CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION (FSI) REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-12422 (DFS 2-4-2)
DATE OF REPORT: 11 Mar 2003
AIRCRAFT TYPE: CH124A Sea King
DATE/TIME: 23 2224Z/1224 Local June 2000
LOCATION: 19 01N-156 58.5W (150NM South of Pearl Harbor)
CATEGORY: "A" Category Accident

This report was produced under authority of the Minister of National Defence (MND) pursuant to Section 4.2 of the Aeronautics Act (AA), and in accordance with A-GA-135-001/AA-001, Flight Safety for the Canadian Forces.

With the exception of Part 1 – Factual Information, the contents of this report shall be used for no other purpose than accident prevention. This report was released to the public under the authority of the Director of Flight Safety, National Defence Headquarters, pursuant to powers delegated to him by the MND as the Airworthiness Investigative Authority (AIA) of the Canadian Forces.

SYNOPSIS

The occurrence crew had completed a rotors running refuel and crew change aboard HMCS PROTECTEUR and launched on an Anti-Submarine Warfare exercise. 25 minutes after take-off (2224Z/1224 local), hovering at a range of approximately 25 nautical miles (NM) from HMCS PROTECTEUR, the pilot noticed a "Main Transmission Oil Hot" (TRANS OIL HOT) light on the caution panel. The temperature gauge read 150°C (gauge maximum) and the pilot decided to declare an emergency and return to the ship for landing. The Australian frigate HMAS ADELAIDE was in company with HMCS PROTECTEUR and both ships closed the aircraft's position at top speed. During the transit toward the ship, the main transmission gearbox pressure gauge began to fluctuate as the pressure decreased steadily. The decision was made to enter the hover and wait for the ship to arrive. Subsequently, the crew noticed a burning metal-like smell in addtion to the intense heat felt by the pilot on his neck and left shoulder. A MAYDAY was transmitted and the crew conducted a controlled ditching from the hover. The engines were shutdown, the floatation bags were deployed and the crew stepped into the multi-place inflatable raft via the cargo door. At 2306Z the aircraft was observed rolling inverted and sinking below the surface. The water depth at that location is approximately 4600 metres, therefore salvage was not attempted. There were no injuries in this accident.

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1. FACTUAL INFORMATION

GENERAL

The helicopter, Sea King CH12422, was operated by 443 Maritime Helicopter (MH) Squadron from Pat Bay, BC, primarily in the Anti-Submarine (ASW) and Anti-Surface Warfare roles. The primary roles for the aircraft involve low-level day/night/VFR/IFR operations over water in national and international theatres of operations. The normal crew consists of two pilots, one tactical co-ordinator (TACCO), and one airborne electronics sensor operator (AESOP). The overall responsibility for the mission rests with the Maritime Helicopter Crew Commander (MHCC) who is designated from either the pilot or the TACCO; in this crew the pilot was designated as MHCC and was also the Detachment Commander. All CH124 aircraft are equipped with a variable-depth sonar, radar, sonobouys, a rescue hoist, and can be armed with a door-mounted machine gun and anti-submarine torpedoes.

1.1 History of the Flight

The occurrence mission was the second mission of four scheduled in support of EXERCISE RIMPAC 2000. The crew briefed the mission requirements and the pilot authorized the flight. A crew change and refuel was conducted with the rotors running. The occurrence crew took their positions in the aircraft as follows: the pilot in the right seat, the co-pilot in the left seat, both the TACCO and AESOP at the side-facing console behind the pilots' seats, and the passenger in the rear cabin troop seat. With the crew change and refuel complete, the helicopter took off from HMCS PROTECTEUR, approximately 150 NM south of Honolulu, Hawaii, and proceeded at 110 Knots (kts) and 200 feet to a position approximately 22 nautical miles (NM) away to commence an ASW exercise.

Approximately 24 minutes into the mission (2224Z/1224 local) and during the third hover SONAR search sequence, the pilot noticed a TRANS OIL HOT light on the caution panel with an associated Master Caution light (see Annex H: Sequence of Indications). The crew then noted that the main transmission gearbox (MGB) temperature gauge read 150°C (gauge maximum). The last time that the MGB temperature gauge had been positively identified as being in the normal range was during the "pre-dip check" carried out three to four minutes prior to the over-temperature indications.

At 2227Z, the pilot instructed the TACCO to declare an emergency and ordered the AESOP to recover the SONAR. As soon as the SONAR dome was recovered, the crew departed the hover and began to transit towards HMCS PROTECTEUR at 100 feet and 90 kts.

During the transit toward the ship, the MGB pressure began to fluctuate up to ±10 PSI, within the normal operating pressure range, but with the low end of the fluctuation steadily decreasing. The AESOP conducted a cabin check, specifically looking out the left cabin window for signs of an oil leak, but saw nothing abnormal. The pilot reviewed the MGB emergency procedure in the checklist, and subsequently decided to enter the hover at approximately 18 NM from HMCS PROTECTEUR; his stated intention was to assess the MGB condition and allow the ship to close the distance. At this time, both HMCS PROTECTEUR and HMAS ADELAIDE were approaching at top speed.

Once in the hover, the AESOP conducted another cabin check. No signs of oil leakage were discovered, but the crew noticed a burning smell which they described as similar to "burning metal." MGB pressure was observed at 40-45 PSI as pressure fluctuations increased to ±30 PSI. The pilot also felt an uncomfortable heat on his neck and left shoulder, and assessed that the observed symptoms of high temperature, lowered pressure, increased pressure fluctuations, "hot smell," and radiant heat indicated an imminent failure of the MGB and therefore ordered the crew to prepare to ditch (see Annex H: Sequence of Indications). At 2229Z, both the TACCO (on the UHF radio) and the AESOP (on the HF radio) sent MAYDAY calls. The pilot and co-pilot then jettisoned their windows before conducting a controlled ditching from the hover. The ocean conditions were relatively calm with a 1-2 metre swell.

The pilot's initial intention once on the water was to remain rotors-running. Noting that the main rotor blades were coming uncomfortably close to the ocean swell, the pilot ordered an emergency shutdown to be carried out. The engines were secured, the floatation bags deployed, and the rotor brake was used once the Rotor RPM slowed below15%.

The crew proceeded to the aft cabin to deploy the multi-place inflatable life raft. Initial attempts to inflate the multi-place life raft from the cargo door were unsuccessful. While initial difficulties with the inflation lanyard were being resolved, the pilot returned to the cockpit to grab the Emergency Locator Transmitter, ELT. Once the raft was successfully inflated and deployed, the crew egressed the aircraft directly from the cargo door into the life raft. As the life raft drifted away, the aircraft began to settle slowly by the tail at approximately 2253Z.

HMAS ADELAIDE arrived on scene at 2257Z and rescued all four aircrew and the passenger using its rigid hull inflatable boat. At 2306Z, the aircraft was observed to roll inverted and then sink below the surface before either HMAS ADELAIDE or HMCS PROTECTEUR, which was just arriving on scene by this time, could undertake any salvage attempt. As the aircraft quickly disappeared from view, hydrostatic pressure released the helicopter's Crash Position Indicator, CPI.   Due to the approximate water depth of 4600 meters, salvage Operations were not attempted.

1.2 **Injuries to Personnel**

Table 1: Injuries to Personnel

Injuries	Crew	Passengers	Others
Fatal	0	0	0
Serious	0	0	0
Minor	0	0	0

Although no physical injuries occurred, one member did suffer post-occurrence psychological discomfort; this is covered under a separate confidential medical report.

1.3 **Damage to Aircraft**

The extreme depth of water precluded recovery of the aircraft resulting a classification of "A" category damage.

1.4 **Collateral Damage**

Nil.

1.5 **Personnel Information**

Table 2 : Personnel Information

	PILOT	**CO-PILOT**	**TACCO**	**AESOP**	**PASSENGER**
Rank	CAPT.	CAPT.	CAPT.	WO	CPL

Category valid	YES	YES	YES	YES	—
Medical Category valid	YES	YES	YES	YES	—
Total flying time	2579	406	310	2370	—
Hours on type	2262	175	140	135	—
Hours last 30 days	55	32	45	42	—
Duty time last 24 hrs	6	6	12	12	—

Training records identified that all aircrew had met mandatory training requirements and qualifications.

1.6 Aircraft Information

The occurrence aircraft was a CH124 Mk 1 Sea King helicopter, registration number 12422; the CH124 originally entered service with the Canadian Forces in 1963. The Mk 1 variant is equipped with T-58-8F engines and a 21000 series MGB. The occurrence aircraft, CH12422, embarked HMCS PROTECTEUR on 23 May 00. The aircraft was fitted with MGB serial number C-39 and was declared fully serviceable at the time of embarkation. Maintenance actions related to the MGB were conducted in the days leading up to the accident (see Annex B: Related Maintenance Activity). The aircraft was deemed serviceable when it launched for the final flight.

1.7 Meteorological Information

The meteorological observation taken at 232230Z from HMCS PROTECTEUR was: 13015KT P6NM FEW025 26/21 A2993 CU2

Sea state was reported as a 1-2 meter swell.

1.8 Aid to Navigation

Nil.

1.9 Communications

At the time of occurrence, the aircraft was operating within UHF range of the controlling ship. Distress calls were made on UHF and HF, but only acknowledged on UHF.

Once in the life raft, UHF communications were established, using a PRQ 501, with a United States Navy (USN) P3 Orion that was despatched to locate the crew. The initial contact was weak but readable; however, the signal faded to squelch within 5 minutes. A second PRQ 501 was subsequently activated. The second radio functioned properly for the duration of the emergency.

1.10 **Aerodrome Information**

HMCS PROTECTEUR is an auxiliary oiler/replenishment (AOR) supply ship with a flight deck located on the after end. The AOR can hangar three CH124 aircraft; the flight deck has no "Helicopter Haul-down and Rapid Securing Device" capability. Shipboard helicopter landings must be made from a hover, after which the aircraft is secured to the deck with chocks and chains.

The controlling ship for the ASW exercise was HMCS PROTECTEUR. HMAS ADELAIDE was an accompanying Australian frigate participating in the exercise.

1.11 **Flight Recorders**

The CH124 is not equipped with any onboard recording devices. It is worthy to note that had this aircraft been fitted with an ejectable cockpit voice and flight data recording device, it would have been of significant benefit to the investigation.

1.12 **Wreckage and Impact Information**

The ditching was controlled and the aircraft remained intact until the tail section filled with water and submerged. The right floatation bag then separated from the sponson and the aircraft rolled inverted and sank about 37 minutes after the aircraft landed on the water. A seat cushion, the right floatation bag, and the crash position indicator (CPI) were salvaged from the accident site.

1.13 **Medical**

Members of the crew were taken aboard HMAS ADELAIDE and given a cursory medical examination and dry clothing. Once the crew returned to HMCS PROTECTEUR, they provided toxicological samples to the ship's doctor for analysis at Tippler Military Hospital. The results of blood and urine analysis were normal.

1.14 **Fire, Explosives Devices, and Munitions**

At the time of ditching, the aircraft was armed with three Sonobuoys, six C2A1 Smoke Markers, and two MK-82 SUS (Signal Underwater Sound). These types of munitions are salt-water activated. Video evidence showed that the smoke markers ignited in the chutes as soon as the aircraft rolled inverted.

1.15 **Survival Aspects**

The one to two metre sea-state and good ambient light conditions assisted the crew in evacuating the aircraft under controlled conditions. No reference was made to the Water Operations Checklist. The multi-place life raft was deployed, after some initial difficulty, and all five occupants stepped directly from the aircraft into the life raft.

