CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-CH12419 (DFS 2-4-2)
DATE OF REPORT: 5 August 2005

AIRCRAFT TYPE: CH124A Sea King
DATE/TIME: 21 1115 Z August 2003
LOCATION: 26º 24' N 55º 53' E (Straits of Hormuz)
CATEGORY: "D" Category Incident

SYNOPSIS

The incident crew and one technician from HMCS CALGARY were conducting a rotor smoothing maintenance test flight. After having already returned to the flight deck for adjustments after the first rotor smoothing, the aircraft re-launched for a second rotor smoothing. Just prior to the second recovery, the aircraft flew down HMCS CALGARY's starboard side from stern to bow and, once abeam the bridge, commenced a left climbing turn across the bow. As the aircraft passed in front of the bridge the main rotor blades struck an antenna and its mount on the starboard top-part of the bridge. The aircrew heard and felt two thumps in rapid succession while simultaneously the bridge personnel heard a loud bang. The ship came to Emergency Flying Stations and the aircraft landed without further incident. The ship sufferred minor damage to a guardrail and an antenna while the aircraft sufferred "D" category damage.

TABLE OF CONTENTS

1. FACTUAL INFORMATION

1.1 History of Flight

The Sea King Helicopter Air Detachment (HELAIRDET) was embarked on HMCS CALGARY in support of Operation APOLLO. Although the aircraft's primary roles are anti-submarine and anti-surface warfare, Operation APOLLO roles mainly involved surface surveillance, support to naval boarding operations, and utility flights. The Sea King typically operates in a low-level day/night/visual flight rules(VFR)/instrument flight rules over-water environment in both national and international theatres of operations. An operational crew consists of four members: the pilot, the co-pilot, the tactical co-ordinator (TACCO), and the airborne electronics sensor operator (AESOP). Either the pilot or the TACCO is designated as the crew commander, who has overall responsibility for the mission. The pilot was the designated crew commander and occupied the right seat while the co-pilot occupied the left seat. The incident aircraft was equipped with weather radar, a rescue hoist, a door-mounted machine gun, and a self-defence suite.

The incident crew was conducting a rotor smoothing and vibration analysis (VA) Maintenance Test Flight following a main rotor blade change. In addition to the operational crew, a VA technician was also onboard.

Rotor smoothing and VA involves a ground calibration of the engaged main rotor blades; this is followed by an in-flight check in both the hover and forward flight. After coming to Flying Stations (FS), the aircraft engaged the main rotor blades at 1325L and, after completing the ground calibration, it launched at 1353L. Post-launch, the ship stood down FS. Due to the 3080’ density altitude, calm winds, and a high aircraft all up weight, the aircraft flew for approximately 25 minutes in order to reduce weight so that the hover check could be completed within engine, main transmission gearbox, and torque limits. After completing the airborne checks, the VA was found to be out of limits; therefore, the ship returned to FS and the aircraft recovered at 1433L to make pitch link adjustments.

The aircraft re-launched at 1458L to repeat the VA in-flight checks. These checks were again out of limits so the crew advised the ship that a second recovery would be needed to effect additional adjustments. The Ship’s Air Controller (SAC), who retained air traffic control of the aircraft until passing control to the Landing Signals Officer (LSO), then cleared the aircraft to close the ship. While the ship completed its final stages of preparations for FS, the aircraft, with the co-pilot on the controls, approached the ship’s starboard quarter (ship’s 5 o’clock). The co-pilot intended to pass along the starboard side of the ship, execute a left turn across the foc’sle, and enter the Delta and Delta Hover Astern positions once cleared to do so by the LSO. The Delta is a visual holding pattern oriented into wind and uses the ship as a reference point; it is flown at 200’ and 80 knots. The Delta Hover Astern is a hover point on the ship’s port or starboard quarter (ship’s 5 or 7 o’clock) from which the aircraft conducts its final approach to the flight deck after receiving clearance to land from the LSO. The co-pilot anticipated that by the time the flypast and turn was completed, the ship would have completed preparations for Flying Stations and that the LSO would have been able to take control of the aircraft and clear it to the Delta Hover Astern.

At 1515L the aircraft approached the ship at 60-80 KIAS, 40' above sea level (ASL), and parallel to the starboard side, laterally offset by approximately 70'. When approximately abeam the bridge, the aircraft initiated a 15°-20° bank left turn with a slight climb. At approximately 30°-40° of heading change through the turn, the aircrew heard and felt two thumps in rapid succession; bridge personnel reported hearing a loud bang as the helicopter turned in front of the ship. Uncertain of the origin, the pilot took control of the aircraft and rolled it to a level attitude. A controllability check was conducted and revealed no adverse responses or abnormalities. The crew initially thought that the noise and thump might have resulted from a heavy camera case falling from its mount in the aircraft; however, a quick check confirmed that the case was secure. The SAC then advised the aircraft that an antenna had been struck by the helicopter and that the ship was coming to Emergency Flying Stations (EFS). Air traffic control of the aircraft was then passed to the LSO.

As there were no controllability problems or aircraft malfunctions apparent and because the aircraft was in a position to land immediately under normal FS rather than wait for an additional six minutes until EFS were closed up, the pilot requested an immediate normal recovery to the flight deck. However, the aircraft was directed to the Delta Hover Astern until the ship was closed up at EFS; landing clearance was given by the LSO at 1521L.

After a normal landing and shutdown were completed, a visual inspection of the aircraft found the number one and five main rotor blade tip caps to be damaged; skin rippling and deformity were also noted on both these blades. The ship's damage was confined to the top-part starboard bridge where a guardrail and a fibreglass radio antenna were shattered. The aircraft suffered "D" category damage.

1.2 Injuries to Personnel

One member of the ship's company suffered a broken ankle after falling from a ladder as the ship closed up for EFS.

1.3 Damage to Aircraft

The rotor blade tip caps of the number one and number five blades were damaged and exhibited signs of rippling and deformity (Photo 1). An inspection for sudden blade stoppage was also conducted. This inspection involved a comprehensive review of the main rotor head, main rotor blades, main gearbox, engines, and tail rotor drive shaft, and determined Class 2 damage to be apparent. Class 2 damage is defined as light to heavy damage that requires blade removal and is repairable by local resources or at overhaul level. The damage was originally classified as “C” category and was later reclassified as “D” category.

1.4 Collateral Damage

The blade strike resulted in relatively minor collateral damage to HMCS CALGARY’s upper bridge structure on the starboard forward position approximately 40’-42’ above the waterline. A fibreglass VHF antenna and an aluminium guardrail corner-post were sheared (Photo 2). Antenna and guardrail pieces were scattered on the bridge wing and the starboard boat deck.

1.5 Personnel Information

Table 1: Personnel Information

	PILOT	CO-PILOT	TACCO	AESOP	TECHNICIAN
Rank	CAPT	CAPT	CAPT	WO	CPL
Category	MHC/ MHCC	MHCP	TACCO/1	AESOP/B	514 AVN Tech
Category valid to	27 Mar 04	11 Mar 04	21 May 04	15 May 04	N/A
Min Currency Exp (1 Cdn Air Div)	9 Sep 03	11 Sep 03	19 Sep 03	19 Sep 03	N/A
Medical Category valid to	30 Apr 04	30 Mar 04	14 Jan 04	30 Mar 04	N/A
Total hours flying time	1116.2	3598	2305	2668.9	N/A
Hours on type	843.8	366.1	2235	324.9	N/A
Hours last 30 days	60.8	56.7	58	65.2	N/A
Hours last 48 hours	1.7	1.7	1.7	4.7	N/A
Duty time last 48 hours	12	12	12	12	15
Duty time last 24 hours	9	9	9	9	8

All aircrew met minimum currency and category requirements.

1.6 Aircraft Information

The occurrence aircraft was a CH124A Sea King helicopter. The aircraft was serviceable for the purpose of conducting the rotor smoothing maintenance test flight; however, it was not mission capable as the Operational Tasking Air

Helicopter Order covering the incident time period indicated. The aircraft was airworthy and no mechanical abnormalities or unserviceabilities were evident up to the time of the occurrence.

1.7 Meteorological Information

The meteorological information for 21 Aug 03 was as follows:

AREA AVIATION FORECAST

VALID 210800Z – 211400Z WITH A 12 HR OUTLOOK VLD WITHIN 50NM OF CGAF (HMCS CALGARY)

PROG: THERMAL LOW AND TROUGH OVER SAG DOMINATES WEATHER PATTERN. LGT NELY FLO OVER AREA. AIR MASS MOIST/UNSTABLE LOW AND MID LEVELS.

CLOUDS AND WX: 200 SCT 300 3-5 SM HZ DU

TURBC: NIL

OUTLK: VFR HAZE/DUST

WINDS AND TEMPS: SFC: 06005+34 010: 20010+33 020:21010+32

SEA TEMP: 32.0°C HYPO: 5HR+ SEAS: <1 METER

PA: 440 FT DA: 3080 FT ALT TREND: RISING SLOWLY

TAF WITHIN 5NM OF HMCS CALGARY

TAF: CGAF 210730Z 210814 VRB05KTS 4SM HZ DU SKC TEMPO 1014 3SM HZ DU=

AVIATION WEATHER OBSERVATIONS

METAR: CGAF 210800Z 06005KT 4SM HZ DU SKC 33/30 A2948

METAR: CGAF 210940Z 06005KT 3SM HZ DU SKC 34/29 A2946 (Humidity Index (HUMIDEX) 50)

METAR: CGAF 211100Z 06003KT 3SM HZ DU SKC 35/28 A2944 (HUMIDEX 49)

METAR (at time of incident and Emergency Flying Stations):
CGAF 211115Z 06004KT 3SM HZ DU SKC 35/28 A2944 (Dry Bulb 34.9°C, Wet Bulb 29.4°C, Relative Humidity 65%, HUMIDEX 49°C)

METAR: CGAF 211200Z 06010KT 3SM HZ DU 250SCT 35/29 A2944 (HUMIDEX 50)

WAVE HT: 0 SWELL: 0

1.8 Aid to Navigation

Nil.

