce hot spots, pressure points, and poor fit symptoms (paragraph 56).

166. Medical safety officers should be thoroughly familiar with the prevention and treatment of heat stress, provide squadron members heat stress prevention briefs, and conduct and monitor aircrew acclimatization programs (at least 2 weeks working in the operational environment wearing the A/P22P-9(V) for several hours per day) (paragraphs 63 and 45).

167. Medical safety officers can estimate preflight and in-flight cabin temperatures using tarmac dry bulb temperature and estimate in-flight cockpit temperature by adding 6.0°C (10.8°F) to the tarmac dry bulb temperature (paragraph 63).

168. Shield the dry bulb sensing element (appendix C, paragraph 29).

169. Commanding officers should substitute A/P22P-9(V) flight crew with a qualified ground crew to perform D/T, preflight, and nonflying duties (refueling, loading, etc.) to increase their effective flying time performance (as a minimum, relieve pilots from preflight activities) (paragraphs 73 and 86).

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DETAILED DESCRIPTION OF TEST EQUIPMENT

A/P22P-9(V) RESPIRATOR ASSEMBLY

1. The principal A/P22P-9(V) Respirator Assembly parts are shown in figure 1.

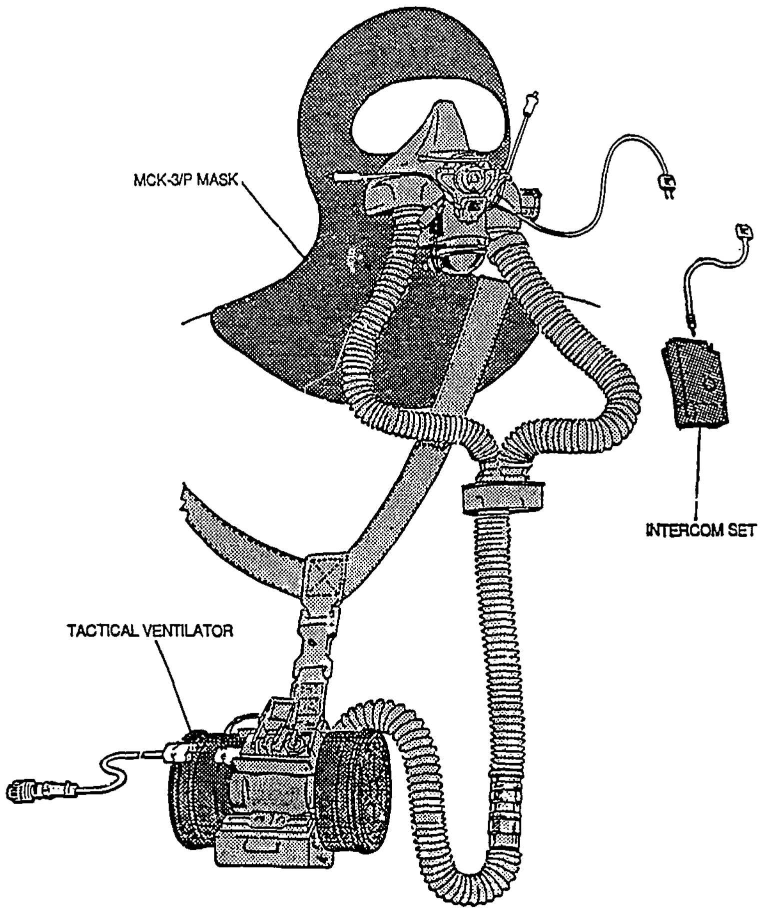

Figure 1
A/P22P-9(V) RESPIRATOR ASSEMBLY

HOOD

2. The respirator hood is currently manufactured in one size. The hood consists of an impervious bromo-butyl rubber, which covers an aircrewmember's entire head and extends down the neck where it is bonded to the upper edge of a bellows. A shoulder skirt is bonded to the lower edge of the outer surface of the bellows. The inner surface of the bellows incorporates a neck seal, made of natural rubber to seal off the head and neck areas.

FACEPLATE

3. The faceplate is constructed of an injection-molded, one-piece, polycarbonate material. The upper part or optical portion of the faceplate is transparent. The lower part (painted black) is shaped in a facial exoskeletal form to support the mask.

MASK

4. The mask is molded of soft rubber and fits over the wearer's nose and mouth; it comes in two sizes (medium and large). A deflector plate constructed of plastic is mounted inside and to the right of the mask. It deflects the blown air across the faceplate to demist the inner surface. The exhalation valve is located at the bottom and center region of the respirator faceplate and extends into the mask. The double exhalation valve consists of an inner compensated valve and an outer stepped exhalation valve. The compensated valve is mounted in the exhalation duct of the mask with its compensated chamber connected into the mask inlet. The stepped exhalation valve is fitted in a plastic holder, which is inserted in the lower part of the mask.

HOOD OUTLET AND SHUTOFF VALVE

5. The hood outlet valve is mounted on the left side of the faceplate below the visual area and above the angled inlet on the mask. The valve consists of a stepped rubber valve and seat, an external slotted cover, and a manually operated shutoff lever.

ANTIDROWN CONNECTOR

6. The antidrown connector located at the end of the mask tube is manually unlocked from the angled inlet on the faceplate by a counterclockwise rotation of a knurled locking ring, which breaks a shear pin. The mask hose is separated from the angled inlet by pulling firmly down on the hose.

DRINKING FACILITY

7. The drinking facility consists of an angled metal feed tube with a capped end and a plastic drinking tube. The metal feed tube passes through the lower right side of the faceplate and terminates in the right inner wall of the mask. The drinking tube, housed in a retractable rubber conduit, is then inserted into the metal feed tube. By pushing the rubber conduit upward, the plastic drinking tube will pass through the mask to the lips of the aircrewmember. The other end of the drinking tube is inserted into a canteen with a MK-17 cap. The water enters the straw by squeezing the canteen continuously or by raising the canteen overhead for a gravity feed.

TOGGLE HARNESS ASSEMBLY

8. The toggle harness assembly is mounted on the front of the faceplate above the microphone. A "V" shaped, hinged bow freely pivots upward or downward and is suspended from two rectangular studs protruding from the mounting plate. Attached at the bow is a clamp that also pivots upward and downward and provides the necessary tension adjustment, in conjunction with the swivel links, for tightening the mask to the helmet. The short lengths of cable are connected to the clamp and each is fitted with an adjustable swivel link to shorten and lengthen the cable and to prevent the cable from twisting while adjusting the tension. The swivel link connects the A/P22P-9(V) respirator mask to the helmet. Before the swivel link is coupled to the helmet receivers, the cables should lie over the "V" bow hooks.

MICROPHONE

9. The microphone assembly consists of a microphone and a microphone lead with a plug (internal amplifier) that can be connected to the socket of an aircrew helmet. The microphone is fitted through the central port of the faceplate and into the rubber port of the mask ensuring an adequate seat of the mask housing within the faceplate. The microphone is retained in place by a plastic cable tie, cinched around the rubber portion of the mask that protrudes outward through the faceplate.

NOSE OCCLUDER

10. The nose occluder assembly is mounted through the nose bridge of the faceplate. The assembly is available in eight sizes ranging from 4mm (short) to 7mm (long), in increments of 1mm. The occluder consists of a pair of shaft subassemblies, with nylon rollers, that can be swept down over the nasal area of the mask. The shaft assemblies are operated by manually raising the stirrup handle that is mounted externally on the faceplate surface.

MANIFOLD

11. The MK-2 manifold is attached to the hood and mask tube inlets. The manifold is constructed of an aluminum alloy housing with three external ports that permit connecting hood and mask tubes to the air hose. The manifold fits into a special pocket with snaps to be attached to the survival vest.

RAPID IN-LINE EMERGENCY DISCONNECT VALVE

12. This quick disconnect is located between the respirator and ventilator air hose coupling. It allows separation of the respirator from the ventilator in the event of emergency water entry and emergency land egress. The male portion is connected to the MK-7 bayonet union plug located at the end of the respirator air hose. When the Rapid In-line Emergency Disconnect (RIED) valve is disconnected, this portion closes, preventing water or contaminants from entering the respirator. When the aircrewmember depresses the perforated tube, he can inhale unfiltered ambient air.

INTERCOM

13. The intercom unit contains an audio frequency amplifier, a single three-position toggle switch, and two jack sockets. The unit is powered by a 9 V battery, which is stowed within the unit's metal case. The unit functions by receiving auditory signals, amplifying the sound, and transmitting the signal to the wearer's headset. The three-position toggle provides three modes: TALK, LISTEN, and OFF. Two jack sockets are available so that two aircrewmembers can plug into one intercom unit to enhance communication independent of aircraft intercommunication system. The unit is snap-hooked to the aircrewmen's SV-2B Survival Vest. When released, the toggle switch returns to the LISTEN position.

VENTILATOR

14. The ventilator consists of an aluminum cast housing, an electrical motor, hoses, strap assembly, power cord, and CBR filters. The ventilator housing contains two compartments. The plenum compartment is sealed from contaminated air and houses a motor, fan, and printed circuit board; it provides threaded openings for the two filter canisters. The second compartment houses the battery and seals when the compartment lid is secured. When the battery is installed, electrical contact is made between the battery and the ventilator motor.

a. A DC permanent magnet motor is used to drive the fan. The fan is attached to the motor spindle and delivers the required airflow. Two filter canisters purify the ambient air passed into the ventilator body by the motorized fan. The ventilator delivery hose is fabricated from bromo-butyl rubber. The hose is reinforced to prevent kinking or overstretching and is securely attached to the ventilator housing. The free end of the delivery hose connects to the RIED valve with a bayonet connector.

b. A printed circuit board provides electrical current control for maintaining the blower motor speed within specified limits over a range of input voltages. A two-position toggle switch is used to actuate the power to the motor. The switch has two positions, "ON" and "OFF", and is shielded against inadvertent actuation. An external jack is provided to allow the ventilator power cord to be connected to 28 V DC aircraft power.

c. Power is supplied to the ventilator via a power cord or a 15 V mercury-zinc (Kalium) battery. A power cord connects the ventilator to the aircraft 28 V DC power during flight operations. The cord is secured to the ventilator to prevent snagging during transit. A battery is used during ground operations or when aircraft power is unavailable or not feasible. When the external power supply is connected, with the toggle switch in the "ON" position, battery power is bypassed with no battery recharge capability. When the external power supply is disconnected and the toggle switch is "ON", the battery supply is utilized. When the ventilator DC motor is switched to its "ON" position, power from the battery or 28 V DC aircraft power energizes the motor. The fan draws ambient air through the filter canisters and into the plenum compartment. The filtered air passes around the body of the motor, acting as a cooling medium, and is propelled into the delivery hose.

d. A shoulder strap can be attached to the ventilator while the aircrewmember is mobile, to allow free hands. A standard mounting bracket, per NAVAIRSYSCOM Drawing 1605AS400, is attached to the ventilator housing for mounting the ventilator to the aircraft.

e. Details on the configuration, function, operation, maintenance, and repair of the respirator assembly components of the A/P22P-9(V) are contained in reference 15.

A/P22P-9(V) BELOW-THE-NECK ASSEMBLY

15. The A/P22P-9(V) below-the-neck assembly is shown in figure 2.

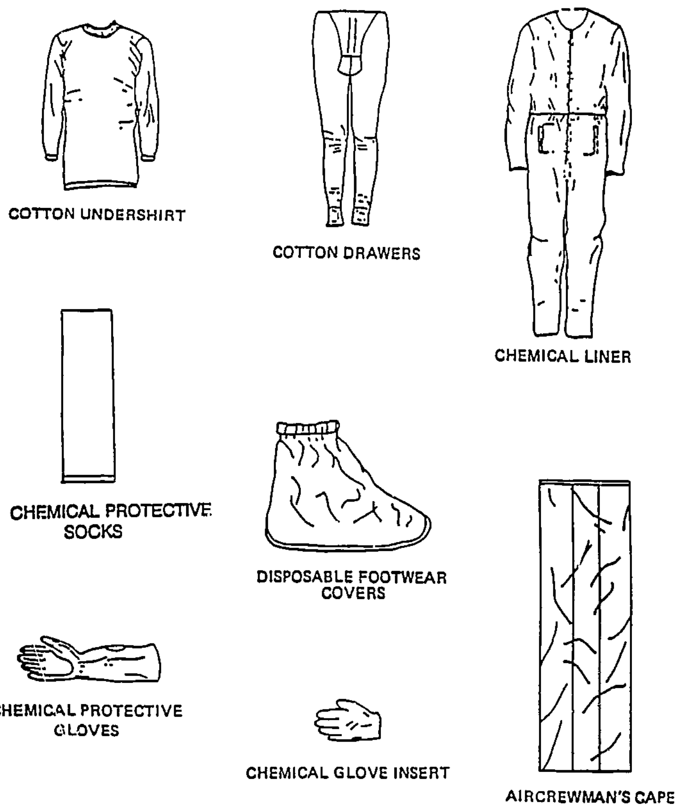

Figure 2
A/P22P-9(V) BELOW-THE-NECK ASSEMBLY

LONG UNDERWEAR

16. The long underwear consists of two pieces: an undershirt and drawers. Both are made of a jersey knit cotton and are worn under the chemical liner. The sleeves and legs cover the limbs down to the wrists and ankles, respectively. The undershirt comes in four sizes and the drawers come in 14 sizes (including regular and long fit). The underwear is reusable after laundering; however, they are discarded after CBR contamination or after more than 100 cumulative hours of wear. Standard cotton socks are worn with the long underwear, and together these undergarments comprise the first step in the donning procedure.

CHEMICAL PROTECTIVE SOCKS

17. The socks are made of 4-mil thick polyethylene. They are worn over cotton socks and under the standard flight boots. The socks are a "tube sock" design and come in one size to fit all. They are discarded after each use, regardless of CBR contamination.

