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OPERATION FRICTION: DEVELOPMENT AND INTRODUCTION OF PERSONAL COOLING FOR CH124 SEA KING AIRCREW

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OPERATION FRICTION: DEVELOPMENT AND INTRODUCTION OF PERSONAL COOLING FOR CH124 SEA KING AIRCREW

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EXECUTIVE SUMMARY

In August 1990 the Directorate of Maritime Aviation (DMA) advised the Defence and Civil Institute of Environmental Medicine (DCIEM) that five Sea King helicopters and their crews would be deployed to the Persian Gulf as part of Canada's participation in United Nations activities against Iraq. Due to the high ambient temperatures in the Gulf region and the anticipated need for use of Chemical Defence (CD) ensembles, DMA requested that DCIEM provide personal cooling systems for the aircrew.

DCIEM procured a system built by Exotemp of Pembroke, Ontario and adapted and installed it in the deploying Sea Kings. A team from DCIEM went to CFB Shearwater to include the cooling related modifications in the extensive pre-deployment modifications of the Sea Kings. Suitable cooling unit carriers were designed, manufactured and installed at five positions aboard each helicopter. The aircraft electrical system was modified to provide aircraft power to the cooling units. Aircrew were issued with the cooling system jersey which is worn next to skin. A "pass- through" in the CD ensemble for the supply and return lines connecting the internal jersey to the aircraft mounted cooling unit was designed and manufactured at DCIEM and installed at CFB Shearwater.

A member of the DCIEM team was deployed aboard HMCS Protecteur as far as Gibraltar to complete the integration of the personal cooling system and aircrew training in the use and maintenance of the system. During this time, freezer space for the ice supply was coordinated with the ship's company and arrangements were made to have power provided for cooling units in the hanger and at the LSO position. Evaluations of technical and operational suitability and effectiveness of the cooling system were also conducted.

The Exotemp personal cooling system was rapidly modified and integrated into Sea King operations for Operation Friction. All aircrew indicated that personal cooling was a requirement and most recommended the use of the Exotemp system even though they felt further development would improve its overall effectiveness. This is the first aircrew personal cooling system known to have been used in wartime. It made Canadian Sea King aircrew unique amongst our allies: in unconditioned aircraft, in one of the hottest environments in the world, dressed in the full CD ensemble, they could function without being limited by heat stress.

ABSTRACT

Sea King aircraft and aircrew were deployed to the Persian Gulf as part of Canada's support to the United Nations actions against Iraq. Due to the expected high ambient temperatures and requirement to operate in the Aircrew Chemical Defence (CD) ensemble, personal cooling was required to maintain operational effectiveness. A system, that had been developed by Exotemp of Pembroke (Ontario) for cooling bomb disposal personnel, was adapted for this purpose. This included not only manufacture and delivery within one week, but also design and implementation of CD ensemble and aircraft modifications. Through concerted efforts of many individuals and agencies, equipment developments and modifications were completed in the one week available prior to sailing. The development of doctrine, operational use of the cooling ensembles, and training of aircrew and support staff were accomplished aboard ship enroute to Gibraltar. Physiological and operational evaluations of the cooling system show that the operational capability of our aircrew is significantly enhanced by the personal cooling system. Indeed, this is the first aircrew personal cooling system known to have been used in wartime. It made Canadian Sea King aircrew unique amongst our allies: in unconditioned aircraft, in one of the hottest environments in the world, dressed in the full CD ensemble, they could function without being limited by heat stress.

INTRODUCTION

Background

1. DCIEM was contacted by the Directorate of Maritime Aviation (DMA) on 10 August 1990 and advised of the requirement to send SeaKing aircrew to the Persian Gulf aboard the Canadian ships involved in Operation Friction. Temperatures in the Gulf can exceed 45°C (113F) and it was recognized that crews would require some sort of personal cooling in order to operate effectively. This would be especially true if aircrew were required to wear the chemical defence (CD) individual protective ensemble (IPE), because of its insulative nature and impermeable components.

2. DMA inquired about the status of DCIEM efforts in personal cooling and asked us to investigate the feasibility of providing a personal cooling system for these aircrew. DCIEM had conducted numerous physiological studies to evaluate the benefits of personal cooling, both with normal flight clothing and the chemical defence ensemble. DCIEM had also developed and tested both liquid and air-cooling torso vests. These were designed to be worn over the long underwear. Methods to connect and route the chilled air or liquid through the layered chemical defence ensemble were in the prototype stage of development. While DCIEM had been investigating suitable chiller systems for mounting in aircraft, little progress had been made in the identification, development or acquisition of a suitable system because there had been no stated operational requirement for personal cooling.

Aim

3. The aim of this report is to detail the activities and preparations that resulted in a personal cooling capability for the SeaKing aircrew involved in Operation Friction, provide results of physiological and operational evaluations, and make recommendations to improve the personal cooling system and hot weather capabilities of SeaKing aircrew for this and future operations.

SUMMARY OF ACTIVITIES

4. DCIEM was advised on Friday, 10 August 1990 that Operation Friction would deploy within one to two weeks. Round-the-clock operations began at DCIEM to accomplish the following activities by 14 August 1990:

   a. review available personal cooling systems and determine their feasibility of use in the intended environment in consultation with DMA, Maritime Air Group (MAG) and the operational squadron (HS 423);

b. select a suitable personal cooling system (PCS) and arrange procurement of sufficient quantities of all components for the 24 or more aircrew involved in the operation;

c. conduct a physiological evaluation of the cooling benefits of the system under operationally realistic climatic and exercise conditions, when worn with both normal flight clothing and the CD ensemble;

d. develop suitable modifications to integrate the cooling system with both normal flight clothing and the CD ensemble, permitting donning and doffing of the CD ensemble without cross-contamination of liquid chemical agent; and

e. manufacture cooling tube "pass-through" modification kits for incorporation into CD suits at CFB Shearwater.

5. The DCIEM Integration Team travelled to CFB Shearwater commencing on 14 August 1990 to accomplish the following activities prior to deployment of the Task Group on 24 August 1990:

a. brief Op Friction aircrew on heat stress/strain, dehydration, salt balance, prevention of thermal strain, benefits of active body cooling, and description of the personal cooling sytem selected;

b. train and assist Safety Systems personnel with modification of the CD clothing to incorporate the cooling tube "pass-through" facilities;

c. coordinate delivery, fitting and issue of the cooling system components;

d. develop a method to integrate the cooling system into the aircraft (provide aircraft power, develop suitable mounting system for cooling pumps);

e. liase with the Op Friction Integration Control Team (ICT) who implemented necessary aircraft electrical modifications, conducted Electromagnetic Interference (EMI) and flight tests, and approved chiller mounting system;

f. train and assist Safety Systems personnel with fabrication and installation of aircraft mounting pouches for the chiller pumps (and CD batteries);

g. evaluate the effect of using the cooling system on emergency water egress procedures by conducting a dunker trial;

h. draft pertinent details and procedures for inclusion in Aircraft Operating Instructions (AOI's); and

i. prepare a questionnaire on the design and effectiveness of the cooling system, for completion by Op Friction crews after their deployment.

6. The Canadian Task Group deployed on 24 August 1990. One member of the DCIEM Integration Team, Captain L. Bossi, travelled aboard HMCS Protecteur to assist with CD integration and accomplish the following before arrival at Gibraltar on 2 September 1990:

a. train aircrew and supporting groundcrew in the use and routine maintenance of the cooling system;

b. liase with Ship's Supply to arrange logistics of ice supply;

c. liase with Ship's Engineering to arrange installation of cooling pump power source at the Landing Safety Officer's (LSO) position and in the hangar (for intermittent cooling of stand-by crews); and

d. assist with operational and technical evaluation of the cooling system and development of solutions to problems encountered.

DISCUSSION

Personal Cooling System (PCS)

Selection of the PCS

7. Air cooling was ruled out for this operation because of the lack of an environmental conditioning system or appropriate source of chilled air in the SeaKing. The DCIEM-developed liquid cooling vest was not yet commercially available but sufficient quantities could be produced by DCIEM or AMDU in time for this operation. The necessary liquid cooling line connectors were commercially available, although their cost had sky-rocketed (over $500 per aircrew ensemble). The feasibility of using the Acurex liquid chiller, previously installed and evaluated in the SeaKing (1), was considered. The system provides chilled liquid to two of the DCIEM liquid cooling vests at a time. Because of the chiller's large size, excess weight, limited available cockpit space (because of other systems being installed for Op Friction), unknown availability of the chillers (DCIEM had only four), and poor performance during operational trials (2), it was decided to investigate other systems that were commercially available. Both cooling garmentry and chillers were considered.

8. Through continual monitoring of progress in the field of personal cooling, DCIEM was aware of a commercially available portable liquid cooling system that had been developed by Atomic Energy Canada Ltd. for bomb disposal or chemical cleanup operations. The system consisted of a portable battery-powered pump with ice/water container and heat transfer garments. Chilled water could be pumped through flexible tubing sewn into the garmentry. The manufacturer (Exotemp Ltd., Pembroke, Ontario) was contacted immediately to determine the system capabilities and potential for use in military flying operations. Although DCIEM had never tested the system, it appeared to be promising with some modifications, and so DCIEM decided to procure 30 sets, with spare components, for the Op Friction aircrew. One unmodified set was immediately forwarded to DCIEM for physiological and integration evaluation. The company dropped all other contract work and managed to deliver the required equipment to CFB Shearwater in under two weeks at a cost of approximately $50,000. Details of system procurement are available at Annex A.

PCS Description

9. *Cooling Garmentry.* The available cooling garmentry consisted of a long-sleeved shirt for cooling the torso and arms, long-legged pants for leg cooling and an open-faced hood for head cooling. Past DCIEM studies indicated that torso cooling alone is sufficient to maintain thermal balance at expected aircrew work levels, and so, it was decided to procure only the cooling shirt. It would also be difficult to integrate the hood with the flight helmet or CD ensemble. Finally, the shirt alone would also be the most comfortable configuration (due to liquid temperature, weight, and pressure of the tubing against the skin).

10. The cooling shirt (Figure 1) is made of flame retardent "Nomex" stretch fabric with plasticised PVC tubing (3/32" ID) stitched throughout the inside. It is worn next to the skin and simply replaces the turtleneck underwear normally worn under the flight suit or charcoal suit of the CD ensemble. The distinct advantage of this cooling shirt over the DCIEM-developed cooling vests is that it does not impose any additional thermal load when a source of chilled liquid is not available.

11. The shirts were available in three sizes. The Op Friction aircrew had not yet been identified and so their size requirements were not known. After trying a medium-sized shirt on a number of individuals, it was decided to procure all 30 shirts in that size (advertised to fit heights 5'7" to 6'0", weights 154 to 198 lb., but stretchy enough to accommodate larger individuals). The shirts may be hand or machine-washed (warm water, gentle cycle) but must be hung to drip dry.

12. The shirts were ordered with the delivery and return tubing located at the bottom left side of the shirt (groin height). This location was selected to avoid interference with torso clothing and equipment, arm movement, the CD filter-blower (worn on the right), and seat harnesses. It was decided to have very short delivery/return tubing on the shirt to ease integration with the CD ensemble. Two

male, self-sealing quick-release disconnects were attached to this tubing. Shirt tubing is designed in such a way that either of the tubes exiting the shirt can act as the delivery or return line. The wearer need not differentiate between them when connecting to the chilled liquid source.

13. *Chilled Liquid Source.* Chilled liquid is supplied through tubing from a portable pump unit (Figure 1) with a two litre plastic bottle containing ice cubes and water. It should be filled completely with ice cubes and then topped up with cold water. At an ambient temperature of 35°C, the system was advertised to provide at least 20 minutes of cooling. Extra bottles (all that were available, quantity 88) were ordered so that ice could be quickly replaced and cooling duration could be lengthened to that of an average mission. The pump has a six-position on/off and speed selector switch. To prevent burning out the pump, the unit may not be operated dry or with any restriction to chilled liquid flow. The commercial system operates on nine six-volt DC battery power, with rechargeable batteries lasting approximately one hour. The pump and bottle are carried in an insulated pouch with velcro and straps that allow it to be worn either on the leg or around the waist. It was decided to procure the waist carrier as it would not require modification of the CD ensemble (leg carrier requires velcro on suit leg) and would be more stable, given the size and weight of the pump system (weight less battery 6.725 lb., dimensions 6.5"W x 6"D x 11.5"H) .

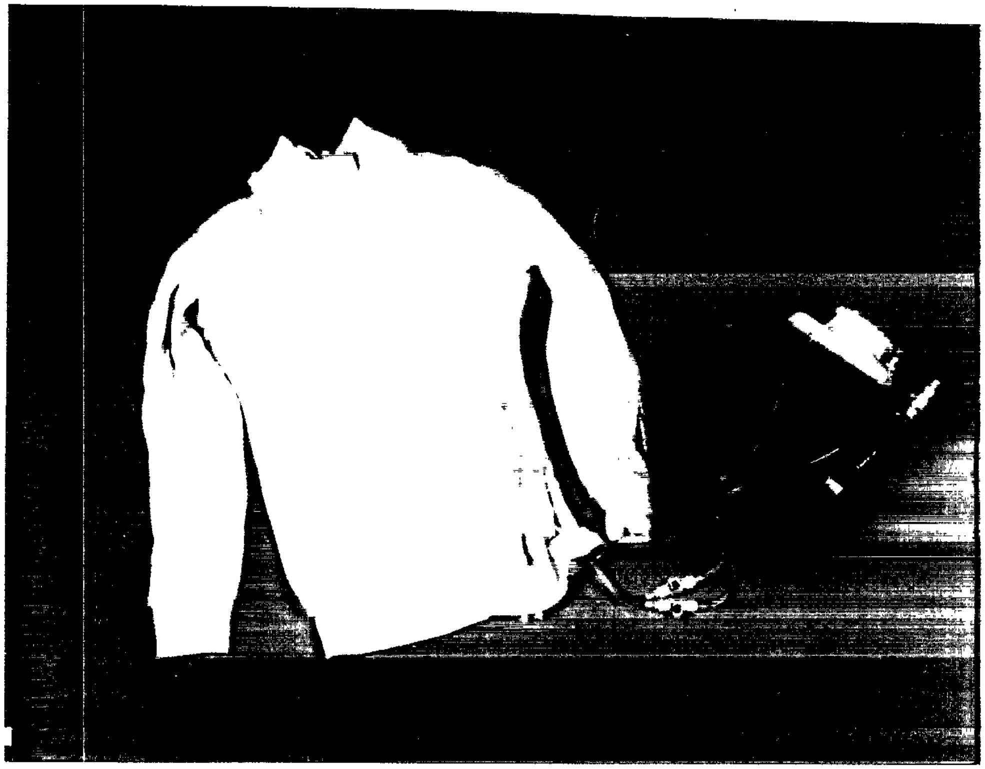


Figure 1. Cooling Shirt and Pump Unit Procured for Op Friction Aircrew

14. It was decided to order a 28 volt DC system that could use aircraft power because of the logistical problems associated with replacing batteries every hour and because it is a lighter system (battery weighs 0.5 kg). This decision was made after discussion with Maritime Air Group and confirmation that aircraft modifications to provide power for the system at every crew position would be included on the list of aircraft modifications coordinated by the ICT at Shearwater. This of course meant that the system would no longer be as portable. It could be used only at crew stations in flight, at designated sites on the ship where appropriate power was available, or at the end of an electrical or cooling line tether. However, it is quite heavy and large to be carried along with all the other gear the aircrew would be required to wear and carry in the cramped cockpit and it must also be upright for proper operation. Portability was therefore not felt to be as critical as the logistical problems associated with the batteries. The pumps were ordered without electrical connectors to permit flexibility during aircraft integration of the system.