1.9 Communications

At the time of occurrence the aircraft was operating within UHF range of HMCS CALGARY, the controlling ship. The crew did not initiate a distress call as they did not experience any unusual flight characteristics or associated problems.

1.10 Aerodrome Information

HMCS CALGARY is a HALIFAX Class frigate that is equipped with an after-end flight deck and hangar for one Sea King helicopter. HALIFAX Class frigates have a "Helicopter Hauldown and Rapid Securing Device" which is used to assist the aircraft during landing from the hover, to secure it to the flight deck post-landing, and to traverse the aircraft into the hangar.

HMCS CALGARY's SAC controlled the aircraft during the mission from just after take-off until just prior to landing. The SAC provides operational and tactical information to the helicopter and can conduct a ship-controlled approach, which is equivalent to a non-precision radar approach, to 100' and ½ nautical mile (NM) minima.

The Landing Signal Officer is a pilot who controls the helicopter for take-off and landing sequences.

Prior to helicopter operations, the ship must come to Flying Stations. FS ensure that the ship has met a minimum standard for damage control so that in the event of an emergency it can respond efficiently and effectively to protect not only aircrew, the flight deck crew, and the helicopter, but also the ship. In times of an aircraft emergency, the ship comes to Emergency Flying Stations. EFS is an increased damage control state above normal FS. This bolstered posture ensures that maximum safety and protection measures are in place before allowing an aircraft the use of the ship's flight deck.

1.11 Flight Recorders

The aircraft was not equipped with any onboard voice or flight data recording devices (CVR/FDR).

1.12 Wreckage and Impact Information

Nil.

1.13 Medical

Post-incident, the aircrew provided toxicology samples to HMCS CALGARY's medical staff. The ship's Physician's Assistant also conducted general physical examinations of the crew. Due to a miscommunication between the ship and the in-theatre Flight Surgeon based at Camp Mirage, the Flight Surgeon was led to believe that the blade damage was due to a ground-towing incident not involving the aircrew. Consequently, the aircrew toxicology samples were not processed under the supervision and control of the Flight Surgeon and, as a result, they were deemed to have been compromised and of no value.

Medical examination revealed no abnormalities with the exception of some vision blurring experienced by the co-pilot. The co-pilot's visual acuity was assessed and found to be within V1 vision criteria. The co-pilot reported post-incident that he felt that he might have been affected by heat stress.

Food intake by the aircrew was adequate and no alcohol had been consumed within the preceding 24 hours. Due to environmental conditions, dehydration was a concern and, therefore, all HELAIRDET personnel had a high rate of water intake. However, no electrolyte replacement beverages were used and no formal water intake guidelines or heat exposure limits were in force.

Sleep patterns for the aircrew were normal though the co-pilot indicated that he typically had six hours of sleep per night and a daytime nap that were generally of poor quality.

1.14 Fire, Explosives Devices, and Munitions

Nil.

1.15 Survival Aspects

Nil.

1.16 Test and Research Activities

Nil.

1.17 Organizational and Management Information

The HELAIRDET, comprised of aircrew and technicians from 443 Maritime Helicopter (MH) Squadron, Patricia Bay, BC, who were deployed on board HMCS CALGARY for Operation APOLLO in Southwest Asia.

1.18 Additional Information

Nil.

1.19 Useful or Effective Investigation Techniques

Due to the remote location from Canada, the reduced availability of military transportation, and the special authority required for in-theatre Technical Assistance Visits, the Flight Safety Investigation Team did not arrive on board HMCS CALGARY until 29 Aug 03. A Board of Inquiry and the Canadian Forces National Investigation Service also conducted separate and independent investigations.

2. ANALYSIS

2.1 General

Although the damage to both the aircraft and the ship was relatively minor, the potential for significant damage or even loss of aircraft and life was present. As no indications of mechanical failure were evident, the Flight Safety Investigation (FSI) Team focused primarily on human factors.

The FSI Team arrived on board HMCS CALGARY approximately one week post-incident and conducted interviews over a two-day period. The Canadian Forces (CF) National Investigative Service (NIS) had already completed its investigation by the time the FSI Team embarked. The NIS confiscated some original ship's documentation and debris that resulted from the blade strike - small pieces of fibreglass antenna and aluminum guardrail. Although the FSI Team had no requirement to perform materiel analysis of ship or helicopter components, there existed the potential to compromise the FSI due to the NIS' confiscation of evidence. It should be noted that a third investigation team, a Board of Inquiry, arrived on HMCS CALGARY as the FSI Team concluded its field portion of the investigation.

Subsequent informal discussions between the Air Force Provost Marshal and the Director of Flight Safety in 2005 indicated that definitive guidance in this matter remains to be established.

2.2 The Aircraft

The aircraft was conducting a rotor smoothing and VA maintenance test flight following a main rotor blade change and was returning to the ship for further maintenance when the occurrence took place. Although another VA run was required after on-deck adjustments, the out-of-tolerance vibrations had no effect on the handling characteristics or responsiveness of the flight control system. To put the out-of-tolerance vibrations in perspective, the damage to the two main rotor blades did not result in any adverse control responsiveness post-incident.

2.2.1 Vibration Analysis Procedures

VA procedures involve a pre-flight ground run to acquire baseline flat main rotor pitch data. If the subsequent in-flight data is out-of-tolerance, the aircraft lands, the main rotor is disengaged by shutting down the number two engine, pitch link adjustments to the rotor blades are made, the number two engine is restarted, the rotor is engaged, and the aircraft then re-launches for another VA run. The number of cycles required to achieve a serviceable VA can vary and cannot be predicted due to the dynamics of minor differences between rotor blades and their cumulative or combined effect upon one another.

2.3 The Aircrew

2.3.1 Aircrew Currency

The occurrence aircrew were current and qualified in accordance with all applicable requirements.

2.3.2 Aircrew Experience

The pilot was in his first tour and had approximately 1100 hours total. The co-pilot had a diverse background of both military and civilian flying. Although he had approximately 3600 hours total time, he had no previous MH experience. The TACCO, a Royal Navy exchange officer, had approximately 2300 hours primarily on Sea Kings. The AESOP, with 2700 hours mostly on Auroras, was also in his first MH tour.

When younger, junior personnel are in a position of authority and command over older, more experienced individuals, there exists the potential for the phenomenon of “role reversal” to occur. Role reversal, as defined by the Human Factors investigator from Defence Research and Development Canada (Toronto) (DRDC (T)), “occurs in the cockpit when the normal hierarchy of authority (i.e. the pilot in command, co-pilot, and other subordinates) is reversed when a subordinate crewmember is perceived by a superior crewmember to have more authority due to either age, experience, knowledge, or other potential factors. This may manifest itself in the superior crewmember being reluctant to challenge the subordinate crewmember's actions or in delays [of the superior] in assuming aircraft control in order to avoid creating cockpit tension or awkwardness.” When decisions or actions are required, role reversal may result in delays or inaction.

The co-pilot, who was in control of the aircraft, requested approval from the pilot to conduct the flypast. The co-pilot indicated only that he would fly down the starboard side and then conduct a left turn. Because the pilot trusted the judgement of the higher flight time co-pilot, there was no discussion with respect to height, speed, obstacle clearance minima, or the turn point; there was also no pilot intervention just prior to the blade strike. Because the pilot was respected for his knowledge of Sea King operations and effective utilization of his crew’s strengths and because the incident crew routinely discussed procedures and tactics together, this lack of discussion of the flypast profile was out of the crew’s character. Those ship’s company and HELAIRDET witnesses interviewed believed that no animosity or tension existed amongst the crew and that no member of the crew usurped the pilot’s authority. Therefore, the presence of role reversal within the cockpit could not be conclusively determined. Although the pre-conditions were present - the young pilot’s tacit acknowledgement of the older co-pilot’s age, greater time in service, and significantly more flying experience on multiple aircraft types – role reversal did not appear to affect the co-pilot’s flypast request to the extent where it was perceived as a statement of intent regardless of the pilot's comfort level. Rather, it was concluded that a lapse in crew resource management occurred in that no discussion occurred regarding the intended flight profile.

2.3.3 Aircrew Duty Day and Maintenance Activities

Duty time for the crew on the day of the incident was within designated limitations. The crew had assisted in a main rotor blade change earlier in the day of the occurrence flight.

A Sea King main rotor blade weighs approximately 200 pounds and is 30' long, requiring a crane or hoist for removal and installation. During removal and installation, numerous personnel are also needed to stabilize a suspended blade in order to avoid an inadvertent or uncontrolled swing that could result in injury or blade damage. Within the restricted and cramped confines of the ship's hangar, heavy maintenance, such as blade removal and installation, is generally conducted ashore or in harbour where the ship's motion is not a complicating factor. However, on the incident day the operational tempo required and a benign sea state permitted that the blade change be conducted while HMCS CALGARY remained at sea. The main rotor blade change was scheduled for 0800 on the day of the incident and, because the ship's manoeuvring was restricted during the blade change, it was necessary for all HELAIRDET personnel to assist in the completion of this maintenance in the confined hangar spaces as expeditiously as possible.

The HELAIRDET was a cohesive team. As such, it was not unusual for the aircrew to occasionally assist the technicians in order to reduce their workload and, in light of the difficult environmental conditions, to minimize their risk of heat injuries. The participation of the aircrew with the main rotor blade change at sea minimized the hazards of this maintenance procedure to all personnel.

During the blade change, detachment personnel required frequent rest and hydration breaks due to the extreme 45°C temperature in the top part of the hangar. Despite these breaks several personnel reported feeling fatigued due to the level of effort and concentration in the hot cramped workspace atop the helicopter.

After completing the blade change at approximately 1100, HELAIRDET work was stood down for lunch and also to prepare for an early afternoon ground run and test flight. The ship went to flying stations at 1307 to complete ground calibration checks prior to launch at 1353. The crew carried out the first airborne VA, which indicated that further ground adjustments and a subsequent airborne VA were necessary. During the second return to HMCS CALGARY the incident crew conducted the flypast that led to the blade strike at 1515.