MK-1 UNDERCOVERALL

18. The MK-1 undercoverall is a one-piece garment constructed of a nonwoven nylon fabric with a small percentage of viscose rayon. The outside of the garment is treated with a fluorochemical to repel liquids and organic chemicals. The undersurface is coated with activated charcoal to adsorb any penetrating contaminating vapor. The undercoverall is worn under the standard flight suit (CWU-27/P for summer/helicopter) and is disposable after agent exposure or 50 cumulative hours of wear. A slide fastener (zipper) with an impregnated fabric backing runs vertically from the neck to the crotch. The fastener is provided with two sliders for ease of donning, doffing, and urinating (uncontaminated environment). The garment has a neckline that allows for overlap when a protective hood is worn. A cord secured to the back of the garment and threaded through loops at each side enables the wearer to take-up loose material around the waist. Two access tunnels in the waist area provide hose passage for a G-suit or personal cooling system.

a. The bottom of each leg has an adjustable elastic stirrup to keep them in place over the chemical protective socks. The sleeves and legs are made long in each of the nine garment sizes to accommodate longer limbed wearers. A turn-back is used where necessary to shorten sleeves to a length that provides adequate wrist coverage during extreme movements (e.g., bending and stretching). After allowance for the turn-back, shorter limbed wearers may trim excess from the sleeves and legs with scissors. The nine sizes accommodate three height classes (short, 65-68 in.; regular, 68-71 in.; and long, 71-78 in.) with three chest sizes for each class (small, 33-36 in.; medium, 36-39 in.; and large, 39-42 in.; for short and regular heights), (small, 36-39 in.; medium, 39-42 in.; and large, 42-45 in.; for long height).

b. The protective properties of the activated charcoal "lining" of the undercoverall are degraded by prolonged contact with perspiration; therefore, garments to be used in a CBR environment should not have been previously worn. Two-piece long underwear is worn underneath the MK-1 to mitigate the "sweat poisoning" of the charcoal undersurface and to prevent skin irritation.

GLOVE INSERTS

19. The glove inserts are made of jersey knit cotton and are worn underneath the chemical protective gloves. They come in three sizes. The glove inserts are reusable after laundering; however, they are discarded after CBR contamination or after more than 50 cumulative hours of wear.

CHEMICAL PROTECTIVE GLOVES

20. The gloves are made of 7-mil thick butyl rubber to cause minimal degradation of hand mobility and dexterity while being sufficiently durable for 12 hr of agent protection. The gloves permit a full range of aircrew tasks and provide continuous CBR protection. The gloves come in four sizes and are worn under the standard nomex flight gloves. The chemical protective gloves are pulled up over the sleeves of the MK-1 undercoverall.

CHEMICAL PROTECTIVE OVERBOOTS

21. The chemical protective overboots are a disposable vinyl plastic outer foot covering intended for wearing to and from the aircraft. They are intended to cause minimal degradation to the aircrewmember's ability to walk or run, while being sufficiently durable for performing the full range of preflight and postflight aircrew tasks and providing continuous CBR protection. The boots come in one size to fit all and are discarded after each day's use, regardless of CBR contamination. They are worn over standard flight boots.

CHEMICAL PROTECTIVE CAPE

22. The cape is a disposable garment made of polyethylene. It is worn to provide continuous protection against liquid chemical agents while in transit from shelter to the aircraft, or from the aircraft to shelter. It is doffed immediately prior to entering the aircraft, and a new cape is donned after landing for transit back to the shelter. In a CBR environment, the cape is discarded after each exposure.

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HELICOPTER FLIGHT TEST PROFILE
PILOT KNEEBOARD CARDS

CARD NO.	1
PROJECT TITLE	A/P22P-9(V) FLIGHT TEST PROGRAM

TYPE (Circle one.)	BUNO.	SIDE NO.	DATE
CH-53 UH-1N			

PILOT NAME

CONDITION (Please circle the type of clothing you are wearing.)

A/P22P-9(V) STANDARD

NOTE (Please note personal performance changes you attribute to the A/22P-9(V).)

PHASE	✓	MANEUVER	KIAS	ALT	TIME (MIN)
GROUND		PREFLIGHT	N/A	N/A	N/A
		ENGINE START			
TAXI		VERTICAL TAKEOFF	0	NATOPS	A/R
		AIR TAXI	NATOPS	NATOPS	A/R
LOW WORK		VERTICAL LANDING	0	0-10'	N/A
		VERTICAL TAKEOFF/LANDING	0	0-10'	A/R
CB PILOT		INTOWIND			
AT THE CONTROLS		CROSSWIND			
		DOWNWIND			
		HOVER	0	10'AGL	30 SEC@
		INTOWIND			
		CROSSWIND			
		DOWNWIND			
		TURN ON A SPOT	0	10'AGL	NATOPS

CARD NO. 2

		RIGHT			
		LEFT			
		SQUARE PATTERNS	0	10'AGL	3 MIN
		SIDE/REARWARD FLIGHT	NATOPS	A/R	A/R
		LEFT 100 METERS			
		RIGHT 100 METERS			
		AFT 100 METERS			
		QUICKSTOP	NATOPS	NATOPS	A/R
LOW WORK		VERTICAL LANDING	0	0-10'	N/A
		VERTICAL TAKEOFF/LANDING	0	0-10'	A/R
HAC		INTOWIND			
RELIEVE CB PILOT		CROSSWIND			
OF CONTROLS		DOWNWIND			
		HOVER	0	10'AGL	30 SEC@
		INTOWIND			
		CROSSWIND			
		DOWNWIND			
		TURN ON A SPOT	0	10'AGL	NATOPS
		RIGHT			
		LEFT			
		SQUARE PATTERNS	0	10'AGL	3 MIN
		SIDE/REARWARD FLIGHT	NATOPS	A/R	A/R
		LEFT 100 METERS			
		RIGHT 100 METERS			
		AFT 100 METERS			
		QUICKSTOP	NATOPS	NATOPS	A/R

CARD NO. 3

PATTERN	☐	NORMAL TAKEOFF	NATOPS	NATOPS	NATOPS
APPROACH/LAND	☐	NORMAL APPROACH			
	☐	RUNNING LANDING/TAKEOFF			
	☐	NO HOVER APPROACH			
CB PILOT	☐	DEGRADED AFCS/SCAS			
AT THE CONTROLS	☐	PRECISION APPROACH			
	☐	SIMULATED EXTERNALS (x2)			
	☐	SIM. AUTOROTATIONS (x2)			
	☐	FCLP (x6)			
PATTERN	☐	NORMAL TAKEOFF	NATOPS	NATOPS	NATOPS
APPROACH/LAND	☐	NORMAL APPROACH			
	☐	RUNNING LANDING/TAKEOFF			
	☐	NO HOVER APPROACH			
HAC	☐	DEGRADED AFCS/SCAS			
RELIEVE CB PILOT	☐	PRECISION APPROACH			
OF CONTROLS	☐	SIMULATED EXTERNALS (x2)			
	☐	SIM. AUTOROTATIONS (x2)			
	☐	FCLP (x6)			
FORMATION	☐	TACTICAL CRUISE (CBR LEAD)	80-100	500-1000	10 MIN
Turns/descents	☐	LEAD CHANGE			
	☐	TACTICAL CRUISE (CBR WINGMAN)			10 MIN
	☐	SECTION LANDINGS (CBR WING,x4)	NATOPS	NATOPS	NATOPS
	☐	LEAD CHANGE ON DECK			
	☐	SECTION LANDINGS (CBR LEAD, x4)			
FORMATION	☐	TERRAIN FLIGHT (CBR LEAD)	NATOPS	NATOPS	20 MIN
TACTICS	☐	LEAD CHANGE			
	☐	TERRAIN FLIGHT (CBR WINGMAN)			20 MIN

CARD NO.
4

TACTICS		CALs (CBR PILOT x2, HAC x2)	NATOPS	NATOPS	NATOPS
Single ship		SIM. EXT. LOADS (CBR x2, HAC x2)			
CBR PILOT		SLOPE LANDINGS	NATOPS	NATOPS	NATOPS
		NOSE UP (x2)			
		RIGHT WING UP (x2)			
		LEFT WING UP (x2)			
HAC		SLOPE LANDINGS	NATOPS	NATOPS	NATOPS
		NOSE UP (x2)			
		RIGHT WING UP (x2)			
		LEFT WING UP (x2)			
TACTICAL		90° (CBR, x2 / HAC, x2)	NATOPS	NATOPS	NATOPS
APPROACHES		180° (CBR, x2 / HAC, x2)			
		360° (CBR, x2 / HAC, x2)			
TRANSITION		FORWARD FLIGHT			
AIRWORK		STRAIGHT/LEVEL FLT (CBR LEAD)	80	1000'	3 MIN
(BASIC)		STRAIGHT/LEVEL FLT (HAC)			3 MIN
		TURN PATTERN (CBR LEAD)			
		TURN PATTERN (HAC)			
		OSCAR PATTERN (CBR LEAD)			
		OSCAR PATTERN (HAC)			
TRANSIT		RETURN TO BASE/HOME FIELD			
SHUTDOWN		PRECISION APPROACH (CBR)			
		NON-PRECISION APPROACH			
		PRECISION APPROACH (HAC)			
		NON-PRECISION APPROACH			
READY ROOM		CLOTHED AND NUDE WEIGHTS QUESTIONNAIRE (CBR ONLY)			

DETAILED METHOD OF TESTS

TABLE OF CONTENTS

SUBJECTS

1. Twenty-eight male USMC helicopter aircrewmen participated in the evaluation. All test aircrew had current NATOPS qualifications and flight physicals and were on flight status. Average pilot flight time in helicopter type was 2,000 hr. Average crew chief flight time in helicopter type was 1,400 hr. Subjects were not randomly selected; they volunteered or were assigned to this test program by a commanding officer. Each subject received a thorough brief of test objectives and the potential participation risks (note Test Termination Criteria, appendix D) and signed the Safety Checklist (appendix J) prior to test participation (the Safety Checklist served as an Informed Consent). NAVAIRWARCENACDIV Patuxent River, Maryland, test pilots and crew participated in testing conducted at Patuxent River. Marine Aircraft Group-46, Detachment Bravo full-time fleet reserve pilots and crew chiefs participated in testing conducted at NAS New Orleans.

2. Subjects were paired by aircraft type and mission duties; for example, CH-53 pilots formed one pair, while the crew chiefs formed a second pair. On a given test day, one of each subject pair was the "test subject" while the other in the pair was the "control/safety subject". The Helicopter Aircraft Commander (HAC) was the control/safety pilot. Test subjects were required to wear the A/P22P-9(V), while control/safety subjects wore standard Aviation Life Support Systems (ALSS). On subsequent test days, roles were switched (figure 1).

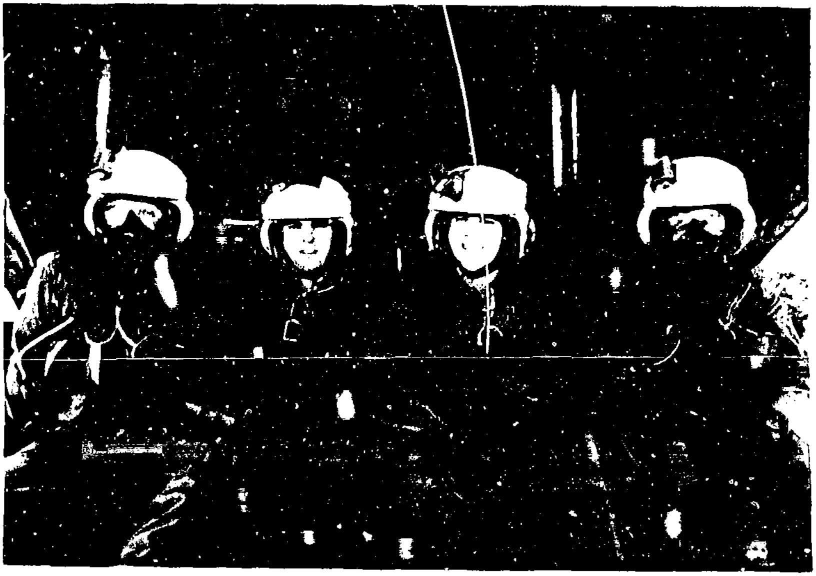

Figure 1
CH-53 CREW CHIEFS AND PILOTS
(Test Subjects Wearing A/P22P-9(V) Ensembles)

HEALTH

3. The following averages provide an overview of the subject population:

a. Age: 32.5 years (SD = 4.6).

b. Weight: 181.0 lb (SD = 20.9).

c. Height: 70.7 in. (SD = 2.69).

d. Resting Heart Rate: 69 beats/min (SD = 10.3).

4. No formal acclimatization program was employed, nor was any attempt made to modify aircrew lifestyle habits. (The intent was to evaluate USMC aircrew as they normally exist and without intervention.) However, for safety reasons, test aircrew were required to complete a baseline medical questionnaire (appendix E) prior to test participation. A 24-hr pretest questionnaire (appendix G) was also completed prior to each test day. These completed questionnaires served a dual function. First, each questionnaire was thoroughly reviewed to screen subjects who were at a greater than normal risk of succumbing to a heat-related injury: for example, a history of heat illness, taking medication, lack of sleep, poor diet, or high alcohol consumption. Secondly, these questionnaires created lifestyle profiles that were instrumental in understanding unique individual responses.

TESTING SEQUENCE

FAMILIARIZATION

5. Prior to the first test day, test aircrew were familiarized with the test equipment; test procedures; objectives; heat stress signs, symptoms, and treatment; safety and emergency procedures; and test termination criteria (appendix D). Aircrew were sized and fitted with a respirator assembly and below-the-neck ensemble. They were required to don the respirator assembly and demonstrate their ability to connect communication leads and the helmet retention system. Each was also required to adeptly operate all safety features of the respirator assembly and perform basic troubleshooting procedures. All received personal copies of the test plan for review. Before participating in testing, test aircrew were required to sign the test plan Safety Checklist (appendix J), endorsing their understanding and participation in the test program.

PRETEST SEQUENCE

6. Pretest procedures were as listed below:

a. Complete and review Pretest Questionnaires (appendix G).

b. Review Test Termination Criteria and Safety Procedures (appendix D).

c. NATOPS brief by the HAC (flight testing).

d. Measure resting heart rates, calculate target heart rates, enter value in Squirrel Data Meter/Logger as alarm limit (appendix I).

e. Measure resting blood pressures.

f. Collect urine samples, measure specific gravity (references 49 and 50).

g. Measure nude weights.

h. Configure with physiological sensors and leads.

i. Measure initial core temperature.

j. Don A/P22P-9(V) or standard ALSS.

k. Fill canteens (2000 ml tap water) and assign.

l. Measure clothed weights.

Prior to each test, items a., d., and e. above were criteria for screening subject test participation.