15. Once filled with ice and topped up with cold water, the plastic bottle is placed inside the insulated pouch on top of the pump unit. The pump is connected to the bottom of the bottle. Chilled liquid is pumped through a filter, connectors and tubing to the cooling shirt. Water that has been warmed by the body returns through parallel connectors and tubing back to the top of the ice/water bottle.

16. *Cooling Connectors.* The connectors are lightweight thermoplastic (1/8" ID). The female connectors have a stainless steel spring and latch for quick-disconnect. The plastic ice bottles have a female connector at both the top and bottom. The pump has two male connectors, one to connect to the bottom of the bottle, the other to connect to the cooling lines to the cooling shirt. The shirt was made with two male connectors as described previously. Polyethylene tubing (1/8" ID, 1/4" OD) and additional connectors were ordered so that cooling lines between the pump and cooling shirt could be made once integration with the CD ensemble, normal flight gear and crew stations was evaluated.

17. The company had a limited supply of self-sealing (check-valve) type connectors. It was decided to use these only on the cooling shirts to avoid their draining when disconnected from the cooling system. The remaining available connectors would not have this feature and it was recognized that a small amount of water would leak from delivery/supply lines when they were not connected. Because of limited supplies, two types of the female connector were supplied. One of them had a recessed release latch (P/N PMC 17-02), the other was raised (P/N PMC 16-02). The implications of this difference will be discussed under "Operational Evaluation".

Physiologic Evaluation

18. A sample cooling shirt and pump unit were received at DCIEM on the morning of 13 August 1990. During the following two days, it was possible to conduct a quick physiological assessment of the cooling capabilities of the system when worn with both standard flight clothing and the CD ensemble. Test methodology and results are detailed at Annex B. The study demonstrated that the system was effective in reducing thermal strain to acceptable levels under ambient temperatures as high as 46°C. The major limitation of the system was that the ice cubes and water had to be replenished every 20 to 30 minutes to maintain continuous cooling.

PCS Integration

Integration with the CD Ensemble

19. Once the sample cooling system was received at DCIEM, it was necessary to develop a method of connecting the cooling shirt to the pump unit through the layers of the CD ensemble. The connector/tubing design and CD suit modifications had to permit the CD ensemble to be donned/doffed in layers avoiding cross contamination of liquid chemical agent, and permit use with standard flight clothing as well.

20. The delivery/return cooling tubes, with male connectors, were located at the bottom of the cooling shirt on the left side. It was necessary to modify the charcoal coverall by cutting four inches of the side seam open at groin height and

sewing velcro into the seam so that the coverall may be closed around the short (approximately two inches) cooling tubes from the shirt. The outer CD coveralls were also modified by cutting open the side seam at groin level, inserting an "elephant trunk" or sheath (approximately four inches long) of the liquid-repellent fabric, and stitching two cooling tubes inside the elephant trunk. On the inside of the trunk, female connectors were attached to the tubing for connection to those on the cooling shirt. (It was decided to use the female connectors with the raised release latch because it was easier to release with three layers of CD gloves.) At the outer end of the elephant trunk, male connectors were attached to the tubing. These connected with the tubing from the pump unit.

21. By using the same type of connector on both the outside of the CD coverall and cooling shirt the cooling system was compatible with both standard and CD clothing. In the standard flight clothing, the cooling lines connect directly to the cooling shirt through a hole cut in the side seam of the flight suit (i.e. section of tubing sewn into outer CD coverall eliminated).

22. Extension tubing is required between the pump unit and suit (configured with female connectors on both tubes at the suit-side, and both a male and female connector to connect to the bottle/pump at the other). The length of extension tubing was determined during cockpit integration of the system at CFB Shearwater, as described later.

23. The connectors are friction fit inside the polyethylene tubing. While tight enough to prevent inadvertent disconnect, the connectors and tubing could be pulled apart by the force of an individual standing up from his seat, thus permitting "automatic-release" in the event of emergency aircraft egress (provided the pump or tubing is secured in the aircraft). To prevent damage to the cooling shirt or inadvertent loss of the connectors during laundering, it was recommended that the male connectors on the shirt tubing be glued in place.

24. Annex C provides instructions for modifying the charcoal and outer CD coveralls. CD suit modification kits (comprising velcro closure sets, outer CD suit elephant trunks and CD suit adapter tubing with connectors) were manufactured at DCIEM and taken to CFB Shearwater. All charcoal suits and outer CD coveralls were modified by the Base Safety Systems section and DCIEM technicians at CFB Shearwater. Extension cooling lines with appropriate connectors were produced for each crew position in each of the designated aircraft once the cooling system was integrated into the cockpit. Insufficient quantities of connectors were available to incorporate into the elephant trunk on both pairs of issued outer CD coveralls. The modification to the second outer coverall will either have to be completed when the first coverall is discarded, or more connectors will be needed.

Aircraft Integration

25. DCIEM contacted MAG on 10 August 1990 confirming that aircraft

modifications would be incorporated to provide 28V DC power for cooling pumps at each crew position. Upon arrival at CFB Shearwater, the team found that these modifications were not on the Integration Control Team (ICT) list, but Major M. Creighton, XO of HS 423 and the operational member of the ICT, convinced the ICT to place the modifications at the top of the priority list. His argument was that all the other aircraft modifications were of little use if the aircrew were suffering from heat exhaustion and could not effectively use them.

26. *Electrical Modifications.* A representative of IMP, on site at CFB Shearwater for Op Friction preparations, was aware of previous aircraft electrical modifications to provide power for the CD filter-blower at all crew stations. A prototype installation of these CD modifications had been completed on one aircraft for the evaluation of the CD ensemble by HOTEF (3). It had meanwhile been decided by the Chemical Defence Project Management Office, DAS Eng 4-4, to use battery rather than aircraft power for filter-blowers in the SeaKing because of the low perceived chemical threat for these aircraft and as a cost-saving measure. This decision turned out to be fortuitous as it allowed the use of the existing wiring design for the rapid integration of the cooling pumps for Op Friction. The drawings were obtained from IMP and wiring was provided to each crew position in a prototype installation. Sufficient lengths of the electrical wire were provided to the TACCO and AESOp positions to enable them to wear the cooling pump and have complete access to the aft cabin. Five circuit breakers, located extreme aft on the overhead central panel, were used for the installation.

27. The cooling pumps were ordered without electrical connectors and it was decided to use standard intercom connectors, male connectors on the pump units and female connectors on the aircraft power lines. Their location, wire size and colour was determined to be adequate for differentiation from the intercom connectors.

28. *EMI Testing.* The Aerospace Engineering Test Establishment (AETE) representatives on the ICT conducted an evaluation of Electromagnetic Interference (EMI) caused by cooling pump operation. Results of EMI testing on the bench and in a powered aircraft (no engines turning) were extremely poor. The pumps created a high-pitched noise on the aircraft intercom (which varied with pump speed). When tested with the aircraft running (all five pumps operating), the background intercom noise was present but was not noticed by the test aircrew until it was brought to their attention and they made an effort to listen for it.

29. An in-line filter, probably larger than the pump itself, would be required to eliminate the radiated emissions. It was also too late to have battery-powered pumps produced and delivered. Since the cooling system was considered to be very beneficial, cooling system electrical modifications of all Op Friction aircraft were made without any attempt to filter the noise.

30. *Cooling Pump Mounting System.* The cooling pumps were mounted at each crew position in the aircraft, so as to:

a. permit ready access for in-flight removal and replacement of ice/water bottles;

b. permit removal of the entire pump unit for maintenance, repair, and in-flight portability by back-end crew;

c. permit access to the pump's on/off and variable speed selection knob by aircrew when strapped into their seat;

d. be simple in design and easy to manufacture in the limited time available;

e. not involve any permanent alterations to aircraft structure (this constraint was imposed by the ICT and higher authority);

f. be crashworthy either by positioning or design;

g. secure the pump well enough so that cooling lines will disconnect upon emergency aircraft egress; and

h. minimize its space requirements

31. The DCIEM team developed a "low-tech" solution, using fabric pouches for the pump assemblies that could be hung or mounted on the seats or bulkheads either by velcro or use of existing screws. The team produced a prototype installation, described as follows:

a. Pilot Position (right seat): Space and time limitations required the cooling pump to be located on the floor just aft of the raised cockpit floor where the pilots sit and forward of the TACCO seat (Figure 2). This requires the TACCO's assistance to make tubing connections, turn the pump on/off and select pump speed. The pump's pouch was secured to the port side of the broom closet. The cooling extension lines were approximately three feet long;

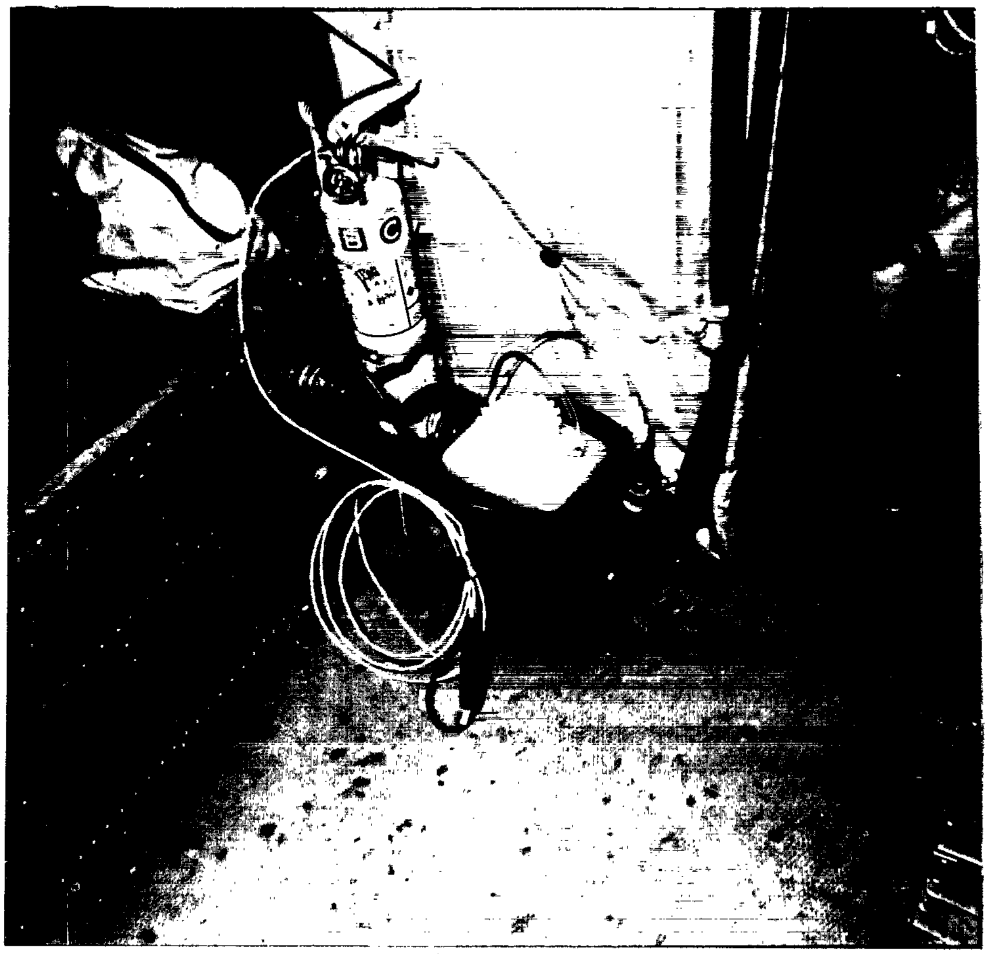


Figure 2. Aircraft Mounting of Pilot's Cooling Pump Assembly

b. <u>Co-Pilot (left seat)</u>: The pump's pouch was hung from the left back of the seat and held in place by velcro attached to the front surface of the seat (Figure 3). The pump control knob faced the left side and was within reach by the co-pilot when he was strapped into the seat. Cooling extension lines were approximately two feet long;