2.3.4 Aircrew Medical Issues

2.3.4.1 General

All aircrew were deemed medically fit, though the co-pilot experienced a slight loss of visual acuity in his left eye. This deterioration was identified during his last annual medical examination prior to the incident; it was, however, at that time still within V1 category limits. The co-pilot also indicated that the vision in his left eye had deteriorated over the deployment, improving somewhat within two days post-incident. This slight vision impairment was not believed to have been contributory to this incident.

Given that the co-pilot felt that he was possibly affected by heat stress during the flight and also since one crewmember believed that cockpit resource management during the incident flight was impaired by exposure to high temperatures, it became relevant to explore the effects of high temperature on human performance and on MH operations.

2.3.4.2 Orders and Regulations Governing Flight Operations in High Temperature Environments

Currently there is little firm direction to guide aircrew and technicians in the performance of their duties in high temperature environments. Within an MH context, high temperature environments typically refer to the hangar, flight deck, and aircraft (both while airborne and on the flight deck). However, inclusion of the LSO's compartment on destroyers, frigates, and possibly supply ships must also be made. This is evident when looking at the recent unauthorized modifications made to LSO compartments by HELAIREDT personnel during Operation APOLLO. Due to insufficient air conditioning, both temporary and more permanent shields were constructed over the hardened glass roofs of LSO compartments in an effort to block the sun's radiation and thereby reduce the "greenhouse" effect. Considering that LSO's frequently work in the compartment for extended periods of time just prior to going flying, they can potentially be affected by heat stress even before entering the cockpit.

In order to determine what direction (relevant to this occurrence) is currently available, DAODs, CF Flying Orders, 1 Cdn Air Div Orders and 12 Wing Orders were reviewed.

Defence Administrative Order and Directive (DAOD) 5021-2 refers to heat stress as an "illness caused by a mix of excessive exposure to heat and physical exertion." It is often not apparent to the sufferer, but it is to others. "Loss of operational efficiency, both mental and physical, occurs under various degrees of heat stress. If heat stress is severe enough, it may lead to cramps, fatigue, exhaustion, disability and/or death." Though it identifies the issue of heat stress and some basics about how to prevent and handle it, the DAOD is not specific to air operations and does not provide direction on exposure limits, work/rest cycles, or water replacement rates.

B-GA-100-001/AA-000 Flying Orders (B-GA-100) does not refer to the exposure of personnel to high temperatures or operations in high temperature environments.

Concerning high temperature flight operations, 1 Canadian Air Division (Cdn Air Div) Orders Volume 2, Article 2-007, Paragraph 12 Climatic Conditions states only that "Restrictions to flying operations as a result of climatic conditions are to be promulgated by Wing Commanders."

12 Wing Orders Volume 5A-Operations, Article 5-080 Severe Weather/Environmental Operations, Paragraph 1 then identifies that "Flight operations under severe weather/environmental conditions shall be in accordance with CFP 100, aircraft AOIs [Aircraft Operating Instructions], Wing and Squadron orders, as applicable. In addition, all units whose personnel are required to work, flying or otherwise, under severe weather/environmental conditions shall ensure that all personnel are provided briefings on the effects of these conditions and the safety considerations involved." Paragraph 2 of Article 2-007 goes on to state "Supervisors must be familiar with the effects of heat and cold on both personnel and equipment, and be prepared to advise higher command on these matters." The guidance in this article is minimal in that it mandates some education for personnel. This guidance does not, however, provide direction for operations in severe environmental conditions that is based on objective clinical data.

Interestingly, the Aerospace Engineering Test Establishment (AETE) report titled "CH124 Cabin Ventilation and Temperature Survey – January 1972" concluded that Wet Bulb Globe Temperature (WBGT) values of 28.9°C or above indicate an unacceptable level of crew heat stress in the aircraft cabin. Additionally, the report also concluded that flight operations with cockpit windows and the cargo door open were unsatisfactory in providing temperature relief in that the induction of exhaust heat and fumes from the right engine via the cargo doorway created intolerable crew conditions. Use of the aircraft fan was also found to be unsatisfactory in providing relief from heat stress. The report concluded with the recommendation that an air conditioning system be installed. Currently Aircrew Order 04/04, dated 14 July 2004, recognizes that "aircraft ventilation is of crucial importance for aircrew safety in high ambient temperatures and several aircraft cooling ventilation options are currently being examined at the technical level to provide a more effective system." As a result, "the removal of the cargo door window is authorized as an interim measure to improve in-flight cabin ventilation." The Sea King remains one of very few non-air-conditioned aircraft in MH theatres of operation.

The FSI Team conducted additional research on the impact of hot environmental conditions on air operations. This research revealed the following information that could be used to formulate quantifiable direction on this subject:

a. Canadian Centre for Occupational Heath and Safety. The Canadian Centre for Occupational Heath and Safety (CCOHS) defines "heat stress" as “the net (overall) heat burden on the body from the combination of the body heat generated while working, environmental sources (air temperature, humidity, air movement, radiation from the sun or hot surfaces/sources) and clothing requirements.”

Personnel working in conditions involving high air temperatures, radiant heat sources (the flight deck or the aircraft cabin), high humidity, direct physical contact with hot objects (the flight deck), or strenuous physical activities (aircraft maintenance) have a high potential for inducing heat stress. Work that requires personnel to wear semi-permeable or impermeable protective clothing, such as dual layer flight clothing and aircrew life support equipment or personal protective equipment, is also likely to cause heat stress without strict adherence to precautionary measures.

In hot and humid environments, the cooling of the body due to sweat evaporation is limited by the capacity of the ambient air to accept additional moisture. When the air temperature or humidity rises above the optimal range for comfort, problems can arise. The initial effects are subjective in nature and relate to how a person feels. Exposure to continued heat stress will manifest itself in reduced performance of skilled sensorimotor, mental, or vigilance jobs as the result of fatigue, impaired efficiency, judgement, and co-ordination. At the early stage, there is no treatment except to remove the heat stress before a more serious heat-related condition, such as heat exhaustion or heat stroke develops.

Some of the problems personnel encounter and the symptoms they experience between comfortable limits (20°C-27°C) and the highest tolerable limits are summarized below in Table 2: Symptoms and Problems Caused by High Temperatures.

Table 2: Symptoms and Problems Caused by High Temperatures

Temperature Range (°C)	Effects	
20-27	Comfort Zone	Maximum Efficiency
As temperature increases...	Discomfort: -Increased irritability -Loss of concentration -Loss of efficiency in mental tasks	Mental Problems
	Increase of errors: -Loss of efficiency in skilled tasks -More incidents	Psycho-physiological problems
	Loss of performance of heavy work: -Disturbed water and electrolyte balance -Heavy load on heart and circulation -Fatigue and threat of exhaustion	Physiological problems
35-40	Limit of high temperature tolerance	

In moderately hot environments, the body rids excess heat so it can maintain its normal temperature. The heart rate increases to pump more blood through outer body parts and skin so that excess heat is lost to the environment and sweating occurs. Changes in blood flow and excessive sweating reduce a person's ability to do physical and mental work. Manual work produces additional metabolic heat and adds to the body's heat burden. When the environmental temperature rises above 30°C, it may interfere with the performance of mental tasks. By not recognizing these early symptoms of heat stress and responding to them, a person's physical condition can quickly deteriorate further, eventually succumbing to the effects of the more serious conditions of heat exhaustion and heat stroke.

b. Canadian Forces General Safety Orders and Medical Service Instruction CF 8000-114. In Chapter 39 of C-02-040-009/AG-001 Canadian Forces General Safety Orders (GSO), the Directorate of General Safety provides guidance for occupational exposure to sunlight, as per Treasury Board Safety Advisory 6-05, and prescribes its implementation within DND and the CF based upon the Canada Labour Code Part II. Although this standard does not apply to military operational activities or equipment such as ships, combat vehicles, aircraft, and equipment of special design used in direct support of these or other specialized military applications, it is pertinent to identify this GSO to enhance supervisory awareness of existing direction for personnel operating in high temperature environments. Medical Service Instruction (MSI) CF 8000-114 Physical Hazards Surveillance Program, still in draft form, has superseded Canadian Forces Medical Order 40-02 Heat Stress. However, MSI CF 8000-114 details that exceptions may be made from adherence to specific health and safety standards. When exceptions are made, not only shall a Commander employ recognized risk management practices to determine an appropriate course of action, but also a Commander must be prepared to justify the decision. MSI CF 8000-114 instructs that "Consideration must also be given to possible performance decrements in personnel engaged in more sedentary but critical tasks, e.g., flying….While it might not be possible to curtail essential operational activities to a great extent, the potential adverse effects of heat strain on operational efficiency and safety must be taken into account." Therefore, it would be prudent, though not currently mandated, for a similar decision process to occur when subjecting aircrew and technicians to environmental conditions beyond the threshold limit values identified within both the GSO and the MSI CF 8000-114.

The threshold limit values (TLV's) from the GSO identified in Table 3: General TLV's for Personnel Exposed to High Temperature Environments, indicate the activity schedule for various work loads in WBGT conditions for acclimatized personnel.

Table 3: General TLV's for Personnel Exposed to High Temperature Environments

Hourly Activity	**Workload in Temperature Conditions (WBGT°C)**		
	Light	Moderate	Heavy
100% Work	29.5	27.5	26.0
75% Work 25% Rest	30.5	28.5	27.5
50% Work 50% Rest	31.5	29.5	28.5
25% Work 75% Rest	32.5	31.0	30.0

Note: These TLV's assume that acclimatized personnel work an eight-hour day, five days per week, and are dressed in a light permeable summer work uniform. It is, therefore, logical to expect that modification of this TLV schedule is needed to reflect the increased demands placed on personnel by an operational environment where flight operations can occur for 12 hours per day for extended periods of time and in attire specific to either aircrew or technician personnel.

In high temperature conditions, light permeable clothing is essential for the body's dissipation of heat. Thermally insulating clothing, on the other hand, forms an evaporative barrier that severely restricts sweating, the primary and most effective bodily heat removal process. As a result, a corrective WBGT factor must be applied to TLV's when heavy, restrictive clothing is worn.