The life raft is stored just forward of the troop seat, on the left side of the aircraft cargo compartment. With the assistance of the passenger, the AESOP moved the raft to the cargo door, secured the safety line (painter) to his hand, placed the raft in the water, and pulled the inflation lanyard. The attempts to activate the inflation bottle by normal means failed until the TACCO located the inflation bottle and pulled the activation lanyard at the bottle itself.

Prior to egressing the aircraft from the cargo door, the pilot re-entered the cockpit area to recover the AN/URT-505 Emergency Locator Transmitter (ELT) The CH-124 ELT is not configured to automatically activate upon impact but must be physically turned on by the crew after the antenna is manually attached. At some time before or during the attempt to connect the antenna to the base unit, the coaxial connector was damaged and the unit was rendered unserviceable.

The crew was able to successfully employ PRQ-501 Personal Locator Beacon (PLB) radios to establish communications with a USN P-3 Orion aircraft overhead. When the first PLB failed after approximately five minutes of use, a second was retrieved from a crewmember’s PR-2 backpack and successfully employed for the remainder of the rescue.

When the crew abandoned CH124422, the first aid kit remained with the aircraft, the aircraft sea anchor was not deployed, the landing gear was in the up position and the SONAR dome was seated.

The AN/URT 506 (V) Crash Position Indicator (CPI) was hydrostatically activated and released from the side of the aircraft. HMCS PROTECTEUR confirmed operation of the CPI, which was recovered following rescue of the passenger and crew.

1.16 **Test and Research Activities**

The following items were sent to Quality Engineering Test Establishment (QETE) for technical analysis:

a. right floatation bag;

b. MGB Oil Filter removed on 15 Jun 00 subsequent to a Chip Light un-serviceability;

c. SOAP samples taken after the 17 Jun 00 oil leak and another set taken after the 15 June Chip Light; and,

d. aluminium MGB lubrication fitting replaced 21 Jun 00.

The multi-place life raft, the failed PRQ 501 PLB, and the ELT were delivered to the Defence and Civil Institute for Environmental Medicine (now Defence Research and Development Canada - Toronto) for further investigation.

1.17 **Organizational and Management Information**

The occurrence aircraft and crew from Maritime Helicopter (MH) 443 Squadron, Pat Bay, BC, were deployed aboard HMCS PROTECTEUR to participate in EXERCISE RIMPAC 2000, a Pacific-rim multinational exercise.

1.18 **Additional Information**

N/A

1.19 **Useful or Effective Investigation Techniques**

Maintenance data and contractor records were used to track the history of the occurrence MGB in CH12422 as well as in other previous aircraft installations.

2. ANALYSIS

2.1 General

The Transmission Hot Light, the MGB temperature gauge reading, fluctuating MGB pressure, and an unusual burning metal smell all point to failure of the MGB. With the airframe unrecoverable in extremely deep water, only crew testimony and deductive reasoning is available to determine which of the possible failure modes was most probably responsible. The solubility of the magnesium alloy MGB casing when immersed in salt water would likely have rendered information to be gleaned from its recovery inconclusive. Of note, CH124 aircraft are not fitted with Flight Data Recorders (FDR) or Cockpit Voice Recorders (CVR). Had the helicopter been equipped with ejectable FDR/CVR equipment, the data would have been of significant benefit to the investigation.

2.2 The Aircraft

A description of the 21000 Series MGB, the only system failure suspected in this occurrence, and its associated sub-systems is included as Annex A. Though MGB over temperature indications are common, no MGB failures due to this condition have been observed in the CH124 fleet. The total maintenance history of this MGB was reviewed, including MGB related unserviceabilities in the week prior to the occurrence.

2.2.1 Maintenance History of the MGB

Maintenance records show that CH12422 was deemed fully serviceable when embarked on HMCS PROTECTEUR on 23 May 00. At the time of the last documented maintenance action, the aircraft had accumulated 537.6 hrs since last periodic inspection and had completed a number 21 Supplementary Inspection (No. 21 Supp) 15.5 hrs prior to the accident. Archived Automated Data for Aerospace Maintenance (ADAM) and Flight Safety (FS) data related to CH12422 was reviewed to ascertain whether significant anomalies or system trends were evident. It is noteworthy that on 27 Aug 98 MGB Serial Number C-39 reached a reported temperature of 144°C, a reading that is impossibly accurate for this type of gauge (see Annex A, Figure 1- MGB Oil Temperature and Pressure Gauges). Subsequently on 16 Jul 99 and 29 Jul 99, overtemps of 130°C and 140°C, respectively, were also reported. Of note, there is no means of determining or confirming actual maximum MGB temperature from post-flight data sources.

MGB C-39 had previously been installed in CH12410 (see Table 3: Installation History of MGB Serial Number C-39), during which time that transmission experienced two overtemps, two Main Rotor over speeds and two MGB chip occurrences (see Table 4: Historical Maintenance Events of MGB Serial Number C-39).

Table 3: Installation History of MGB Serial Number C-39

Aircraft	Install Date A/F Hrs	Removal Date A/F Hrs	Time Since Installed	Time Since Overhauled
12410	11 AUG 94 9487.2	08 AUG 96 10448.9	961.7	961.7
12423	14 OCT 97 10237.9	21 OCT 97 10237.9	0	961.7
12422	05 JUN 98 10960.9	N/A	640.1	1601.8

Table 4: Historical Maintenance Events of MGB Serial Number C-39

#	AC	DATE	MGB TSO	EVENT	CF 349 ENTRY
1	410	10-01-95	121.2	130°C	Cooler Visually Inspected and Belts Checked Serviceable (“S”)
2	410	04-03-95	259	4 x Chip Lts	SOAPs “S” IAW AJO/MF-000
3	410	07-03-95	267.6	NR>117%	Over speed Inspection “S”
4	410	26-04-95	297.6	123°C	No Fault Found
5	410	16-06-95	396.4	NR>117%	Over speed Inspection “S”
6	410	23-06-96	843.7	2 x Chip Lts	Refer to chip detector record serial # 1 item 2&3
7	422	21-08-98	994.9	144°C	Trouble shooting “S” as per part 2, fig 2-17 & fig 7-6
8	422	15-07-99	1292.4	130°C	MGB troubleshot IAW AJO/MF pg 3-9, para 14. No Fault Found
9	422	28-07-99	1307.2	140°C	MGB serviceability check “S”

2.2.2 Recent History

HMCS PROTECTEUR’s Helicopter Air Detachment’s (HELAIRDET) deployed ADAM, Aircraft Record Set, Aircraft Servicing Set, and FS data were reviewed to ascertain if there was a possible correlation between the MGB overtemp occurrence, maintenance actions performed, and anomalies reported since embarkation. This review revealed one additional overtemp, one chip occurrence, and a leaking MGB Oil Lubrication Fitting (followed by a Special Inspection (SI) to replace that fitting) since embarkation. Details of these related maintenance actions are discussed at Annex B: Related Maintenance Activity.

2.2.3 Incorrect Maintenance Procedure

Testimony of maintenance personnel directly involved with the occurrence aircraft indicated that experienced technicians routinely disregarded the requirement for torque wrenches, because, as one member indicated, "*I know what 150 inch-pounds feels like*." Maintenance supervisors indicated that they were aware of this deviation, but that it was an accepted practice. Analysis of the details at Annex B indicated that the routine disregard of the requirement to use torque wrenches in the installation of lube fittings was mitigated not only by the MH 443 SAMEO directive to replace the suspect fitting, but also by the SI conducted on the day prior to the occurrence. The only way, however, to reasonably rule out a maintenance cause factor was to analyse the possible failure modes to determine if an MGB oil leak was present and causal to the occurrence.

2.3 **MGB Failure Analysis**

2.3.1 Possible Failure Modes

The crew experienced cockpit indications of an MGB over temp of unknown magnitude (gauge pegged, caution light illuminated), MGB oil pressure fluctuations, reduced mean MGB pressure, a burning/welding smell, and radiant heat eminating from the transmission area. On the basis of these events, the crew elected to conduct an emergency water landing. Analysis of the following scenarios is required to reach a conclusion with respect to possible MGB failure:

a. failure of the temperature and oil pressure indicating system;

b. failure of the oil cooler;

c. failure of an MGB lubrication line or fitting; and

d. an overtemp similar to previous 21000 series MGB overtemps that have neither been satisfactorily explained nor caused any known damage.

2.3.2 <u>Failure Of The Temperature and Pressure Indicating Systems</u>

2.3.2.1 Analysis

Statements by the occurrence aircrew indicated that all gauges were scanned at least three times between launch from PROTECTEUR and the first overtemp indication. The last cockpit instrument check was carried out as part of the standard pre-dip check, three to five minutes before the crew noticed the overtemp; normal temperatures and pressures were observed. Given that the “TRANS OIL HOT” light, the MGB oil temperature indicator, the ”TRANS OIL PRESS” light, and the MGB oil pressure indicator receive their information independently of one another from separate sensors and indicated logical values during the flight, it is likely that these systems were functioning correctly. The components’ locations and separate power sources and the statistical remoteness of random order multiple system failures supports this analysis.

2.3.2.2 Temperature and Pressure Indicating Systems Conclusion

The failure of the temperature and pressure indicating systems is considered improbable.

2.3.3 Failure Of The Oil Cooler

2.3.3.1 General Operation

The Master Caution Panel “TRANS OIL HOT” light is activated via a plugstat relay that is fitted in the oil pressure line between the oil cooler and the MGB lubrication jets. The location of the plugstat is in an area where the coolest oil in the system is located (if the cooler is functioning). The “TRANS OIL HOT” light will illuminate when the temperature at the plugstat reaches 120°C. Conversely, the oil temperature gauge is controlled via a resistive bulb located at the bottom of the MGB sump. The sump is the area where the hottest oil in the system is found. From the sump, the used hot oil is routed back to the oil cooler. In the event of a cooler failure where uncooled oil is circulated throughout the MGB and its lubrication system, including past the temperature caution light sensor, the temperature of the oil would remain fairly consistent throughout the MGB; the temperature gauge would indicate this temperature.

2.3.3.2 Causes of Oil Cooler Failure

There were no audible indications, such as grinding noises, that would have been indicative of an in-flight impeller bearing failure, catastrophic impeller blade(s) failure, or slippage or failure of one or both blower drive belts. There was no visible evidence of MGB fluid leaking inside the aircraft or evidence of external fluid leakage or airframe damage that might suggest a failure of a dynamic part (impeller blades) under load. It is highly likely that an in-flight failure of dynamic components spinning at over 3000 RPM would cause severe damage to the airframe and/or supporting oil cooler structure. The sudden failure and obvious dynamic impact would likely have been felt and heard by all aircrew.

When the pilot first noticed the "TRANS OIL HOT" caution light, he immediately noted that the MGB oil temperature gauge was indicating 150ºC (max reading on the gauge - see photo at Figure 1- MGB Oil Temperature and Pressure Gauges). Given that the gauge reading exceeded 150ºC before the "TRANS OIL HOT" light illuminated, it is assessed that the cooler was working normally and was simply unable to reduce the temperature of the MGB oil below 120ºC. QETE reports that the oil cooler is capable of cooling transmission oil by approximately 30ºC. Therefore, if the cooler had failed and un-cooled oil was circulated from the sump past the caution light sensor, the temperature on the gauge would have read approximately 120ºC when the “TRANS OIL HOT” light first illuminated instead of the indicated 150ºC.