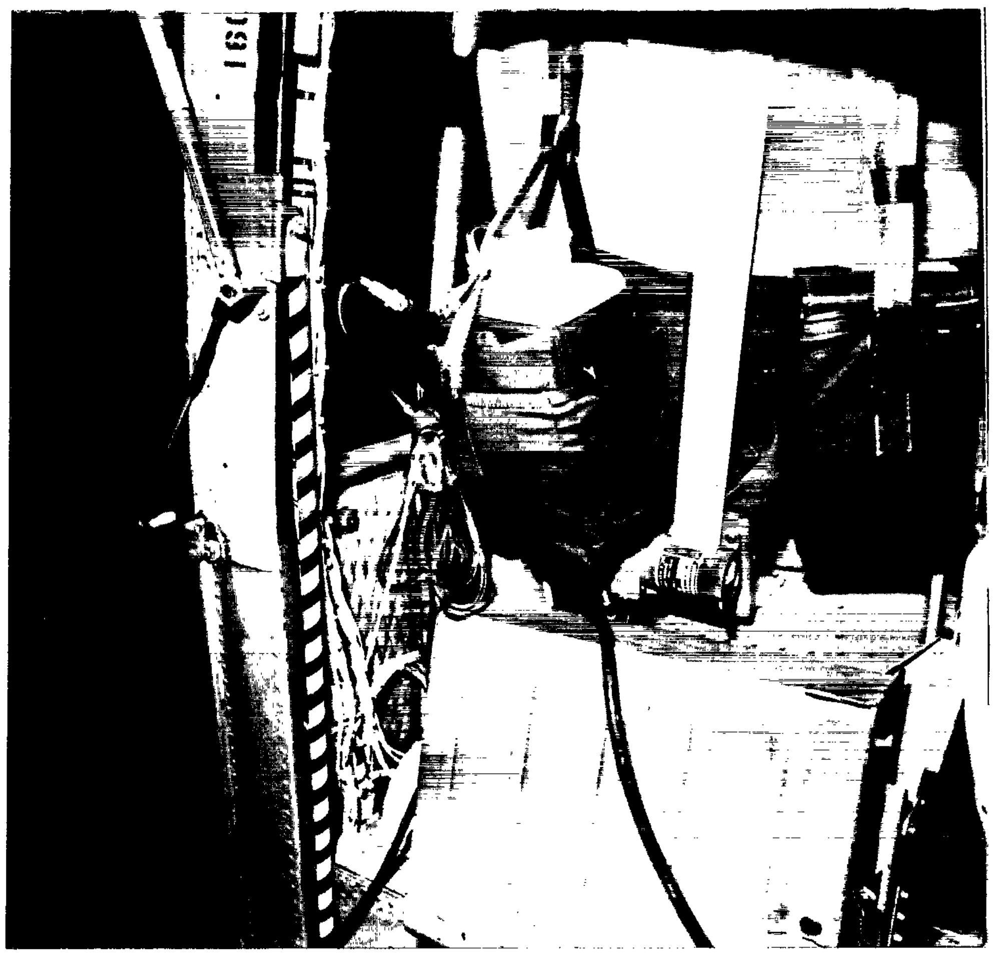


Figure 3. Aircraft Mounting of Co-Pilot's Cooling Pump Assembly

c. <u>TACCO</u>: The pump's pouch was secured with screws to the forward side of the TACCO console, with the on/off and speed selection knob facing the TACCO (Figure 4). An additional console drill hole was required to secure the pouch properly. Cooling extension lines were approximately four feet long;

Figure 4. Aircraft Mounting of TACCO's Cooling Pump Assembly

d. AESOp: The pump assembly was mounted in a fabric pouch that was hung on the port side of the haul-down housing, on the TACCO's right side (when he faces his console), with the control knob facing forward (Figure 5). Cooling extension lines were made approximately four feet long;

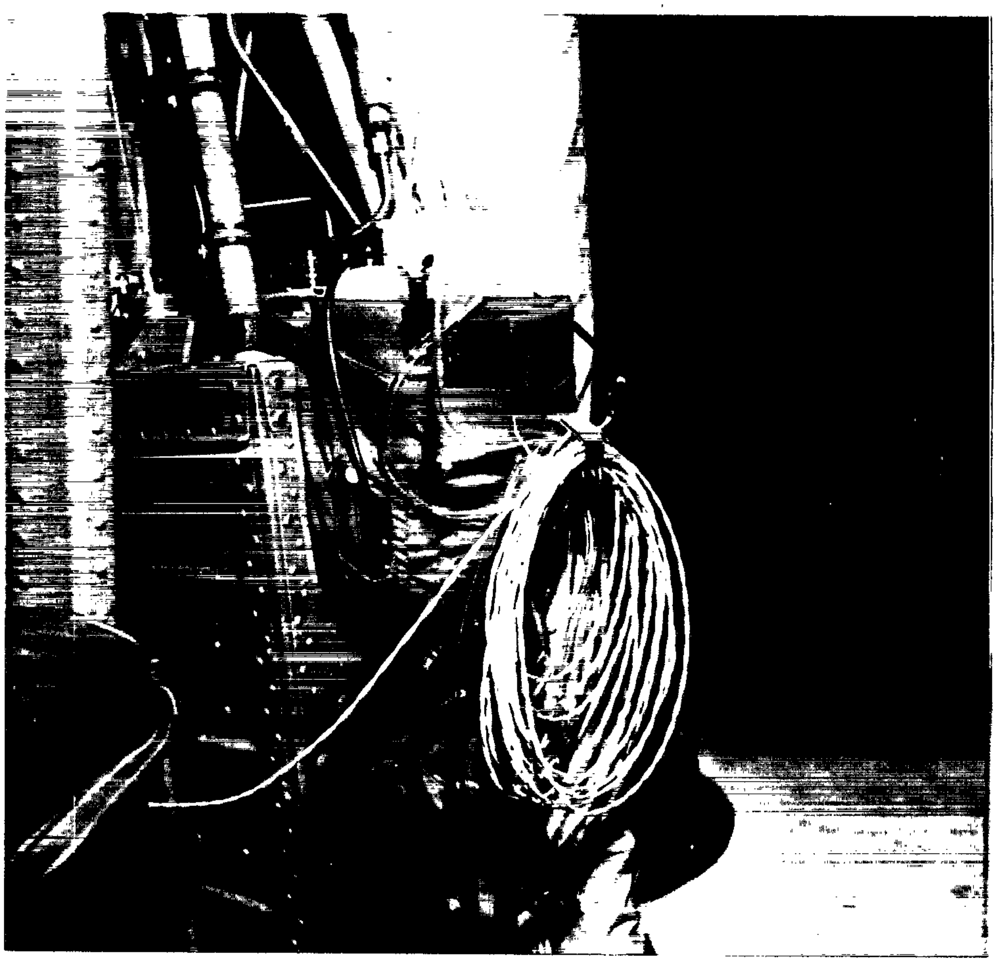


Figure 5. Aircraft Mounting of AESOp's Cooling Pump Assembly

e. Aft Cabin: The pump's pouch was mounted on the floor, just aft of the cargo door, secured to the starboard bulkhead. Cooling extension lines were made approximately four feet long.

32. *In-Flight Usage.* When the TACCO or AESOp need to work in the aft cabin, they can disconnect from their own cooling pump for short durations or remove the pump from its aircraft-mounted pouch and strap it around their waist. The electrical supply cables at their crew stations were long enough to permit the unit to be carried throughout the cabin. Alternatively, the TACCO or AESOp could connect to the aft cabin pump for extended back door operations in those situations when wearing their own pump unit with an electrical tether is impractical.

33. The ICT approved the prototype installation and the Safety Systems section and DCIEM team manufactured and installed the mounting fixtures into all Op Friction aircraft.

Ship Integration

34. The cooling pump operates only in the aircraft (relying on aircraft 28 volt DC electrical power). It was recognized that cooling would also be required aboard ship, especially under chemical conditions. SeaKing crews have duties, aside from flying, that must be performed outside the ship's citadel (toxic free area). These duties include acting as Landing Safety Officer (LSO), aircraft preparation and preflight inspection. Based on results of the CF188 trial (4) it was recommended that SeaKing aircrew remain in their CD ensemble between missions, resting in the hangar, rather than go through the fatiguing and lengthy CD ensemble undressing and redressing procedures, to obtain relief in the cooler ship's citadel. Therefore, aircrew might have to remain encapsulated in their CD ensemble for extended periods aboard ship.

35. During the trans-Atlantic voyage, ship's engineering personnel were asked to install a 28V DC power source for the cooling pumps at both the LSO position and in the hangar of each ship. The pump in the hangar could be shared by crews on standby, providing intermittent cooling. Constrained by the limited number of available cooling pumps, intermittent cooling in the hangar was considered to be better than none at all. Because of higher priority engineering projects, these electrical modifications were not installed prior to arrival of the Task Group at Gibraltar. To DCIEM's knowledge, these electrical modifications had not been implemented at the time of writing this report.

Logistics of Ice Supply

36. When the cooling system bottles were filled with ice chips and topped up with water, the ice lasted only 20 to 30 minutes at 45°C (refer to DCIEM physiological study described at Annex B). The feasibility of using solid ice to extend this duration was evaluated at Shearwater. Filling the bottles two thirds full with water, and freezing them on their sides (to avoid blockage/damage to bottles valves) increased their cooling capacity dramatically. Providing sufficient freezer space was available, this offered an alternative to using ice cubes aboard ship. All bottles were marked to indicate the maximum water level for freezing (before use, bottles must

be topped up with water).

37. Because ice had to be replenished throughout flights, picnic coolers were used to store extra ice bottles aboard the aircraft. Two coolers (capacity ten bottles each) were placed in each aircraft providing cooling for a mission length of three hours (six bottles per crew member, four in use and 20 stored in coolers at a time). There was insufficient time during pre-deployment to manufacture brackets for rigid mounting of the coolers in the aircraft. The coolers were located in the aft cabin of the aircraft, secured to the bulkhead with webbing straps or bungee cord, positioned to maximize crash-worthiness and to permit ready access to the ice bottles.

38. Because freezer space was not yet available to freeze water in the bottles, the bottles were filled with ice cubes for most missions flown during the trans-Atlantic voyage. Standard residential-type chest freezers were available on the ship but were being used to store the extra food required for the Task Group. As they were emptied of food, the Ship's Supply personnel planned to make a freezer made available to each Air Detachment to produce the necessary block ice for the cooling system. This was accomplished by the time the Task Group arrived in the Persian Gulf. Communications with Air Detachment personnel indicate that the freezers were located inside the citadel (just outside the aircrew ready room) on HMCS Athabaskan, and outside the citadel (in the dispersal area) on HMCS Protecteur. These freezers are also being used to freeze the gel packs for the Steele Ice Vests (passive cooling system) procured by Maritime Command for the ship's company. Because of the freezer capacity and warm temperatures in the Gulf, the bottles take approximately two days to freeze solid. Either additional bottles will be needed (so that ice will be available for all missions) or higher capacity freezers procured. (Standard household chest freezers have only approximately 0.1 horsepower, whereas 0.8 to 1.5 hp is needed to freeze this amount of water overnight.)

<u>Integration with Operational Procedures</u>

39. The integration of a personal cooling system required some changes to operational procedures. A brief description of the cooling system, procedures for its operation, connection/disconnection, bottle freezing and bottle replenishment were drafted and passed to HOTEF for inclusion in the new Aircraft Operating Instructions (AOI's). Procedures for connecting and disconnecting the cooling system were incorporated into aircrew CD dressing/undressing procedures, described in a separate report (5). Procedures for preparing the pump units, ice bottles and loading coolers onto the aircraft were also included in pre-flight and aircraft launch/recovery procedures (5). The following basic changes to procedures and distribution of responsibilities were recommended to speed aircraft launch/recovery and turnaround, and to minimize aircrew fatigue and thermal stress:

a. designated ground crew fill ice bottles (2/3 full) with water and load bottles properly into freezer (at least one night before flight);

b. designated ground crew top up frozen ice bottles with water and load bottles into cooler(s) just before flight launch;

c. designated ground crew load chiller pump units (if not already done) into the mounting pouches in the aircraft, connecting to aircraft electrical supply (ensuring that pumps are turned "OFF"), during the **B Check;**

d. AESOp and/or designated ground crew load full cooler(s) onto aircraft, AESOp properly securing load;

e. AESOp loads fresh bottles into pump units at each crew position before flight, and replenishes bottles during flight;

f. TACCO assists both pilots with strap-in and connection to pump units;

g. at the end of the flight, all aircrew ensure their pump units are turned "OFF" before disconnecting their cooling shirts;

h. after flight, AESOp gathers all bottles into coolers, unloads coolers;

i. designated ground crew ensure all pump units are "OFF", remove any remaining bottles/coolers from aircraft during the **A Check**; and

j. designated ground crew responsible for preparing bottles for re-freezing (first emptying some of the water).

NBC Hardening

40. The exposed parts of the cooling system (pump, bottles, tubing) are not "hardened" against chemical agents. Contamination of the outer surfaces with liquid agent could result in contamination of the fluid being pumped through the cooling shirt. There is a possibility that this contamination could be transferred to the skin of the wearer. However, since the cooling pumps and extension tubing are located inside the cockpit (or on ship, in the LSO shack or hangar), the cooling system components will not come into contact with liquid agents directly. Providing care is taken to handle the components with clean or decontaminated hands, the risk of potential secondary contamination can be minimized. All aircrew and supporting ground crew must be aware of this limitation and handle the equipment accordingly. Some components may easily be hardened. For example, the tygon tubing in the cooling adapter and extension tubes can either be sheathed in liquid repellent fabric or replaced with butyl rubber tubing. The pump unit's insulating pouch could be hardened by using a liquid-repellent fabric and providing more coverage of the ice bottle.

41. The effect of exposure of the cooling system components to chemical agents in vapour form is not known. The amount of vapour that could be absorbed into the tubing is considered to be minimal. Given that this will be diluted by the circulating fluid, which is replenished regularly, that very little vapour, if any, would desorb from the tubing, and that the charcoal liner of the CD ensemble would absorb whatever was desorbed, vapour contamination is not considered to be a problem. Nonetheless, this aspect of hardening should be evaluated by DREO or DRES.

User Training

42. A briefing on thermal stress was presented to aircrew assigned to Op Friction on 15 August 1990. The physical and physiological bases of thermoregulation were reviewed to provide a background understanding of thermal stress and how it leads to thermal strain in the body. Interactions of environmental parameters, clothing, and metabolic rate were demonstrated via the results of DCIEM's study of thermal stress in CF188 aircraft operations in Germany (4). The effects of elevated deep body temperature on physiology and psychomotor performance were discussed, along with an overview of the signs, symptoms, and treatment of heat illnesses such as heat cramps, heat exhaustion, and heat stroke. Water intake, salt balance, and dehydration were reviewed and discussed.

43. Prevention of thermal strain was the key focus of the briefing and this was addressed on two main fronts. The mechanism of heat acclimation and its role in ameliorating heat strain were presented. Personnel were encouraged to exercise daily in the heat for at least one hour per day for seven to ten consecutive days to achieve some degree of acclimation. The second thrust regarding prevention was the use of active body cooling. The test results of DCIEM's evaluation of the liquid cooling system procured for Op Friction were presented to show that the system is capable of reducing thermal strain to acceptable levels under otherwise intolerable environmental conditions.

44. Judging by the attentiveness of the audience and the questions asked, the briefing was well received. Personnel were left better informed of what to expect of their physiological responses to the heat, and they were comforted with the knowledge that the cooling equipment provided for this operation would prevent serious thermal strain and permit them to carry out their assigned tasks successfully.