GROUND TESTING

Anthropometry and Fitting

7. Thirteen of the total twenty-eight test aircrew participated in ground testing. In addition to height and weight, a Naval Aerospace Physiologist measured 10 anthropometric dimensions per test subject using an anthropometer and tape measure. Measurements included shoulder height sitting, functional reach, sitting height, bideltoid breadth, buttock knee length, knee height sitting, chest circumference, waist circumference, hip circumference, and neck circumference. Percentiles were determined according to reference 51. Anthropometric data were used in MK-1 sizing and assessing fit quality. MK-1 undercoverall sizing was according to published sizing tariffs for the ensemble and modified to correspond with USN flight suit sizing (appendix K).

Donning and Doffing

8. Test aircrew donned and doffed the A/P22P-9(V); some assistance was provided. Time to don the A/P22P-9(V) began with donning the cotton undergarments and ended with donning the plastic overboot. Doffing procedures were the reverse order donning procedures. Aircrew were asked to evaluate the following:

a. Adequacy and completeness of donning/doffing procedures (appendix H).

b. Ability to achieve a comfortable fit.

c. Misleading or error-inducing wording of instructions.

d. Vocabulary of instructions relative to the target population.

To decrease extraneous physiological differences caused by donning, great care was taken to closely match the A/P22P-9(V) and standard ALSS donning evolutions (figure 2). For example, when the A/P22P-9(V) test subject was donning socks and boots, the control subject was also donning his socks and boots.

Figure 2
TEST AND CONTROL SUBJECTS DURING MATCHED DONNING
(CH-53 Pilots and Crew Chiefs)

ALSS Compatibility

9. Once in the A/P22P-9(V), subjects were asked to evaluate its compatibility with their standard ALSS. They were asked to access and operate (with the required three layers of gloves) the following items:

a. Respirator assembly helmet retention system.

b. Flight suit and survival vest zippers.

c. Tie boot laces.

d. Locate/actuate strobe light, survival mirror, and PRC-90 radio.

Mobility Evaluation

10. Test aircrew evaluated their mobility wearing the A/P22P-9(V) below-the-neck clothing. Each was asked to perform the following movements while wearing the complete ensemble:

a. Head and neck:

(1) Look up and back.

(2) Look down.

(3) Look side-to-side.

b. Shoulder and arms:

(1) Arms down and back.

(2) Arms up and back.

(3) Arms extended horizontally and back.

(4) Fold arms across chest.

c. Torso and waist:

(1) Standing, bend over and reach for toes.

(2) Sitting, bend over and pick-up pen off the floor.

d. Legs:

(1) Squat down with arms straight overhead.

(2) Sitting, raise knee to chest.

e. Manual dexterity:

(1) Disconnect/connect RIED valve.

(2) Actuate hood outlet valve.

(3) Actuate antidrown connector.

(4) Switch ventilator, on/off.

(5) Remove/replace ventilator filter canisters and battery.

f. Fine motor dexterity:

(1) Hand write or print with pen or pencil.

(2) Complete the first eight questions of the Posttest Questionnaire (appendix I).

Aircraft Compatibility

Daily/Turnaround and Preflight Procedures

11. Test aircrew conducted routine aircraft inspections of their respective aircraft (AH-1, UH-1N, CH-53, or CH-46 helicopter) according to applicable NATOPS manuals (references 20 through 24). Pilots performed preflight and prestart procedures; aircrew performed daily/turnaround (D/T), internal cargo loading, tie down, and unloading. These test procedures were repeated until one of the test termination criteria was met (appendix D). Workrate was not controlled; test aircrew were instructed to perform at their normal rate. Water was available at all times, and drinking was not controlled.

Ingress, Egress, and Emergency Egress

12. Ingress, egress, and overland emergency egress trials were performed to evaluate subjects' ability to get in and out of their crewstations easily, safely, and quickly. At the time of testing, there were no approved Water Survival Procedures for the A/P22P-9(V) Respirator Assembly. Test aircrew were not required to complete water survival trials prior to flight test participation: all flights were conducted over land or within autorotation distance of land. As an extra precaution, all test aircrew were briefed on A/P22P-9(V) Respirator Assembly water survival procedures and were required to demonstrate their ability to perform the procedures on land. To evaluate whether the below-the-neck ensemble would be restrictive during water survival procedures (appendix F), eight test aircrew and three test personnel donned the entire A/P22P-9(V) and completed the water survival procedures. Several trained USN Aerospace Physiologists and Corpsmen also evaluated the A/P22P-9(V) during underwater egress from a 9D5A Multiplace Dunker.

FLIGHT TESTING

13. All flights were conducted in day, visual meteorological conditions and encompassed the hottest portion of the day. CH-53 flight testing was conducted in the NAVAIRWARCENACDIV Patuxent River local flying area. UH-1N flight testing was conducted in the NAVAIRWARCENACDIV Patuxent River and NAS New Orleans flying areas. No AH-1 or CH-46 flight tests were conducted (see Results and Discussion, Helicopter Model Effect). For water survival safety, all flights were conducted over land or within autorotation distance of land.

14. Test aircrew completed the pretest (see Pretest Sequence, paragraph 6) portion of testing then donned the appropriate test ensemble (A/P22P-9(V) or standard ALSS). Aircrew completed the necessary paperwork for aircraft release and proceeded to the tarmac. As pairs, crew chiefs conducted D/T and preflight inspections, and pilots conducted preflight and prestart procedures. When possible, problems discovered during preflight inspections were corrected vice canceling the test. Time required to repair an aircraft was added to the test aircrew's total time in the gear (deemed representative of fleet flight operations). Sortie flight durations were approximately 1.5 hr for familiarization flights and up to 4 hr for flight test missions.

15. During NAS New Orleans UH-1N flight testing, the flight test matrix was modified to evaluate two additional scenarios. The first scenario compared standard ALSS against wearing the above-the-neck respirator assembly with <u>standard ALSS below-the-neck</u>. Test aircrew were asked to complete D/T and preflight inspections plus a 4-hr flight mission. The second scenario evaluated the complete A/P22P-9(V) ensemble against standard ALSS; however, the comparison was between conducting preflight inspections and no preflight inspections (that is, the aircrew left the ready room and immediately took-off).

POSTTEST SEQUENCE

16. Following taxi and aircraft shutdown, aircrew completed necessary postflight procedures and returned to the ready room. Each subject then followed the posttest sequence below:

a. Measure clothed and nude weights.

b. Doff A/P22P-9(V) or standard ALSS.

c. Remove physiological sensors and leads.

d. Collect urine samples and measure specific gravity.

e. Measure canteen water volume.

f. Interview and complete the Posttest Questionnaire (appendix I).

INSTRUMENTATION AND DATA COLLECTION

ANTHROPOMETRIC DATA

17. Each body dimension was recorded as an average of three anthropometer or tape measure readings.

SUBJECTIVE DATA

18. Subjects evaluated A/P22P-9(V) subjectively in interviews and posttest questionnaires (appendix I). There were two types of questions in the questionnaires: "Yes/No" responses ("Yes" indicating an affect) and 5-point rating scales, from "1", very favorable, to "5", very negative.

PHYSIOLOGICAL DATA

Squirrel Data Meter/Logger

19. Grant Squirrel Data Meter/Loggers (SQ32-1U/7U/HR) (reference 52) recorded heart rate, rectal core temperature (T_{core}), six skin temperatures (T_{sk}), and ambient dry bulb temperature (T_{db}), with a 3 per minute sampling rate. SQ32's were worn by A/P22P-9(V) and standard ALSS subjects throughout each test in the left survival vest pocket (figure 3). Real-time viewing was convenient to monitor data error and subject safety. For instance, an unreasonable core temperature reading might be caused by a slipping probe and could then be corrected.

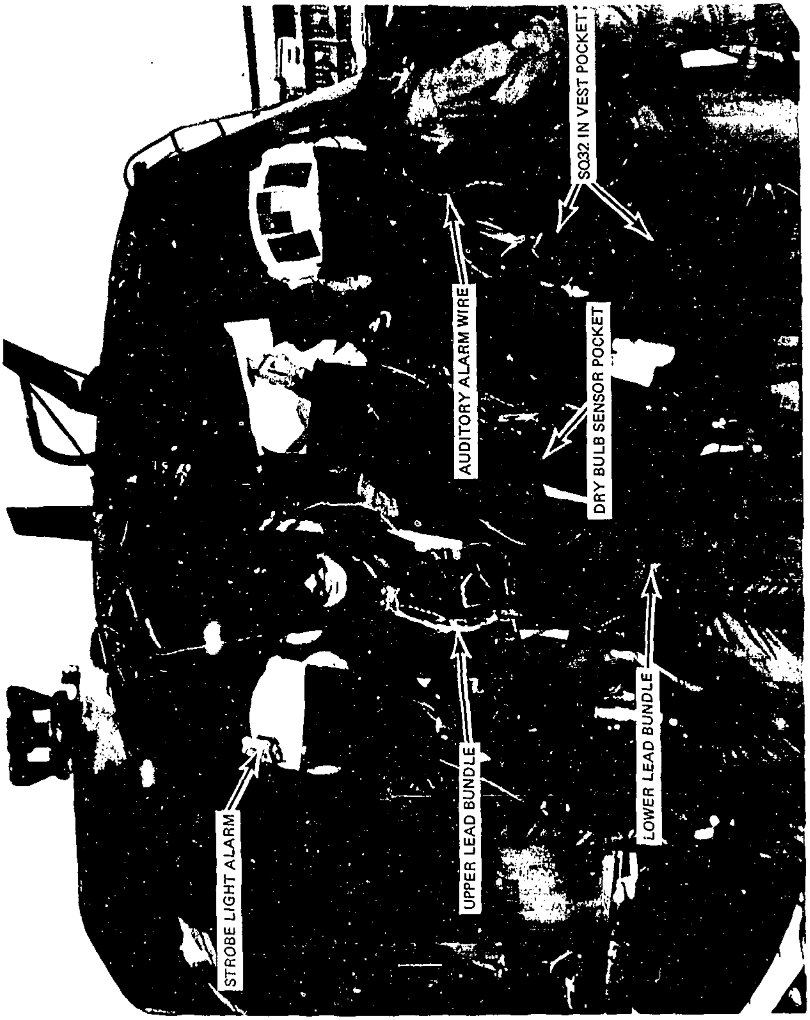

Figure 3
SQ32 PLACEMENT AND WIRE BUNDLES
(UH-1N Crew Postflight)

Subject Safety

20. For subject safety, physiological limits were set at T_{core} >38.5°C (>101.3°F), heart rate >70% of estimated maximum for age, or T_{sk} closer than 0.5°C (1°F) to T_{core}. A dual-alarm feature included a 90 dB auditory alarm, which was inside the subject's helmet ear cup, and a standard USN strobe light, which was velcroed to the helmet. Exceeding the T_{core} or heart rate safety limit, a subject would trigger the auditory alarm and cause the strobe light to flash (figure 3).

Physiological Sensors and Configuration

21. Each subject wore 10 physiological leads connected to an SQ32. Seven above-the-waist leads were bundled, threaded out the ensemble neckline to enter the top of the left survival vest pocket into the SQ32. Three below-the-waist leads were bundled, threaded out the base of the ensemble's center zipper to enter through a small hole cut in the survival vest pocket base into the SQ32.

22. Temperature thermistors were Grant thermistors manufactured by Yellow Springs Instruments (YSI) and calibrated to National Bureau Standards. Prior to testing, all leads were calibrated again by the Patuxent River Airborne Instruments and Calibration Department using a Rosemount Temperature Bath. In the 25-40°C range, thermistor accuracy was ±0.2°C (3σ).

Heart Rate

23. Heart rate sensors included two subclavicular electrodes, one left, one right, and one mid-axillary electrode in the sixth intercostal space.

Skin Temperature

24. Grant's EU-U-F1 thermistors were taped to the skin with 3M Micropore® tape at six sites. Always on the right side of the body, the six sites were the cheek, below the zygomatic arch; the upper arm, posterior and mid-humeral; the chest, 5th intercostal space, nipple line; the back, subscapular; and the leg, medial and lateral mid-femural. The mean weighted skin temperature (T_{sk}) was defined as (reference 53):

$$T_{sk} = [.070\ T_{am} + .100\ T_{ck} + .125(T_{ct} + T_{bk} + T_{lt} + T_{mt})]/.67 \qquad (1)$$

where:
- T_{am} = arm temperature
- T_{ck} = cheek temperature
- T_{ct} = chest temperature
- T_{bk} = back temperature
- T_{lt} = lateral thigh temperature
- T_{mt} = medial thigh temperature

Core Body Temperature

25. The rectal thermistor was a Grant's REC-U-F1 thermistor, placed at 10 cm beyond the anal sphincter.

Specific Gravity

26. Boehringer Mannheim Diagnostic Chemstrip reagent strips and a refractometer tested the specific gravity and trace materials contained in the two urine samples, collected prior to and at the end of each test. The difference of the two specific gravities provided dehydration information.

Weights and Volumes

27. A Healthometer Portable Scale weighed the nude and clothed weights before and after each test. Total water intake and urine volume were also recorded.

Ambient Conditions

Wet Bulb Globe Temperature

28. The Reuter Stokes RSS-214 Data Logger Wibget® Heat Stress Monitor (reference 54) recorded Wet Bulb Globe Temperatures (WBGT's), with a 1 per minute sampling rate. Wibget® is compact, portable, and battery operated. (During high radiant loading conditions, the dry bulb sensors were shielded from the radiant source to eliminate radiant absorption errors in these sensors.) The unit also computed indoor and outdoor WBGT from wet bulb (WB), dry bulb (DB), and globe temperature (GT) as:

$$\text{indoor WBGT} = 0.7WB + 0.3GT, \qquad (2)$$

$$\text{outdoor WBGT} = 0.7WB + 0.2GT + 0.1DB. \qquad (3)$$

One Wibget® was placed in the cockpit, another in the cabin, and a third on the tarmac (figures 4 and 5). Data were analyzed from one, two, or all three sites depending on the type of test and subject function. For example, during ground testing, cabin and tarmac WBGT data were best to describe the crew chiefs ambient condition, and in flight, the cockpit WBGT was most suitable to monitor the cockpit environment.

Figure 4
WIBGET STARBOARD MOUNT ˉOR UH-1N CABIN

Figure 5
WIBGET MOUNTED ON TRIPOD FOR WBGT RAMP DATA COLLECTION

Dry Bulb

29 In contrast to the Wibget* registering the general ambient environment, the S(/ bulb sensor recorded subjects' immediate environment since the sensor was in r survival vest pocket (figure 3) to keep out the direct radiant exposure. During the entire test record, the maximum temperature recorded was 43°C (110°F); however, by placing the sensor in the survival vest pocket, the sensor may have recorded an undesirable micro-environment and resulted in higher than the true temperature readings. For safety sake, these test temperature maximums were compared with local weather station temperature reports and were reduced by 3°C (5.4°F). Recommend for future use, wrap cardboard loosely around the sensor to shield it from a radiance effect, but not tight enough to create a micro-environment.