2.3.3.3 Oil Cooler Failure Conclusion

The above discussion supports the theory that the cooler and blower installed on the accident aircraft were operating within their design parameters. Thus, a failure of any part of the aircraft oil cooler assembly is considered unlikely.

2.3.4 Failure of an MGB Lubricating Line or Fitting

2.3.4.1 General

Considerable investigative attention was initially focused on this failure mode due to several maintenance actions carried out on CH12422 from 15-22 Jun 00. The significant maintenance actions were reviewed (see Annex B). Of primary concern to the investigation team was the evidence of widespread disregard for the requirement to use torque wrenches when installing fittings. It is possible that under or over-torque of a critical lubrication fitting may have caused a failure allowing an oil leak to precipitate the occurrence sequence of events. Therefore, an analysis of the sequence of events was used to verify the possibility of an oil leak causing the overtemp.

2.3.4.2 Temperature versus Pressure

The MGB lubrication system operates under positive pressure between 45-90 pounds per square inch (PSI). A sudden and complete fracture of a lubrication line under pressure would likely be accompanied by a continuous loss of oil pressure as indicated by fluctuating and decreasing oil pressure on the pressure gauge. A temperature increase would not occur unless the condition was permitted to continue to the point where insufficient oil to cool the MGB remained. Pressure fluctuations were noted to be the first indication of an MGB oil leak that was observed at Hickam Air Force Base, 17 Jun 00. If a fractured line had caused the accident indications, it is probable that the temperature increase would have been steady and readily noticeable. More importantly, it is certain that pressure fluctuations would have preceded the initial temperature indications. Note that in the accident sequence of events, pressure fluctuations were not observed until several minutes after the temperature had reached maximum.

2.3.4.3 Visual Evidence

Given the throughput capacity of the two internal pumps to move the 50 litres of MGB oil at a constant rate, a complete lubrication line fracture would result in a marked and continuous depletion of MGB oil and a corresponding continuous decline in pressure in addition to pressure fluctuations resulting from air ingestion into the line. A partial fracture of a line or a failed fitting would have similar indications, though at a slower rate. Soon after the partial or complete fracture had taken place, the oil pressure would likely reach the low oil pressure limit of 12 PSI or might stabilize at some other lower than normal pressure. Oil being discharged under pressure would likely be dispersed in and around the upper most portion of the aircraft and eventually make its way to external portions of the airframe where it would be clearly visible. Despite two cabin checks over a period of five minutes, neither the aircrew nor anyone involved in the recovery and rescue operation reported any evidence of fluid leakage from internal or external aircraft sources. Furthermore, the “TRANS OIL PRESS” light on the master caution panel, which activates at a gauge pressure of approximately 12 PSI, did not illuminate, indicating positive oil pressure in the MGB at all times.

2.3.4.4 Ruptured MGB Lubrication Line or Fitting Conclusion

With mean pressure of approximately 40-45 PSI, the reported pressure gauge fluctuations of up to ± 30 are notable but not likely attributable to any type of MGB oil leak (see 2.3.5 for causes of pressure fluctuations). It is therefore concluded that the absence of an MGB oil leak indicates a rupture of a lubrication line or fitting did not occur. It then follows that maintenance procedures discussed in 2.2.3, although noteworthy, can also be eliminated as being causal to any lubrication line or fitting failure.

2.3.5 <u>Inherent Overtemp of the 21000 MGB</u>

2.3.5.1 General

The MGB overtemp occurrence on CH12422 was similar to other documented overtemp occurrences that have manifested themselves over several decades of CH124 operations. Flight safety statistics show that since 1980, of the 99 total MGB related occurrences, 45 involved high temperatures. Of those 45 occurrences, 27 addressed the problem by retarding the #1 Speed Selector Lever (referred to as the #1 SSL procedure – see para 2.3.5.2) to reduce MGB temperature. Furthermore, a significant number of these occurrences indicated that MGB pressure fluctuations were among the overtemp indications. When used, the retarding to the ground idle position of the #1 SSL was 100% successful in not only preventing further increases to MGB temperature, but also in reducing it. Furthermore, each of the overtemps that required MGB replacement (temp exceeded 145º) was subjected to inspection prior to repair and overhaul. None of these inspections revealed any damage to the internal components or a technical cause for the overtemp condition. Ten of these occurrences involved pressure fluctuations that manifested themselves after an overtemp condition had been established.

FS data also showed that the occurrence MGB experienced six reported overtemps since last overhaul in Mar 94. This is the second highest overtemp rate in the fleet.

The USN and the Canadian Sea King communities recognized that the 21000 MGB is susceptible to overtemp conditions ("Inherent Overtemp") with no known technical explanation. A review of historical engineering and maintenance information pertaining to this phenomenon found insufficient evidence to positively explain the condition. In 1983 the USN commissioned Sikorsky to conduct an engineering analysis and flight test evaluation in an attempt to ascertain if the overtemp condition was related in any way to aircraft attitude, manoeuvres relative to aircraft gross weight, altitudes, airspeeds, centre of gravity limits, angle of bank, and pitch attitude. Neither Sikorsky nor the USN engineering community could duplicate an overtemp condition. Recommendations from the report included: (1) inspection of the firewall for any holes or areas where hot air could escape into the transmission compartment; (2) periodic cleaning of the oil cooler core, duct, and aft discharge grill; and (3) frequent inspection of the blower drive belts. All of the aforementioned recommendations had already been incorporated in the CH124 maintenance program.

2.3.5.2 Speed Lever Procedure

Experience with 21000 MGB overtemps has revealed a corresponding phenomena that has proven effective in mitigating the rise in MGB temperature once an overtemp condition has occurred. It has been known for some time by both the CH124 and USN H-3 communities, but first formally documented and presented to Maritime Air Group Flight Safety in 1994, that in circumstances other than massive oil loss or oil cooler failure, retarding the # 1 SSL to the ground idle position would cool the MGB temperature. While the respective communities were aware of the procedure, it was not until Sep 99 that this procedure was published to MH aircrew in the form of an advance notice of change to the AOI. The change did not mandate aircrew to use this procedure in the event of an overtemp scenario, but rather it left discretion for its use with the pilot. The engineering community, including the USN and Sikorsky, could not determine with certainty why this particular procedure worked, primarily because they could not reproduce the indications in their trials. Had this information been backed by the technical findings, the procedure's acceptance and use would likely have been universal.

Although Sikorsky does not have test data to support the procedure, their report offers a possible explanation as to why it reduces the temperature of the main gearbox oil. The report which was not available to aircrews at the time of accident, provides the following information:

> *"…when the #1 SSL is reduced, the amount of heat being generated by dynamic components within the gearbox is also reduced. The oil that was used to cool the dynamic components (gears and bearings) in the #1 input (1st stage spur mesh and the 2nd stage helical mesh and bearings) is also cooler. The cooler oil from the #1 (unloaded components) now mixes with the hotter oil from the #2 components which results in a cooler average oil temperature. This cooler oil exits the input housing at a lower temperature. (Note: The sump temperature bulb is in the same area where the oil exits the input housing). Retarding the #2 SSL is not effective due to the location of the second stage gear mesh (located lower than #1 and surrounded by oil). The oil shields in this area are designed to prevent the oil from churning and generating more heat…"*

Technical explanation aside, FS data demonstrated that the Canadian Forces' experience of using the #1 SSL procedure, when employed to mitigate an MGB overtemp condition, was 100% successful. The procedure was not embodied within the Transmission Section of the Pilot Checklist despite publishment in the advance notice of change to the AOI. Discussion revealed that some aircrew understood that the intent of the procedure was to prevent MGB temperature from reaching 145ºC (the temperature at which MGB replacement is mandatory), though no intent is stated in the AOI or elsewhere. As it was a discretionary procedure, the occurrence pilot opted not to use the #1 SSL procedure because the maximum temperature of the MGB had already been exceeded and he believed that no benefit could be therefore gained by its use; he did not realise the procedure actually cooled the transmission thereby mitigating the overheat condition. As earlier stated, had this information been backed by technical authority, the procedure's acceptance and use would likely have been universal.

2.3.5.3 Effect of Temperature

The 21000 series MGB utilises a synthetic brand of lubrication oil corresponding to the MIL-L-23699 specification. Analysis of the temperature versus viscosity/pressure regime revealed that as the temperature increases the dynamic viscosity of the oil starts to decrease. Viscosity versus temperature charts from Shell Oil Corporation show a very large drop in both dynamic and kinematic viscosity at temperatures exceeding 100°C. At higher temperatures, the viscosity drop is even more significant. At extreme internal temperatures, degradation in the synthetic qualities of the oil will prevent the oil from effectively lubricating the moving parts. This is particularly pertinent because the meshing of poorly lubricated gears moving at high RPM will result in localized heating of the MGB oil. In this case, it is possible that internal oil seals were unseated and/or experienced deformation due to the excessive heat. This would cause internal leakage and possibly foaming, cavitations, and pressure spiking within the system. Given that the temperature gauge cannot indicate temperatures in excess of 150ºC and the cooling SSL procedure was not employed, the actual temperature was quite likely considerably higher. QETE was unable to reproduce cavitations in laboratory testing, possibly because they were limited to a maximum input temperature of 177ºC.

The occurrence MGB could have entered a situation in which the cooler could not keep pace with the overtemp condition, resulting in a rapid increase in temperature, probably exceeding 200ºC. It is possible that the MGB, once heated to such temperatures, could have produced pressure fluctuations due to foaming and/or cavitations. Additionally, it is possible that an extremely hot MGB casing could have produced the radiant heat felt by the aircrew and that the subsequently heated oils and greases external to the MGB could have created the "burning metal" smell also noticed. It must be noted that statistical analysis makes it highly probable that timely use of the #1 SSL procedure, despite the lack of original equipment manufacturer (OEM) confirmed technical information to conclusively support current theory, would have arrested the overtemp process, reduced MGB temperature, and averted the subsequent indications of fluctuating pressure, radiant heat, and burning odours which influenced the crew in their decision to ditch.

2.3.6 Conclusion of All Possible Failure Modes

Because the aircraft wreckage was not recovered, the cause of the MGB indications seen by the crew cannot be conclusively stated. However, analysis of possible failure modes leads to the conclusion that the temperature and oil pressure indicating system, the oil cooler assembly, and the MGB lubrication lines or fittings were not likely at fault; the occurrence was initiated by an inherent overtemp condition that, although technically unproven, is theorized to have occurred. Furthermore, it is considered that the pressure fluctuations experienced subsequent to the overtemp were a result of the overtemp condition. The heating of the MGB casing and surrounding lubricants likely caused the heat and odour noted by the crew. With respect to the 100% prior success rate in reducing inherent MGB overtemp situations using the #1 SSL procedure, it is statistically probable to conclude that the decision not to use the #1 SSL procedure allowed the MGB to reach a temperature high enough to cause symptoms and indications which were worrisome enough for the pilot to decide that ditching the helicopter was the safest course of action.

2.4 **The Aircrew**

2.4.1 Aircrew Training

A review of the Unit Aircrew Proficiency Record (UAPR) of the occurrence crew indicated that each member was current and qualified in accordance with all applicable requirements. Nevertheless, testimony indicated that there was some variance between procedures taught at the OTU and those followed by this crew. Furthermore, though the checklist was used for reference in the MGB emergency, it was not referred to when a water landing became a possibility, nor was it used for the landing and subsequent egress. For these reasons the training history of the crew was reviewed in detail.