45. Enroute to Gibraltar, the aircrew and supporting ground crew were also given instruction on proper use and maintenance of the cooling system. The cooling system was used by all aircrew on almost all training flights during the cross-Atlantic voyage. While ambient temperatures were moderate (between 20 and 32°C), most of these missions were flown in the CD ensemble, and the use of the cooling system allowed the identification of any technical or compatibility problems and development of appropriate solutions. Aircrew completed two questionnaires,

one to assess the operational effectiveness of the CD ensemble (portions relating to thermal comfort are included in Annex D) and a questionnaire on the effectiveness of the cooling system (at Annex E). Results are discussed under "Operational Evaluation".

Operational Evaluation

Dunker Trial

46. The effects of the CD ensemble and cooling system on underwater egress was evaluated during a trial on 21 August 1990 in the Rotary Wing Underwater Egress Trainer (RWUET, dunker) at Survival Systems Ltd., Dartmouth NS. The test subject, an experienced HS 423 pilot, wore the complete CD ensemble and cooling shirt for all test runs. It was decided not to connect to and mount a cooling pump during the test runs because of the potential for pump damage and due to the lack of a representative mounting system. However, during one of the test runs, the cooling shirt leads (from the outer CD coverall) were connected to extension tubing. This extension tubing was tied to the seat to simulate connection to a cooling pump (secured in its mounting pouch). The test subject had no difficulty egressing the aircraft. The cooling shirt disconnected from the extension tubing (tubing pulled off of connectors) simply by moving away from the seat.

User Trial Conduct

47. *Flight Experience.* During the trans-Atlantic voyage to Gibraltar, the 23 Op Friction aircrew used the cooling system during many of their training flights in the CD ensemble. Most flights were two hours in duration. At the end of the ten day voyage, aircrew were asked to complete questionnaires relating to their new cooling and CD equipment (at Annexes D and E). Thirteen aircrew (seven pilots, five TACCO's, one AESOp) completed and returned the questionnaires (three from HMCS Protecteur, ten from HMCS Athabaskan). The following results are based upon questionnaire responses, discussions with aircrew, personal observations and subsequent correspondence.

48. Aircrew wore the cooling shirt during an average of four missions (range 1-8). The cooling shirt was worn in conjunction with both the CD and standard flight ensembles It should be noted that most flights during the voyage were, in fact, CD training flights. The cooling shirt was not worn during all missions by all aircrew. Aircrew on the HMCS Protecteur tended to wear the cooling shirt more often than those on the HMCS Athabaskan, perhaps influenced by the presence of the DCIEM Project Officer. Approximately half of the aircrew chose not to wear the cooling shirt during some missions indicating that conditions were not severe enough. Ambient temperatures averaged 25°C and did not exceed 32°C.

49. The cooling system was not operated during four percent of missions in

which the cooling shirt was worn. In every case, the cooling shirt was not used because it was not functioning properly. The cooling system was not used throughout the entire mission on those missions in which it was used. This was attributed to equipment malfunction in most cases. Other reasons included cool ambient conditions, discomfort from the low temperature of the chilled liquid, and the bulkiness of the cooling pump for wear during cargo door operations.

<u>User Trial Results -Technical Aspects of the PCS</u>

50. *Aircraft Power Supply.* All Op Friction aircraft were modified to provide 28V DC power to cooling pumps at each crew position (as described previously under "Aircraft Integration"). The length of electrical wire was found to be adequate in all crew positions except that of the pilot (right seat). The wire was delivered just behind the seat on the pilots right side. The cable was too short in most aircraft to travel behind the pilot's seat to the cooling pump located on the floor. This problem was rectified by simply removing a portion of the wire from the wire bundles behind the pilot, and re-routing the wire to come out on the port side of the broom closet, close to the pilot's pump unit. This simple modification was implemented by Air Detachment technicians enroute to Gibraltar.

51. *Feasibility of a Totally Body-Mounted Cooling System.* Only three aircrew reported wearing the pump unit on the body (waist-mounted) in-flight. The TACCO's and the AESOp's did not consider a totally body-mounted system to be feasible because of the weight and bulk of the system and cramped cockpit space. It was therefore recommended that an additional cooling pump be provided in the aft cabin so that both the TACCO and AESOp can have cooling during cargo door operations. Since Op Friction deployment, the manufacturer of the cooling system has developed some improvements to the system. For example, the ice reservoir has been made flatter (taller, same capacity) so that is does not protrude as far from the body. This change might make body-mounting of the system more acceptable to back-end aircrew. If cooling pumps are procured in the future, aircraft integration will have to be re-examined and new mounting pouches may have to be made and installed in all the aircraft.

52. *Feasibility of an Aircraft-Mounted System.* Pilots indicated that a totally aircraft-mounted system with electrical or cooling lines would not present a problem. However, all remaining aircrew indicated that such a tether could be a problem for operations and that cooling or electrical lines must be kept as short as possible. Long power cables were provided to the cooling pumps at the TACCO and AESOp positions, but most of these crew members preferred to disconnect from their cooling pump for aft cabin activities, rather than deal with tangling and snagging of the electrical cables. One of these crew members could use the pump already located in the aft cabin, but two pumps should be provided. The long wires should be left in the Op Friction aircraft so that crews in future rotations have the choice of wearing the cooling pumps for aft cabin activities. If acceptable to aircrew, battery-powered cooling pumps could be procured in the future. This would

eliminate the need for long electrical cables, aircrew might find wearing the cooling pump more acceptable for aft cabin activities, and the number of cooling pumps needed per aircraft would be reduced from six to four.

53. *Cooling Pump Serviceability.* Three of the pump units burned out and were no longer functional after the ten days of flight training with the cooling system. It is essential that the pump be turned "OFF" when bottles are changed, if flow is blocked for any reason (i.e. disconnect of cooling tube connectors, hose kinking), when the cooling suit is not connected or if there is no fluid in the cooling bottle. This important caution must be stressed to all aircrew and supporting technicians. The unserviceable pump units should be returned to the manufacturer to determine if it is possible to repair them. If not, the units should be replaced.

54. *Cooling Fluid Blockage.* The biggest problem encountered with the cooling system was cessation of fluid flow through the cooling shirt. On many occasions, the connection between the cooling shirt and inside of the CD coverall came apart. It was not possible to reconnect the tubing during the mission because of all the layers of clothing and equipment worn. This caused much frustration, during CD training missions in particular. As discussed previously, the female connectors used on the inside of the CD coverall had a protruding release latch (P/N PMC(D) 16-02). These were selected to make disconnect easier with the CD gloves. Unfortunately, the exposed release latch led to inadvertent disconnect. It was therefore recommended that the female connectors with the recessed release latch (P/N PMC(D) 17-02) be used on the inside of the suit. These connectors were available on the pump and external cooling tubes. Either type of connector can be used external to the suit where they can be easily accessed and re-connected if necessary.

55. However, changing the female connectors solved only some of the problems of cooling fluid cessation. A number of aircrew experienced cooling tube crimping or pinching that blocked fluid flow. This appeared to be caused by excess length of tubing on the vest (length varied from vest to vest). The excess length formed a loop under the coverall that tended to bend or become pinched by equipment worn over the suit. In many cases, the tube pinching could be prevented by stiffening the shirt's cooling tubes. HMCS Athabaskan crews simply wrapped "gun tape" around the tubing to stiffen it. It was also recommended to all aircrew that they shorten the tubes on the cooling shirt so that they do not form a loop before joining the tubing in the outer coverall. The length of the tubing must be optimized on an individual basis (with aircrew wearing the cooling shirt, charcoal suit and outer suit to the waist). Both of these solutions reduced, but did not entirely eliminate, the incidence of cooling fluid blockage. Aircrew suggested that the flak vest, web belt or seat harnesses might be pinching off the tubing. Adjustment of the connectors and tubing, through manipulation from the outside of the suit, enabled some aircrew to resume cooling fluid flow. However, this distracts aircrew from their mission at hand and is not considered to be an acceptable solution.

56. It has since been suggested that the cooling tubes pass through the CD suits higher up on the body, approximately two to three inches under the armpit, to alleviate pinching of tubes by web belts, seat harnesses and flak vests (6). Since this would require procurement of new cooling shirts (with either longer tubes to reach under the arm or re-location of tubing entrance/exit from shirt), re-modification of all CD suits, and because of potential interference with arm movement and the pistol holster, DCIEM recommended first pursuing other tube stiffening options (7). DCIEM has procured metal springs/coils that fit around the tubing on both the vest and outer CD suit adapter tubing. The springs should prevent bending or collapse of the tubing and should be forwarded to the Gulf for evaluation by Op Friction aircrew. If this still does not solve the problem, the option of moving the tubing pass-through location should be pursued.

57. Until the problem of cooling tube blockage is resolved, modifications to the CD ensemble must continue to be implemented locally. Once the integration with the CD ensemble is optimized, and the PCS introduced into more aircraft types, consideration should be given to incorporating suit modifications at the manufacturer. The numbers of cooling shirts and SeaKing aircrew using them does not warrant implementation of these modifications yet, although it should be noted that the modifications will not degrade the CD ensemble when cooling is not available.

58. *Personal Issue of Cooling Shirts.* Op Friction aircrew were issued only one cooling shirt each. These can be machine-washed, but they must be hung to dry. The shirts become quite sweat-laden after only a few hours. Therefore, the shirts will not always be completely dry by the next mission or next day's missions. Not only is the dampness unpleasant to the wearer, but the shirt's sweat-absorbing capacity will be reduced. Sweat absorption is an important function of the shirt as it minimizes sweat-poisoning of the charcoal in the CD ensemble. For these reasons, aircrew should be issued more than one cooling shirt, just as they are issued more than one set of aircrew underwear.

59. *Cooling Shirt Degradation.* After only a few months of wear, and multiple washings, aircrew reported that the stitching on the cooling shirts was coming apart (6,8). This occurred both at the seams and around the tubing. Further investigation revealed that the stitching was most damaged around tubing in the neck region. This suggests that the tubing may be located too close to the shirt's neck opening. While the cooling shirts can be repaired, stitching should be reinforced and fabrication made more robust for future procurements. Given the rate of wear of the cooling shirts and reported damage that is occurring, Op Friction aircrew indicated that shirts may have to be replaced after six months of wear (8). Aircrew also recommended producing the cooling shirts in a darker fabric, to minimize the unsightly stains caused by the charcoal from the CD ensemble. The manufacturer has been advised of these shortcomings and recommendations. A repair kit is now available and should be provided to users. Hand washing of cooling shirts is also

recommended to minimize damage to the suit.

60. *Ice Duration.* Aircrew reported that the ice in the cooling pump reservoir lasted, on the average, over 40 minutes (range 30 minutes to two hours). The variability of response can be attributed to a number of factors. Cockpit temperatures ranged between 25 and 40°C (reported rather than measured temperatures). Ice duration also depends on how long the cooling system is operated during the mission since the body warms the water being pumped through the cooling shirt. Finally, the higher reported ice durations (one-two hours) might reflect how long the pumped water was perceived to be cooler than the body, rather than actual duration of the ice itself. Physiological measurements were not taken during the flight trial, so it is not known if the cooling system actually prevented rises in core temperature for the longer reported periods.

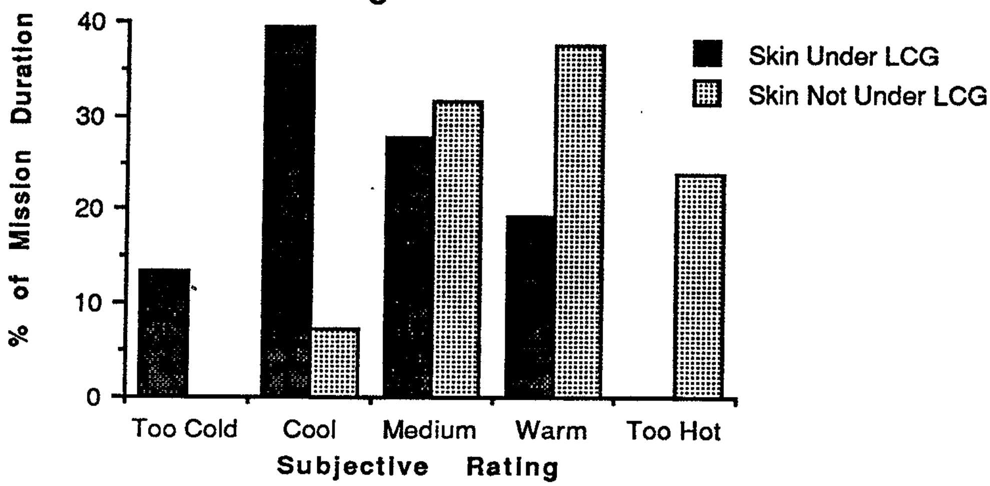
61. Since Op Friction deployment, the manufacturer of the cooling system has developed some improvements to the system. The fluid return and delivery valves are re-located to the top of the bottle so that the bottle can be filled to near capacity (rather than only 2/3 full) and then frozen. In addition, the insulating pouch/carrier has been designed to cover more of the ice bottle. These changes should extend the cooling duration of each bottle and reduce the number of bottle changes.

User Trial Results - Thermal Aspects

62. *Pump Speed Selection.* Selection of cooling pump speed varied and depended on thermal comfort of the crew member and temperature of the circulating water; the lower the water temperature, the lower the pump speed selected. On average, the pump was set at a low speed for the majority of time.

63. *Skin Temperature Sensations.* Almost all aircrew reported that the cooling fluid was too cold on the skin immediately after bottle replenishment. This perception passed quickly, as the body adjusted to the change (skin temperature drops). Aircrew were asked to estimate the percentage of time in a mission that they experienced sensations of cold and heat on the skin both under the cooling shirt and not under the cooling shirt. Results are provided at Figure 6.