DATA ANALYSES

OBJECTIVE

30. Ultimately, the objective was to establish safe boundaries for effective A/P22P-9(V) use by USMC helicopter aircrew. Physiological responses to the following factors were analyzed:

a. Wearing the A/P22P-9(V) and standard ALSS.

b. Different helicopter types.

c. Cockpit or cabin crewstation.

d. Preflight and flight difference.

e. No preflight prior to flight.

f. Respirator assembly only (no below-the-neck).

g. Water intake.

h. Mission duration.

i. WBGT and dry bulb temperature.

EXPERIMENTAL DESIGN

31. The experimental design was a two-way nested incomplete, unbalanced design. Each standard ALSS test subject served as the control for his own A/P22P-9(V) test data.

a. The clothing treatment had two levels: A/P22P-9(V) and standard ALSS.

b. The helicopter treatment had four levels: AH-1, UH-1, CH-53, and CH-46.

c. The UH-1, CH-53, and CH-46 helicopters each had two nested locations: cockpit and cabin; the AH-1 had only a cockpit.

d. Cockpit and cabin locations each had two nested subjects: two pilots and two crew chiefs, respectively.

e. Test duration variations and unequal cockpit and cabin numbers contributed to an unbalanced and incomplete design.

APPROACH

Anthropometric Data

32. The maximum, minimum, mean ($\overline{X}$), and standard deviation (SD_x) for each body dimension were calculated. Percentile ranges (reference 51) were determined using maximum and minimum values to ensure that the subject population represented a broad anthropometric range.

Subjective Data

33. Since the five-point scale was a continuous opinion scale, the average score, $\overline{X}$, for each question elicited a general opinion. $\overline{X}$ was computed as:

$$\overline{X} = \frac{\sum_{i=1}^{5} i\, f_i}{n}$$

where: i = 1,...,5 response
f_i = number of the i^{th} response occurred
n = number of subjects (≈ 28)

If a general opinion was significantly greater than the neutral opinion, "3", it reflected a strong negative response. If insignificant, it was necessary to review all answers and interview responses to find "4s" or "5s" to determine whether any A/P22P-9(V) deficiency existed (considered any negative opinion potentially significant to the evaluation). Similarly, for "Yes/No" questions, the proportion of "Yes" responses to "No" was tested. If "Yes" and "No" responses were equal, individual "Yes" responses were treated similar to the five-point scale above.

Ambient Temperature

34. The correlation between physiological responses and all five components of the Wibget® records and SQ32 dry bulb data was computed.

Regression Analyses

35. To estimate safe mission durations and ambient temperature for aircrew wearing the A/P22P-9(V), regression analyses, with time as the only regressor, were performed on T_{core} and T_{sk} (1 or 5-minute-smoothed-data). Within the scope of these tests, ambient temperature was not controlled and was correlated with time, this made the validity of using a linear model with multiple regressors (T_{db} and time) in the regression analyses infeasible. Therefore, from these data, the changing rate of any physiological parameter with time under a specific ambient temperature

could not be predicted. So the application of the resultant models is set for similar ambient conditions to this test program. Since T_{core} and T_{sk} were highly autocorrelated, these analyses used the SAS/ETS "AUTOREG" procedure.

Analyses of Covariance

36. With time as a covariate, the analyses of covariance used a two-way nested incomplete, unbalanced general linear model (paragraph 31). (For the same reasons noted in paragraph 35, T_{db} could not be used as a covariate.) These analyses tested the significance of the following effects: clothing configuration, the four helicopter types, and cockpit and cabin locations at the significance level, $\alpha=.05$. Least-squares estimates from the general linear model will be used as estimates for T_{core}, T_{sk}, and heart rate.

Physiological Data

37. It was essential to select similar ambient temperature test days and monitor uniform activities for paired subjects. In the experimental design, each A/P22P-9(V) data set was compared with its own standard ALSS control data, as well as other similar data sets. Physiology response versus time plots and T_{db} plots were used initially to understand general data trends. To reduce sporadic variations caused by ambient conditions (wind, cloud, etc.), workrate, or SQ32 sensor attachment, obvious accountable errors were edited and interpolated. Then data were smoothed to one measurement per minute or one measurement per five minutes, by averaging one minute or five minute intervals of raw data (later referred to as 1-minute-smoothed-data and 5-minute-smoothed-data). During subsequent analyses, 1-minute-smoothed-data provided detailed information, and 5-minute-smoothed-data provided general data trend information. For example, 1-minute-smoothed-data were used to construct heart rate distributions, while the smoother 5-minute-smoothed-data were necessary to study more general heart rate trends.

38. While the strong point of this field testing was operational realism, the drawback was lack of laboratory controls. Uncontrolled variations added ambiguities to data interpretations. (For instance, a long term T_{core} cooling could be confused with a gradual core probe slipping.) Often to achieve a reasonable interpretation of diversities and search for dominant trends, it was necessary to study various statistical analysis levels for each person and each test. Unusual responses were always emphasized. Physiological response differences were also evaluated based on different age groups and resting heart rate intervals. Data reduction, editing, plotting, and analyses were conducted using SAS/STAT, SAS/ETS, and SAS/GRAPHS statistical software on a VAX 11/750.

Heart Rate

39. Many commonly used statistical procedures displayed robustness or insensitivity to the heart rate data. Nevertheless, heart rate proved to be a keen thermal stress indicator. To study A/P22P-9(V) and standard ALSS heart rate distributions, bar-chart histograms were constructed for each subject. With one-minute-smoothed-data, the height of each rectanglar bar represented the frequency of heart rates that occurred within that interval. For example, the first bar, 55 beats/min, represented the frequency of heart rates that occurred within a 50 to 60 beats/min interval; the next bar, 65 beats/min, represented the frequency of heart rates that occurred within a 61 to 70 beats/min interval, etc. Nonparametic

methods were then applied, such as chi-square test, rank-sum test, and median test, to study the heart rate characteristics under the A/P22P-9(V) and standard ALSS clothing treatments.

Water Intake Effect

40. A 3x3 contingency table was constructed to test the dependence of physiological response on water intake. Water intake and the means and maximums of each T_{core}, T_{sk}, and heart rate from every event were grouped into low, medium, and high levels. A 3x3 contingency table, with low, medium, and high levels each way, tested the dependence of water intake and physiological response.

41. Using the equations below, body water changes were calculated and accounted. Individual and average values were compared to a "normal" water balance equation to estimate an A/P22P-9(V) hydration schedule. Water gains or intake were easily attributable to water drunk by the subject. Accounting for water losses was considerably more complicated. Review equation (4):

Water loss = urine + sweat absorbed in clothes + water evaporated (sweat & insensible loss) (4)

In equation (4), urine, like water intake, was easily accountable. Accounting for sweat produced was far less precise. Theoretically, of sweat produced, a portion remains on the skin, a portion is absorbed in clothing, and a portion of that evaporated. The difference between sweat absorbed and sweat evaporated would indicate clothing permeability. Unfortunately, sweat evaporated could not be separated from insensible water losses from the lungs, which average a significant 900 ml per day (reference 46). Realizing this accounting shortfall, coupled with nude and clothed weight measuring error, the ensuing hydration schedule can only be considered a guideline and not absolute.

Water loss = (NWT1 + H2OT) - (NWT2 + Urine) (5)

Note: equation (5) = equation (6) + equation (7)

Sweat absorbed = (CWT2 - NWT2 - H2O2) - (CWT1 - NWT1 - H2O1) (6)

Water evaporated = CWT1 - CWT2 + Urine + H2OE (7)

Note: equation (7) = insensible losses from the lungs + sweat evaporation

Percent body weight gain/loss = (NWT1 - NWT2) / NWT1 x 100 (8)

where:
- NWT1 = pretest nude weight
- NWT2 = posttest nude weight
- CWT1 = pretest clothed weight
- CWT2 = posttest clothed weight
- H2O1 = original canteen volume
- H2O2 = water remaining in canteen
- H2OE = water in addition to original canteen
- H2OT = total water intake (H2O1 + H2OE - H2O2)

Helicopter Model Effect

42. Physiological data collected during ground and flight testing were analyzed to test significant difference, α=.05, attributable to helicopter model differences.

Cockpit and Cabin Environment Differences

43. UH-1N and CH-53 cockpit and cabin WBGT and T_{db} data were compared. Pilot and crew chief physiological responses in the respective locations were also compared.

Preflight and Flight Differences

44. Physiological time plots and ambient plots revealed different behaviors in these two operations. It would require separate analysis to evaluate the two operations.

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TEST TERMINATION CRITERIA AND SAFETY PROCEDURES

1. The following are criteria by which test missions were terminated. It was expected that subjects would experience some performance degradation due to the thermal burden of wearing of the A/P22P-9(V). Subjects were stressed and uncomfortable during testing, but their safety was the first priority. Subject risk was minimized by monitoring heart rate and skin and core temperatures and making certain that they did not exceed established safety limits. Thermal stress research literature was reviewed and physiological safety limits established. The following test termination criteria were used during ground and flight testing to protect test subjects' health and safety (also, see figure 1):

a. Heart rate - Target heart rate calculated as follows:

Target heart rate = (220 - age - RHR) .70 + RHR (reference 45)

where: RHR = resting heart rate

b. Core temperature - Not greater than 38.5°C (101.3°F).

c. Core/skin temperature gradient - Not closer than 0.5°C (1.0°F).

d. Objective or subjective signs of severe discomfort, fatigue, or thermal stress; for example, nausea, syncope, dry skin, headache, disorientation, or performance deterioration.

e. Any malfunction or mechanical difficulties with the aircraft or the physiological monitoring system.

f. Subject aircrewmember desired termination.

g. Safety pilot or safety observer(s) detected deterioration in the mental ability or performance of the test subject.

h. Inclement weather or nightfall.

2. If the flight was terminated for the test pilot's safety, the controls of the aircraft were given to the safety pilot. For any termination reason, the helicopter was immediately flown back to base. On no occasion was it necessary to contact hospital emergency services for assistance.

3. The safety pilot landed the aircraft at the base staging area and the thermally stressed subject was assisted into the hangar or air-conditioned ready room. Every attempt was made to cool the subject as quickly as possible.

4. Any subject who was thermally or psychologically distressed unzipped the protective clothing and removed the protective mask, if he so desired. If the subject required assistance, a safety observer assisted by removing the protective clothing and administering water or cold packs.

EMERGENCY DECISION MATRIX

ONE OR MORE TEST TERMINATION CRITERIA ARE MET

ASYMPTOMATIC SUBJECT
or
SYMPTOMATIC AIRCREW

SYMPTOMATIC
PILOT

* Relinquish test responsibilities.
* Open flight suit/BTN and remove AR5.
* Drink as much water as possible.
* Radio ground team and apprise of situation (call for ambulance if there is a symptomatic subject).

* Return to base as soon as possible.

* Land aircraft as soon as possible.
* Remove pilot from his seat to the cabin.
* Place safety crewmember in pilot seat (right).
* Safety pilot will return the aircraft to base immediately.

EN ROUTE TO BASE

* Remove additional clothing if necessary.
* Place ice pack behind subject's neck and under the arms.
* Dowse with water if necessary.
* Continue to monitor vitals.
* Administer artificial respiration or cardiopulmonary resuscitation (as needed).

ONCE ON THE GROUND

* Assist subject to the ready room, continue to monitor, continue cooling modalities.

* Keep subject in the aircraft. Keep aircraft turning to provide cooling. Assist ambulance crew.

Figure 1
EMERGENCY DECISION MATRIX

5. Subject health and safety were of utmost concern since wearing CBR protective clothing in warm and hot temperatures was known to produce heat stress. Subjects were well-trained on heat-related injuries, their symptoms and remedies. An explanation of heat exhaustion, heat pyrexia, and heat stroke are presented:

a. Heat Exhaustion: This disorder is caused by a water deficiency (dehydration) or salt deficiency. Dehydration is due to inadequate replacement of water during prolonged sweating. It is characterized by thirst, fatigue, giddiness, profuse sweating, oliguria (diminished urine output), or pyrexia (fever). Salt-deficient heat exhaustion is due to inadequate salt replacement during prolonged sweating. It is characterized by fatigue, nausea, vomiting, giddiness, muscle cramps, and possible cardiac failure.

b. Heat Pyrexia: Heat pyrexia is a more serious condition than heat exhaustion: the core temperature rises above normal and the person's sweating mechanism may or may not begin to shut down. Other symptoms include euphoria, headache, dizziness, drowsiness, numbness, restlessness, purposeless movements, uncoordinated movements, aggressiveness, mania, suicidal tendencies, mental confusion, delirium, and may result in coma and heatstroke.

c. Heatstroke: This is a failure of the body's thermoregulatory system. It is characterized by high core temperature >40.6°C (>105°F), no sweating, dry and red skin, and disturbances of the central nervous system. It is frequently fatal.

d. Prevention: Prevention of all heat-related injuries requires deliberate drinking of water before noticeable thirst. The amount of water needed depends on several variables, but the most important deal with how hard and how long the person is working in the chemical protective ensemble. Environmental conditions are a secondary concern because the wearer of a chemical protective ensemble is, in essence, separated from his external environment. A normal, well-balanced diet should provide enough salt; however, if salt-deficient heat exhaustion occurs and persists, a medical emergency team may start an IV of Normal Saline. Salt tablets are not recommended.

e. Treatment: In addition to preventative measures, treatment hinges upon cooling the victim as quickly as possible. Ice packs, cool water, and shade are the best primary care for a thermal stress victim. As the severity of the heat injury increases, more drastic treatment will be required, and the assistance of an emergency response team is recommended.

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BASELINE DATA QUESTIONNAIRE

The information you provide on this questionnaire will be used to determine your eligibility for participation in this test program, as well as identify possible areas for concern during your participation. Information will be kept confidential; your name will not be used in any reports, published or unpublished. Please answer all questions.

Rank/Name: ____________________

Work Phone: ____________________

Date of Birth: ____________________

Age: ____________________

Normal Crewstation(s): ____________________

1. List aircraft you are qualified to fly/crew? Please note hours in each.

____
____
____
____

2. What was the date of your last flight physical? ____________________

3. Are you aware of any changes in your physical condition since your last physical?

YES NO

If YES, please explain.