2.4.2 Operational Training Unit (OTU) Training

As indicated in 1.5, the pilot was experienced; however, the co-pilot, TACCO, and AESOP were inexperienced on type having recently graduated from the OTU, Helicopter Training 406 Squadron, in the months prior to the accident. The investigation team therefore conducted a review of OTU training. This document review concluded that the occurrence crew had followed the Course Training Syllabus/Course Training Plan (CTS/CTP) for all phases of conversion training, and that the training received was adequate. Upon graduation from the OTU, aircrew must successfully complete a Unit Check-Out (UCO) with a designated Squadron Standards Officer. This UCO is intended to confirm that the aircrew member has achieved the standard of performance stated in the CTS/CTP. As such, the UCO is more a confirmation of the OTU standard than a check of the graduate's proficiency. In the months prior to the accident, MH 443 confirmed, through the UCOs of the three junior crewmembers, that the skill level demonstrated by the occurrence aircrew was satisfactory and in accordance with their expectations of OTU graduates. It was therefore concluded that the OTU training was conducted in accordance with published standards, which were adequate and appropriate.

2.4.3 Waterbird Training

It was reported by the co-pilot that his lack of Waterbird training hobbled his effectiveness in assisting the pilot with emergency handling; he had not previously been exposed to the surprise and reality of having to land a helicopter on the water, even if in a controlled training environment. Throughout his OTU training, the co-pilot could not recall any airborne or simulator training that involved emergency scenarios progressing past the decision to ditch or force-land. Continuing past the decision-making process to ditching or force-landing involves following the scenario to its conclusion: concentrating on the details involved with the Pilot Checklist Water Operations Section, handling techniques, and post-shutdown actions, for example. In this occurrence, it was felt by the co-pilot that the failure to consult the Water Operations Checklist for the controlled ditching procedure, internal stores jettison, and sea anchor deployment, in addition to not lowering the landing gear and variable-depth sonar (lowering the centre of aircraft gravity and increasing stability for salvage) for example, were indicative of incomplete training. Therefore the Waterbird training conducted by the OTU was examined.

The training encompasses both classroom and in-flight sessions covering landing on, taxiing on, and taking off from the water's surface in the event that the Sea King is in an emergency situation requiring such a response. Scenarios requiring these skills and techniques both on and off the water, including use of the Water Operations Checklist, are also taught; aircrew gain experience in aircraft stability, performance, and reaction to water motion. The simulator is also used to compliment water operations procedures: training is conducted by OTU instructors for not only OTU students but also for qualified aircrew on squadrons returning to complete semi-annual simulator training requirements. It is OTU policy to challenge students with emergency scenarios that require ditching actions to be carried out. The experience of Waterbird training, including water operations procedures during simulator sorties, translates into a greater ability and confidence for aircrew, during an actual ditching scenario, to concentrate on such requirements as water operations checklist completion, aircraft shutdown or taxi, aircraft egress, and subsequent survival procedures.

Due to seasonal constraints inherent with scheduling of OTU training, the Waterbird syllabus was not completed by the co-pilot, TACCO, and AESOP. This training can only be conducted during the summer and fall seasons when local conditions at 12 Wing Shearwater, NS, permit the use of a nearby lake. OTU students that graduate during the winter season must wait until the summer for complete syllabus exposure; this can result in, as in this case, the deployment of aircrew who have not completed Waterbird training.

It is recognized that there is no substitute for actual hands-on experience with respect to water operations. The current Waterbird training syllabus has existed for some time and, although it is only able to be fully completed during part of the year, its effectiveness is apparent: of the two reported ditchings within the past 10 years, one crew reported that Waterbird training assisted in their ditching of the aircraft while another crew, after ditching, successfully employed the OTU-taught techniques to take off and recover the aircraft. While operating within seasonal constraints, the OTU addresses the lack of winter in-flight Waterbird training through the use of classroom lecture and discussion and simulator training. The current method and content of Waterbird training during the out-of-season period is therefore concluded to be sufficient and effective within the constraints placed on it. Para 2.5.1 further discusses the clarity and accuracy of the AOI and Pilot Checklist.

2.4.4 Recurrent Training

The content and periodicity of recurrent training was reviewed and found satisfactory. It was concluded, based on the occurrence crew's currency in all required training (bail-out and ditching drills, underwater egress training, wet dinghy drills, Waterbird (pilot only), etc) that the crew was qualified to conduct the mission for which they were tasked.

2.4.5 Individual Crew Training

The co-pilot, TACCO, and AESOP each had between 120 and 180 hours on type. Given their collective inexperience, the pilot, who was responsible for crew training, found it necessary to dedicate portions of each mission to the training of individual members. The implication of having three crewmembers concurrently undergoing the upgrade process was that the available time had to be shared between them. Although every flight builds on crewmembers' experience levels and provides learning opportunities, mission task performance can be slow when required to train multiple crewmembers. It is impractical, for example, to interrupt the AESOP's hoisting practice to give the co-pilot a practice MGB malfunction. Consequently to achieve the MGB malfunction practice, another hover/hoisting evolution must be conducted and thereby requires twice as much time.

Given that safety of flight and initial emergency response is the domain of the pilot, the investigation reviewed the training that the co-pilot received post-OTU completion, the majority of which was while embarked. It was routine for the pilot and co-pilot to share flying time at the controls; the co-pilot was also given one practice emergency per flight. The entire detachment had participated in numerous ground training sessions; however, the only MGB-specific session involved a briefing given by the co-pilot on the differences between the 21000 and 24000 series MGB.

Upon graduation from the OTU, a graduate co-pilot is capable of flying the aircraft under normal conditions and reacting to emergencies listed in the checklist. Experience, however, is required before a co-pilot is expected to correctly analyse and react to complex malfunctions. This experience, in part, is gained through training for which the pilot was responsible. It was thus deemed appropriate to look at the manner in which pilots conduct that training and how they are equipped to accomplish that training mandate.

2.4.6 Upgrading Process

The primary guidance utilised by a pilot in training a co-pilot to higher category is the Category Upgrading Plan (CUP). The CUP is a checklist that ensures specified ground and airborne manoeuvres are conducted during the upgrade process and that the candidate possesses identified performance skills prior to being granted the next higher category. The Maritime Helicopter Crew Commander qualified pilot overseeing the upgrade of junior aircrew members is responsible to ensure that CUP training opportunities are available, that the CUP requirements are met, and that progression of CUP requirements continues until upgrade completion. Overseeing this process when ashore is the responsibility of the Detachment Commander and the squadron Readiness Officer and when embarked, the Detachment Commander.

The evaluation of the upgrade process was and continues to be a dynamic process that involves a squadron's Standards Officer assessment of MHCC Annual Proficiency Checks (APC) and quarterly performance reports written on upgrading aircrew; these reports are also tracked by squadron Readiness Officers. The APC consists of an airborne assessment of aircraft and tactical knowledge, aircraft handling, crew management, crew training ability, and a closed-book exam. This process remains a valid method in assessing those responsible for the upgrading of others.

Approximately 10 years prior to the occurrence, a rudimentary MHCC course was developed to improve the quality of the CUP process; however, this course did not last long and was soon discontinued. The failure to continue the course eliminated any formal instructional training that an MHCC may have been provided either during his CUP or after achieving MHCC status. Then in mid-1999 the MHCC course was re-established, by MH 443 Squadron, to provide formalized training in upgrading and instructional techniques for MHCC's to use in the course of their upgrading of junior aircrew members. Although the occurrence pilot had not attended this newly constructed course, he did attend the initial one in 1991. Instructional techniques, however, were not part of the original syllabus.

It is clearly impractical to expect senior squadron pilots charged with upgrading junior pilots to be instructor qualified, and the majority of them are not. It is also recognized that not all senior pilots holding an MHCC category are equal in professional knowledge, motivation, experience, or instructional ability. Furthermore, due to operational and training requirements, it is not uncommon for a junior pilot to transfer often from one detachment to another and have several senior pilots responsible for his/her upgrade process; this can result in a lack of continuity, a key element in any training process. Prior to the accident, senior pilots were not given training in the basic instructional principles of AMOL and EDIC (aim, motivation, outline, link; and explain, demonstrate, imitate, critique). There were no instructional tips or lesson plans for senior pilots to refer to when planning, preparing, and executing their training responsibilities. As a result, the progression of the occurrence crew's upgrading was dependent upon the initiative, motivation, training ability, and experience of the pilot. Although junior crewmembers were provided a CUP to outline the knowledge and skills that they were required to master in the course of their category upgrade, the occurrence pilot had never been provided the skills necessary to fulfill his responsibilities for crew training. In fact, all MHCC qualified pilots without instructional experience were required to carry out a critical task for which no training or guidance was provided.

2.4.7 Crew Reaction to the Emergency

Through examination of the sequence of events (Annex H) and the appropriate checklist procedures (Annexes C and D), it is evident that the initial indication of high temperature required the crew to LAND AS SOON AS PRACTICABLE. The crew correctly decided to terminate the exercise and transit at 100' and 90 Kts towards HMCS PROTECTEUR. Pressure fluctuations were then noted and the decision not to use the #1 SSL procedure was made. The subsequent pressure fluctuation increase to greater than the normal limits of ±5 PSI and outside the normal range of 45-90 PSI raised the reaction criteria to LAND AS SOON AS POSSIBLE. The crew then became increasingly uneasy and established a hover in order to wait for the ship to arrive. At this point it was not the pilot's intention to ditch; although the conditions for "LAND IMMEDIATELY" did not yet exist, the pilot was anticipating the possibility of that eventuality. Although neither taught at the OTU nor promoted by the MH Standards Evaluation Team, the idea of a precautionary hover for MGB malfunctions has existed in the MH community for some time. Hover flight is required only for an in-flight illumination of the Rotor Brake advisory light as described in Annex G.

With the addition of unusual heat and smell, the pilot believed that indications were consistent with imminent MGB failure and carried out the LAND IMMEDIATELY actions of the Pilot Checklist. Once it is established that MGB failure is imminent, it is taught that the aircraft be shut down immediately upon landing to avoid the serious danger of total MGB failure while under power. However, after conducting a controlled ditching, the pilot's intention was to keep the rotors running in order to maintain aircraft stability and thereby assist salvage operations once the ship arrived on scene. Due to the amplitude of the ocean swell, the engines were shut down to prevent rotor blade-ocean contact which could have destabilized and possibly capsized the aircraft, thereby compromising successful crew egress. In the event, the crew egressed once the rotor blades had stopped.

There are three aspects of the crew's reaction to the emergency worth analyzing in detail:

a. the decision to not use the #1 SSL procedure;

b. the decision to enter the hover; and

c. once in the hover, the decision to ditch.

2.4.8 The Decision to Not Use the #1 SSL Procedure

To examine the validity of the decision to not use the #1 SSL procedure, both courses of action must be compared: the use of the procedure and its actual non-use as seen in this occurrence. Table 5: Differences In #1 SSL Procedural Use, compares these two courses of action (italics are used to identify where the scenarios diverge). Recall 2.3.5, the statistical probability data and the effect of temperature information: both explain the likely effect on MGB temperature and pressure and their relationship to the use of the #1 SSL procedure in the event of inherent overtemps. This information was used to construct the likely sequence of events shown in column 2 of Table 5.