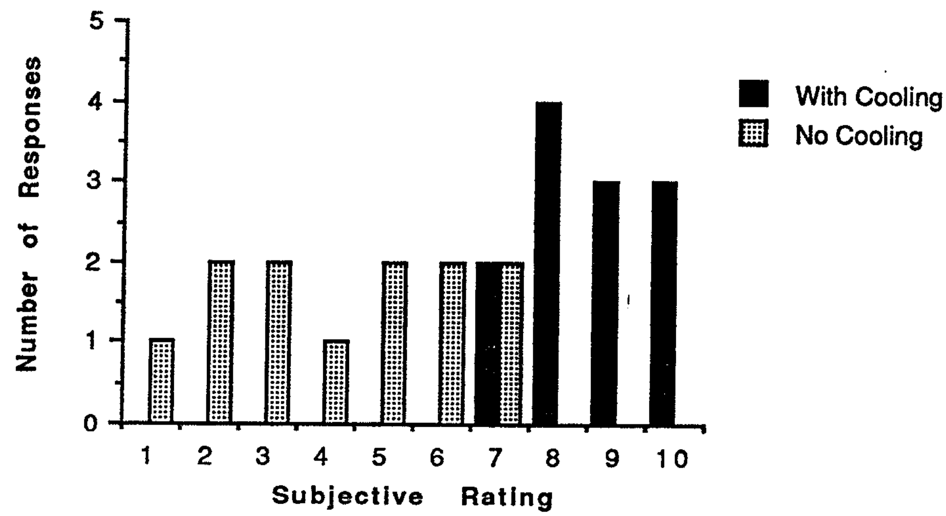
Figure 6. Average Skin Temperature Ratings Throughout Mission



64. Most of the time, the skin under the cooling shirt was perceived to be cool or at a medium temperature, indicating that the cooling shirt was providing some degree of thermal comfort. For short periods, the skin under the cooling shirt was perceived to be too cold, reflecting initial reaction to a new ice bottle. Warm ratings were also given for short periods, possibly reflecting fluid temperature after the ice had melted. The skin not under the cooling shirt was perceived to be warm or too hot most of the time. This was expected given the finding that the periphery of the body gains heat from these hot environments (Annex B).

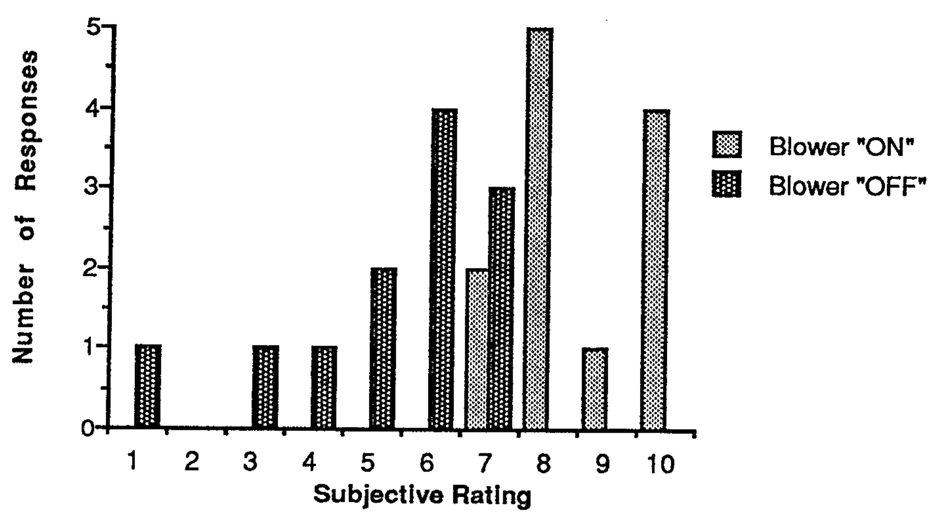
65. *Heat Build-up and Sweating.* Aircrew were asked to rate the acceptability of heat build-up and sweating under the CD ensemble in a number of areas of the body. The ten point rating scale is defined at Annex D. Results for the torso are provided at Figure 7. Clearly, the cooling shirt has a marked positive effect on torso heat build-up and sweating. With cooling, all aircrew were satisfied with thermal comfort in the torso area. Without cooling, almost half of the aircrew found the degree of torso heat build-up and sweating to be unacceptable. One can expect this difference to be even more obvious at the higher ambient temperatures expected in the Persian Gulf.

Figure 7. Torso Heat Build-up and Sweating



66. The only other areas of the body that received unacceptable ratings for heat build-up and sweating were the face and the hands. This is not surprising, given that both the respirator and gloves are composed of impermeable rubber. The cooling shirt has little or no effect on thermal comfort in these areas. Fortunately, the aircrew respirator may be provided with filter-blown air. Intended to provide positive pressure and enhanced eye and respiratory protection from chemical agents, the ventilation also improves thermal comfort by evaporating the sweat on the face. The subjective benefits of this ventilation were quite evident from aircrew ratings of facial comfort with and without the filter-blower (Figure 8). The problem of sweat accumulation in the rubber CD gloves was the subject of frequent complaints. Development and introduction of either a supra-absorbent glove liner or ventile CD glove is considered essential.

Figure 8. Facial Heat Build-up and Sweating



67. *Overall Thermal Comfort.* Aircrew were asked to rate their overall thermal comfort at various work levels, both with and without cooling. Results are provided at Figures 9 and 10 for light and heavy workloads. Activities of SeaKing pilots are considered to represent light workloads. Heavy workloads are typified by aircraft loading or TACCO/AESOp duties during cargo door operations (i.e.. hoisting, slinging, in-flight refueling, rescue).

Figure 9. Perceived Thermal Comfort (Light Workload)

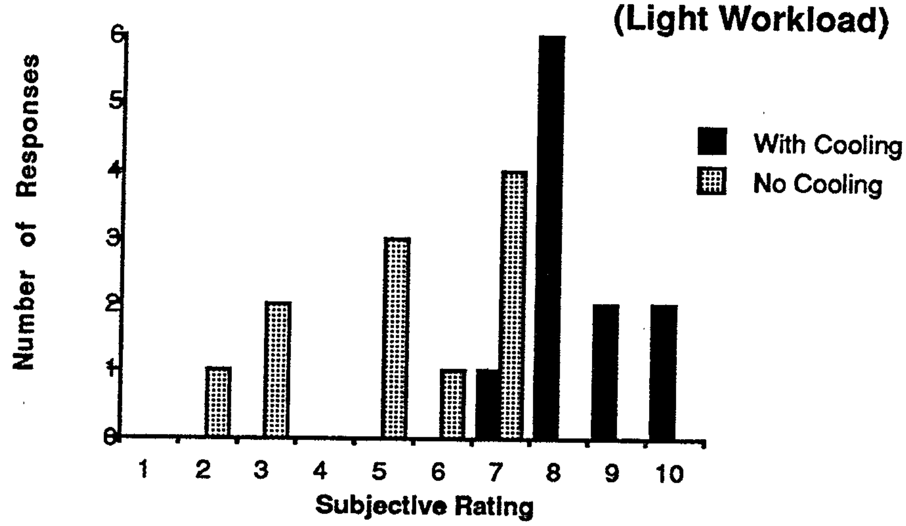
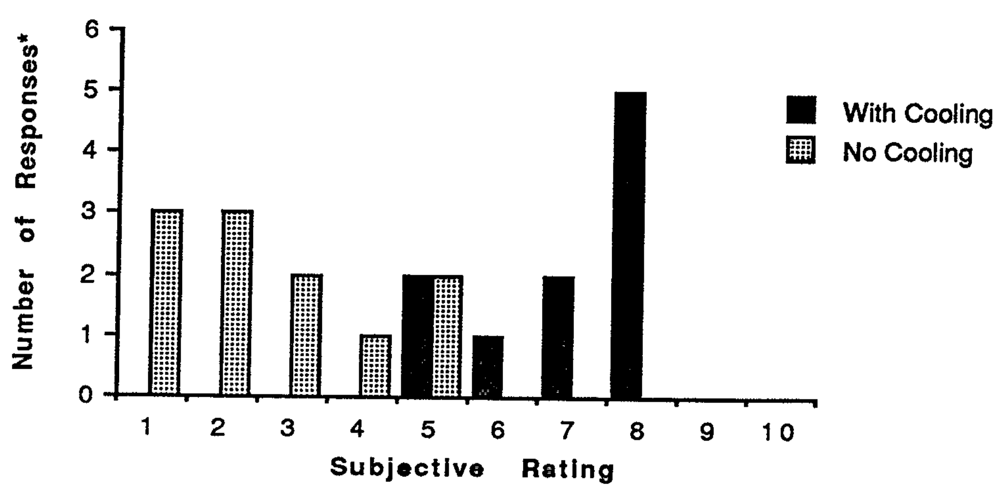


Figure 10. Perceived Thermal Comfort (Heavy Worklo

(* not all subjects answered all questions)



68. Even at light workloads, some aircrew rated the non-cooled configuration as unacceptable (rating of four or less). This is significant considering that ambient temperatures during the cross-Atlantic voyage were fairly moderate. With cooling, even at heavy workloads, the majority of aircrew gave a "good" rating for thermal comfort and not a single unacceptable rating was given.

69. *Overall Effectiveness of the Cooling System.* The overall effectiveness of the liquid cooling garment was rated to be good or excellent by all but one crew member. Because of problems with hose pinching, that individual gave the cooling shirt a fair rating. The effectiveness of the fluid supply in providing cooling for the vest (fluid temperature, heat removal capacity, cooling duration, logistics of supply) was rated to be excellent by four aircrew, good by six aircrew and fair by three aircrew.

70. *Operational Effectiveness.* All aircrew indicated that the cooling shirt was useful in enabling them to perform their duties effectively. The majority of aircrew (69%) indicated that their operational effectiveness was increased by using the cooling system. Two aircrew (15%) reported no change, while three aircrew reported a decrease in operational effectiveness. This decrease was attributed solely to the problems encountered with cooling tube disconnect and pinching inside the CD ensemble, and the efforts required in-flight to rectify these problems.

71. The success of the cooling system in alleviating thermal strain was demonstrated when crews from the British ship, HMS Gloucester, made inquiries about our aircrew CD clothing and equipment. They wondered how our crews were able to fly missions exceeding two hours in duration, when they were limited by fatigue and thermal strain to missions of only one hour (9,10). The enhanced capabilities of our crews may be attributed to the personal cooling system that they have been provided. To DCIEM's knowledge, it is the first and only personal cooling system in the world to be used operationally by aircrew. Indeed, the success of this development and integration has gained international recognition. The British, United States and Australian Forces have expressed much interest in this Canadian system, and it is possible that the cooling system will be procured for their crews operating in the Persian Gulf. User satisfaction with the system and word-of-mouth advertising in the theatre have put Canada's efforts on the map!

72. *Recommendations Regarding Personal Cooling.* All aircrew indicated that cooling is required, especially in the CD ensemble. This endorsement of the cooling system would be even more emphatic under higher ambient temperatures than those experienced during the trial. Most aircrew (77%) recommended the use or further development/refinement of this cooling system to resolve the problems of hose crimping and inadvertent disconnect. Three crew members recommended development of an entirely new/different cooling system that would provide longer cooling times, and reduce the time required to replace bottles. Ideally, future developments should aim to eliminate the requirement to produce and replace ice. Such a cooling system would require a chiller unit, rather than a simple pump.

However, no suitable aircraft-mountable system is commercially available. Until this ideal cooling system is identified, the ExoTemp cooling shirt and pump are recommended and should be procured for aircrew use in hot climates. Improvements to this system should be pursued and implemented for Op Friction aircrew.

CONCLUSIONS AND RECOMMENDATIONS

73. Within a short period, the ExoTemp personal cooling system was successfully modified and integrated with the clothing, life support equipment, crew stations and operations of CH124 SeaKing aircrew for the Operation Friction deployment. All aircrew indicated that personal cooling is a requirement. The system is capable of alleviating thermal strain under the severe ambient conditions of the Persian Gulf, even under chemical defence conditions. While technical problems still need to be resolved, most aircrew recommended use and further refinement of this cooling system. The success of this development and operational evaluation is evidenced by the international interest generated, in this, the first known aircrew personal cooling system in the world to be used operationally.

74. The following actions and cooling system improvements are recommended:

a. incorporate metal stiffening coils around return/delivery tubes on the cooling shirt (and inside the CD suit elephant trunk) to prevent kinking and blockage;

b. manufacture cooling shirts with more robust stitching, and in the meanime, launder shirts by hand to minimize damage, and provide repair kits to users;

c. issue two cooling shirts per aircrew, and replace these when local repair is no longer feasible (expected after six months of daily wear);

d. issue appropriately-sized cooling shirts (to ensure cooling tubes remain in close contact with the body on small individuals, and to prevent damage to stitching on larger individuals);

e. implement CD suit modifications (to pass through the cooling tubes) locally;

f. do not implement CD suit modifications at time of manufacture until integration and technical problems are resolved and the cooling system is integrated with other aircrew operations;

g. improve CD gloves (either make them air-ventile, or improve their sweat absorption) to minimize sweat accumulation;

h. evaluate the benefits of the ExoTemp cooling system (including hood and cooling pants) for other personnel and applications, including ground crew, navy and army personnel;

i. "chemically harden" cooling system components, by using liquid agent resistant materials. In the meantime, special care must be taken when handling cooling bottles, pumps and tubing, to avoid contact with liquid agents. The potential hazard from vapour agents should also be investigated;

j. install 28V DC power for cooling pumps in hangar and at the LSO position;

k. procure battery-powered cooling pumps (in addition to those already in place) and fast-chargers for LSO's and standby crews aboard ship (five pumps per ship recommended), and for portable cooling in the aft cabin in-flight (one pump per aircraft recommended);

l. procure battery-powered cooling pumps for future applications. The benefits of the battery-powered system (portability, no aircraft electrical modifications required, reduced EMI problems, eliminate electrical tether, easier integration in other aircraft and operations) outweigh the logistical problems of battery replacement and recharging;

m. evaluate the improved cooling pump (with flatter bottle, larger block ice capacity, better insulation, longer ice duration) for its compatibility with aircraft mounting pouches, with a view to eventually replacing all existing cooling pumps;

n. use block ice, rather than ice cubes, to extend cooling capacity of each bottle; procure more spare bottles, or higher-performance freezers to ensure sufficient ice availability;

o. prepare a Statement of Capability Deficiency (SCD) to document the need for aircrew personal cooling in hot areas and for CD operations (Sea King and other aircrew); and

p. monitor technical improvements in small liquid chillers with a view to eliminating the logistical problems of using ice.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the tremendous support provided by many agencies and personnel, without whom, the successful introduction of this cooling system would not have been possible. Thanks go especially to the other members of the DCIEM Integration Team, Sgt "Baz" Belzile, MCpl Steve Remus and Mr. Jean Steffler for their dedication and many long days spent on development, testing and manufacture of the CD suit modifications and aircraft mounting fixtures. Implementation of these modifications depended on the exceptional support provided by the CFB Shearwater Base Safety Systems Section. Many thanks are extended to WO Allen and his staff for their expert advice, their intense efforts to complete manufacture of all suit modifications and fixtures for all Op Friction aircraft, and for graciously making their facilities available to the DCIEM team.