____
____
____
____

4. Are you presently under medical treatment, or have you been grounded in the last 30 days?

YES NO

If YES, please explain.

____
____
____
____

5. During the summer, approximately how many hours per day do you spend outside between the hours of 1000 and 1400? ____

6. Do you exercise or play sports regularly?

YES NO

If YES, which activities or sports?

____

____

____

Hours per day: ______________________________
Days per week: ______________________________
Time of day: ______________________________
Indoors or outdoors: ______________________________

7. Have you ever experienced heat cramps, heat exhaustion, or heat stroke?

YES NO

If YES, when did it occur and under what circumstances?

____

____

____

____

8. Describe your fitness level?

POOR FAIR AVERAGE GOOD EXCELLENT

9. Will you be TDY or on leave during scheduled testing?

YES NO

If YES, when?

____

10. PLEASE COMPLETE THE ATTACHED MEDICAL HISTORY FORM (SF93).

SY-62R-91

STANDARD FORM 93
REV OCTOBER 1974
GSA FPMR 101-11.8

APPROVED
OFFICE OF MANAGEMENT AND BUDGET No. 29-R0191

REPORT OF MEDICAL HISTORY

(THIS INFORMATION IS FOR OFFICIAL AND MEDICALLY-CONFIDENTIAL USE ONLY AND WILL NOT BE RELEASED TO UNAUTHORIZED PERSONS)

1. LAST NAME—FIRST NAME—MIDDLE NAME	2. SOCIAL SECURITY OR IDENTIFICATION NO.
3. HOME ADDRESS *(No. street or RFD, city or town, State, and ZIP CODE)*	4. POSITION *(title, grade, component)*
5. PURPOSE OF EXAMINATION / 6. DATE OF EXAMINATION	7. EXAMINING FACILITY OR EXAMINER, AND ADDRESS *(Include ZIP Code)*

8. STATEMENT OF EXAMINEE'S PRESENT HEALTH AND MEDICATIONS CURRENTLY USED *(Follow by description of past history, if complaint exists)*

9. HAVE YOU EVER *(Please check each item)*

YES	NO	*(Check each item)*
		Lived with anyone who had tuberculosis
		Coughed up blood
		Bled excessively after injury or tooth extraction
		Attempted suicide
		Been a sleepwalker

10. DO YOU *(Please check each item)*

YES	NO	*(Check each item)*
		Wear glasses or contact lenses
		Have vision in both eyes
		Wear a hearing aid
		Stutter or stammer habitually
		Wear a brace or back support

11. HAVE YOU EVER HAD OR HAVE YOU NOW *(Please check at left of each item)*

YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*	YES	NO	DON'T KNOW	*(Check each item)*
			Scarlet fever, erysipelas				Cramps in your legs				"Trick" or locked knee
			Rheumatic fever				Frequent indigestion				Foot trouble
			Swollen or painful joints				Stomach, liver, or intestinal trouble				Neuritis
			Frequent or severe headache				Gall bladder trouble or gallstones				Paralysis (include infantile)
			Dizziness or fainting spells				Jaundice or hepatitis				Epilepsy or fits
			Eye trouble				Adverse reaction to serum, drug, or medicine				Car, train, sea or air sickness
			Ear, nose, or throat trouble								Frequent trouble sleeping
			Hearing loss				Broken bones				Depression or excessive worry
			Chronic or frequent colds				Tumor, growth, cyst, cancer				Loss of memory or amnesia
			Severe tooth or gum trouble				Rupture/hernia				Nervous trouble of any sort
			Sinusitis				Piles or rectal disease				Periods of unconsciousness
			Hay Fever				Frequent or painful urination				
			Head injury				Bed wetting since age 12				
			Skin diseases				Kidney stone or blood in urine				
			Thyroid trouble				Sugar or albumin in urine				
			Tuberculosis				VD—Syphilis, gonorrhea, etc.				
			Asthma				Recent gain or loss of weight				
			Shortness of breath				Arthritis, Rheumatism, or Bursitis				
			Pain or pressure in chest				Bone, joint or other deformity				
			Chronic cough				Lameness				
			Palpitation or pounding heart				Loss of finger or toe				12. FEMALES ONLY: HAVE YOU EVER
			Heart trouble				Painful or "trick" shoulder or elbow				Been treated for a female disorder
			High or low blood pressure				Recurrent back pain				Had a change in menstrual pattern

13. WHAT IS YOUR USUAL OCCUPATION?

14. ARE YOU (Check one)

☐ Right handed ☐ Left handed

93-102

YES	NO	CHECK EACH ITEM YES OR NO. EVERY ITEM CHECKED YES MUST BE FULLY EXPLAINED IN BLANK SPACE ON RIGHT	
		15. Have you been refused employment or been unable to hold a job or stay in school because of: A. Sensitivity to chemicals, dust, sunlight, etc.	
		B. Inability to perform certain motions.	
		C. Inability to assume certain positions.	
		D. Other medical reasons *(If yes, give reasons.)*	
		16. Have you ever been treated for a mental condition? *(If yes, specify when, where, and give details).*	
		17. Have you ever been denied life insurance? *(If yes, state reason and give details.)*	
		18. Have you had, or have you been advised to have, any operations? *(If yes, describe and give age at which occurred.)*	
		19. Have you ever been a patient in any type of hospitals? *(If yes, specify when, where, why, and name of doctor and complete address of hospital.)*	
		20. Have you ever had any illness or injury other than those already noted? *(If yes, specify when, where, and give details.)*	
		21. Have you consulted or been treated by clinics, physicians, healers, or other practitioners within the past 5 years for other than minor illnesses? *(If yes, give complete address of doctor, hospital, clinic, and details.)*	
		22. Have you ever been rejected for military service because of physical, mental, or other reasons? *(If yes, give date and reason for rejection.)*	
		23. Have you ever been discharged from military service because of physical, mental, or other reasons? *(If yes, give date, reason, and type of discharge: whether honorable, other than honorable, for unfitness or unsuitability.)*	
		24. Have you ever received, is there pending, or have you applied for pension or compensation for existing disability? *(If yes, specify what kind, granted by whom, and what amount, when, why.)*	

I certify that I have reviewed the foregoing information supplied by me and that it is true and complete to the best of my knowledge.
I authorize any of the doctors, hospitals, or clinics mentioned above to furnish the Government a complete transcript of my medical record for purposes of processing my application for this employment or service.

TYPED OR PRINTED NAME OF EXAMINEE	SIGNATURE

NOTE: HAND TO THE DOCTOR OR NURSE, OR IF MAILED MARK ENVELOPE "TO BE OPENED BY MEDICAL OFFICER ONLY."

25. Physician's summary and elaboration of all pertinent data *(Physician shall comment on all positive answers in items 9 through 24. Physician may develop by interview any additional medical history he deems important, and record any significant findings here.)*

TYPED OR PRINTED NAME OF PHYSICIAN OR EXAMINER	DATE	SIGNATURE	NUMBER OF ATTACHED SHEETS

REVERSE OF STANDARD FORM 93

☆U.S. G.P.O. 1983-381-526/8247

A/P22P-9(V) WATER SURVIVAL TRAINING

1. Verify subject's water survival training currency and assess swimming ability.

2. Don A/P22P-9(V) respirator assembly.

3. Enter the shallow end of the pool.

4. Practice swimming strokes and floating to become comfortable with the Respirator Assembly portion of the ensemble.

5. Practice drown-proofing procedures (including hood outlet valve operation) and simple snorkeling techniques with the RIED valve.

6. Practice head-above-water and head-under-water swimming procedures.

7. Continue familiarization by placing back of legs on edge of pool, alternate floating on back and submersing head backward underwater.

8. Get out of pool.

9. Fit subject with below-the-neck components (MK-1 undercoverall, gloves, and cotton underwear) according to the donning and doffing procedures described in appendix H.

10. Reenter pool (LEU not inflated).

11. Practice floatation.

12. Practice snorkeling and drown-proofing.

13. Practice head-above-water and head-under-water swimming procedures.

14. Practice using the A/P22P-9(V) respirator hood outlet (antidrowning) valve while wearing the CBR protective gloves and standard flight gloves.

15. Inflate life preserver.

16. Locate and obtain survival aids in SV-2B survival vest.

17. Enter one-man and multiplace rafts.

18. Enter the 9D5A Device and follow the established procedures for underwater egress.

19. Subjects will be interviewed on the adequacy of the training, performance of the A/P22P-9(V), human factors and survival issues involved, and any other potential problem areas.

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PRETEST QUESTIONNAIRE

The information you provide on this questionnaire will be used to determine your eligibility for participation in this test program, as well as identify possible areas for concern during your participation. Information will be kept confidential; your name will not be used in any reports, published or unpublished. Please answer all questions.

NAME: ______________________ DATE: ______________________

CREW POSITION: ______________________ AIRCRAFT: ______________________

TEST (Circle One): GROUND or FLIGHT

CONFIGURATION (Circle One): CBR GEAR or STANDARD GEAR

---

1. Describe your general state of health in the last 24 hours.

Poor Fair Average Good Excellent

2. Did you sleep your normal amount last night?

YES NO

If NO, how many hours less? ______________________

3. Circle the response which <u>best describes</u> what you have had to eat in the past 24 hours.

Little to no food	Not much, just one large, nutritious meal	Mostly junk food and fast food	Two or three nutritious meals and healthy snacks

4. Have you taken any drugs in the last 24 hours, e.g., aspirin, cold relief medicine, diet aids, nasal spray, other?

YES NO

If YES, what drug(s) and at what dosage(s)? ______________________

____

5. Have you donated blood in the last 7 days?

YES NO

6. Have you recently had any problems with your balance or vision?

YES NO

If YES, please describe the problem and dates. ____________________

____

____

____

7. Circle the types of beverages you drink each day and estimate the quantity you consume.

Caffeine	Coffee	_____	cups
	Tea	_____	cups
	Soda	_____	cans
Decaffeinated	Coffee	_____	cups
	Tea	_____	cups
	Soda	_____	cans
Alcoholic	Beer	_____	12 oz
	Wine	_____	8 oz
	Liquor	_____	drinks
Water		_____	8 oz
Fruit Drinks		_____	8 oz

8. Do you use tobacco products?

YES NO

If YES, how many per day?

Cigarettes	_____	
Cigars	_____	
Pipe	_____	
Chewing Tobacco	_____	pinches

Do you inhale the smoke into your lungs?

YES NO

9. Have you felt "stressed-out" about anything in your life lately?

YES NO

If YES, why? ____________________

____

____

Do you feel fit to participate in testing?

YES NO

A/P22P-9(V) DONNING AND DOFFING PROCEDURES

INTRODUCTION

1. The following donning and doffing procedures were proposed for use in a contaminated environment. The procedures outlined here relate only to NAVAIRWARCENACDIV Patuxent River, Maryland, testing of the A/P22P-9(V) Helicopter Aircrewman Chemical, Biological, Radiological (CBR) Protection Assembly. Refer to appropriate training manuals for approved fleet procedures.

DONNING PROCEDURES

2. Before aircrew begin the donning procedures, make certain all A/P22P-9(V) components are available. Install a fresh 15 V battery and canisters in the ventilator. Turn the ventilator ON; check airflow; turn ventilator OFF. Install a fresh 9 V battery in intercom and check operation.

EVENT 1 Don two-piece cotton underwear and socks. Tuck undershirt into drawers. Pull socks over the legs of the drawers.

EVENT 2 Don ARS spectacles (if required) and skull cap or sweatband (if desired).

EVENT 3 Don aircrew chemical protective socks.

EVENT 4 Carefully separate the inside of the MK-1 undercoverall to avoid tearing the suit.

EVENT 5 Don the MK-1, fasten the slide fastener, and tie the waist cord in a bow knot. If the sleeves or legs are too long, they may be folded back so that the sleeves extend slightly beyond the wrists and the legs extend slightly beyond the ankles. Wear the legs of the undercoverall over the chemical protective socks. Adjust the stirrups under the insteps.

EVENT 6 Don the cotton glove inserts and butyl chemical protective gloves. Both should lie under the MK-1 sleeve.

EVENT 7 Open hood outlet valve on the mask.

EVENT 8 Don the mask by placing two hands inside the mask neck seal and widening it as much as possible. Hook the neck seal under the chin and pull the hood back over the head. The subject can be assisted by holding his skull cap and ARS spectacles in place while he pulls the mask down over his face. Check that the neck seal lies smoothly on the neck and that the apron lies smoothly over the shoulders.

EVENT 9 Connect the manifold inlet base to the ventilator delivery base with the RIED valve in-line. Turn the ventilator ON.

EVENT 10 Don the CWU-27/P flight suit. The shoulder cowl should be under the flight suit. Close the slide fastener without pinching the mask's shoulder cowl. The neck bellows should be outside the flight suit.

EVENT 11 Don the ventilator support strap diagonally across the chest so that the quick-release is on the right hip and low enough to clear the bottom of the survival vest once it is donned. Check that the support strap is under the manifold tubes and hoses.

EVENT 12 Attach the ventilator to the support strap.

EVENT 13 Don flight boots with MK-1 undercoverall over boot tops.

EVENT 14 Don survival vest. DO NOT CLOSE YET.

EVENT 15 Attach manifold retention pouch to the survival vest by at least two snaps. Four snaps provide vertical adjustment to optimize head mobility.

EVENT 16 Place the manifold in the manifold retention pouch and close the slide fastener.

EVENT 17 Close the survival vest slide fastener. Engage the life preserver waist hooks and the helicopter hoist strap. Route the leg lines. Check that all tubes and hoses are on the outside of the vest.

EVENT 18 Secure the ventilator hose to the survival vest. Grasp the hose with your left hand midway between the ventilator and the RIED valve. Place the hose in the hook and pile retainers on the far left side of the survival vest.

EVENT 19 Don the flight helmet, secure the chin strap, and adjust the nape strap.

EVENT 20 Secure the mask to the helmet by connecting the two toggle harness terminals to the helmet receivers. The toggle harness cables should lie over the hooks on the facepiece. Rotate the "V" bow down and lock into the flight position. Readjustment of the toggle harness assembly may be required. Check exhalation valve operation and then the facepiece for leaks.

EVENT 21 Secure the intercom unit to the survival vest by clipping the snap hook on to one of the upper "D" rings.

EVENT 22 Connect the microphone lead from the mask to the pigtail on the back of the helmet. The PREAMP, if installed, must be temporarily removed for the intercom to operate properly.