Table 5: Differences In #1 SSL Procedural Use

Stage of Flight	#1 SSL Procedure Used	#1 SSL Procedure Not Used
Initial Hover (crew notes overtemp emergency condition)	Land as Soon as Practicable Criteria present: Master Caution Light, Trans Oil Hot Light, Trans Oil Temp Gauge 150°C	Land as Soon as Practicable Criteria present: Master Caution Light, Trans Oil Hot Light, Trans Oil Temp Gauge 150°C
Transit (crew reaction to initial overtemp conditions)	Land as Soon as Possible Criteria present: MGB Pressure Fluctuations ±10 PSI, Mean Pressure Drops, still in green arc	Land as Soon as Possible Criteria present: MGB Pressure Fluctuations ± 10 PSI, Mean Pressure Drops, still in green arc
	#1 SSL retarded	*#1 SSL NOT retarded*
	MGB temp increase stops, MGB temp decreases	*MGB temp continues to increase, MGB temp remains high*
	MGB Press Fluctuations stabilize, reduce, then cease	*MGB Press Fluctuations increase to ±30 PSI*
	Aircraft does not enter Hover	*Aircraft enters Hover*
Final Hover (crew reaction to worsening emergency indications)		*Land Immediately Criteria present: Intense heat and fumes present*
Landing	*Aircraft lands on nearest flight deck*	*Aircraft Ditches*

To summarize Table 5, had the #1 SSL been retarded, it is probable that a temperature decrease and pressure stabilization would not have resulted in the decision to enter the hover. Without the final hover, it is likely that radiant heat and fumes would not have been noticed by the crew and would therefore not have added to the cumulative sum of information that compelled the crew to ditch. This analysis indicates that the non-use of the #1 SSL procedure exacerbated the situation, the question why it was not utilized must now be examined.

As noted in 2.3.5.2, the intent of the #1 SSL procedure, as perceived by some, was to stop overtemp conditions before the maximum MGB temperature was exceeded, therefore avoiding the requirement for major maintenance action. In the face of mounting evidence that the inherent overtemp condition did not historically damage MGB components, the introduction of the #1 SSL procedure, although left to the pilot's discretion, was a prudent course of action that saved CH124 resources (section 2.3.5.1). There was evidence before this accident, however, that the procedure was useful in not only preventing further temperature increases, but also reducing MGB temperature and other symptoms. Several "inherent overtemp occurrences" had resulted in MGB pressure fluctuations. The importance of this fact was not grasped by earlier post-occurrence analysis and therefore not distributed to aircrew and maintenance personnel, so some aircrew, including the occurrence pilot, continued to see the #1 SSL procedure strictly as an MGB maintenance saving technique. Clearly, there was a lack of information and direction concerning the #1SSL procedure before this accident, and the pilot's decision to not use the procedure was consistent with the information he had been provided. There is some argument, with the history of its effectiveness, that the procedure should have been made mandatory for this critical emergency despite the lack of OEM information.

It is entirely likely that the decision not to use the #1 SSL procedure, for the reasons noted above, permitted the MGB temperature to remain abnormally high and the MGB pressure fluctuations to develop. These conditions, in turn, contributed to the decision to enter the hover. Once in the hover, it is probable that heat and fumes emanating from the MGB were no longer vented from the cabin spaces and became noticeable by the crew, further stimulating the decision to ditch. From this analysis, it is concluded that the lack of complete published information on the over-temperature phenomenon, the relationship between MGB over-temperature and subsequent pressure fluctuations, and the utility of the #1 SSL procedure as a valid means to cool the MGB all combined to contribute to the ultimate decision to ditch.

2.4.9 The Decision to Enter the Hover

It is difficult to assess the appropriateness of crew responses to emergency scenarios without being immersed in the emergency: circumstances at the time, the crew's interpretation of the circumstances, the pressures affecting them, and their emotions. Furthermore, while emergency reaction must be instinctive and immediate, there must be room for crews to tailor the reaction to unique and complex scenarios. In that context, the decision to enter the hover must be assessed on the basis of the adequacy of information in the AOI and the Pilot Checklist to correctly respond to the emergency.

Emergency procedures indicate that during LAND AS SOON AS POSSIBLE conditions, flight is continued to the first site at which a safe landing can be made. Over water, the logical and common interpretation of a "safe place" is the nearest flight deck or suitable point of land. The procedure taught by the OTU for MGB malfunctions is to establish and maintain as constant as possible a minimum torque-required-for-flight and only change that setting as required for landing. The technique is designed to minimize frequent torque adjustments and reduce high power settings that could aggravate the malfunction, thereby maximizing time before MGB failure. While establishing a hover would reduce the time required to ditch in the event of MGB failure or imminent failure, the resulting high and variable torque could also reduce MGB time to failure. Furthermore, the time required for the ship to transit to the helicopter would be greater than if the helicopter maintained forward flight and steady state power settings. The investigation confirmed that some CH124 pilots support the election to hover and await the ship (dubbed the "precautionary hover" for the purposes of this report), however, this procedure is neither in the Aircraft Operating Instructions (AOI) or the checklist, nor is it taught or supported at the OTU for other than an in-flight illumination of the Rotor Brake advisory light (see Annex G).

Supporters of the precautionary hover during LAND AS SOON AS POSSIBLE situations would feel more comfortable in the hover than in forward flight given favourable sea state and water conditions. Some also favour ditching rather than risking continued flight under some circumstances. In rough sea conditions, at night or in extreme cold, however, they would not enter the hover in response to a LAND AS SOON AS POSSIBLE emergency due to the reduced likelihood of crew survival when ditching. This implies an expectation that the precautionary hover would be followed by ditching if the ship does not arrive before fuel runs out or the transmission shows signs of imminent failure. They have thus applied the LAND IMMEDIATELY criteria which the Pilot Checklist defines as "consequences of continued flight are more hazardous than those of landing at a site normally considered unsuitable" (the term "unsuitable" by implication applies to water landings because of the likelihood of hull loss) to a scenario which the AOI defines as LAND AS SOON AS POSSIBLE. The AOI clearly intends that pilots respond to LAND AS SOON AS POSSIBLE emergencies by continuing flight until the first safe landing site is reached, regardless of the sea state or outside air temperature.

Notwithstanding the above logic flow, the crew testified that they did not intend to ditch when they entered the precautionary hover, nor did they consider MGB failure to be imminent. Therefore in their mind LAND AS SOON AS POSSIBLE criteria existed, yet the crew chose not to continue to a safe landing site. Thus, at the time of entering the hover, the crew did not continue flight in accordance with the AOI and Pilot Checklist procedure. That established, the investigation focused on understanding why pilots would choose a procedure at variance with the AOI and checklist. A representative sampling of CH124 pilots' interpretation of MGB emergencies was made to establish, if possible, where the "Precautionary Hover" procedure was developed.

The Investigation Team found that the procedures taught at the OTU are not universally accepted on the operational squadrons. The opinion that procedures must be maintained sufficiently vague to permit the pilot to react to a fluid situation was espoused by many senior personnel on both operational squadrons. Detailed interviews asked crews what their reaction would be to a scenario similar to this occurrence. 12 out of 12 operational pilots (three co-pilots, one aircraft captain and eight crew commanders stated that they would choose a low and slow profile to return to the ship, but few agreed on exactly what that meant (anything from 300 feet and 100 kts to a hover taxi profile). Eight pilots chose to establish a hover when they became uncomfortable with the MGB indications. Three pilots chose to continue to the ship and one indicated that he would have landed in the water as soon as the pressure fluctuation went below the green arc, and then taxi back towards the ship. Given conditions and indications identical to the occurrence flight, 75% of the pilots questioned would have reportedly resorted to a ditching before the ship could arrive at the scene.

A similar scenario was posed to the staff and students at the OTU. All of the three students and five instructors consulted would have elected to continue low and slow (again some disagreement on the exact profile) back to the ship. Additionally, there was unanimity as to the logic of maintaining near constant and minimum possible torque during the transit. The circumstances requiring an immediate landing (suspected loss of all MGB Oil, or imminent failure (chip lights, grinding noises, decaying Nr, et)) were clearly articulated by all instructors. None would land on the water until those criteria were met, and none would transition to the hover in anticipation of potential future “LAND IMMEDIATELY” indications.

This disparity between what is taught at the OTU and what is accepted at the operational squadron obviously affected the outcome of this occurrence. This suggests tacit support for the establishment of “procedure through discussion” in the crew room rather than via formally sanctioned processes such as the AOI committee. Bypassing these checks and balances can lead to incidents such as CH12405’s inadvertent ditching in December 1999 – a pilot-induced engine failure caused directly by adopting and using locally derived procedures. Based on the divergence of opinion between the operational squadrons and the OTU, it is concluded that emergency procedures with respect to MGB malfunctions were not uniformly applied. See 2.5.7.2 for a further example of incorrect procedural use.

Finally, a lack of aircrew confidence in the 21000 MGB may have also influenced the decision to enter the hover. As discussed earlier in 2.4.9, corporate knowledge within the operational community accepted a precautionary hover if the sea and weather conditions favoured a water landing. The implication was that if a crew could get out with little risk before LAND IMMEDIATELY criteria were identified by imminent MGB failure, then the loss of the aircraft was acceptable. For the mishap detachment, superimposed on the notion of a precautionary hover was the recent history of MGB malfunctions noted in Annex B. The mishap crew spoke often of the possible catastrophic results of an MGB failure during missions leading up to the occurrence. All detachment aircrew indicated that they were closely monitoring the MGB instruments on every mission. Taken collectively, it is concluded that elements of the operational community may have lacked confidence in the 21000 MGB. When crews become uncertain of an evolution, task, or mission, a common response is to slow down the tempo or even stop in order to analyze the situation; entering hover flight and discussing available options can often be the safest thing to do. It was possible that the occurrence crew was predisposed to believe, consciously or not, that the MGB would fail, and that this predisposition contributed to their decision to enter the hover.

2.4.10 The Decision to Ditch from the Hover

Once in the hover, the crew experienced the highly unusual indications of radiant heat and a burning smell. These two final indications, compounded with the initial indications of high temperature, lower than normal pressure, and large pressure fluctuations, were sufficient, in their mind, to redefine emergency criteria from LAND AS SOON AS POSSIBLE to LAND IMMEDIATELY. Given that the radiant heat and severity of burning smell had never before been experienced in the CH124, their conclusion that these were symptoms of internal MGB breakdown and imminent MGB failure was reasonable, and, from the hover, their decision to ditch in a controlled manner was appropriate and safe.

LAND IMMEDIATELY actions are carried out to minimize risk to personnel and equipment. Once on the ground or water as a result of such actions, it is universal procedure for all CF aircraft to shut down and for personnel to egress. In this occurrence, the decision to keep the rotors turning appears not to have considered the hazard of allowing high-inertia internal MGB components to remain running at up to 18966 RPM. Had the MGB failed while under power, a sudden rotor blade system stoppage would have resulted in probable MGB mount failures, an uncontrolled change of the tip path plain, and cabin and tail rotor drive shaft strikes by the rotor blades. The resulting imbalance of these high-inertia components could have caused serious injury to personnel. It is felt that, post-ditching, an emergency shutdown should have been initiated rather than remaining rotors-running in order to facilitate salvage.

2.5 **Other Flight Safety Concerns**

2.5.1 Clarity and Accuracy of the AOI and Pilot Checklist

As noted above, the investigation found that the AOI and Pilot Checklist offered inadequate guidance for response to MGB and water operations emergencies.