Working models for TLV's applicable to both aircrew and technicians were constructed from the above data and are presented in Annex B: TLV Models for MH Aircrew and Technicians.

The WBGT Index has been selected by the Canadian Forces Advisory Group on the Operational Effectiveness of Personnel as the one measurement to be used in describing physiological environments for the Canadian Forces, and it shall be employed to express environmental heat stress. Medical personnel, not Meteorological Technicians or Safety personnel are responsible for advising Commanders concerning physical activity levels in hot environments. Recommendations to Commanders to prevent heat injuries are to be based on the WBGT and not on the HUMIDEX.

MSI CF-8000-114 refers to the CCOHS when defining HUMIDEX: "Humidex is an equivalent temperature intended for the general public [as informed by Environment Canada] to express the combined effects of warm temperatures and humidity. It provides a number that describes how hot people feel, much in the same way the equivalent 'wind chill factor' describes how cold people feel. Humidex is used as a measure of discomfort that results from the combined effect of excessive humidity and high temperature." HUMIDEX is not applicable as an occupational TLV, so it is not to be applied in lieu of the WBGT for CF members. However, it could be used as a guide that provides qualitative information concerning personnel comfort levels within the work environment. This information is presented in TABLE 4: Environment Canada HUMIDEX Range.

Table 4: Environment Canada HUMIDEX Range

HUMIDEX Range (°C)	Degree of Comfort
20-29	Comfortable
30-39	Some Discomfort
40-45	Great Discomfort; avoid exertion
46-53	Dangerous
54+	Heat Stroke Imminent

From this table it can be seen that the 50°C HUMIDEX environment experienced by HMCS CALGARY HELAIRDET personnel on the day of the incident can be qualified as "dangerous."

c. <u>Heat Stress Directive.</u> A thermal physiologist from DRDC (T) authored the Area Support Unit (Toronto) Heat Stress Directive that has identified body fluid replacement rates. These fluid replacement rates were derived from research conducted by the United States Army

Research Institute for Environmental Medicine and are indicated in Table 5: Water Replacement Rates in High Temperature Environments. Though requiring clinical adaptation to the specifics of MH personnel and their operational environment, this body fluid replenishment data indicates that research is available for use in constructing formal hydration policy and direction, something that was not in effect at the time of this incident. At the time of incident on HMCS CALGARY, no electrolyte replacement beverages were required and no formal water intake guidelines or heat exposure limits were in force.

Table 5: Water Replacement Rates in High Temperature Environments

	Light		**Moderate**		**Heavy**	
Heat Category (temperatures in °C)	**Hourly Activity**	**H_2O Intake Litres/Hour** (L/H)	**Hourly Activity**	**H_2O Intake** (L/h)	**Hourly Activity**	**H_20 Intake** (L/h)
1 (25.5)	100% Work	0.5	100% Work	0.75	67 % Work 33% Rest	0.75
2 (27.8)	100% Work	0.5	83% Work 17% Rest	0.75	50% Work 50% Rest	1.0
3 (29.4)	100% Work	0.75	67% Work 33% Rest	0.75	50% Work 50% Rest	1.0
4 (31.1)	100% Work	0.75	50% Work 50% Rest	0.75	33% Work 67% Rest	1.0
5 (> 32.2)	83% Work 17% Rest	1.0	33% Work 67% Rest	1.0	17% Work 83% Rest	1.0

Application of Table 1 from Annex B to the above fluid replacement data in Table 5 results in an approximate fluid replacement/TLV model for MH Aircrew that can be found in Annex C: Water Replacement Rates and TLV's for MH Aircrew Exposed to High Temperature Environments.

d. <u>Advisory Publication 61/115/24.</u> Advisory Publication 61/115/24 Maintenance of Operational Fitness in Hot Air Environments specifically focuses on the roles of military personnel in high temperature environments. The Air Standardization Coordinating Committee, to which the Canadian Forces, the United States Air Force and Navy, the Royal Air

Force, the Royal Australian Air Force, and the Royal New Zealand Air Force are signatories, published this document. One key point that is made with respect to the effect of heat stress in flying operations is that the most extreme heat exposure occurs in closed spaces which involve a combination of radiant heating and poor ventilation, both of which are found in the Sea King helicopter. The effects of heat stress on performance are many. Mental performance may be impaired without self-awareness of the problem. A slowing of routine tasks and decision making can occur as can mechanical mistakes such as the hand-eye coordination required of flying. Under hot conditions, a person who says that they feel well can still make excessive errors. Problems in one person are often indicative of impending trouble for an entire group. Sleep deprivation also reduces heat tolerance and heat stress interferes with sleep. As the co-pilot noted, he thought that he may have been affected by heat stress and he had been sleeping poorly throughout the deployment. When looking at what sort of tasks are most affected, monotonous, repetitive, or boring tasks top the list; although slightly different in profile, the VA test flight was similar to most surface surveillance missions flown in-theatre.

Advisory Publication 61/115/24 goes on to identify several special aircrew considerations. Most importantly, "even moderate heat stress can impair aircrew performance enough to tip the balance toward mission failure or even loss of an aircraft. Aircrews must be protected from pre-flight heat stress and physical exertion." Aircrew participation in the blade change maintenance precluded adequate protection from pre-flight heat stress and physical exertion.

Finally, "Commanders must provide for constant monitoring of personnel performance and adherence to preventative measures…Staff and command responsibilities are to educate and enforce measures." Although there was an awareness of the danger of excessive heat exposure and the subsequent requirement to remain well hydrated, as indicated during discussion with senior personnel at both operational MH squadrons in late 2003, there were no formal re-hydration or work/rest schedules in force in and around the time of incident; education was evident yet enforcement was not.

e. <u>Cooling Options for Shipboard Personnel Operating in Hot Environments.</u> This DRDC (T) published report provides information and guidance about the use of cooling vests for shipboard personnel exposed to hot environments. The report discusses different options of keeping personnel exposed to the extreme temperatures experienced in Gulf of Arabia-like climates, one of which is the "Steele Vest" that is in use with the United States Navy. Studies have shown that this cooling vest can "effectively double tolerance times during light exercise in hot environments (in excess of 40°C)." Although the report deals specifically with shipboard personnel involved in upper deck, boarding party, boiler room, or hangar fire fighter work, it should indicate that CF research facilities are currently capable of addressing the issue of extreme temperature operations in an air operations context.

The report makes the important point that, at about 35°C, ambient air temperatures can exceed skin temperatures and therefore convective heat loss no longer becomes possible. Recall that the HELAIRDET experienced 35°C temperatures for the entire duration of maintenance and the test flight. "In fact, radiative and convective heat transfer would be directed towards the body and would represent a source of heat gain. As a result, the only avenue for heat dissipation in these environments is through the evaporation of sweat at the skin surface and through respiration. Depending on the clothing that is worn and the rate of heat production that will vary with activity it is quite possible that the evaporative heat loss required to maintain a thermal steady-state can exceed the maximal evaporative capacity of the environment. In these uncompensable heat stress situations, the body constantly stores heat. This results in body temperature continuing to increase until exhaustion and collapse occurs…" Thus it can be seen that the HELAIRDET faced significant environmental stress during the blade change. With significantly restrictive clothing preventing evaporative heat dissipation during the entire test flight process, the aircrew were likely affected more than the technicians.

2.3.4.3 Environmental Effects Acting on the Incident Aircrew's Performance

The detachment had been in-theatre for approximately two months. As a result of a hot weather briefing, all personnel were cognizant of the adverse effects of heat and the importance of preventing heat exhaustion by maintaining fluid intake and minimizing physical activity outside of air-conditioned spaces; however, no guidelines were documented directing maximum exposure limits, minimum rest periods, or water replacement rates. According to HMCS CALGARY's Physician's Assistant, approximately half the ship's company were acclimatized, with the aircrew better than most; this was logical to expect given that HELAIRDET operations take place outside of the air-conditioned spaces of the ship. All HELAIRDET personnel believed that they took appropriate measures throughout the day to avoid becoming dehydrated or physically fatigued. Yet as the incident workday turned out to be somewhat longer than planned, some personnel felt that by mid-afternoon they were no longer at their peak performance.

Although the incident crew was within the duty period and they had received adequate rest the night before the incident, they were subjected to extended periods of exposure to extreme heat during both the morning's blade change and the afternoon's test flight. The actual time spent in the cockpit by the aircrew prior to the blade strike was not abnormal, but a large portion of it was spent disengaged on the deck waiting for pitch link adjustments to be completed. With poor ventilation, no air-conditioning, the hot main transmission gearbox located just above the crew positions, and the inherent “greenhouse effect” acting on the aircraft, cockpit temperatures were higher than the ambient air temperature and created an environment more uncomfortable and fatiguing than when airborne. In addition, with dual layer clothing protection and aircrew life support equipment worn, the capability for the aircrew to regulate their body temperatures was further limited. The 35°C ambient temperature around the time of incident combined with the humidity to create an equivalent 50°C HUMIDEX value that is defined in Table 3 as a “dangerous” degree of discomfort. It is interesting to note that aircraft outside air temperature gauge readings of 50°C (the maximum limit for the gauge) and HUMIDEX temperatures of up to 62°C have been previously recorded by other HELAIRDETS. Although cooling vests were available for use, they were only authorized for use when worn with NBC protective clothing, which the crew was not wearing.

Even though preventative measures to deal with the heat were taken by the crewmembers, once the ambient air temperature inside the cockpit approached the internal body temperatures of the crewmembers, without proper air circulation the simple process of sweating no longer became adequate to cool their bodies. At this point extended exposure to the high temperatures resulted in increased internal body temperature. Related to this temperature increase was reported degradation of alertness and mental capacity.