EVENT 23 Connect the communication cable to the helmet communication block and to the intercom. Check speaking and listening capabilities.

EVENT 24 Don standard flight gloves over the MK-1 and under the standard flight suit.

EVENT 25 Connect the drinking facility to the canteen and to the facepiece entry port.

EVENT 26 Don plastic footwear covers and disposable cape (watch for static electricity).

DOFFING PROCEDURES

3. To doff the A/P22P-9(V), simply remove the equipment in the reverse order in which it was donned.

EVENT 1 Remove the cape and overboots.

EVENT 2 Remove flight gloves.

EVENT 3 The aircrewman disconnects his helmet communication lead from the intercom unit, detaches the unit from his survival vest.

EVENT 4 Remove the hose from the hook and pile retainer on the left side of the survival vest.

EVENT 5 Take off the survival vest.

EVENT 6 Remove the ventilator from the buckle support strap and then remove the strap.

EVENT 7 Unzip the flight suit and take it off to the waist.

EVENT 8 Remove the mask. If wearing, take off the skull cap or sweatband.

EVENT 9 Remove plastic footwear covers and flight boots.

EVENT 10 Finish taking off the flight suit and MK-1.

EVENT 11 Doff chemical protective socks and gloves.

EVENT 12 Remove cotton glove inserts, socks, and underwear.

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POSTTEST QUESTIONNAIRE
DATA COLLECTION SHEET

RANK/NAME: ____________________ DATE: ____________________

WORK PHONE: ____________________ AGE: ____________________

CIRCLE AS APPROPRIATE: FLIGHT TEST OR GROUND TEST

CHEMICAL GEAR OR STANDARD GEAR

CANTEEN VOLUME (ml), PREFLIGHT ________

URINE SPECIFIC GRAVITY, PREFLIGHT ________

WEIGHT, PREFLIGHT NUDE ________

RECTAL TEMPERATURE, PREFLIGHT ________

HEART RATE, PREFLIGHT RESTING ________

BLOOD PRESSURE, PREFLIGHT ________

TARGET HEART RATE

220
-_____ AGE

-_____ HEART RATE, RESTING

x_____ .70

+_____ HEART RATE, RESTING

=_____ TARGET HEART RATE

TIME BEGAN A/P22P-9(V) DONNING ________

TIME COMPLETED DONNING GEAR ________

TIME SQUIRREL LOGGER ON ________

WEIGHT, PREFLIGHT CLOTHED ________

TIME TO TARMAC ________

TIME WIBGET* ON ________

DATA COLLECTION SHEET (Cont'd)

TIME BEGAN PREFLIGHT ____________

TIME COMPLETED PREFLIGHT ____________

TIME BEGAN PRESTART CHECKLIST ____________

TIME COMPLETED PRESTART CHECKLIST ____________

TIME TAXI/TAKEOFF ____________

TIME OF LANDING ____________

TIME WIBGET* TURNED OFF ____________

TIME TO READY ROOM ____________

WEIGHT, POST-FLIGHT CLOTHED ____________

TIME SQUIRREL TURNED OFF ____________

WEIGHT, POST-FLIGHT NUDE ____________

URINE SPECIFIC GRAVITY, POST-FLIGHT ____________

CANTEEN VOLUME, POST-FLIGHT ____________

POST-FLIGHT QUESTIONNAIRE ____________

HEART RATE, POST-FLIGHT RESTING ____________

BLOOD PRESSURE, POST-FLIGHT ____________

VOLUME ADDITIONAL WATER (ml) ____________

URINE OUTPUT AS REQUIRED (ml) ____________

DURATIONS

DONNING ____________

PREFLIGHT ____________

PRESTART ____________

FLIGHT ____________

SQUIRREL ON ____________

G E A R S I Z I N G

1. List gear sizes worn for test:

(a)_____MK-1 UNDERCOVERALL

(b)_____PROTECTIVE GLOVES

(c)_____A/P22P-9(V) OVERBOOTS

(d)_____A/P22P-9(V) MASK/HOOD

(e)_____COTTON DRAWERS, LONG

(f)_____COTTON SHIRT, LONG

(g)_____COTTON GLOVE INSERTS

(h)_____NOMEX FLIGHT GLOVES

(i)_____FLIGHT BOOTS

(j)_____HELMET

(k)_____FLIGHT SUIT

2. Identify from the list above, any item(s) you found difficult to don. Circle the item(s) by letter.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

3. Rate the ease of donning the A/P22P-9(V) assembly.

1 2 3 4 5

VERY EASY VERY DIFFICULT

4. Identify any item(s) you found difficult to doff.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j) (k)

5. Rate the ease of doffing the A/P22P-9(V) assembly.

1 2 3 4 5

VERY EASY VERY DIFFICULT

6. What changes, if any, would you make to the donning and doffing procedures? Please be specific.

____
____
____
____
____
____

ALSS COMPATIBILITY

7. Rate the following standard flight gear items for compatibility with the A/P22P-9(V) assembly.

1	2	3	4	5
VERY COMPATIBLE				NOT COMPATIBLE

SURVIVAL VEST_____ FLIGHT SUIT _____

FLIGHT HELMET_____ FLIGHT BOOTS _____

FLIGHT GLOVES_____ OTHER_____ _____

COMMENTS: ____
____
____
____
____

FREEDOM OF MOVEMENT

8. Rate your <u>overall</u> freedom of movement while wearing the A/P22P-9(V) assembly.

1	2	3	4	5
VERY GOOD				VERY POOR

9. Rate the following for freedom of movement.

HEAD/NECK MOBILITY	1	2	3	4	5	LEGS	1	2	3	4	5
SHOULDERS/ARMS	1	2	3	4	5	FEET	1	2	3	4	5
HANDS/FINGERS	1	2	3	4	5	WAIST	1	2	3	4	5

1	2	3	4	5
VERY GOOD				VERY POOR

10. Please note if any particular movements were more difficult or uncomfortable to perform while wearing the A/P22P-9(V) assembly.

____
____
____
____
____
____

11. Describe the fit of the A/P22P-9(V) below-the-neck ensemble (circle one)?

GOOD FIT BAGGY FIT TIGHT FIT

A I R C R A F T C O M P A T I B I L I T Y

12. How did the assembly affect your ability to perform the following?

1	2	3	4	5
NO EFFECT				SEVERE EFFECT

ACTUATE CONTROLS, SWITCHES, KNOBS	1	2	3	4	5
ACCESS EQUIPMENT	1	2	3	4	5
PERFORM MISSION DUTIES	1	2	3	4	5

Please specify which controls, equipment, or duties were affected.

____

13. In your opinion, to what degree do you think the assembly affected the following:

1	2	3	4	5
NO IMPACT				SEVERE IMPACT

PREFLIGHT/DAILY TURNAROUND	1	2	3	4	5
INGRESS	1	2	3	4	5
EGRESS	1	2	3	4	5
EMERGENCY EGRESS	1	2	3	4	5

Please explain your answer.

C O M F O R T

TEMPERATURE

14. Did you experience physical discomfort due to a buildup of heat?

YES NO

Do you feel the heat buildup was due to wearing the A/P22P-9(V) as opposed to only standard flight equipment?

YES NO

15. On figure 1 below, please circle the area(s) where you experienced physical discomfort due to heat buildup.

Please rate the degree of discomfort by selecting the appropriate number from the side key and writing it into the circled area(s).

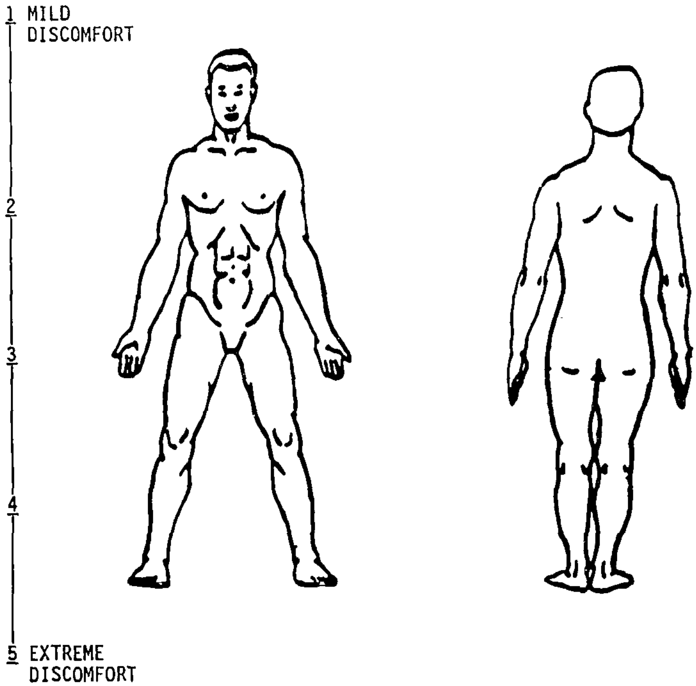

Figure 1
AREAS OF DISCOMFORT

16. **How well did you tolerate the heat buildup?**

1	2	3	4	5
TOLERATED WELL				FOUND IT INTOLERABLE

17. To what degree did the heat buildup hinder your performance?

1	2	3	4	5
NO PROBLEM				GREATLY HINDERED

Please comment:

____
____
____
____
____
____

18. How would you describe your perspiration while wearing the A/P22P-9(V)?

1	2	3	4	5
SAME AS STANDARD GEAR				PROFUSELY

19. Did perspiration interfere with your performance?

1	2	3	4	5
NO PROBLEM				GREATLY INTERFERED

If perspiration adversely affected you, please explain in greater detail.

____
____
____
____
____
____
____
____

20. On figure 2 below, circle the area(s) where perspiration was greatest.

Please rate the degree of discomfort by selecting the appropriate number from the side key and writing it into the circled area(s).

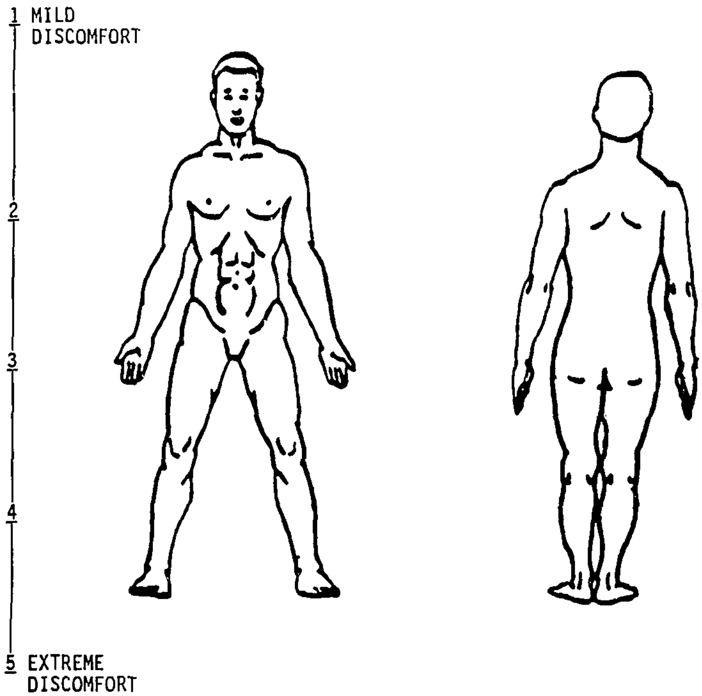

Figure 2
PERSPIRATION AREAS

21. Did you experience any of the following while wearing the A/P22P-9(V) (please check the applicable condition(s))?

UNUSUAL FATIGUE	____	DISORIENTATION	____
HEADACHE	____	SENSE OF CONFINEMENT	____
MUSCLE CRAMPS	____	EYE STRAIN	____
SKIN IRRITATION	____	DIZZINESS	____
NAUSEA	____	PRESSURE POINTS	____
HEAD HOT SPOTS	____	EXTREME THIRST	____

OTHER (specify) ______________________________

Please comment on your above response. ______________________________

____
____
____
____

HYDRATION

22. Did you adequately hydrate before this flight?

YES NO

23. Could you easily and adequately use the canteen and drinking tube to hydrate during the test?

YES NO

PREVIOUS CBR ASSEMBLY EXPERIENCE

24. Have you ever used a different CBR protective assembly?

YES NO

If YES, which assembly(ies) have you used previously?

____
____

Compare the A/P22P-9(V) (this assembly) with the one you have previously used.

____
____
____
____

CBR GLOVE EVALUATION

25. Rate your tactile (touch) sensitivity while wearing the CBR protective gloves.

1	2	3	4	5
VERY GOOD		SAME AS FLIGHT GLOVES		VERY POOR

26. Rate your manual dexterity (finger movement) while wearing the CBR protective gloves.

1	2	3	4	5
VERY GOOD		SAME AS FLIGHT GLOVES		VERY POOR

27. Were you able to perform your job while wearing the CBR protective gloves (e.g., actuate controls, knobs, switches, dials...etc).

YES NO

CBR OVERBOOT EVALUATION

28. Rate the slip resistance provided by the CBR overboots.

1	2	3	4	5
VERY GOOD		SAME AS FLIGHT BOOTS		VERY POOR

29. Rate the fit of the CBR overboots.

1	2	3	4	5
VERY GOOD		ADEQUATE		VERY POOR

Please explain your answer further.

___

___

___

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SAFETY CHECKLIST

The purpose of this checklist is to stimulate thought in the area of safety. Most of these questions have been written from lessons learned from past accidents in the RDT&E community.

Notes:

(1) This checklist will be completed and signed by the project officer, all project pilots and the project engineer(s).

(2) Simple yes-no answers are not satisfactory, if an item is not applicable, so state.

(3) Any changes to the Test Plan or Safety Checklist will be formally submitted as an addendum.

1. In accordance with NATCINST 3960.10 series and current directorate instruction, list the category testing to be conducted. If category varies with different phases of testing, so state. Ensure that pilot's workload during critical flight maneuvers is taken into consideration. (Refer to test plan if appropriate).

According to Naval Air Test Center Instruction 3710.15D, the test categories are ground testing and flight testing C and B. Flight test classifications C and B were selected to note the known potential hazards of wearing CBR protective clothing.

2. Flight crew qualifications as of 17 July 1990.

Aircraft	Pilot/Copilot	Total Flight Hours	Total Flight Hours in Type	Flight Hours Last 60 Days	Category Qualified

Privacy Act Information Removed

3. List the flight restrictions officially placed on the project and those restrictions/special pilot procedures that have been/ will be added to the aircraft information sheet.

a. All flight maneuvers will be normal as prescribed in the applicable NATOPS and Tactical manuals. Flights will be conducted over land or within autorotation distance to land.

b. Additional procedures that will be added to the aircraft information sheet include ventilator mounting bracket location and use, ventilator electrical connection, and communication cord interface with the intercommunication system.

c. Test termination criteria and procedures are provided in appendix C.