At the time of the occurrence, the AOI indicated that MGB oil pressure fluctuations within the green arc were permitted and required only a maintenance report at the end of the mission if greater than ±5 PSI. Pressure fluctuations within the green arc (45-90 PSI) in concert with high temperature as experienced in this occurrence, were not specifically mentioned in the AOI or checklist. Furthermore, these references provide no suggestion that the combination is indicative of component degradation or requires any action beyond that required for the overtemp situation. Though each situation individually constitutes a "LAND AS SOON AS POSSIBLE" scenario, nothing suggests that temperature and pressure fluctuations together satisfy the "LAND IMMEDIATELY" criteria unless the loss of all MGB oil is suspected. Nowhere in the AOI, Pilot Checklist, or Standard Manoeuvre Guide (SMG) is this kind of amplifying guidance regarding MGB emergency procedures provided.

The fact that the crew did not utilize the Pilot Checklist during and after the ditching led the investigators to review the information included in the AOI and Pilot Checklist on water operations (Annex F: Water Ops Checklist). The water operations checklist was not logically organized: the critical functions of stores jettison, water take-off, floatation bag actuation, sea anchor deployment, and controlled ditching are not in a logical sequence. Out of sequence critical checklist items require frequent flipping back and forth of checklist pages during a time-critical emergency, an undesirable characteristic of any efficient checklist. Although the water take-off procedure is clearly articulated, the controlled ditching section is not and does not identify critical considerations such as rotor RPM, internal stores, transition profile, rough or calm water entry, wind, maximum water taxi speed, water ingress reduction, floatation bags, shutdown procedures, egress responsibilities, and emergency calls. As a result, the crew indicated that the shutdown and egress phase, although successful, was less organized and less complete than it might otherwise have been.

Furthermore, the review found that the AOI, SMG, and Pilot Checklist did not include valuable information that is generally well known to experienced Waterbird instructors, for example that the application of torque when water taxiing cones the blades and helps avoid blade-to-wave contact (vaguely referred to in AOI) and that stopping on the water accelerates water ingress whereas maintaining forward speed allows the keel scupper valves to function properly. Additionally, some indication of the techniques required for taxiing in various sea states may have better prepared the pilot for what he mistakenly expected to be a "flat calm" environment. It is therefore concluded that the organization, content and lack of clarity of the AOI, SMG and checklist with respect to water operations is incomplete.

2.5.2 Crew Experience and Composition

Sea King crews have in the past reported that an experienced backseat crewmember can contribute significantly to resolving malfunctions that are typically designated as a pilot responsibility. Time permitting, discussion with other experienced crewmembers is a more complete decision making process than when only one experienced member is involved. This often results in the determination of better courses of action that in turn lead to more favourable outcomes because more than one experienced individual can consider more factors and explore a greater number of options than the single individual could.

With the rest of his crew relatively inexperienced, the pilot did not have access to this kind of resource and that may have contributed to his decision against risking continued flight while “LAND AS SOON AS POSSIBLE” criteria were present.

Although there is no regulated requirement to do so, individual aircrew experience levels are considered by MH squadrons when HELAIRDET crews are formed so that each operational crew ideally has an experienced pilot and TACCO or AESOP combination. This is done in part to facilitate crew training and ensure that sufficient time and technical expertise is available to the embryonic aircrew. However, as with the occurrence crew, there are occasions when a single experienced crewmember is required to oversee and upgrade the entire crew. These situations are generally infrequent and, when required, a senior pilot, such as the occurrence pilot, is placed in charge of the crew.

2.5.3 Maintenance Supervisors’ Experience

While not assessed as causal in this accident, the investigation identified several maintenance actions that were conducted in such a way as to bring into question the expertise of senior CH124 maintainers. It is recognized that experience level of senior maintenance personnel is decreasing throughout the Air Force and not just within the Sea King community, but in the interest of reducing the potential for lower levels of expertise to jeopardize flight safety and airworthiness, it was felt appropriate to investigate this issue further. The investigation team thus conducted a detailed analysis of the experience and training of the senior Sea King maintenance personnel. For brevity, only the findings of this analysis are identified:

a. The mean experience level of senior maintenance personnel in the CH124 environment had been steadily decreasing;

b. Deployed maintenance managers demonstrated a willingness to accept non-standard maintenance practices (ie torque procedures) on the recommendation of qualified but junior technicians. Testimony indicated that a culture supporting the use of undocumented “best methods” existed on some detachments; and

c. The maintenance manager’s course, which is provided to indoctrinate senior maintenance personnel in the challenges of independent deployed operations, was insufficient preparation for the duties required of senior deployed maintenance personnel.

2.5.4 Accepted Maintenance Deviations

Investigators observed that qualified technicians were careful to use the Canadian Forces Technical Orders (CFTO) when training subordinates. However, these same technicians also confirmed that they knew and used “better” techniques not detailed in CFTOs when the trainees were not around.

These types of maintenance practices, which included hand-tightening fittings that normally required specific torque values, was understood and accepted by the maintenance supervisors. There was no attempt to hide these practices nor was there an indication that anyone thought the practices imprudent. The acceptance of “better” by the maintenance detachment was considered the result of a combination of maintenance manager’s inexperience and the misplaced confidence of the qualified technicians.

2.5.5 Floatation Bags

The recovered floatation bag was delivered to QETE for testing. It was determined that the rivets on the metal strip that attaches the bag to the sponson failed in overload, as expected. The floatation bag is not designed to keep the aircraft afloat indefinitely, just to stabilize it long enough for the crew to evacuate. However, in the course of the investigation it was noted that the configuration of the rivet attachment varied in the size and number of rivets on almost every aircraft. It is concluded that the type and number of rivets used on the right sponson could have contributed to the failure of the floatation bag, and therefore accelerated the capsizing and eventual sinking of the aircraft (see Annex E: Floatation Bag Attachment).

2.5.6 Salvage Operations

Although HMCS PROTECTEUR did not arrive on scene in time to mount a salvage operation, testimony revealed that the equipment and procedures used to recover a Sea King were not well understood by the salvage crew. Although the required equipment was available on board, no instruction on its use had been undertaken and no detailed standard operating procedure (SOP) existed on board. Had a salvage operation had been required, the salvage crew would not have been able to properly connect the floatation collar or the recovery strop. Since the accident, training information and SOPs developed by HMCS PRESERVER have been made available to HMCS PROTECTEUR.

2.5.7 Aircrew Life Support Equipment (ALSE) Failures

2.5.7.1 Radios and Beacons

The occurrence crew indicated that one PRQ-501 and the ELT did not function properly post-aircraft egress. Investigation revealed that the PRQ-501 was serviceable and no explanation could be found for the apparent malfunction. With respect to the ELT, its antenna is not connected to the transmitter during storage and so must be attached prior to use. Given that this equipment is periodically inspected for serviceability, it was most likely functional when retrieved for use by the pilot. It is therefore concluded that the connecting pins where bent, rendering the equipment unserviceable, during the attempt by the pilot to connect the antenna to the ELT.

2.5.7.2 Multi-Place Life Raft

The crew experienced difficulties inflating the multi-place raft prior to egress as a result of not employing egress and inflation SOPs. Examination indicated that the raft was serviceable, but it malfunctioned due to the method of activation used. Helicopter water egress procedures taught by Safety Systems personnel call for the entire crew to enter the water with the un-inflated raft, clear away from the aircraft and the rotor arc, and only when all crew members are together is the inflation lanyard to be pulled (one hand on the lanyard, one hand on the raft). In this case, with all the crewmembers standing in the cargo door and with the raft free-floating outside the cargo door, the lanyard was pulled. There was no force on the raft opposing the lanyard pull and, as a result, the pin was not withdrawn from the CO2 bottle and the raft was drawn toward the aircraft's side. The TACCO then grabbed the lanyard where it attached to the CO2 bottle and, while steadying the raft with his left hand, he pulled the pin with his right hand. Once inflated, the crew then entered the raft and moved away from the aircraft. Deployment and inflation of the raft in accordance with SOPs would have averted these inflation difficulties. It should be noted that the reason for not inflating the raft until clear of the helicopter rotor arc is to avoid striking the raft and crew with a rotor blade (or other sharp objects) in the event that the helicopter capsizes. Should this occur, it is possible that raft and crew could be dragged under the water as the helicopter continues to roll inverted or sink. By inflating the raft from inside the helicopter, the crew not only delayed their egress from the helicopter, but also risked loss of the six-man life raft, injury and/or loss of life.

It is worth mentioning that of the seven CH124 ditchings, three have been uncontrolled and four have been controlled. In the two previous controlled ditchings (CH12409, CH12411) aircraft egress was similar to that of the crew from CH12422, ie not conducted in accordance with instructed procedures. Three out of four controlled ditchings (75%) show that incorrect egress procedures appear to be accepted practice within the MH community. The risk of damage to survival equipment and of injury or death due to incorrect survival techniques cannot be outweighed by the aircrew propensity to create and utilize untrained ad hoc procedures.

3. CONCLUSIONS

3.1 Findings

3.1.1 The aircraft was serviceable prior to the occurrence.

3.1.2 The crew was medically fit at the time of the accident.

3.1.3 The crew was qualified and authorized for the mission.

3.1.4 The weather was suitable for the mission.

3.1.5 Favourable sea conditions contributed to the success of the egress.

3.1.6 The MGB in the occurrence aircraft and the 21000 series MGB in general have a history of unexplained or “inherent” overtemps.

3.1.7 The occurrence crew was aware of an MGB oil leak and a subsequent Special Inspection on this aircraft’s MGB lubrication fitting three days prior to the occurrence.

3.1.8 In the days leading up to the occurrence, the crew had discussed the fact that the earlier MGB oil leak could have been catastrophic had it occurred over water.

3.1.9 Maintenance personnel routinely deviated from the CFTO with respect to the use of torque wrenches for the installation of MGB lubrication fittings. This deviation was known and accepted by maintenance supervisors.

3.1.10 There was no evidence of an MGB oil leak.

3.1.11 Maintenance is not considered to be a contributing factor in the accident.

3.1.12 The indications of high temperature, reduced pressure, and fluctuating pressure described in the occurrence are representative of a known inherent overtemp deficiency in the 21000 series MGB.

3.1.13 The noted pressure fluctuations were likely a result of MGB oil property degradation caused by excessive heat within the MGB.

3.1.14 The noted heat and fumes were likely a result of generalized heating of the MGB casing and oils and grease external to it.

3.1.15 There is no means of accurately establishing the maximum temperature of the MGB oil in excess of 150°C.

3.1.16 The MGB oil temperature probably reached temperatures in excess of the 177°C available during QETE testing in order to generate pressure fluctuations without a leak.

3.1.17 It is probable that had the #1 SSL procedure been used, it would not only have prevented further MGB temperature increase, but also would have reduced it.

3.1.18 It is likely that had the #1 SSL procedure been used, the decision to enter the hover would not have been made until ready to land on a flight deck.

3.1.19 With only the presence of Land As Soon As Possible criteria the crew elected not to continue flight to the first site at which a safe landing could be made, ie the nearest flight deck.

3.1.20 With the belief that MGB failure was imminent, the crew conducted a controlled ditching from the hover.

3.1.21 The Water Operations section in the Pilot Checklist was not consulted in preparation for conducting the controlled ditching or post-ditching activities.

3.1.22 The OTU syllabus, including Waterbird training, was adequate and appropriate.

3.1.23 Waterbird training is essential for all aircrew in preparing them to react effectively to water landing scenarios.

3.1.24 The junior aircrew members were not prepared to react effectively to the occurrence water landing scenario likely because they did not complete the practical flight portion of the training.

3.1.25 The pilot had no specific training or defined skill set to utilize in fulfilling his requirement to upgrade junior crewmembers.

3.1.26 There now exists a comprehensive process, the MHCC Course, by which MHCCs are prepared for the duties of training and upgrading junior aircrew members.