The cooling system would not have functioned without the considerable efforts of the ICT, CFB Shearwater's BAMEO organization, HOTEF and IMP. Much credit goes to Maj Mike Creighton, ExO HS423, for his tireless support of our efforts and invaluable assistance with implementing aircraft modifications. Thanks must also go to Base Supply personnel and the ICT for their support in procurement and delivery of cooling system components. Appreciation is also extended to Capt Brian Wallebeck, HS 423, for arranging the dunker trial and volunteering to test the cooling system and CD ensemble and Capt Carl Wohlgemuth, VU32, for his advice and assistance during the dunker trial.

Thanks to the efforts of the Ship Supply personnel on both HMCS Protecteur and Athabaskan, freezers were made available so that block ice could be used and cooling system capacity extended. CFB Shearwater Base Photo and DCIEM Photo and Graphic Arts personnel are thanked for their photographic support.

Naturally, the successful introduction of the cooling system would not have been possible without the enthusiastic support of HS423, and especially, all Op Friction aircrew during integration and testing of the system and development of improvements.

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PERSONAL COOLING SYSTEM
PROCUREMENT DETAILS

ITEM	P/N	COST (14 Sep 90)
Pro-Kool Nomex Hood	CD400	$ 31.47
Pro-Kool Nomex Pants, High Performance, Size Medium	CDHP-300M	203.26
Pro-Kool Nomex Pants, Size Medium	CD-300M	176.32
Pro-Kool Nomex Shirt, Size Small (150-175 cm, 40-75 Kg)	CD-200S	358.18
* Size Medium (170-185 cm,70-90kg)	CD-200M	
Size Large (175-193 cm, 85-110kg)	CD-200L	
Portable Cooling Unit, 28v DC*	CD-100-28	500.00
Portable Cooling unit, 9.6v DC c/w battery	CD-100	590.00
Fast Charger, (Battery charger)	CD-2000	80.00
Semi-Portable Cooling Unit, c/w 120v AC adaptor	IC-100-1	697.80
10 Foot Cooling Line	IC-800-10	113.78
Thermoplastic Couplings*:		
Male connector, c/w check valve	PMCD 22-02	
Male connector, no check valve	PMC 22-02	
Female connector (recessed latch) c/w check valve	PMCD 17-02	
Female connector (recessed latch), no check valve	PMC 17-02	
Female connector (raised latch), c/w check valve	PMCD 16-02	
Female connector (raised latch), no check valve	PMC 16-02	

Source of Supply:

ExoTemp Ltd
Boundary Road
Pembroke, Ontario
Canada K8A 7R8
Telephone: (613) 735-3996
Fax: (613) 735-3814

* indicates those items procured for Op Friction Sea King aircrew

PHYSIOLOGIC EVALUATION OF THE PERSONAL COOLING SYSTEM

Objective

1. The purpose of the DCIEM evaluations was to get a quick laboratory assessment of the capability of a liquid cooled undershirt to reduce thermal strain to acceptable levels under the thermal conditions anticipated for the Persian Gulf. The protocol of an on-going aircrew thermal stress study was adopted directly. Lack of time precluded a detailed scientific evaluation with proper comparative measurements, so the results must be viewed as an exploratory survey only. There were, however, sufficient data to permit some conclusions to be drawn.

Cooling Equipment

2. The liquid-cooled suit consisted of a long-sleeved turtleneck onto which plastic tubing (3/32" ID, 5/32" OD) had been sewn in parallel serpentine loops to the inner side with overstitching. Cooling fluid was circulated through the network of tubing from a 2 litre plastic bottle of ice water sitting atop a pump via two pieces of 1 metre long plastic tubing (1/8" ID, 1/4" OD). The ice water reservoir and pump were contained in an insulated nylon pouch, but the interconnecting tubes were left uninsulated. This is essentially the configuration of the system as supplied by the manufacturer, except for the increased length of tubing between the reservoir and the garment.

Clothing Ensembles

3. The cooling system was evaluated in combination with both F18 aircrew standard (STD) and chemical defence (CD) flight clothing as outlined below. Control tests (ie, no cooling) were conducted by replacing the liquid-cooled shirt with the standard aircrew turtleneck underwear.

Common Items	STD	CD
Undershirt	MBU-12/P oxygen mask	Charcoal socks
Longjohns	Standard flight suit	Charcoal-foam liner
Wool socks		AR5 respirator
Wool glove liners		Filter-blower
Leather flying gloves		Bromobutyl rubber gloves
Survival vest/PFD		CD coveralls/flight suit
Combat boots		
190A Helmet		

Environmental Conditions and Protocol

4. The tests were conducted in an environmental chamber set at a dry bulb temperature of 46°C and 30% relative humidity. Subjects entered the chamber and walked on a treadmill at 4 km/hr for 10 minutes to simulate aircraft walkaround activities, and then sat down to rest for 20 minutes. Thereafter, each half hour consisted of 10 minutes of light arm exercise (arm curls with 1 kg weights at a rate of 1 up or down movement per second) followed by 20 minutes of rest, for a target chamber exposure time of 150 minutes. Subjects were to be withdrawn from the chamber if deep body temperature exceeded 39°C or rose by more than 2°C, if heart rate exceeded 80% of the subject's maximum predicted heart rate for 3 minutes, or if the subjects themselves chose to terminate the test for any reason. Subjects (in the cooled clothing configuration) were connected to the cooling pumps after the 10 minute treadmill walk. They were permitted to control cooling pump speed to suit their own comfort throughout the evaluation. Cooling bottles (packed with crushed ice and topped up with water) were replaced when the ice had completely melted.

Physiological Parameters and Data Analysis

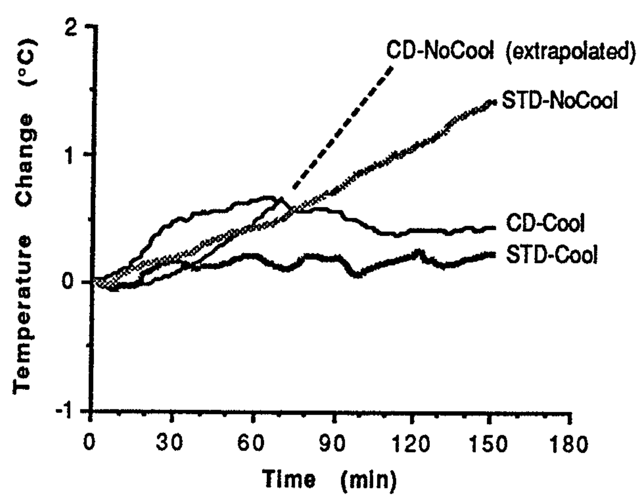
5. Deep body temperature was measured with a thermistor probe inserted into the rectum 15 cm beyond the anal sphincter. Skin temperature and body heat flux were measured with 12 heat flux transducers attached to the skin at standard sites using Transpore surgical tape. For brevity, heat flux results are not shown in this report. Mean skin temperatures were calculated separately for the cooled and non-cooled regions of the body using area-weighted averages of the respective cooled and non-cooled measurement sites.

6. Time constraints did not permit a full comparative study to be carried out using repeat tests on the same subjects; comparisons between conditions therefore include intersubject variations. Data was collected for runs in STD and CD clothing, both with and without cooling. The test run in CD clothing without cooling was aborted prematurely for personal reasons unrelated to thermal stress. Since the early results of this aborted test were so similar to those from numerous other non-cooled CD tests conducted at this laboratory (the only difference in conditions was a slight increase in dry bulb temperature from 42°C to 46°C), the non-cooled CD results have been projected with some confidence.

Results and Discussion

7. Figure B1 shows the change in rectal temperature as a function of time for the STD and CD clothing configurations, both with and without cooling. Change in rectal temperature normalizes the results somewhat against variations in initial temperatures between subjects. The liquid-cooled shirt was very effective in alleviating thermal strain. Whereas non-cooled subjects in both STD and CD clothing showed increases in rectal temperature that were approaching the allowable tolerance limit of 2°C (the CD non-cooled subject would only have lasted about 130 minutes). Both cooling garment runs stabilized at only marginally-elevated core temperatures (<0.5°C) and could have continued indefinitely, at least with regard to deep body temperature.

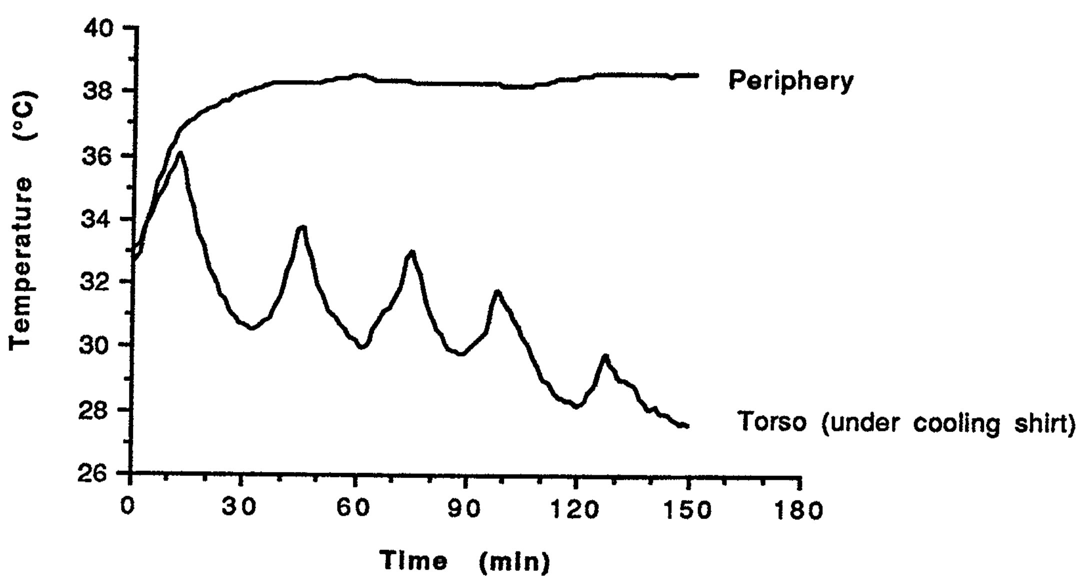
Figure B1. Change in rectal temperature



8. Figure B2 shows the skin temperature data for the subject wearing CD clothing with the cooling garment. There are large differences in temperature between the cooled (Torso) and non-cooled (Periphery) areas of the body. The run began with a comfortable skin temperature of 33°C. After an initial warming during the 10 minute treadmill walk, those body sites covered by the cooling garment were comfortably cooled (cold discomfort is felt at about 20°C), while the non-cooled areas rose to very high levels. Peripheral skin temperatures were higher than rectal temperature, indicating heat gain from the environment in those body regions. Heat flux data showed that peripheral sites were gaining heat at about 40 watts per square metre. The torso was losing heat to the cooling garment at an average rate of just over 100 watts per square metre. Considering metabolic heat production and body heat storage, these figures are consistent with the observed ability of the cooling system to maintain core temperature.

9. Figure B2 also shows a fairly regular cycling of torso temperature. This reflects the depletion and replenishment of the ice in the cooling fluid reservoir, and indicates that the reservoir must be serviced at 20-30 minute intervals (as was done in this experiment) for continuous cooling. The cooling capacity available from a single charge of ice water depends upon the quantity of ice in the bottle.

Figure B2. Mean Skin Temperature of Torso and Periphery (CD Clothing with Cooling)



10. Most subjects selected minimum speed on the pump immediately after replenish-ment of the ice. Numerous liquid cooling garment studies have shown that cooling fluid should be in the 12-15°C range for optimal balance between heat removal and discomfort. While the idea of automatic temperature control of the cooling fluid may seem good, experience with such systems suggests that the effort and expense are generally not warranted. The present system with a 5 speed pump control was adequate.

Conclusions

11. This brief study demonstrated that the liquid-cooled garment was effective in reducing thermal strain to acceptable and tolerable levels under ambient temperatures as high as 46°C. The major limitation was that the reservoir of ice water had to be replenished every 20-30 minutes to maintain continuous cooling.

DRAFT MODIFICATION INSTRUCTIONS

MODIFICATIONS NECESSARY TO INTEGRATE EXOTEMP PERSONAL COOLING SYSTEM WITH THE AIRCREW CD ENSEMBLE

PURPOSE

1. To describe the modifications necessary to integrate the liquid cooling system with the layered aircrew CD ensemble. Modifications permit the CD ensemble to be safely donned and doffed without cross-contamination of liquid chemical agent.

WHEN MODIFICATION SHALL BE EMBODIED

2. As directed by NDHQ

INSTALLATIONS AFFECTED

3. N/A

EQUIPMENT AFFECTED

4. Charcoal-impregnated foam coverall/liner (NSN 8415-21-891-3731) and outer liquid-repellent flying coverall (NSN 8415-21-891-3742) of the Aircrew Chemical Defence Ensemble, for those aircrew who have been issued the Exotemp Personal Cooling System.

TRAINING AIDS AFFECTED

5. As required.

BY WHOM WORK WILL BE PERFORMED

6. Operating Units

RESOURCES REQUIRED

7.
   a. SS Tech (531) - two hours
   b. Down Time - N/A
   c. Tools Required - Normal Base Facilities
   d. Material -

	Stock/Part No.	Description	UI	Qty.	ACC
1.	8305-21-112-0544	Webbing Nylon OG 9/16"	yd	4 in	C
2.	8310-21-845-9894P/N VT-295	Thread Nylon OD size E	cn	AR	C
3.	8315-21-843-7432	Velcro Hook Black	yd	4 in	C
4.	8315-21-843-7433	Velcro Pile Black	yd	4 in	C
5.	4020-21-807-0588	#8 Linen Cord	cn	AR	C
6.	(Note 1)	CD outer garment material	yd	1 sq yd	C
7.	P/N N-06408-47 (Note 2)	Tubing Tygon 1/4" OD x 1/8" ID	yd	8 in	C
8.	P/N PMC 17-02 (Note 3)	Connector Cooling Female	ea	2	C
9.	P/N PMC 22-02 (Note 3)	Connector Cooling Male	ea	2	C

Notes:

1. Available from DCIEM/MLSD, telephone 416-635-2052.

2. Available from Cole-Parmer International, 7425 North Oak Park Ave., Chicago, Illinois, 60648, USA, Telephone 312-647-7600.