4. List aircraft downing discrepancies which are applicable to the aircraft system(s) to be tested.

a. Malfunction of the ventilator mounting bracket or electrical connections will result in aborting the test.

b. Normal aircraft downing discrepancies will ground the aircraft.

5. What background material (contractor reports, previous NAVAIRTESTCEN reports on similar aircraft or equipment, discussion with contractor's pilots, Naval Safety Center data) and known problem areas have been studied so the "surprises" will be minimized?

a. The physiological effects of wearing the A/P22P-9(V) and similar CBR protective gear have been extensively researched, see references listed in this test plan.

b. Summary Report of Literature on Crew Performance in Hot Weather While Wearing Chemical/Biological (CB) Protective Clothing, CDRL Item A004 of Task 0182, Contract N00421-85-D-0074. This bibliography covers related documents from 1987-1977; there are over 200 entries.

6. What ground checks will be conducted to assess proper operation of project equipment and emergency equipment unique to the test airplane?

a. Respirator assemblies will be checked on a portable test set to assure proper operation. All flight equipment will be RFI (Ready for Issue) by a qualified survival equipmentman (PR).

b. Proper A/P22P-9(V) fit will be ensured by trained personnel.

c. Ventilator interface with aircraft and ventilator operation in aircraft will be verified prior to flight test.

d. Communications interfaces between aircrewmen and aircraft and proper operation of portable intercommunication unit will be verified prior to flight test.

7. In order to ensure that no undue hazard to ground personnel or possible damage to equipment exists, what changes or special precautions to normal aircraft maintenance and/or ground handling procedures are required? Are crew changes with engines running required? If so, describe procedures. Does removal/installation of project equipment constitute PMCF criteria?

a. No deviations from normal maintenance or ground handling procedures are required.

b. Crew change with engines running is not required.

c. Removal/installation of equipment does not require PMCF; however, an EMC SOFT is required after initial installation of bracket and respirator wiring.

8. If locally manufactured components are necessary for the completion of the project, what steps have been taken to ensure that adequate detailed drawings/schematics and operating instructions are prepared, components are inspected and tested prior to installation in accordance with current quality assurance/configuration control instructions?

a. Detailed drawings of ventilator mounting bracket locations and electrical connection hook-up for each helicopter will be provided to NAVAIRTESTCEN Range Directorate.

b. Installation will be performed by Range Directorate.

c. Installation inspection will be performed by NATC/Systems Engineering Test Directorate and Rotary Wing Test Directorate.

9. Have aircraft discrepancy review procedures been established to avoid potential adverse impact on evaluation flights? The project officer and engineer will review and include as part of the preflight brief all up discrepancies prior to each flight to ensure that no potential exists for interference with scheduled test maneuvers.

a. Aircraft discrepancies will be documented and reviewed prior to each test by the pilots, aircrew and project physiologist.

b. Following each flight test, the project physiologist, test aircrew, and test personnel will meet to determine if any interference with scheduled test maneuvers or safety-of-flight issues exist.

10. Do test instrumentation systems under any conditions prevent the normal operation of aircraft systems? Describe fully. Has the system been checked for EMC safety-of-flight in accordance with NATCINST 13050.3 series? Are instrumentation controls easily identified and conveniently placed? Have they been checked by SETD Aircrew Systems Branch? What is the established envelope for externally carried instrumentation?

a. Test instrumentation does not prevent the normal operation of aircraft systems. Test instrumentation consists of a man-mounted physiological monitoring system, aircraft-mounted wet bulb globe temperature sensors and the A/P22P-9(V) itself. The aircraft interface is via the ventilator, the communication cord/intercom, and the aircrewmembers' interface with aircraft system controls. The ventilator, communications, and visual systems

interfaces have been verified in previous testing by the SETD Aircrew Systems Department. The hands-on controls interfaces will be evaluated during this test program. An EMC SOFT will be performed prior to and in conjunction with the familiarization flight in each model helicopter.

b. No externally carried instrumentation exists.

11. Engineering design deficiencies are not uncommon in project equipment; therefore, a hazard analysis and risk assessment is required so that we can systematically determine possible hazards and minimize surprises.

a. A hazard analysis for the A/P22P-9(V) Respirator Assembly was performed and all known hazards were eliminated or controlled.

b. The A/P22P-9(V) MK-1 undercoverall is currently in service for the USAF and the Canadian and United Kingdom air forces. Heat stress in extreme heat is the only known hazard.

a. Asking the questions "What if" and "how", what aircraft system and subsystem failure modes can be identified?

(1) A/P22P-9(V) ventilator failure.
(2) A/P22P-9(V) ventilator battery power supply failure (battery or aircraft power supply).
(3) Intercommunication unit failure.
(4) Test aircrew may incur heat-related illness.

b. If the failure mode cannot be eliminated, what special precautions, emergencies, and emergency procedures are anticipated?

(1) An extra ventilator, intercommunication units and appropriate batteries will be available to replace any failed unit. Aircraft/respirator assembly ICS failure procedures will be briefed prior to flight.

(2) If the aircraft power supply fails, battery power will automatically supply power to the ventilator. If no power gets to the ventilator, the subject will be able to maintain normal lung-powered breathing.

(3) If heat build-up or stress occurs in any test subject, the procedures listed in appendix C will be in effect. A safety pilot will be present on all flights.

c. If any safety devices or interlock will be bypassed or overridden in these tests, what additional hazards are involved and what steps will be taken to reduce these risks?

There is no such device involved.

12. Discuss the desirability for project flight crew members to preview high risk/workload data points and compound emergency procedures in a flight simulator.

Pilot physical/cognitive workload is planned to be at normal levels. In the event that heat stress becomes a problem for any crew member, the termination procedures in appendix C will be followed. All emergency procedures for flight tests will be previewed in a briefing and practiced in an appropriate fashion. For example, flight performance in the A/P22P-9(V) respirator assembly will be checked during FUME flights.

13. What are the real time and/or post-flight critical parameters to be monitored during the test? Specify who will monitor the real-time critical parameter. Describe data management techniques to detect adverse trends in these parameters.

The critical parameters to be monitored and recorded are core temperature, heart rate, and skin temperature at six different sites. At least one safety observer will monitor subjects in the UH-1N and CH-53 flights. The safety observer will be the project physiologist, an Aerospace Physiologist, a qualified paramedic or a hospital corpsman. A dual alarm system will be wired to the test pilot and the safety pilot which will be triggered should either subject exceed a safety limit. See appendix C, Test Termination and Safety Criteria for details on safety limits.

14. What logical build-up is planned for high risk/pilot workload data points?

a. No high risk/pilot workload data points are planned. Pilot physical/cognitive workload is planned to be at normal levels.

b. Subjects' physiological condition will be monitored during ground tests and FAM flights to determine the potential for hazard during flights of a longer duration or more difficult nature. Following tests, the project physiologist, test aircrew, and test personnel will meet to determine if the A/P22P-9(V) interfered in any way with scheduled test maneuvers or safety-of-flight. An objective is to determine aircrewmembers' ability to function at normal workloads while wearing the A/P22P-9(V) without exceeding physiological guidelines.

15. For high angle of attack test, provide a pre-maneuver check list.

Not applicable.

16. Specify who will be required to attend pre/post flight briefings. Preflight briefing shall include a review of:

The pre/post flight briefings will be attended by all test aircrew, Aircrew Systems Department test personnel and the photographer.

17. List the following Go-NO-Gc criteria:

a. **Weather criteria (specific ceiling/visibility criteria is required).**

(1) **Terminal: 500 ft/1 statute mile**

(2) **Area: 1500 ft/3 statute mile and clear of clouds.**

b. **Chase requirements: Not applicable**

c. **Instrumentation requirements: Squirrel Data Meter/Logger and Wibget® Heat Stress Monitor and Data Logger.**

d. **Other: Answers on the Baseline Data Questionnaire and the Pre-Test Questionnaire indicating unsatisfactory condition of subject. See also appendix C for Test Termination Criteria.**

18. For flight operations away from Patuxent River, face-to-face briefings with resident operations officers and support personnel will be conducted prior to first project flight, to include: local traffic pattern, radio communication procedures, hazardous area, available crash/rescue equipment, emergency procedures, local warning or civil avoidance areas, emergency ejection, fuel dump or ordnance jettison areas, GSE availability, and details of tests to be conducted.

All flights are planned to be conducted within the local flying area. Confined Area Landings (CAL's) will be flown at MCCDC Quantico, VA under preventative control provided by MCAF Tower. Appropriate arrangements will be made for flight testing at NAS New Orleans.

19. Have other agencies, both military and civilian, who have conducted similar tests been consulted so that benefit can be realized from consideration of their standard procedures and lessons learned?

a. **Yes, in addition to the references listed in this test report, an extensive literature search was conducted and a bibliography of over 200 entries was compiled.**

b. **More specifically, the following agencies were contacted: Naval Air Development Center - DT-I test results; USAF - Tactical Air Warfare Center, Eglin AFB - USAF TECHEVAL of similar CBR ensemble in F-4 and F-15 aircraft; and USAAMRL, Ft. Rucker - Testing of similar CBR ensemble while flying the UH-1H helicopter in hot weather.**

20. How will any modifications or restrictions to the project aircraft be entered in the Aircraft Discrepancy Book for pilot review?

A/P22P-9(V) ventilator mounting bracket, electrical and communication connections are documented in NATOPS information packages which have been forwarded to NADEP/Pensacola and NADEP/Cherry Point for incorporation into NATOPS manuals. The inrtallation does not restrict the aircraft in any way and will be documented on NDW-NATC-3710/1 (Pink Sheet).

21. What steps will be taken to guard against the in-flight loss of any ordnance, pod or aircraft equipment and to protect persons or property on the ground should such an in-flight loss occur?

No ordnance, pods or external aircraft equipment will be used.

22. Is ECM required? If so, who is responsible to ensure that the requirement of OPNAVINST 3430.9 have been complied with?

ECM is not required.

23. Project Security

a. What is the overall security classification of the project?

Unclassified.

b. Have classification guides (OPNAVINST C5513.2 for most Naval Aviation Equipment) for all project aircraft and support equipment been reviewed for appropriate classification?

Aircraft and support equipment are standard.

c. Are any components of equipment classified? If so, are procedures established for storage and shipment in accordance with OPNAVINST 5510.1G?

Not applicable.

d. Will project data be classified? If so, how will it be protected?

No, project data will not be classified.

e. Will any classified equipment or ordnance be delivered to or shipped from NAVAIRTESTCEN during the project? If so, have proper arrangements been made and accepted procedures followed to ensure its safeguard?

No classified equipment or ordnance will be involved with these tests.

24. I have read and fully understand this test plan.

NAME	CREW POSITION
NAME	CREW POSITION
NAME	CREW POSITION

PRIVACY ACT INFORMATION NOT DISCLOSED

MK-1 UNDERCOVERALL SIZING MATRIX

MK-1		Tariff	ORIGINAL SIZING	USN FLIGHT SUIT SIZING
Short 65-68" Height (5'5"- 5'8")				
1	Small-Short	4.5	33-36" Chest	36-38" Chest
2	Medium-Short	9.9	36-39"	38-42"
3	Large-Short	8.7	39-42"	42-46"
Regular 68-71" Height (5'8"- 5'11")				
4	Small-Regular	6.5	33-36" Chest	36-38" Chest
5	Medium-Regular	19.7	36-39"	38-42"
6	Large-Regular	21.6	39-42"	42-46"
Long 71-76" Height (5'11"- 6'4")				
7	Small-Long	11.4	36-39" Chest	36-38" Chest
8	Medium-Long	13.4	39-42"	38-42"
9	Large-Long	4.3	42-45"	42-46"

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ADDITIONAL DATA ANALYSES

CORE TEMPERATURE

1. The following examples apply test data to the T_{core} linear model:

$$T_{core} = \beta_0 + \beta_1 \times time + \epsilon \qquad (1)$$

where: β_0 = T_{core} intercept at time = 0, and denotes its estimate as $\hat{\beta}_0$
β_1 = $\Delta T_{core} / \Delta time$, and denotes its estimate as $\hat{\beta}_1$
ϵ = error

During preflight, $\hat{\beta}_1$ was always positive. Example 1 provides $\hat{\beta}_1$ comparisons between A/P22P-9(V) and standard ALSS CH-53 preflights:

Example 1 Figure 1 compares CH-53 preflight operations in A/P22P-9(V) and standard ALSS. Each lasted ≈ 100 min in the mid-20°C (≈ 77°F) range. $\hat{\beta}_1$ was 0.009°C/min (0.02°F/min), though ambient temperature decreased ≈ 3°C (5.4°F) during the course of the preflight. At the end of the preflight, T_{core} increased as follows:

$$\Delta T_{core} = .009°C/min \times 100\ min = .9°C\,(1.6°F)$$

Comparatively, from the standard ALSS control data, $\hat{\beta}_1$ was 0.0003°C/min, so the T_{core} change was negligible.