As discussed above, given the pre-flight blade change activities and the environmental conditions, it was possible for degraded cognitive ability and performance to have affected the aircrew without anyone noticing it. In acknowledging post-incident that he felt that he might have been affected by heat stress during the flight, the co-pilot confirms that he most probably was affected by heat stress and the associated hazards. Unfortunately, the delay in medical assessment prevented a definitive clinical assessment of all the crewmembers’ physical dispositions. From a clinical standpoint the co-pilot’s swift and precise reaction to the blade strike seemed to contradict the notion that heat stress affected his ability to control the aircraft. However, individuals react differently and will exhibit varying degrees of the signs and symptoms of any given condition such as, in this case, heat stress. The FSI human factors expert, from DRDC (T), concluded that the morning’s physical activity and the constant exposure to high temperatures resulted in some degradation of aircrew performance. This is further supported by a crewmember who indicated that cockpit resource management was impaired due to the lengthy exposure to the high HUMIDEX values. Though this loss of performance was not to the extent that the crew became incapacitated, it was likely present to the extent that a “dragged out” feeling existed where simple tasks became a chore, mental awareness and the ability to anticipate was not at full capacity, minor errors were either accepted or left un-corrected, and the communication flow between crew members reduced. As noted in Section 2.3.4.2 d., this effect can be compounded when coupled with, as the co-pilot reported, routinely poor quality sleep. Because a VA and rotor smoothing test flight can vary significantly in duration, the crew should have carefully considered the potential length of the mission and avoided the morning's physical activity. Though this would have increased the workload for the other detachment personnel, the aircrew would have been better prepared to deal with the afternoon's flight in challenging environmental conditions.

2.3.4.4 Summary to Aircrew Medical Issues

The preceding discussion highlights the fact that there is currently very limited direction on how heat stress is to be addressed for flying operations. However, there is a great deal of information available on this subject and consideration should be given to applying occupational health and safety standards for threshold limit values, work/rest cycles and water replacement rates to MH and other Air Force operations. It is recognized that the unique demands required of operational units precludes the unmodified application of those current health and safety threshold limit values and exposure limits. However, it is important to note that these health and safety limits are enforced on jobs and functions within the CF. Additionally, there is sufficient data to adapt these health and safety limits specifically to MH operations and to CF air operations in general. Finally, there are also commercial cooling vest technologies that may be readily adaptable to MH operations. As this incident demonstrates, there is a need for these types of guidelines to be in place and enforced and there is also a need for cooling aircrew (technician) life support equipment to be introduced in order to better enable HELAIRDETS to operate safely in high temperature environments while minimizing exposure to unnecessary risk.

2.4 The Incident Flypast

Though not on approach to land, the helicopter was closing the ship from astern in anticipation of receiving clearance to land when the crew was informed by the SAC of a two to three minute delay in coming to Flying Stations. The crew elected to remain above safe single engine speed, thus minimizing time spent in the hover and, therefore, they did not enter the Delta Hover Astern until HMCS CALGARY was closed up at FS. The co-pilot, flying the aircraft from the left seat, intended to pass along the ship's starboard side and execute a wide left turn to reposition astern of HMCS CALGARY in anticipation of receiving landing clearance from the LSO. It should be noted that the sun, which was behind the aircraft, created no adverse lighting effects. Because the ship's starboard side was completely illuminated, the pilots' views were unaffected by contrast, shadow, or brightness.

The aircraft approached the ship's starboard quarter (5 o'clock position) on a slightly converging course. As the aircraft approached the stern at 60-80 knots and 40' ASL, it turned slightly right to parallel the ship's track, about 70' abeam.

Although the co-pilot had never before conducted such a close flypast, there was no discussion amongst the pilots or crew about the intended profile except that the co-pilot would fly down the starboard side and execute a left turn ahead of the ship. When the co-pilot initiated the turn approximately abeam the bridge, the pilot believed it to be early, though with sufficient clearance. Although witness accounts were inconclusive, the most likely flight profile was that of a 20° left climbing turn in front of the bridge. Approximately 30°-40° through the turn, the main rotor blades struck the guardrail and VHF antenna.

The damaged railing (Photo 3) indicates a cut angle of approximately 20°, which approximates the bank angle plus or minus blade coning and flapping angles. Based on a 20°bank angle and a 31' blade length, the blade tips struck the guardrail at approximately 42' above the water line; the fuselage was approximately 10' higher at 50' ASL.

The ship's speed of 20 knots and the helicopter's speed of about 70 knots resulted in a closing speed of 50 knots as the aircraft passed along the ship's side. The co-pilot perceived the 50-knot overtake and expected that the turn track would be safely ahead of the ship. When the left turn was initiated, the relative overtake speed immediately began to diminish due to heading and track change. 40° through the turn, the relative speed differential had decreased by about 20 knots and resulted in the actual flight path being closer than the co-pilot expected. Because the aircraft was already very close to the ship, there was insufficient time for either pilot to assess or react to the rapid and dynamic relative speed reduction as the turn progressed.

As the co-pilot had previously conducted only one foc'sle hoist transfer, to a Maritime Coastal Defence Vessel during the year prior to the deployment, he likely did not fully understand the significance of the ship's motion while executing a turn from a close-in parallel course to a perpendicular course that crossed the ship's bow. There was no evidence to suggest that the co-pilot intended to fly as close to the ship as he actually did. Given that he was completely surprised by the subsequent rotor impact, it was concluded that the co-pilot was not adequately aware of how close the tip path plane actually was to the ship. The co-pilot's error was therefore one of inaccurately assessing the aircraft/ship closure rate and the clearance between the two. Additionally, based on the lack of operational requirement to conduct the flypast manoeuvre, it is evident that the pilot's and co-pilot's decision to conduct the flypast was poor. Therefore, it was necessary to examine not only why the co-pilot's error in perception occurred (Section 2.5), but also how cultural influences of the Maritime Helicopter community contributed to the flypast (Section 2.6).

2.5 Relative Motion

Relative motion occurs with the movement of one object in relation to another. For aircrew, most relative motion occurs between aircraft and fixed objects on the ground and is identified by a specific object's change of bearing relative to the aircraft. Relative motion of moving objects, such as another aircraft on a potential collision course, is something that pilots experience and compensate for. As a fixed or constant relative bearing (no apparent motion) ultimately results in a collision, it is essential to initiate speed or track adjustments to create a relative opening or closing in order to allow the other aircraft to pass clear.

Relative velocity between an aircraft and ship exists whether or not the ship is underway. There is a tendency for inexperienced MH pilots to overlook even minimal ship movement particularly when the helicopter is moving at 100 knots or more and the ship is moving at slow or medium speeds. Because the pilot assumes the ship to be stationary, he flies a track, adjusted for wind drift, directly towards it. When the ship begins to open bearing and, if the aircraft track is not adjusted, the helicopter ends up behind the ship. With experience, pilots adapt and learn to "lead" the ship based on the distance to close and the ship's speed. With greater experience the judgement of lead distance improves and results in fewer or no track adjustments.

Any change in speed or track of either the aircraft or the ship immediately changes the dynamics of relative motion and must be compensated for by the pilot. The greater the distance between the helicopter and the ship, the easier it becomes to assess relative motion and make appropriate adjustments. If too close, there may be insufficient time or distance to assess closure rates and angle changes. A pilot's skill in assessing relative motion and determining its impact on flight path is developed through deck landing and deck evolution training, both of which are structured within the MH Captain Category Upgrade Program (CUP).

Because the co-pilot was still in the process of completing his CUP, he had not yet mastered all the various evolutions that involve operations within close proximity to the ship. As a result, the co-pilot likely had not yet gained total appreciation for the resultant relative motion between the ship and the helicopter or the lead required to compensate for the ship's velocity relative to the helicopter. Due to the helicopter's proximity to the ship, there was essentially no time for either the co-pilot or pilot to react to and rectify any errors in the co-pilot's perception of ship/helicopter spacing or flight path across the ship's bow. Regardless, the conduct of the flypast, at 60-80 Kts, 40' ASL, and 70' (about one rotor length) abeam HMCS CALGARY, was not consistent with the broad scope of authorized flight deck evolutions that are taught and trained for within the MH community.

2.6 The Culture of Low-Level Operations and Flypasts Regulations

2.6.1 Low-Level Operations

The primary roles of the Sea King include anti-submarine warfare, anti-surface warfare, surface surveillance, and search and rescue. In addition to these operational MH roles, there are several additional tasks that require Sea King crews to operate at low-level over the water and in close proximity to vessels. These include but may not be limited to take-offs, approaches, landings, and the following:

a. hoist transfers;

b. vertical replenishment;

c. helicopter in-flight refuelling;

d. naval boarding party support;

e. vessel reconnaissance and identification; and

f. photo intelligence gathering.

After 42 years of conducting these maritime operations from Her Majesty's Canadian Ships, Sea King crews have become adept at and conditioned to operating at very low levels and in close proximity to ships. Emphasizing how routine low-level operations are for MH crews, it should be noted that they can operate almost exclusively, often for weeks on end and during night and in instrument flying conditions, between 40'-150' ASL. This repetitive and common flight profile has therefore conditioned MH aircrew such that operating at these very low levels has generally become second nature. Hazards to operating in this low level environment include familiarity, complacency, and over-confidence; these human factors are well documented and can unwittingly and negatively affect crew performance while they operate in close proximity to the surface.

2.6.2 Flypasts

MH aircrew have become conditioned to operating in close proximity to ships, as several of the required manoeuvres, such as takeoffs and landings, bring the main rotor tip path plane to within 15' of the ships superstructure while hovering 15' over a rolling and pitching deck.

Familiarity with low-level operations, combined with the comfort of routine operations in close proximity to ships, has in the past facilitated aircrew to becoming habituated or conditioned to flying past the ship at low-levels. This culture of low flying, although not intended to be reckless, has persisted within the MH community for many years. However, as advances in crew resource management and particularly risk management have been made during the mid- to late 1990's, this behaviour has diminished. The MH community, including the Navy, does not tolerate reckless flight discipline.

Undoubtedly this blade strike incident has served as a strong reminder to the Air Force that low flying is a hazardous endeavour, even more so when it is un-authorized or not required to meet the goals of any given mission. In today's MH community, leadership has made it very clear that un-authorized low flying will not be tolerated. However, advances must continue to be made so that these attitudes and lessons learned do not disappear as corporate memory fades.