3. Available from Exotemp Ltd., Boundary Rd, Pembroke, Ont., telephone.613-735-3996

MATERIAL RENDERED SURPLUS

8. N/A

MODIFICATION OF SPARE ITEMS

9. N/A

MODIFICATION EMBODIMENT PROCEDURES

10. The following procedures describe the modifications to the charcoal foam liner:

a. Cut open four inches of the side seam, on the left side of the suit, at groin height, commencing approximately four inches down from the seam at the waist for suit sizes 4,5,6,6X and six inches down from the waist seam for suit sizes 7,8,9,9X. Ideally, the height of the opening should be determined on an individual basis,with the crewember wearing the cooling shirt and charcoal suit to the waist;

b. Cut one piece each of two inch wide hook and pile (Items 3 & 4), each four inches long;

c. Cut two pieces of nylon webbing (Item 1), each two inches long, and sew each to the back side of the hook and pile pieces as indicated at Figure C1. All sewing to be done using nylon thread (Item 2), at nine stitches per inch;

d. Referring to Figures C2 and C3, sew edge of hook and pile pieces into opening in side seam of charcoal suit, one at a time, overlapping back side of hook or pile with seam allowance of charcoal suit. Hook and pile right sides should face together, forming a closure for the opening in the suit. The nylon tabs should be located on the side of the hook orpile that is furthest from the suit; and

e. Close opening in suit by mating hook and pile pieces. If necessary, stitch along side seam in suit, above and below hook and pile, to en-sure that there is no opening in the suit.

11. The following procedures describe the modifications to the outer CD flying coverall:

a. Cut open 2 1/2 inches of the side seam, on the left side of the suit, at groin height, commencing approximately three inches down from the seam at the waist for suit sizes 4,5,6,6X and four inches down from the waist seam for suit sizes 7,8,9,9X. Ideally, the height of the opening should be determined on an individual basis, with the crewmember wearing the cooling shirt and both charcoal and outer CD suits up to the waist;

b. Cut a piece of outer suit material (Item 6) six inches square. Serge three sides of the material using nylon thread (Item 2);

c. Double fold (1/4 inch each fold) raw edge towards right side of material and stitch. All sewing to be done using nylon thread (Item 2) at nine stitches per inch;

d. Fold material in half, right sides together, with double folded edge on inside. Sew along length (1/2 inch seam allowance), leaving 1/2 inch unsewn at serged edge. This forms the "elephant trunk" through which the cooling tubes pass. Refer to Figure C4;

e. Sew the serged end of the "elephant trunk" into the opening in the side seam of the CD coverall by placing right sides of material together;

f. Cut two pieces of Tygon tubing (Item 7) four inches in length. Insert a male and female cooling connector (Items 8 & 9) into the opposite endsof each tube; and

g. Insert both tubes into the elephant trunk on the CD coverall, female connectors towards the inside of the suit. The cooling tubes should be placed so that they are at least one inch apart, with the male connectors protruding 1/2 inch from the "elephant trunk. Secure the tubing using wax cord (Item 8) and hand-stitching, through the "elephant trunk" around the tubing close to each connector (4 sites). Refer to Figures C5 and C6.

WEIGHT, BALANCE AND STABILITY DATA

12. No effect.

RECORDING PROCEDURES

13. As directed by NDHQ.

REPORTING PROCEDURES

14. As directed by NDHQ.

FUNCTIONAL CHARACTERISTICS OF EQUIPMENT ALTERED

15. No effect on form, fit or function of CD charcoal liner or outer coverall. Note that the charcoal liner must be returned to its mylar pouch (with drying agent) and the bag sealed (heat-seal) once modifications are completed.

ANNOTATION TO APPLICABLE TECHNICAL ORDERS

16. As directed by NDHQ.

ADDITIONAL INFORMATION

17. This procedure will provide a method to safely integrate the Exotemp Personal Cooling System with the dual-layered nature of the CD ensemble and donning and doffing procedures.

REFERENCES AND OTHER DATA

18. Required or Background references - Nil.

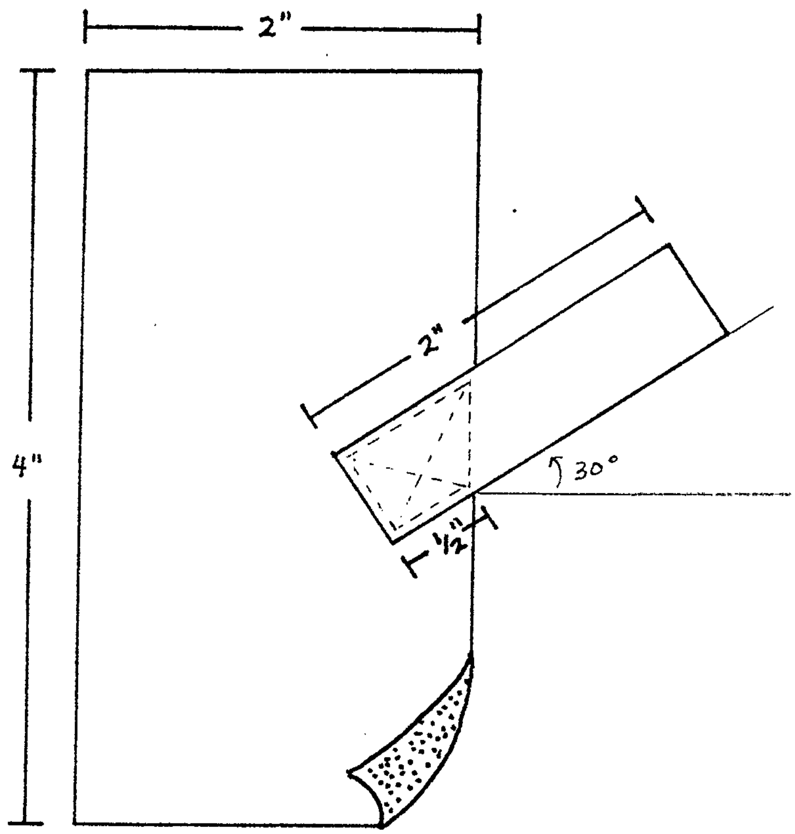


Figure C1. Hook or Pile With Nylon Webbing Attached

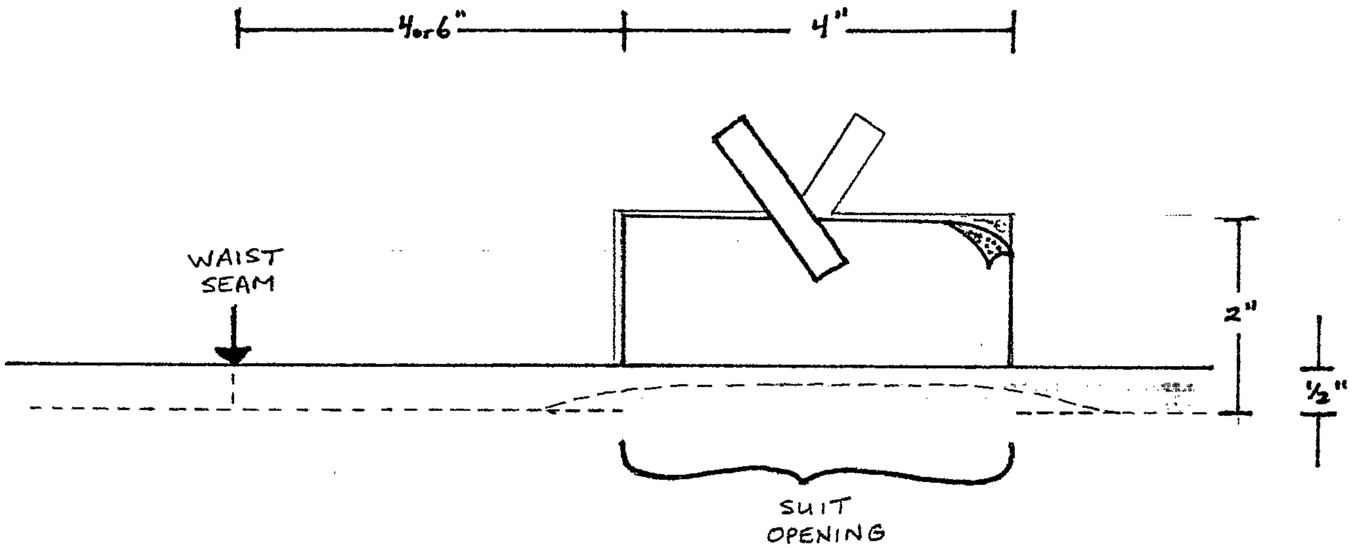


Figure C2. Hook and Pile Closure Sewn into Charcoal Coverall

Figure C3. Hook and Pile Closure Sewn into Charcoal Coverall

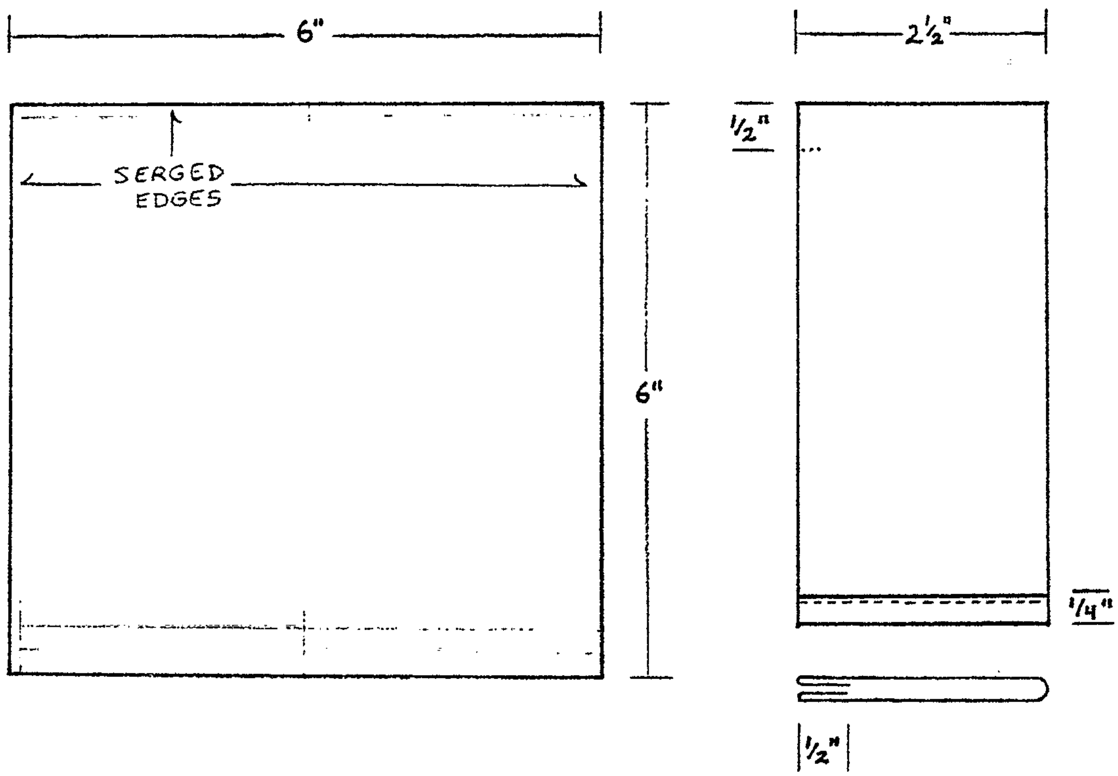


Figure C4. Fabrication of CD Coverall "Elephant Trunk"