3.1.27 MGB emergency procedures were not applied in a standardized fashion by 12 Wing aircrew.

3.1.28 Some aircrew, including the occurrence crew understood that the #1 SSL procedure was intended only to prevent the MGB from reaching 145°C.

3.1.29 The AOI and Pilot Checklist did not give adequate direction or information with respect to the symptoms of and reactions to an inherent MGB overtemp condition.

3.1.30 The OEM would not recommend a procedure (#1 SSL) to rectify the overtemp condition because they could not reproduce it during their theory validation trials.

3.1.31 The AOI and Pilot Checklist provided incomplete guidance with respect to MGB emergencies.

3.1.32 The AOI, Pilot Checklist, and SMG provided incomplete guidance with respect to Water Operations emergencies.

3.1.33 The inexperience of the junior crewmembers did not contribute to the pilot's detailed analysis and resolution of this complex emergency situation.

3.1.34 The occurrence aircraft detachment maintenance manager routinely deferred questions of airworthy practices to the technician with the most experience on the detachment.

3.1.35 A culture of accepting undocumented best practices over CFTO procedures existed on some detachments.

3.1.36 The Maintenance Manager's course was insufficient preparation for deployed operations.

3.1.37 The salvage crew aboard HMCS Protector was not familiar with the helicopter auxiliary floatation devices or the proper means to connect them to a Sea King.

3.1.38 The pilot likely bent the ELT antenna pins during the attempt to connect the antenna to the ELT.

3.1.39 It remains undetermined as to why the PRQ 501 malfunctioned during the occurrence.

3.1.40 Non-standard egress and multi-place life raft inflation techniques were utilized post-water landing and shutdown.

3.2 **Cause Factors**

3.2.1 For unknown reasons the MGB reached an overtemp condition that caused subsequent reduced pressure, pressure fluctuations, ambient heat, and burning smells.

3.2.2 The lack of published information about the known inherent overtemp condition of the 21000 series MGB, resulted in an incomplete understanding of the cockpit indications and the required response by the crew.

3.2.3 The lack of published information about the #1 SSL procedure and its utility contributed to the decision against its use and thereby prevented reduction of the severity of the symptoms.

3.2.4 A published procedure to reduce the severity of indications with respect to the MGB overtemp condition was not utilized.

3.2.5 The helicopter entered the hover despite published procedure directing the continuation of flight to a safe place to land.

3.3 **Contributing Factors**

3.3.1 Recent history of CH12422 MGB malfunctions created an environment in which the crew was predisposed to believe that the MGB would fail.

3.3.2 The junior crewmembers' inexperience minimized the assistance that they could provide to the pilot in evaluating the emergency, and thus likely did not contribute to the in-flight emergency handling and decision-making process.

3.3.3 The lack of standardization between the OTU and the operational squadrons permitted non-standard procedures to be developed and accepted at the unit level, likely contributing to the loss of the aircraft.

4. SAFETY MEASURES

4.1 **Safety Measures Taken**

4.1.1 A Day VFR operational restriction was imposed by Commander 12 Wing in consultation with 1 CAD on the CH124, pending investigation into the circumstances of the ditching of CH124422. The restriction was subsequently lifted for any aircraft with the modified 24000 series MGB. Following a careful review of the evidence and the implementation of mitigating action, the Ops restriction was cancelled.

4.1.2 12 Wing instituted a policy whereby aluminium lubrication fittings shall not be reused.

4.1.3 12 Wing initiated a training program to ensure that line maintenance personnel are aware of torquing procedures in accordance with the CFTO and that the techniques are uniformly applied.

4.1.4 Staff work was initiated by 12 Wing to address both the experience levels and training offered to HELAIRDET senior NCMs.

4.1.5 An AOI amendment was initiated, and temporarily published in aircrew orders, for:

a. MGB Emergencies to include pressure fluctuations in excess of ±5 PSI; and,

b. Use of the #1 SSL procedure.

4.1.6 An SOP and training package for salvage operations was created. Embodiment of the applicable documents and procedures in SHOPS is pending.

4.1.7 Amendment action was initiated for Fleet Operating Procedures to ensure that ships maintain an aviation lifeguard (HF flight guard) during flights greater than 20 NM from the ship.

4.2 **Further Safety Measures Required**

It is recommended that:

4.2.1 the MGB emergency procedures be reviewed to give aircrew specific direction with respect to the unofficial “Precautionary Hover”.

4.2.2 the CH124 AOI and Pilot Checklist be amended to give aircrew a logically flowing sequence of reactions to water operations emergencies. Additionally, concise supplemental information concerning the controlled ditching, pre- and post-landing considerations, and water taxi procedures is required.

4.2.3 current aircraft egress training be reviewed to ensure that correct procedures are adequately emphasized and that the hazards posed by non-standard actions are understood by all aircrew.

4.3 Other Safety Concerns

4.3.1 Consideration should be given to an aircraft modification to install warning lights to indicate when a MGB sump oil temperature of over 120°C and 145°C have been exceeded.

4.3.2 Consideration should be given to an all-fleets applicability of the 12 Wing decision to prohibit reuse of aluminium lubrication fittings.

4.3.3 Consideration should be given to standardizing the method and materials used to attach the floatation bags to the sponson.

4.4 DFS Remarks

Given the history of the 21K series MGB, the exact cause of the overtemp would probably never have been unequivocally determined even if the aircraft had been recovered. Much has happened since this accident, and it would be easy to assume that all the problems causal to this accident have gone away with the fitment of the 24K series MGB, but there were many other factors identified by this investigation, some of which contributed to the outcome, and they could contribute to occurrences in the future if they are not addressed. My hope is that they <u>all</u> get the attention they deserve.

//signed on original//

R.E.K. Harder
Colonel
Director of Flight Safety

Annex A: 21000 MGB Description

1. CH12422 was fitted with a Sikorsky designed 21000 series main transmission, commonly referred to as a Main Gear Box (MGB). The MGB drives the accessories, supports and drives the main rotor, and provides power takeoff to drive the tail rotor. The accessories, which include two generators, two MGB oil (lubrication) pumps, Auxiliary and Primary Hydraulic pumps, the torque-sensing pump, and the rotor tachometer-generator, are all driven through a free-wheel unit. When the rotor head is disengaged, a through shaft geared to the No 1 engine drives the accessories. Lubrication of the MGB is accomplished by a self-priming wet sump system. The 21000 series MGB is lubricated with synthetic based oils that comply with military specification MIL-L-23699.

MGB Temperature Indicating System

2. The MGB temperature indicating system, comprised of an indicator (Figure 1- MGB Oil Temperature and Pressure Gauges) and a resistance bulb, indicates oil temperature from minus 70º C to plus 150ºC in 10ºC increments. Normal MGB operating temperature is between 40ºC-120ºC. The temperature bulb is located in the lower housing cap assembly and indicates the temperature of the MGB oil in the sump. The essential bus, through an overhead control panel circuit breaker, supplies electrical power for the system (28 VDC).

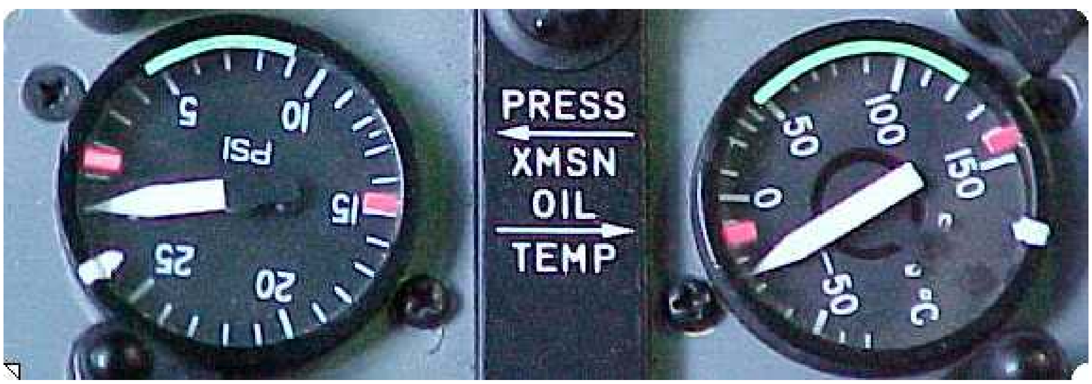


Figure 1- MGB Oil Temperature and Pressure Gauges

MGB Oil Temperature Hot Warning System

3. The MGB Oil Temperature Hot warning system indicates hot oil temperature within the MGB lubrication system, immediately downstream of the cooler. The TRANS OIL HOT caution light illuminates when the MGB oil exiting the cooler exceeds 120ºC. Due to the relative locations of the sensors, given proper cooler function, it is possible to have the gauge indicate in excess of 120ºC without having a corresponding temperature light. Electrical power for the system (28 VDC) is supplied by the essential bus through the warning lights power (WARN LTS PWR) circuit breaker on the overhead control panel.

MGB Pressure Indicating System

4. The MGB oil pressure indicating system reports oil pressure ranging from 0-250 PSI. Normal operating pressure is between 45-90 PSI. The indicator (figure 1) is in increments of 10 PSI. Electrical power for the system (26 VAC) is supplied by the No 1 autotransformer through a circuit breaker on the AC circuit breaker panel.

MGB Low Oil Pressure Warning System

5. The MGB low oil pressure warning system indicates low oil pressure within the MGB lubrication system. The “TRANS OIL PRESS” light on the master caution panel will illuminate when the oil pressure drops below 3 PSI at the end of the jets (which equates to an operating pressure of approximately 12 PSI at the gauge). Electrical power for the system (28 VDC) is supplied by the essential bus through the WARN LTS PWR circuit breaker on the overhead control panel.

Oil Cooler

6. The MGB oil cooler, blower and air-input duct are mounted in the aft rotary wing fairing. The belt driven blower forces air through the radiator. The temperature of the oil is controlled by a thermostatic pressure relief valve that allows oil bypass operation at temperatures below 70ºC or with a localized pressure differential of 40 PSI across the valve.

MGB Indication System-Basic Operation

7. Under normal operating conditions, MGB oil accumulates at the bottom of the MGB (sump) and exits the sump area via two outlet lines. The oil temperature bulb, which controls the cockpit MGB temperature gauge, is located at the lowest portion of the sump. The oil passes through two strainers under pressure exerted by the number one and two MGB oil pumps. The oil is pumped to the oil cooler input port and the thermostatic pressure relief valve. The thermostatic pressure relief valve is designed to allow oil to bypass the cooler and go straight to the MGB input ports if the oil temperature is below 70ºC, or if the pressure portion of the valve senses a pressure differential of 40 PSI across the valve. The pressure bypass feature ensures that oil can be distributed to the MGB in case of a localized oil cooler restriction such as an internal radiator blockage.

8. When the MGB oil temperature reaches 70ºC, the thermostatic valve will fully extend, thus closing the bypass access port. Oil is then forced into and through the radiator portion of the cooler system. Heat transfer takes place between the oil, the radiator metal fins and the surrounding air. A mechanical impeller, that is belt driven off the number two tail rotor drive shaft, aides the radiator’s cooling efficiency by forcing local ambient air into the front portion of the radiator.

9. Cooled oil exits the cooler and is routed to the various MGB oil distribution ports and to the distribution manifold located on the upper front of the MGB. The oil cooler outlet line also feeds the take-off for the oil pressure transmitter, which controls the cockpit MGB oil pressure indicator gauge, and the oil hot plugstat relay, which lights the "TRANS OIL HOT" light on the master caution panel when the MGB Oil temperature exceeds 120ºC.