2.6.3 The Incident Crew's Culture

Discussion between the DRDC(T) Human Factors Investigator and both detachment personnel and ship's company indicated that occasional flypasts of the ship was a common occurrence onboard HMCS CALGARY, though not to the extent that it was a daily or every flight occurrence. This was further supported during interviews between the FSI Investigator in Charge and members of the HELAIRDET flight crews. Onboard HMCS CALGARY no particular dislike for the conduct of flypasts was ever indicated and, in many cases, flypasts were seen as a means to bring the Air Force and Navy elements of the crew together, boosting morale. The fact that neither the co-pilot nor the pilot appeared to other crewmembers to be risk-takers or pilots who would push the limits to impress or show off to others, that there were no leadership or personality conflicts between the crewmembers, and that effective co-ordination within the incident crew was known by other HMCS CALGARY personnel to exist, it was considered to be too out of the pilots' character to believe that a reckless or endangering attitude lead to the main rotor blade strike.

It was concluded that the pilots' decision to allow the co-pilot to conduct the flypast was facilitated by the pilots' familiarity with low-level operations in close proximity to a ship and the routine nature of the flypast itself. The hazards and risks associated with conducting a flypast had become muted by its routine occurrence, as reinforced by the pilot's tacit acceptance of the co-pilot's intent to conduct the flypast without so much as even a discussion about how to conduct it safely.

2.7 Regulations Governing Sea King Low-Level Flight Operations

2.7.1 General

Under the DND and CF airworthiness program, the delegated airworthiness authorities develop rules and standards to regulate, amongst other things, the operation of CF aircraft. Given the occurrence crew's reputation as a professional team that respected the regulations, the decision to conduct what appeared to be an unauthorized flypast of the ship merited further investigation. The FSI Team, at the request of the Airworthiness Investigative Authority, therefore reviewed the applicable orders governing the situation to ensure that they were clear, consistent, practical and well understood within the MH community.

Prior to reviewing the orders, the Sea King operating environment, which is unique in the CF, must be outlined. In the CF, Sea King Maritime Helicopters are authorized to conduct overwater low flying training and operations down to 40 ft ASL for manoeuvring (1 Cdn Air Div Orders, Vol 2, 2-002). These operating altitudes are dictated by several factors including weather conditions, lighting conditions (day or night), tactical considerations and airspace de-confliction requirements with other maritime aircraft assets.

2.7.2 B-GA-100-001/AA-000 Flying Orders

Book 1, Chapter 5, Paragraph 1 of the B-GA-100 states that rotary wing aircraft shall not be flown below 500’ above ground level (AGL) or over water except when taking off, making an approach to land, or landing at an aerodrome; when low flying is authorized for prescribed low flying areas or cross-country routes; when the Commander 1 Cdn Air Div has so designated for “operational or operational training flights;” when required by deteriorating weather to maintain vertical separation from cloud while initiating alternative action; or when special VFR (SVFR) is authorized. The B-GA-100 defines an operational flight as “a military aircraft mission or task in support of operations” whereas an operational training flight is defined as “a military aircraft training mission or task that develops, maintains or improves the operational readiness of individuals or units.” For the purposes of this report, flights that do not meet the definition of either an operational or operational training flight will be collectively referred to as a “non-operational flight.” In the MH context examples of non-operational flights *could* include passenger transfers, materiel supply flights, mail delivery flights, familiarization flights, and photo flights (such as for media, public relations, or otherwise).

The B-GA-100 indicates that on non-operational flights an aircraft shall not be flown lower than 50’ over all obstacles within 200’ of the aircraft’s track when authorized for a low flying exercise over a prescribed low flying area.

The B-GA-100 indicates that for occasions which MH aircraft are required to fly down to 1 Cdn Air Div Orders minima for operational and operational flying training, it may only be done so only in areas specifically authorized for such flights by the Commander 1 Cdn Air Div.

2.7.3 1 Canadian Air Division Orders

1 Cdn Air Div Orders supplement those orders found in the B-GA-100 for specific occasions when diversions from B-GA-100 limits, restrictions, and procedures are required. Therefore it follows that 1 Cdn Air Div Orders also define an operational flight and an operational training flight as indicated in the B-GA-100. When an exception to B-GA-100 orders is made in that the Commander 1 Cdn Air Div has so designated for "*operational or operational training flights,*" these orders authorize maritime aircraft to conduct "overwater low flying training and operations" in accordance with the minima indicated in Volume 2, Order 2-002, Section 5, Paragraph 42, Table 3: Minimum Altitudes for Overwater Flights. MH crews are authorized during day VFR operations to manoeuvre down to 40' ASL and to hover down to 10' ASL and during instrument or night operations to manoeuvre down to 150' ASL and to hover down to 40' ASL (with a serviceable radar altimeter and a radar altimeter warning system) during operational or operational training flights such as anti-submarine warfare or anti-surface warfare. The published height limitations in Table 3 do not include obstacle clearance distances from maritime obstacles (ships, oil rigs, lighthouses, merchant vessels, and other maritime hazards) and do not apply to non-operational flights.

2.7.4 Fleet Operational Flight Procedures (FLOPS)

FLOPS are found in Annex A to Shipborne Helicopter Operating Procedures (SHOPS). SHOPS are promulgated by both the Commander 1 Cdn Air Div and the Commander Maritime Command "for the direction of all Maritime Command and Maritime Air Component units responsible for, or involved with the operation of aircraft at sea." SHOPS and, therefore, FLOPS are "intended to supplement the Canadian Forces Flying Orders [the B-GA-100] and Maritime Command Orders." By inclusion of the term "operational" in its very name, it would appear that FLOPS apply only to "operational" flights, though within the document no such distinction is made.

FLOPS Chapter 3 identify the minimum weather requirements for VFR operations at sea to be a ceiling of 300' ASL and flight visibility of 2 NM. FLOPS defines the aerial control zone about a warship to be from the surface to 500' ASL and out to one half nautical mile. Within this zone, the SAC facilitates aircraft movement and aircraft/ship separation. The SAC also ensures that a ship's radar hazard controls are in place prior to allowing an aircraft to close. Often, in order to de-conflict aircraft traffic with not only other warships but also the mother ship's evolutions, it is necessary for the SAC to give MH aircraft height restrictions within the control zone. When deployed with a task group, it is not unusual for height restrictions as low as 300’ to be imposed on helicopters for mutual aircraft de-confliction.

2.7.5 Summary of Regulations Governing Sea King Low-Level Flight Operations

The review of the applicable regulations revealed a number of issues. First of all, the orders are not clear. One of the key points that govern the minimum altitude that can be flown is whether the flight is operational or non-operational. After discussions with several aircrew members, it became obvious that two schools of thought exist. The first school of thought is that this test flight was a non-operational mission. The rationale was that the aircraft was designated “non-mission capable,” as indicated in Section 1.6, and the maintenance test flight was not a mission or task in support of operations but rather a mission that could have returned the aircraft to a mission capable status. The second school of thought was that the mission was an operational flight because it was flown in a theatre of operations and there was a pressing requirement to return the aircraft to full mission capable status. In addition, there was a plausible scenario that even though the aircraft was on a maintenance test flight, it could have been tasked for an operational mission while it was airborne.

Had the mission been a non-operational flight, the minimum height would have been 500' unless the Commander 1 Cdn Air Div had specifically designated all or part of the theatre as a designated low flying area. In this latter case, flight down to 50' above all obstacles within 200' of track would have been possible if the flight had been specifically authorized to conduct low flying training. Had the mission been an operational flight, the minimum manoeuvring height would have been 40' under the conditions present at the time of the incident. (As it was, the crew of the incident flight were of the opinion that they were on an operational flight). The fact that the same order can be interpreted in two very different ways highlights the lack of clarity of these orders.

A second aspect of this problem concerns designation of airspace by Comd 1 Cdn Air Div. An operational training flight, such as a Crew Operational Readiness Exercise, within the Shearwater or Victoria operations areas, for example, is a clear example of when MH aircraft are authorized to fly down to 1 Cdn Air Div Orders minima. However, when conducting embarked flying outside of a theatre of operations or a formal exercise training area, such as in transit mid-Atlantic, it is not clear whether or not the Commander 1 Cdn Air Div specifically designates an area where the 1 Cdn Air Div Orders minima can be applied for operational training flights.

The second issue identified in this review was that the orders are not consistent. FLOPS weather minima allow VFR flights at sea with ceilings down to 300' AGL. This is inconsistent with the B-GA-100 in that flight below 500’ ASL is required, yet these flights are not identified as exceptions listed within the B-GA-100. In addition, SAC issued height restrictions to non operational flights within a ship's control zone that are below 500' would also be inconsistent with the B-GA-100 unless the aircraft was in the process of taking-off, approaching to land, or landing. Finally, the 1 Cdn Air Div Orders do not include obstacle clearance guidelines for MH operations.

The third issue is that some regulations governing MH operations are not practical. As mentioned earlier, virtually all CH-124 flights at sea are conducted between 40' - 150' ft ASL. In accordance with current orders, Comd 1 Cdn Air Div would have to specifically designate all at sea CH-124 operating areas (including training areas used while ships are in transit) as areas where the 1 Cdn Air Div Orders minima can be applied. If it is assumed that all flights at sea are either operational or operational training flights then Sea King crews are operating in accordance with the regulations. However, as outlined above, it is not clear that all at sea sorties are either operational or operational training missions. If there are missions that do not fall into these two categories, then, they should be conducted above 500' ASL. In many cases, this could not be done practically or safely due to conflicts with other maritime traffic.

Finally, it would appear that the current regulations are not well understood. This conclusion was reinforced by the findings of an informal, post-incident survey of 15 Maritime Helicopter Crew Commanders. The majority of the crew commanders were of the opinion that all embarked flights were either operational or operational training flights. Then, when asked to define the height minima applicable to these operational flights, only one correct and eight partially correct answers were provided. Given the previously mentioned problems, this confusion is understandable.

This discussion serves to highlight that the B-GA-100 Flying Orders, 1 Canadian Air Division Orders, and Fleet Operational Flight Procedures relevant to this situation are not clear, consistent, practical, or well understood. A review of the applicable regulations is therefore required to ensure that MH crews are provided clear and easily understood orders and regulations that will allow them to train and operate in a safe and effective manner.