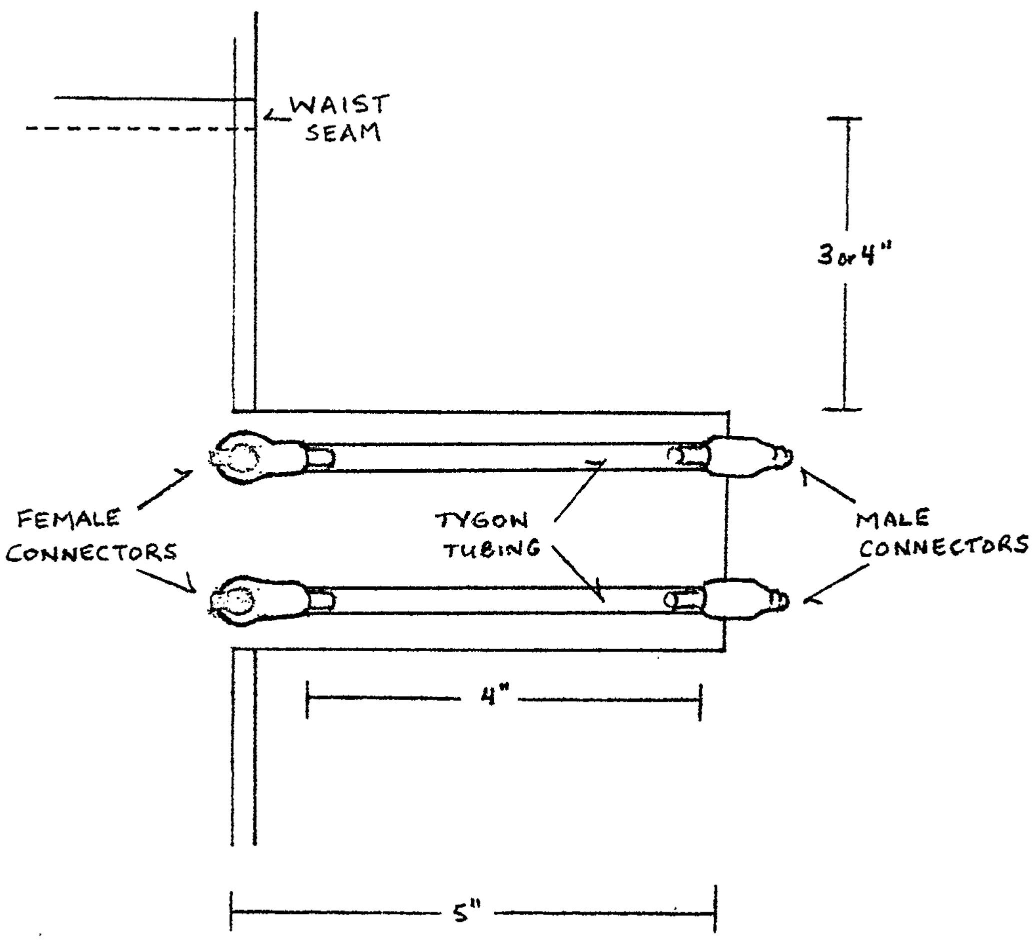


Figure C5. "Elephant Trunk" with Cooling Adaptor Tubing on CD Outer Coverall

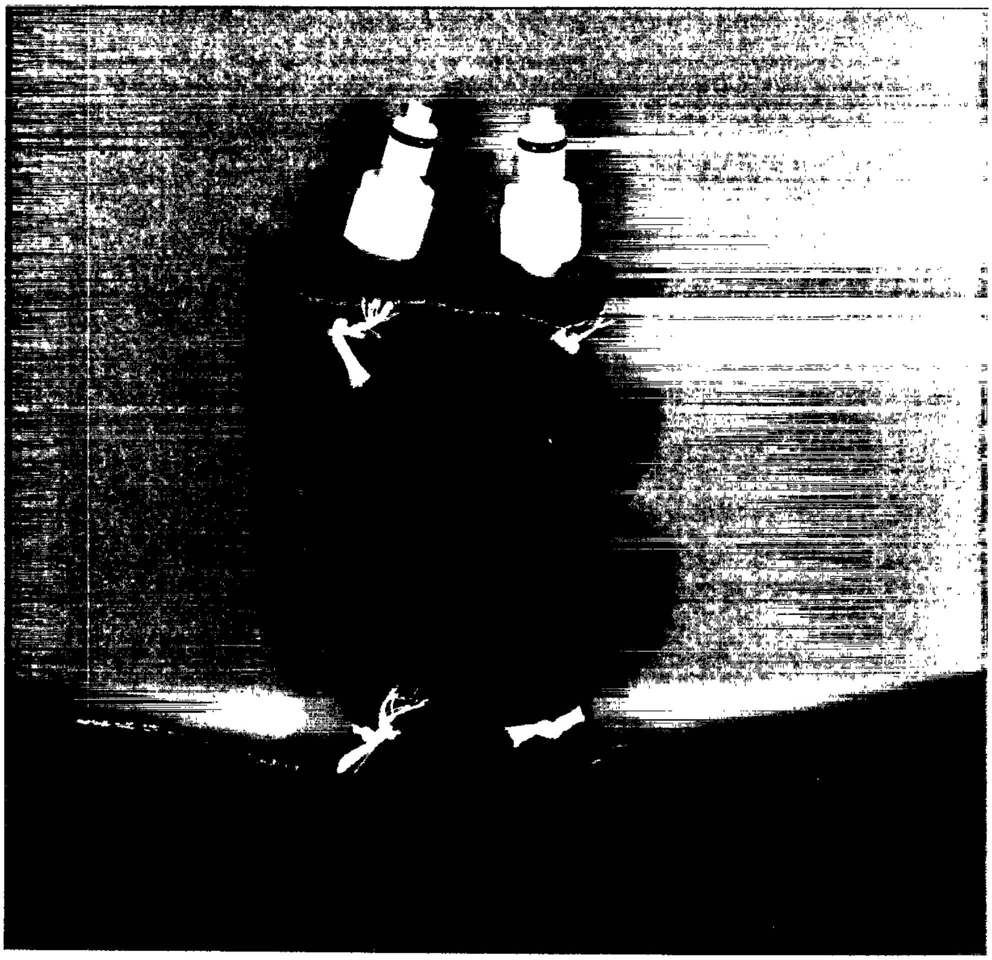


Figure C6. CD Outer Coverall Modified to Incorporate "Elephant Trunk"

AIRCREW C4 RESPIRATOR AND CHEMICAL DEFENCE ENSEMBLE OPERATIONAL EVALUATION

This includes those portions of a questionnaire given to Op Friction aircrew that relate to thermal comfort and the personal cooling system (5).

RATING SCALE

Aircrew were asked to provide a rating (by circling a number from 0 to 10) of the acceptability of various aspects of the CD ensemble and personal cooling system in the operational environment. Aircrew referred to the scale below.

RATING	DEFINITION	MEANING	IMPLICATIONS
10	Outstanding	Exceeds all	Changes
9	Very Good	requirements	not
8	Good	Meets all requirements	required
7	Acceptable	Minor changes desirable	System
6	Acceptable	Some changes very desirable	enhancements
5	Acceptable	Some changes highly desirable	are desired
4	Unacceptable	Minor changes required	CD IPE
3	Unacceptable	Moderate changes required	unacceptable for
2	Unacceptable	Major changes required	operational use
1	Unusable		System design unsafe
0	Not observed		

Heat Stress

22. Rate the acceptability of heat build-up and sweating associated with wearing the full ensemble at TOPP High under the following work loads:

With Cooling:

a.	At rest	0	1	2	3	4	5	6	7	8	9	10
b.	Light Work	0	1	2	3	4	5	6	7	8	9	10
c.	Moderate Work	0	1	2	3	4	5	6	7	8	9	10
d.	Heavy Work	0	1	2	3	4	5	6	7	8	9	10

Without Cooling:

e.	At rest	0	1	2	3	4	5	6	7	8	9	10
f.	Light Work	0	1	2	3	4	5	6	7	8	9	10
g.	Moderate Work	0	1	2	3	4	5	6	7	8	9	10
h.	Heavy Work											

23. Rate the acceptability of heat build-up and sweating in the following areas of the body:

a.	Scalp/Head	0	1	2	3	4	5	6	7	8	9	10
b.	Face (Blower/ON)	0	1	2	3	4	5	6	7	8	9	10
c.	Face (Blower OFF	0	1	2	3	4	5	6	7	8	9	10
d.	Neck	0	1	2	3	4	5	6	7	8	9	10
e.	Check/Back/Torso (with cooling	0	1	2	3	4	5	6	7	8	9	10
f.	Chest/Back/Torso (without cooling)	0	1	2	3	4	5	6	7	8	9	10
g.	Groin	0	1	2	3	4	5	6	7	8	9	10
h.	Thighs/Legs	0	1	2	3	4	5	6	7	8	9	10
i.	Hands	0	1	2	3	4	5	6	7	8	9	10
j.	Feet	0	1	2	3	4	5	6	7	8	9	10

Equipment Compatibility

25. Rate the compatibility of the following clothing/equipment with the AC4 and IPE:

e.	Cooling Vest	0	1	2	3	4	5	6	7	8	9	10

LIQUID COOLING GARMENT EVALUATION QUESTIONNAIRE

The intent of this questionnaire is to gather subjective data on the performance of the liquid cooling garment (LCG) during air operations. The questionnaire can be administered upon completion of a multiple mission exercise or trial during which some missions involved use of the LCG, or after a single mission or test.

Please indicate the nature of this evaluation with an "X"

Multiple Mission (go to question 1) ________ Single Mission (go to bottom of this page) ________

The following questions pertain to a retrospective evaluation of a **multiple mission** trial.

1. How many missions or trial sessions **in total** does this evaluation involve?____

2. During how many of these missions did you **wear** the LCG? ____
(If answer 2 = answer 1 then go to question 4)

3. When you did **not wear** the LCG, for how many missions were the following reasons applicable? (Total should equal answer 1 minus answer 2)

_____ LCG not required (cool ambient conditions)
_____ LCG not available (limited supply)
_____ LCG not issued (control test for comparison)
_____ LCG not desired (too uncomfortable)
_____ Other (explain)______________________________

4. During how many missions did you **wear and use** the LCG? ____
(If answer 4 = answer 2 then fo to question 6 on page 2)

5. When you **wore but did not at all use** the LCG, for how many missions were the following reasons applicable? (Total should equal answer 2 minus answer 4)

_____ LCG not required (cool ambient conditions)
_____ LCG not functional (defective, no ice, etc)
_____ LCG not desired (too uncomfortable)
_____ Other (explain)______________________________

If you **wore but never used** the LCG, go to page 4, indicate your non-usage of the

LCG, and continue with question 19. If the LCG was **worn and used**, please go to question 6 on page E-2.

The following questions relate to the times the cooling garment was **worn and used** during a mission, even if only for a short period of time.

6. Estimate the percentage of the mission time the cooling garment was used at the various pump speeds. Hint: If the fluid was initially cold but only for a short while, you might indicate 0-20% for a low pump speed and more time at higher speeds. If usage was highly variable over multiple missions in a trial, indicate the average or predominant usage with an "X" and indicate the upper and lower bounds of the time range above and below the X with an "O".

Speed	Off	Low	Med.	High
81-100%	______	______	______	______
61 - 80%	______	______	______	______
41 - 60%	______	______	______	______
21 - 40%	______	______	______	______
0 - 20%	______	______	______	______

7. Was the LCG ever used for only a portion of a mission? (Excluding ice/water replenishment downtime.)

Yes (go to question 8) ______________ No (go to question 9) ______________

8. When the LCG was **not used continuously** in a mission, for how many missions were the following reasons applicable? (Total should not exceed answer 4.)

______ LCG not always required (cool ambient conditions)
______ LCG not always functional (defective, no ice, etc)
______ LCG not always desired (too uncomfortable)
______ Other (explain) ______________________________

9. How many minutes did a cooling bottle charge typically last (if highly variable over multiple missions in a trial, indicate average with an "X" and indicate range with "O")

Minutes	<20	20-30	31-35	36-40	>40
	______	______	______	______	______

10. Was the cooling fluid ever too cold on the skin immediately after the bottle replenishment?

Never ______ Sometimes ______ Always ______

The following questions relate to the overall performance of the cooling equipment. Some questions deal with only the **vest,** others with the **fluid supply,** and others with the **whole system** as a unit.

11. How would you rate the overall effectiveness of the LCG **vest** in maintaining your thermal comfort during thermal stress (exclude the performance of the ice/water bottle by focussing on those times when the fluid was actually cool)

Poor __________ Fair __________ Good __________ Excellent __________

12. How would you rate the overall effectiveness of the **fluid supply** in providing cooling for the vest (try to eliminate the vest performance by allowing for other vest designs; focus on parameters such as temperature, heat removal capacity, cooling duration, logistics of supply, etc)

Poor __________ Fair __________ Good __________ Excellent __________

13. Was the fluid supply bottle ever worn or carried on the body during operations?

Yes ______ No ______

14. How would you rate the feasibility of operating with a totally man-carried system (vest, coolant supply, battery power, etc) assuming the system would probably weigh more than the current configuration due to a larger reservoir and battery?

Poor __________ Fair __________ Good __________ Excellent __________

15. Assuming an aircraft-mounted cooling supply were available, would a tether of any kind (liquid lines, electrical lines) be a problem for operations?

Yes ______ No ______

16. Was your operational effectiveness affected by the cooling system?

Decreased ______ No Change ______ Increased ______

17. What is your recommendation regarding **this system?**

Scrap it ______ Use as is ______ Develop more ______

18. What is your recommendation regarding any **personal cooling system?**
None required ______Develop new ______Use/mod current ______

The following questions relate to your **perceived thermal comfort while wearing** or **wearing and using** the LCG. Use an "X" to indicate the requested response. If the response was highly variable over multiple missions, indicate the average response with "X" and the upper and lower bounds of the time range with "O".

Please indicate your usage/non-usage of the LCG:

Worn and used ______ Worn but not used ______

19. Estimate the percentage of time in a mission that you experienced the indicated temperature sensations on the part of your **skin under** the LCG:

Temp	Too Cold	Cool	Medium	Warm	Too Hot
81-100%					
61- 80%					
41- 60%					
21- 40%					
0- 20%					

20. Estimate the percentage of time in a mission that you experienced the indicated temperature sensation on the part of your **skin not under** the LCG:

Temp	Too Cold	Cool	Medium	Warm	Too Hot
81-100%					
61- 80%					
41- 60%					
21- 40%					
0- 20%					

21. Estimate the percentage of time in a mission that you experienced the indicated temperature sensations on your **whole body:**

Temp	Too Cold	Cool	Medium	Warm	Too Hot
81-100%					
61- 80%					
41- 60%					
21- 40%					
0- 20%					

The following questions pertain to the **environmental conditions** under which the LCG was tested or used. Use an "X" to indicate your response. If the conditions were highly variable over multiple missions, indicate the average conditions with "X" and the upper and lower ends of the range with "O". The questions relate to those times the LCG was either **just worn** or **both worn and used.**

22. What were the predominant ambient conditions **outside the aircraft** (estimate if not known accurately)?

Temp °C	<20	20-30	31-35	36-40	>40
	_____	_____	_____	_____	_____

Humidity	Low	Moderate	High
	_____	_____	_____

23. What were the predominant ambient temperatures **inside the aircraft** (estimate if not known accurately)?

Temp °C	<20	20-30	31-35	36-40	>40
	_____	_____	_____	_____	_____

Humidity	Low	Moderate	High
	_____	_____	_____

24. As an overall assessment, was the LCG system useful (or do you think it would have been useful had you used it or been able to use it) in enabling you to perform your duties effectively?

Yes ______ No ______

25. Please indicate your crew station or function in the aircraft:

Pilot ______ Co-Pilot _______ TACCO _______ AESOp _______

Other (please specify) ______________________________________

26. Your identification______________________________________

(optional - only for further clarification if you are willing to be contacted)

Hand written comments can be made on the backs of these pages.

Thank you for taking the time to complete this questionnaire. It is only through effective communication and feedback from the user that we can achieve the goal of providing the best protective equipment possible for the CF.

Please return all questionnaires to Dr. John Frim, Biosciences Division, DCIEM.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

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Operation Friction: Development and Introduction of Personal Cooling for CH 124 Sea King Aircrew

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Sea King aircraft and aircrew were deployed to the Persian Gulf as part of Canada's support to the United Nations actions against Iraq. Due to the expected high ambient temperatures and requirement to operate in the Aircrew Chemical Defence (CD) ensemble, personal cooling was required to maintain operational effectiveness. A system, that had been developed by Exotemp of Pembroke (Ontario) for cooling bomb disposal personnel, was adapted for this purpose. This included not only manufacture and delivery within one week, but also design and implementation of CD ensemble and aircraft modifications. Through concerted efforts of many individuals and agencies, equipment developments and modifications were completed in the one week available prior to sailing. The development of doctrine, operational use of the cooling ensembles, and training of aircrew and support staff were accomplished aboard ship enroute to Gibraltar. Physiological and operational evaluations of the cooling system show that the operational capability of our aircrew is significantly enhanced by the personal cooling system. Indeed, this is the first aircrew personal cooling system known to have been used in wartime. It made Canadian Sea King aircrew unique amongst our allies: in unconditioned aircraft, in one of the hottest environments in the world, dressed in the full CD ensemble, they could function without being limited by heat stress.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

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