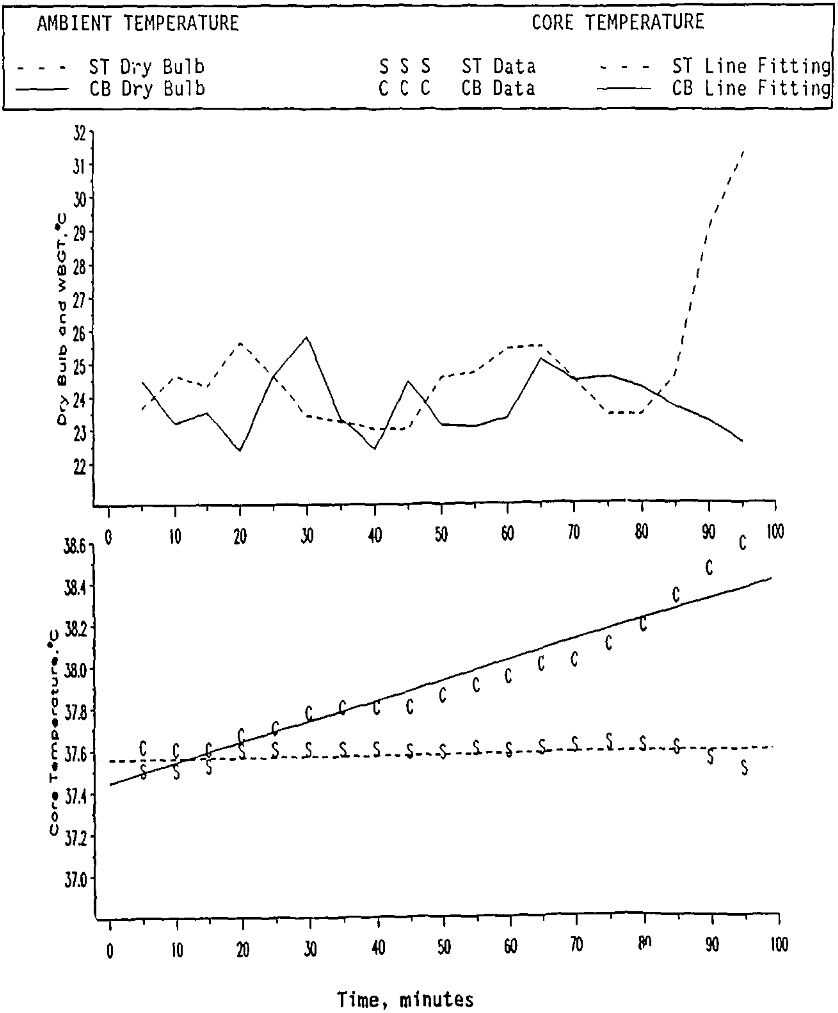

Figure 1
A/P22P-9(V) (CB) AND STANDARD ALSS (ST) CORE TEMPERATURE COMPARISON
PREFLIGHT
(Line Fitting)

In flight, T_{core} typically continued to rise with the rate established during preflight, then leveled off, still within a safe temperature zone, and eventually decreased, see example 2:

Example 2 Figure 2 presents one subject's paired data from A/P22P-9(V) and standard ALSS, where preflight operations lasted 32 min and 42 min in mean T_{db} 26.5°C (79.7°F) and 25.4°C (77.9°F), respectively, and flight operations lasted 281 min and 206 min in mean T_{db} 36°C (96.8°F) and 32.6°C (91.5°F), respectively.

For the A/P22P-9(V), β_1 was 0.01°C/min (0.02°F/min) and remained so after takeoff for ≈ 10 min, then reduced to 0.004°C/min (0.072°F/min), and finally tapered to -0.001°C/min (-0.018°F/min). Notice this pattern occurred during an increasing WBGT flight environment. The standard ALSS control data had a similar pattern but remained cooler than A/P22P-9(V) throughout the entire testing. Table I summarizes the subject's T_{core}: after donning, mean, and maximum during preflight and flight tests. In this table, though the flight mean T_{core} is greater than the preflight mean T_{core}, this does not negate the most important observation in-flight: T_{core} stopped increasing 80 min after takeoff. This T_{core} curve pattern was typical for all A/P22P-9(V) wearer; T_{core} decreased sooner or later with various degrees.

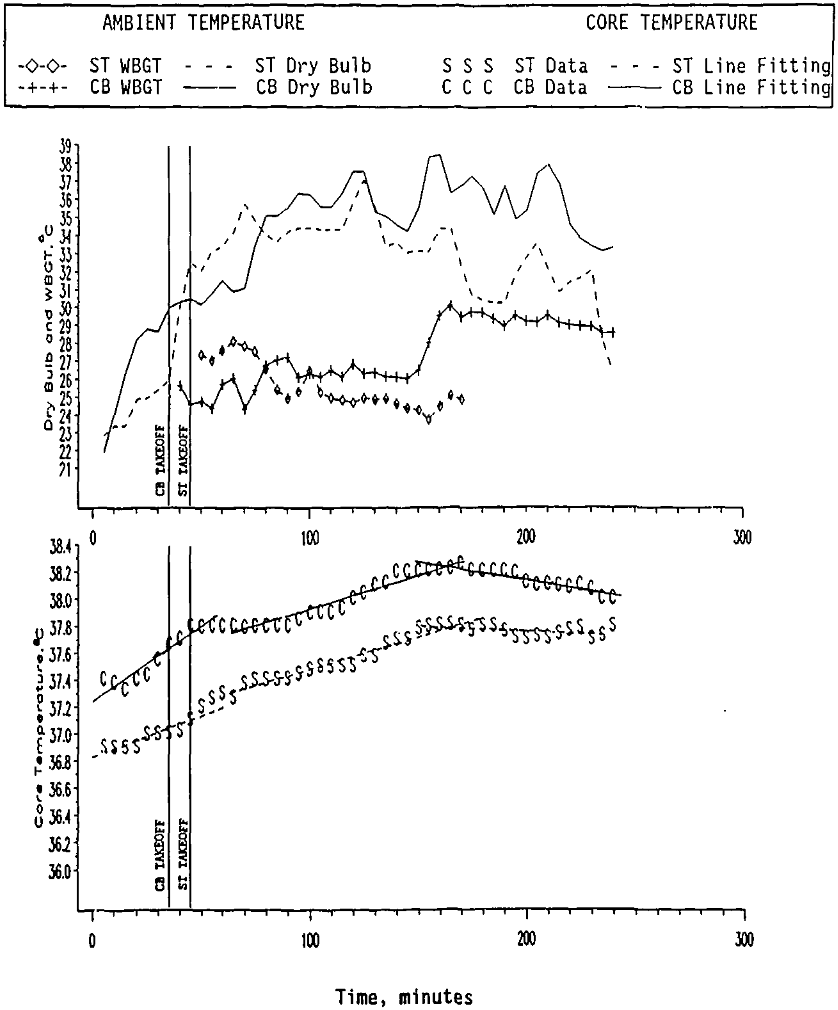

Figure 2
A/P22P-9(V) (CB) AND STANDARD ALSS (ST) CORE TEMPERATURE COMPARISON
PREFLIGHT AND FLIGHT
(Line Fitting)

Table I

SUBJECT'S CORE TEMPERATURE THROUGHOUT A TYPICAL TEST SESSION

Operation	Statistics	A/P22P-9(V) °C (°F)	Standard ALSS °C (°F)
Preflight	After Donning	37.4 (99.3)	36.9 (98.4)
	Mean	37.4 (99.3)	37.0 (98.6)
	Maximum	37.6 (99.7)	37.1 (98.8)
Flight	At Takeoff	37.6 (99.7)	37.0 (98.6)
	Mean	38.0 (100.4)	37.7 (99.9)
	Maximum	38.3 (100.9)	37.8 (100.0)

SKIN TEMPERATURE

2. The following example applies test data to the T_{sk} linear model:

$$T_{sk} = \beta_0 + \beta_1 \times time + \epsilon \qquad (2)$$

where: β_0 = T_{sk} intercept at time = 0, and denotes its estimate as β_0
β_1 = $\Delta T_{sk}/\Delta time$, and denotes its estimate as β_1
ϵ = error

During preflight, β_1 was always positive. Example 3 provides β_1 comparisons between A/P22P-9(V) and standard ALSS CH-53 preflights:

Example 3 In the figure 3 T_{sk} plot (same test subject as example 2), both A/P22P-9(V) and standard ALSS preflight β_1 were similar (0.08°C/min), but standard ALSS skin temperatures were up to 1.5°C cooler. After takeoff, both ensembles' skin temperatures continued to rise with the same slope established during preflight for approximately 60 min. At this time, both skin temperature curves converged and began to decrease with a similar rate. Notice during flight, T_{sk} decreased while T_{db} and WBGT were increasing.

Table II summarizes the subject's T_{sk}: before donning, after donning, mean, and maximum during preflight and flight tests. In this table, though the flight mean T_{sk} is greater than the preflight mean T_{sk}, this does not negate the most important observation in-flight: T_{sk} stopped increasing 60 min after takeoff. T_{core} continued to rise until 80 min after takeoff. This T_{sk} curve pattern was common for all A/P22P-9(V) subjects; T_{sk} decreased sooner or later with various degrees for each subject. Also, the maximum T_{sk} was 36.9, while his T_{core} at this point was 37.9 (see figure 1, appendix L, paragraph 1). The two variables were only 1°C (1.8°F) apart and were within safety limits. Fortunately, T_{sk} started decreasing after this point to avoid the T_{core} and T_{sk} convergence.

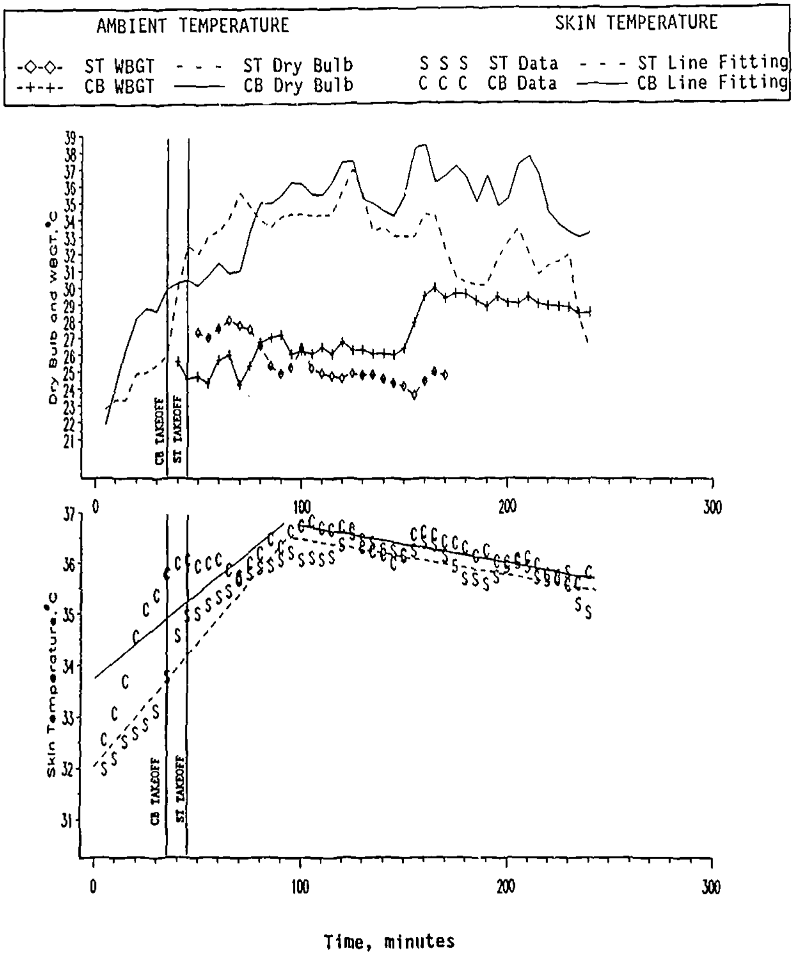

Figure 3
A/P22P-9(V) (CB) AND STANDARD ALSS (ST) SKIN TEMPERATURE COMPARISON
PREFLIGHT AND FLIGHT
(Line Fitting)

Table II

SUBJECT'S SKIN TEMPERATURE THROUGHOUT A TYPICAL TEST SESSION

Operation	Statistics	A/P22P-9(V) °C (°F)	Standard ALSS °C (°F)
Preflight	After Donning	32.4 (90.3)	31.9 (89.4)
	Mean	34.1 (93.4)	33.0 (91.4)
	Maximum	35.6 (96.1)	34.8 (94.6)
Flight	At Takeoff	35.6 (96.1)	34.8 (94.6)
	Mean	36.2 (97.2)	35.8 (96.4)
	Maximum	36.9 (98.4)	36.7 (98.1)

HEART RATE

3. Figures 4 and 5 provide the heart rate frequency for each heart rate interval used in constructing the bar chart histograms (page 48). A/P22P-9(V) heart rate tested significantly higher (α=.05) than standard ALSS with a two-way contingency table CHI-squared result.

Ensemble Heart Rate Interval, beats/min

FREQUENCY PERCENT ROW PCT COL PCT	≥70	≥80	≥90	≥100	≥110	≥120	≥130	≥140	TOTAL
A/P22P-9(V)	3 4.05 9.38 15.00	2 2.70 6.25 12.50	3 4.05 9.38 30.00	6 8.11 18.75 60.00	4 5.41 12.50 100.00	6 8.11 18.75 100.00	7 9.46 21.88 100.00	1 1.35 3.13 100.00	32 43.24
STANDARD	17 22.97 40.48 85.00	14 18.92 33.33 87.50	7 9.46 16.67 70.00	4 5.41 9.52 40.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	42 56.76
TOTAL	20 27.03	16 21.62	10 13.51	10 13.51	4 5.41	6 8.11	7 9.46	1 1.35	74 100.00

Figure 4
HEART RATE FREQUENCY PER INTERVAL
PREFLIGHT

Ensemble Heart Rate Interval, beats/min

FREQUENCY PERCENT ROW PCT COL PCT	≥60	≥70	≥80	≥90	≥100	≥110	≥120	≥130	≥140	≥150	TOTAL
A/P22P-9(V)	0 0.00 0.00 0.00	2 0.41 0.71 15.38	6 1.23 2.14 4.84	23 4.72 8.19 29.87	65 13.35 23.13 80.25	97 19.92 34.52 97.98	72 14.78 25.62 100.00	8 1.64 2.85 100.00	6 1.23 2.14 100.00	2 0.41 0.71 100.00	281 57.70
STANDARD	5 1.03 2.43 100.00	11 2.26 5.34 84.62	118 24.23 57.28 95.16	54 11.09 26.21 70.13	16 3.29 7.77 19.75	2 0.41 0.97 2.02	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	206 42.30
TOTAL	5 1.03	13 2.67	124 25.46	77 15.81	81 16.63	99 20.33	72 14.78	8 1.64	6 1.23	2 0.41	487 100.00

Figure 5
HEART RATE FREQUENCY PER INTERVAL
FLIGHT

DEFINITION OF DEFICIENCIES

Part I indicates a deficiency, the correction of which is necessary because it adversely affects:

a. Airworthiness of the aircraft.

b. The ability of the aircraft to accomplish its primary or secondary mission.

c. The effectiveness of the crew as an essential subsystem.

d. The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

Part II indicates a deficiency of lesser severity than a Part I which does not substantially reduce the ability of the aircraft to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the effectiveness, maintainability, or safety of the aircraft.

Part III indicates a deficiency that appears too impractical or costly to correct in this model but which should be avoided in future designs. Included are violations of specifications for use by the contract negotiator in final settlement of the contract.

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