2.8 Conclusion to Analysis

It is evident that the decision to conduct the flypast was based on poor judgement. However, it must be recalled that the incident crew was part of a HELAIRDET for which ship flypasts were routine and also that this attitude towards flypasts had been previously present within the MH community. The morning’s maintenance activities in difficult environmental conditions contributed to some degradation of the co-pilot’s cognitive abilities; the co-pilot felt that he suffered from some degree of heat stress while a crewmember reported that crew resource management had degraded.

Once the decision to conduct the flypast was made, it was not well planned. The morning’s maintenance and the afternoon’s extended period on-deck, both in extreme temperatures, contributed to fatiguing the pilots such that their performance, intra-cockpit communications, and decision-making were affected. The competent and respected crew normally worked well together and thus it was out of character for them to not have discussed the flypast profile that the co-pilot, who had never before flown one, decided to conduct.

Not only was the flypast not well planned, but it was also not accurately flown. It was concluded that the aircraft struck HMCS CALGARY as the result of the co-pilot's error in perception or assessment of the clearance between the aircraft and the ship. This error was perhaps partially due to an incomplete appreciation of the resultant relative motions between the two. Due to the helicopter's proximity to the ship, there was essentially no time for either the co-pilot or pilot to react to and rectify any errors in the co-pilot's perception of ship/helicopter spacing or the flight path across HMCS CALGARY's bow.

Because of its impact on flight operations, the effects of heat stress were looked at in detail. Although sufficient data exists to develop work/rest cycles, temperature threshold limit values, and water replacement rates, no such guidance relevant to MH operations existed at the time of incident. Similarly, no guidance included commercially available cooling technologies.

Finally, though not directly causal, it was relevant for the Flight Safety Investigation to look at the orders governing low-level MH flight operations. It was found that certain aspects of B-GA-100 Flying Orders, 1 Canadian Air Division Orders, and the Fleet Operational Flight Procedures do not appear to be consistent with one another. Critical to accurate application of these orders is a concise understanding and application of what constitutes an operational, operational flying training, or a non-operational flight. If adhered to as written, these orders could prove to be overly restrictive for the MH community to function effectively. Therefore clarification is required to allow MH crews to train and operate within the constraints and limitations of relevant and concise orders and procedures.

2.9 Other Flight Safety Concerns

2.9.1 Concerns with Medical Support

Immediately post-incident, the pilots were directed to the ship's Physician's Assistant for medical examinations and toxicology sampling. However, several factors contributed to incomplete medical support to the FSI.

Immediately post-incident the in-theatre Flight Surgeon was notified, however, he was led to believe that a ground occurrence not involving aircrew had taken place. As a result, post-occurrence medical examinations were not correctly performed and the toxicology samples were processed by the Flight Surgeon's Physician's Assistant rather than by the Air Force Institute of Pathology, Bethesda, Maryland, USA; this latter fact rendered the samples useless. After eight days post-incident only then did the Flight Surgeon examine the pilots and learn the true nature of the circumstances.

It was indicated to the FSI Team that, during the first 24 hours post-incident, communication difficulties between HMCS CALGARY's Physician's Assistant and the in-theatre Flight Surgeon occurred. However, it could not be determined what difficulties prevented crucial medical assistance from being expeditiously rendered to the Flight Safety Investigation.

2.9.2 Cooling Vests

The Sea King cockpit is not ventilated; its inherent "greenhouse" effect can rapidly increase cockpit temperatures above ambient outside air temperatures. On the incident day the ambient temperature of 34°C combined with the humidity to create an equivalent 50°C HUMIDEX temperature that can be defined as a "dangerous" comfort level. It is reasonable to believe that it was even hotter within the cockpit due to the "greenhouse" effect. HUMIDEX temperatures of up to 62°C have been recorded by other HELAIRDETS in the region. Although cooling vests were available for use, they were only authorized for use when worn with Nuclear, Biological, Chemical (NBC) protective clothing, which the crew was not wearing.

Since about 1990, MH operations began to evolve away from the typically cool North Atlantic environment towards much hotter ones. This change of environment has highlighted the importance of coping with the adverse affects of high temperature operations on the safety, well-being, and effectiveness of both maintenance and aircrew personnel. The current cooling vests for use only with NBC protective clothing have demonstrated their efficacy in lowering body core temperatures. Cooling vests recently used by Canadian athletes during the 2004 Olympics have shown how adaptable and functional they have become. The DRDC (T) report titled "Cooling Options for Shipboard Personnel Operating in Hot Environments" identifies several options available for the reduction of bodily heat already in use by Allied navies, including a vest currently in use with the United States Navy. Efforts should, therefore, be made to adapt, if possible, and introduce similar cooling initiatives for use in embarked non-NBC MH operations in an attempt to improve working conditions for all MH personnel.

3. CONCLUSIONS

3.1 Findings

3.1.1 This incident had significant potential for more serious aircraft damage or even the loss of aircraft and/or life.

3.1.2 The aircraft was serviceable for the test flight. The out-of-tolerance rotor smoothing was not a contributing factor.

3.1.3 The crew was current and qualified in accordance with all applicable requirements.

3.1.4 Notwithstanding the possible effects of heat stress, the crew was medically fit at the time of the incident. The co-pilot reported post-incident that he felt that he may have been affected by heat stress and that his left eye vision experienced some blurring. The co-pilot's vision anomaly later cleared and was not deemed to be a contributing factor to the incident.

3.1.5 During the main rotor blade change prior to the test flight, HMCS CALGARY's ability to manoeuvre at sea was restricted. In order to minimize the time that the ship was restricted in its ability to manoeuvre, all HELAIRDET personnel, including aircrew, were needed to change the blade.

3.1.6 Aircrew participation in the blade change precluded adequate protection from physical exertion and the pre-flight heat stress of the 35°C air temperature.

3.1.7 Despite rest and hydration breaks, several personnel reported feeling fatigued during the morning's work in the hangar, which approached 45°C in the upper parts. Additionally, some personnel felt that by mid-afternoon they were no longer at their peak performance level.

3.1.8 The 50°C HUMIDEX value on the day of the incident can be qualified as "dangerous" according to Environment Canada's Humidex Range Chart.

3.1.9 Embarked MH flight operations and maintenance are demanding activities that, in high temperature environments, are likely to cause heat stress without the education of personnel and strict adherence to precautionary measures. Even moderate heat stress can impair aircrew performance.

3.1.10 The Sea King remains a non-air conditioned maritime aircraft. Therefore, other aircrew defences against heat stress must be found.

3.1.11 HELAIRDET personnel received education with respect to hot weather operations. However, there were no enforceable precautionary measures established with respect to work/rest cycles, water replacement rates, or maximum temperature threshold limit values.

3.1.12 Research data is available for use in constructing formal work/rest cycles, water replacement rates, and maximum temperature threshold limit values that can be adapted to MH operations.

3.1.13 It was possible for degraded cognitive ability and performance to have affected the aircrew without anyone noticing it.

3.1.14 The morning's physical activity and the constant exposure to high temperatures resulted in some degradation of aircrew performance. This facilitated a breakdown of intra-cockpit communications that permitted the co-pilot to carry out an un-briefed close flypast of a ship, a manoeuvre that he had not previously flown.

3.1.15 The incident crew was known to be a cohesive one that employed effective crew co-ordination to achieve positive results. It was out of character for this crew to take unnecessary risks.

3.1.16 Low-level over water operations, and especially those in close proximity to ships, are routine for MH aircrew.

3.1.17 For HELAIRDET crews onboard HMCS CALGARY, it was routine to occasionally conduct flypasts to the ship.

3.1.18 The pilots decision to allow the co-pilot to conduct the flypast was facilitated by the pilots familiarity and comfort level of conducting operations in close proximity to ships.

3.1.19 The decision to conduct the low level flypast was not consistent with either those manoeuvres that are authorized or those that are taught and trained for within the MH community.

3.1.20 The aircrew inadequately assessed the rate of closure between the aircraft and the ship during the flypast.

3.1.21 Due to the proximity of the aircraft to the ship, there was no time for either pilot to take corrective action to avoid striking HMCS CALGARY.

3.1.22 The flying orders that govern maritime helicopter operations require examination to ensure that they are practical, consistent and that they provide clear direction to aircrews.

3.1.23 Poor communication existed between HMCS CALGARY's Physician's Assistant and the in-theatre Flight Surgeon supporting aviation operations. This had the potential to seriously impede the FSI.

3.1.24 Poor awareness of NIS investigators about the flight safety investigative process existed in-theatre at the time of incident. This had the potential to interfere with and impede the FSI.

3.1.25 There is no formal agreement that establishes how investigations will be deconflicted and co-ordinated between DFS and the NIS.

3.1.26 Although the areas of operation for MH crews have significantly moved towards hotter climates over the past 15 years, aircrew cooling equipment remains authorized for use only with NBC equipment.

3.1.27 There currently exists cooling vest technology and cooling procedures in use by other Allied navies that may be readily adapted to embarked MH operations.

3.2 Cause Factors

3.2.1 While conducting the flypast, the co-pilot did not accurately assess the rate of aircraft/ship closure and the clearance between the two just prior to turning across HMCS CALGARY's bow.

3.3 Contributing Factors

3.3.1 The morning's physical activity and the constant exposure to high temperatures resulted in some degradation of aircrew performance. This facilitated a breakdown of intra-cockpit communications that permitted the co-pilot to carry out, un-briefed, a close flypast of a ship, a manoeuvre that he had not previously flown.

3.3.2 The decision to conduct the flypast was facilitated by a familiarity with low-level operations in close proximity to a ship and the routine nature of the flypast itself, which was ingrained within the detachment.

4. SAFETY MEASURES

4.1 Safety Measures Taken

4.1.1 Shortly after the occurrence, HMCS CALGARY promulgated a Ship's Standing Order prohibiting flypasts.

4.1.2 The MH Standards Evaluation Team was tasked, on 4 May 2005, to examine, and re-align if necessary, all flying orders as they pertain to embarked MH operations.

4.1.3 A Statement of Operational Capability Deficiency was issued on 26 April 2005 that stated the need to investigate the requirement for personnel and cabin cooling within the CH124 and CH146 helicopter fleets.

4.1.4 The 1 Cdn Air Div Flight Surgeon was tasked, in mid-May 2005, to investigate appropriate methods to prevent MH personnel working in hot climates from heat-related injuries. Consideration of work/rest cycles, water replacement rates, and maximum temperature threshold limit values for MH operations will also be investigated. The Commander 1 Cdn Air Div accepted that additional preventative measures must be put in place and may include such things as operational directives, cooling vests, proper acclimatization procedures, changes to pre-flight routines, or combinations thereof.

4.1.5 In mid-May 2005, 1 Cdn Air Div initiated the development of a Record of Airworthiness Risk Management for CH124 flight operations in hot weather climates to highlight, mitigate, and accept the responsibility for risk during the conduct of operations in such environmental conditions.

4.1.6 On 24 and 25 May 2005, the 1 Cdn Air Div Flight Surgeon provided guidance to both medical authorities onboard HMC Ships and 12 Wing, Squadron, and HELAIRDET Flight Safety Officers to highlight the required procedures for requesting Flight Surgeon assistance when deployed.

4.1.7 In Spring 2005, Maritime Command initiated the establishment of a new Maritime Command Order that describes the procedures to be followed within Maritime Command for multi-agency investigations into aircraft accidents.

4.1.8 On 20 Jul 2005, the 12 Wing Commander issued an aircrew order 05/05 which specifies the minimum separation required when operating in close proximity to HMC Ships and other vessels.

4.2 Further Safety Measures Required

4.2.1 It is recommended that the MH Standards Evaluation Team review of flying orders ensure that relevant guidance exists for obstacle clearance minima applicable to MH operations overwater.

4.3 Other Safety Concerns

The legal precedence of investigative authority must be clearly identified and documented to prevent possible future interference during the course of a flight safety investigation; all investigative agencies within the CF should be encompassed.

4.4 DFS Remarks

Although this occurrence appeared to be straightforward and was classified as only a D category incident, there was obviously potential for a much more serious outcome. Accordingly, a lot of time and effort were expended on this investigation. As a result of the thorough efforts of the Flight Safety Investigation team, a number of contributing factors were identified and these, in turn, lead to the identification of several recommendations that are worthy of serious consideration.

A significant portion of this report focuses on the potential impact that heat stress had on the incident crew. There is no doubt that this HELAIRDET was dealing with a significant challenge posed by extended exposure to high temperatures and high HUMIDEX conditions. In addition, this particular situation is not unique within the Air Force as a number of other communities are facing similar challenges. Accordingly, the proposed guidelines for threshold limit values, water replacement values and work rest cycles are particularly relevant. Similarly, the procurement of cooling vests for all personnel exposed to high temperature work environments merits serious consideration. Having said that, it is recognized that commanders must consider a number of additional operational factors in their decision making process and that the constraints placed on this process must be kept to a minimum in order to assure mission success. However, these guidelines (or a variation of them) could provide a useful tool to commanders who are placed in an environment in which the Air Force has not traditionally operated.

This report also highlights the fact that CH-124 aircrews work in an extremely demanding and error intolerant environment. Despite this fact, DFS records indicate that there are remarkably few incidents of Sea King rotor blade/ship contact in over 42 years of operations. While this is an enviable safety record, the fact that this incident did occur is a cause of concern. In discussions with CH-124 crews and the leadership of this community, it is obvious that the seriousness of this incident is universally appreciated. The incident has served to heighten awareness of the hazards associated with operating in close proximity to ships with all CH-124 crews. The challenge, as always, will be to maintain this level of awareness.

Finally, the regulation issue identified in this report has sparked a healthy debate within the CH-124 community. It must be emphasized that the intent of raising this issue was to not to determine if this crew was operating within the rules but to ensure that the rules were clear, consistent, practical and well understood. It appears that some work needs to be done in this area and 1 Cdn Air Div HQ is already addressing this issue.

A.D. Hunter
Colonel
Director of Flight Safety

ANNEX A: PHOTOGRAPHS

Photo 1: Blade Tip Damage

Photo 2: Stanchion and Antenna Damage

Photo 3: Blade Cut Angle on Stanchion and Antenna

ANNEX B: TLV MODELS FOR MH AIRCREW AND TECHNICIANS

When correctly dressed and strapped into an insulating seat in the aircraft, a Sea King aircrew member will wear a Nomex flight suit with a second fire-protective layer underneath, dual layer flight gloves, heavy flight boots, a helmet, a Life Preserver Survival Vest, and a survival backpack. Because the permeability of this clothing and equipment is greatly reduced over a light summer work uniform, the exposure TLV's must be reduced. Based on the GSO corrective factors given for cotton coveralls (-2°C) and a winter work uniform (-4°C), interpolation provides a rough order of magnitude correction factor of –3°C; this compares conservatively with the –3.5°C TLV correction factor defined by the CCOHS for woven cloth coveralls. As a result, Table 1: TLV's for MH Aircrew Exposed to High Temperature Environments, can be derived to more accurately reflect TLV's specific to MH operations in high temperature environments.

Table 1: TLV's for MH Aircrew Exposed to High Temperature Environments

Hourly Activity	**Workload in Temperature Conditions (WBGT°C)**		
	Light	Moderate	Heavy
100% Work	26.5	24.5	23.0
75% Work 25% Rest	27.5	25.5	24.5
50% Work 50% Rest	28.5	26.5	25.5
25% Work 75% Rest	29.5	28.0	27.0

Similarly, a Sea King technician will dress with coveralls, a helmet, heavy work boots, heavy gloves, and possibly fire fighting gear or a life preserver. This then indicates a conservative correction factor of either –2 or –4, depending on their order of dress; the TLV correction factor defined by the CCOHS for double cloth coveralls is –5°C. As a result, Table 2: TLV's for MH Technicians Exposed to High Temperature Environments can be derived to more accurately reflect TLV's specific to MH operations in high temperature environments.

Table 2: TLV's for MH Technicians Exposed to High Temperature Environments

Hourly Activity	Workload in Temperature Conditions (WBGT°C)					
	Light		Moderate		Heavy	
	Coveralls	Firefighting Clothing	Coveralls	Firefighting Clothing	Coveralls	Firefighting Clothing
100% Work	27.5	25.5	25.5	23.5	24.0	22.0
75% Work 25% Rest	28.5	26.5	26.5	24.5	25.5	23.5
50% Work 50% Rest	29.5	27.5	27.5	25.5	25.5	24.5
25% Work 75% Rest	30.5	28.5	29.0	27.0	28.0	26.0

Note: These TLV's also assume that acclimatized personnel work an eight-hour day, five days per week. Additionally, no qualifiers for light moderate or heavy workload have been defined for either aircrew or technicians. However, in terms of flight operations, the aircrew member who is working the hardest would be an entire crew's limiting factor. For example, it may be considered that an AESOP conducting hoisting evolutions at the cargo door position is involved in a heavy workload whereas the flying pilot is involved in a moderate workload while the non-flying pilot is involved in a light workload.

ANNEX C: WATER REPLACEMENT RATES AND TLV'S FOR MH AIRCREW EXPOSED TO HIGH TEMPERATURE ENVIRONMENTS

Table 1: Water Replacement Rates and TLV's for MH Aircrew Exposed to High Temperature Environments

Hourly Activity	**Workload in Temperature Conditions (WBGT°C) and Water Replacement Rates in Litres/Hour**					
	Light		Moderate		Heavy	
	TLV	Water	TLV	Water	TLV	Water
100% Work	26.5	0.5	24.5	0.5	23.0	0.75
75% Work 25% Rest	27.5	0.5	25.5	0.75	24.5	1.0
50% Work 50% Rest	28.5	0.5	26.5	0.75	25.5	1.0
25% Work 75% Rest	29.5	0.75	28.0	0.75	27.0	1.0

Note: This table is based only on interpolation and not clinical validation. This table was derived to demonstrate that data is available to construct formal water replacement requirements, TLV's, and work/rest cycles for use by MH Aircrew in high temperature environments. A similar exercise could be conducted for application to MH Technicians exposed to high temperature environments.

ANNEX D: ABBREVIATIONS

AESOP	Airborne Electronic Sensor Operator
AETE	Aerospace Engineering Test Establishment
AIA	Airworthiness Investigative Authority
AGL	Above Ground Level
ASL	Above Sea Level
CCOHS	Canadian Centre for Occupational Heath and Safety
Cdn Air Div	Canadian Air Division
CF	Canadian Forces
CFAO	Canadian Forces Administrative Orders
CUP	Category Upgrade Program
CVR	Cockpit Voice Recorder
DAOD	Defence Administrative Order and Directive
DFS	Director(ate) of Flight Safety
DRDC(T)	Defence Research and Development Canada (Toronto)
EFS	Emergency Flying Stations
FDR	Flight Data Recorder
FFH	Fast Frigate Helicopter
FLOPS	Fleet Operating Procedures
FS	Flying Stations
FSI	Flight Safety Investigation
FSIR	Flight Safety Investigation Report
HELAIRDET	Helicopter Air Detachment
HMCS	Her Majesty's Canadian Ship
HUMIDEX	Humidity Index
IFR	Instrument Flying Rules
KIAS	Knots Indicated Airspeed
LSO	Landing Signals Officer
METAR	Meteorological Aviation Report
MH	Maritime Helicopter
MND	Minister of National Defence
MSI	Medical Service Instruction
NBC	Nuclear, Biological, Chemical
NIS	National Investigative Service
NM	Nautical Mile
PDI	Person of Direct Interest
SAC	Ship Air Controller
SHOPS	Shipborne Helicopter Operating Procedures
SVFR	Special Visual Flight Rules
TACCO	Tactical Co-ordinator
TAF	Terminal Area Forecast
USCG	United States Coast Guard
VA	Vibration Analysis
VFR	Visual Flying Rules
VHF	Very High Frequency
WBGT	Wet Bulb Globe Temperature