Annex B: Related Maintenance Activity

1. 15 JUNE 2000 The occurrence aircraft was declared unserviceable (U/S) due a MGB Chip Detect Light (CF 349 # DDH 256 refers). The chip detectors were removed and revealed two magnetic particles approximately three sixteenths (3/16) inch in length and decimal zero one zero (.010) inch in thickness. Each chip detector had one metal sliver. The MGB was serviced in accordance with the serviceability check guidelines found in C-12-124-AJO/MF-00, Figure 2-4. There was no further evidence of contamination or metal slivers and the MGB/aircraft was declared serviceable (CF 349 DDH258 refers).

2. 17 JUNE 2000 On 17 Jun, while on a refuelling stop at Hickam AFB Honolulu, CH12422 was declared U/S for an MGB oil leak (CF 349 XSF354 refers). The aircrew had noticed MGB pressure fluctuations in the range of ±15-20 PSI. The aircraft captain inspected the exterior of the aircraft for any signs of a leak and found a very large pool of liquid at the foot of the crew door. After shutdown, and upon closer examination, the aircrew noticed fluid on the port side airframe and the fluid trail extended back along the ground taxi route for some distance.

3. A maintenance crew from HMCS Regina, which was alongside at Pearl Harbor was called to affect repairs. The oil leak was traced to a manifold aluminium fitting (AN815-6D aluminium fitting) that is attached to a rigid steel line that carries cooled oil directly to the MGB No 1 input lead sleeve bearing. Upon removal of the steel line and attaching fitting, technicians could clearly see a deep gouge/dent on the end of the aluminium fitting. Despite the fact that HELAIRDET Regina had a new fitting in stock, the decision was made to reverse the old aluminium fitting and reinstall it. On completion of a 15-minute rotors-engaged ground run, no leaks were evident and the aircraft was declared serviceable. Testimony indicates that a torque wrench was not used for the installation of the fitting, as called for in the appropriate CFTO.

4. 20 JUNE 2000 CH12422 was declared U/S for fluctuating MGB oil pressure (CF 349 # DDH265 refers). The oil pressure had been fluctuating ±5 PSI (which is within the serviceable limit of the gauge) but the gauge was changed as a precautionary measure. This technically unnecessary maintenance action was indicative of the extra attention that the aircrew was showing towards the MGB since the leak three days earlier. The slight flicker of the pressure gauge had become a distraction to the aircrew in flight. No pressure fluctuations were noted on the subsequent flight.

5. 21 JUNE 2000 (Supp # 21) The occurrence aircraft was declared U/S to change the damaged AN815-6D aluminium fitting previously installed by HMCS Regina maintainers at Hickam AFB (see 17 June 2000). This maintenance action was carried out upon direction of the maintenance authority at 443 MH (CF 349 # DDH267 refers). The damaged aluminium fitting was removed and a new fitting installed. QETE later determined that the damaged fitting, in addition to the gouges initially discovered, was cracked at the first thread, through 50% of circumference. It is believed likely that this crack was the actual source of the 17 Jun leak.

6. That same day, CH12422 was declared U/S to allow the MGB oil filters to be changed. This maintenance action was a result of the FS incident reported at Hickam AFB and subsequent direction from the maintenance authority at 443 MH (CF 349 # DDH268 refers). The MGB filters were removed and oil samples were routed to 443(MH) for filter debris and SOAP analysis. The aircraft was declared serviceable. QETE analysis of the filters found no anomalies.

7. 22 JUNE 2000 CH124A422 was declared U/S for a Special Inspection (SI) on the MGB attachment fitting (CF 349 # DDH273 refers). This SI was a result of the Hickam incident and the previous incident on CH12441 in Apr 2000. Both occurrences were caused by a fatigue failure of the AN815-6D aluminium fittings attached to the MGB manifold. The SI directed several maintenance actions including either changing out the AN815-6D fitting with a new fitting or conducting an in-situ Non-Destructive Test (NDT) procedure. Given that HMCS PROTECTEUR had already used it’s one spare AN815-6D fitting to accomplish the 21 Jun fitting change directed by the 443 MH maintenance authority, the NDT procedure was carried out on the second fitting only. The technician conducting the test was fully authorized and qualified to conduct the specific procedure. No fracture or other such anomalies were detected and the aircraft was subsequently declared serviceable.

8. Summary The maintenance activities leading up to the occurrence related directly to the MGB and were considered as a possible contributing factor if an oil leak was determined to be causal. Evidence indicates that the CFTO requirement to use torque wrenches for the installation of the lube fittings was routinely disregarded. This makes stress cracking of the lube fitting a more likely finding. The SI and replacement of the damaged lube fitting mitigates the likelihood of a maintenance cause factor in that the suspected part was removed and the remaining fitting was inspected using NDT techniques. The Squadron Air Maintenance Engineering Officer (SAMEO) had detected the risky re-installation of the damaged lube fitting and taken positive action to correct the deficiency. Barring this action it would have been very difficult to eliminate maintenance as a potential cause factor. Analysis of the possible failure modes was required to determine whether an oil leak, and hence a possible maintenance cause factor, contributed to the loss of the aircraft.

Annex C: Landing Priority Definitions

1. The Sea King checklist (C-12-124-A00/MC-001) gives the following definitions:

a. **LAND AS SOON AS PRACTICABLE:** “Extended flight is not recommended; the landing site and flight duration are at the discretion of the aircraft captain.”

b. **LAND AS SOON AS POSSIBLE:** “Continued flight is not recommended; land at the first site at which a safe landing can be made.”

c. **LAND IMMEDIATELY:** “An immediate landing/ditching is mandatory. The consequences of continued flight are more hazardous than those of landing at a site normally considered unsuitable,”

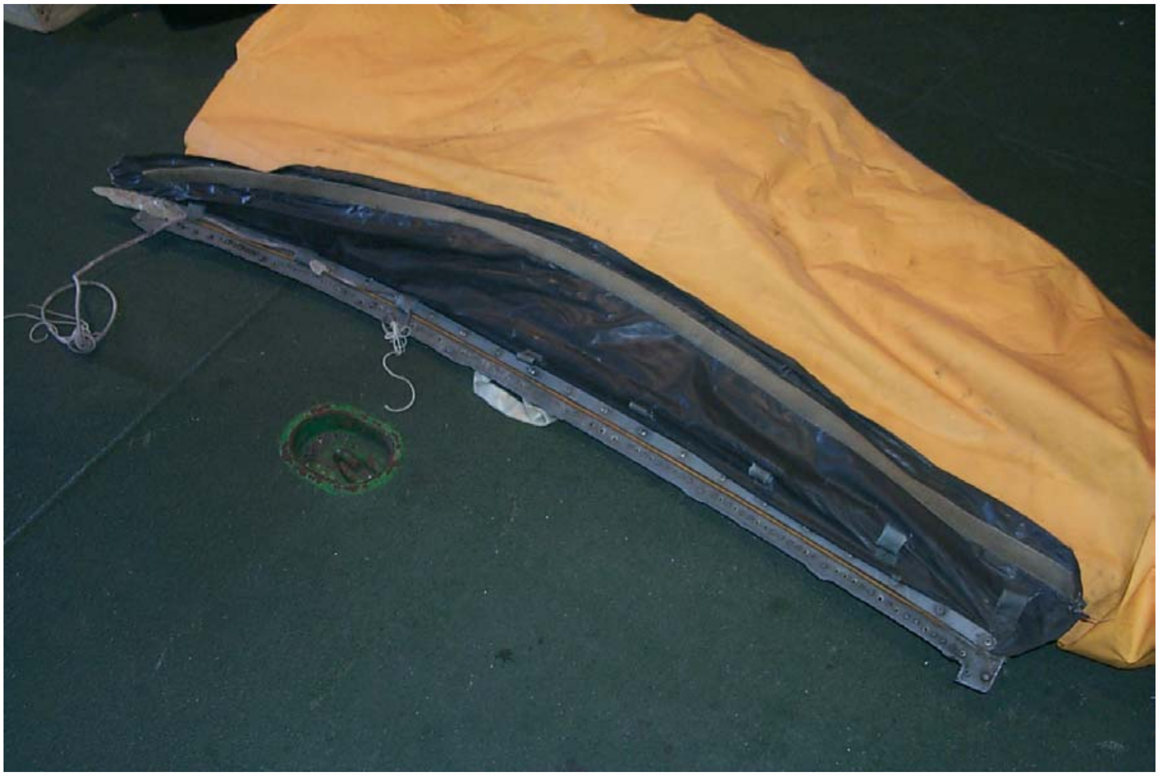
Annex D: Checklist Procedures

Table 3 - Checklist Procedures

LAND AS SOON AS Practicable	**LAND AS SOON AS Possible**	**LAND Immediately**
TRANS OIL HOT light; or TRANS OIL PRESS Light; or Trans Oil Temp outside normal Range; or Suspected Loss of either Trans Oil Pump; or CHIP DET MAIN	TRANS OIL PRESS outside of normal range; or An indication of low pressure and High Temperature; or CHIP DET MAIN and an indication of low pressure or high temperature	Any combination of abnormal Temp, noise, vibration or pressure which would indicate Imminent MGB failure; or When it is suspected that all MGB is being lost.

Annex E: Floatation Bag Attachment

Figure 2 - Recovered Floatation Bag



Annex F: Water Ops Checklist

SECTION 7

WATER OPERATIONS

Stores Jettison

•••••••••••
• **CAUTION** •
•••••••••••

Do not jettison stores while on water. Smoke markers may ignite in the chutes.

1. Master Armament .... ON
2. Store Arming Switch .... SAFE
3. External Stores .... SELECT & RELEASE
4. Internal Stores .... MANUALLY AS REQUIRED

Single Engine Water Take-off

1. Aircraft Integrity .... CHECKED
2. Reduce Aircraft Weight .... AS REQUIRED
3. Landing Gear .... UP
4. Sonar (If Req) .... SEAT OR GUILLOTINE
5. Pitot Heat .... ON
6. SSL .... FULL TRAVEL
7. Windshield Wiper .... ON
8. ASE .... ON
9. BAR ALT .... OFF
10. Horizon .... VISIBLE
11. Tip Path Plane .... 1/4-1/3 DOWN
12. Manual Throttle (Jump Take-off Only) NF 116%
13. Lift Off .... RUNNING or JUMP TAKE-OFF
14. Nr below 91% .... ABORT T/O
15. Secure Manual Throttle when safe altitude and airspeed is attained.

Flotation Bag Actuation

1. Arming Switch .... ARMED
2. INFLATE Button .... Depress

Sea Anchor Deployment

1. Remove large snaphooks and nylon rope from sea anchor pocket.
2. Remove tow-line from outside of helicopter.
3. Connect large sea anchor snaphook to the tow-line.
4. Ensure other large snaphook connected to sea anchor.
5. Connect the red ripcord snaphook to the instrument panel turnbuckle.
6. Throw the sea anchor in the water.
7. Pull the ripcord.

Controlled Ditching

1. **Aircraft Captain**
   a. Give command, "Standby for ditching".
   b. Lock shoulder harness.
   c. Aircraft unstable/taking on water – direct crew to abandon aircraft when rotors stopped.
   d. Deploy CPI.
   e. Attempt to take the first aid kit.

2. **Co-pilot**
   a. Lock shoulder harness.
   b. Switch IFF to EMER.
   c. On command – lower landing gear, secure engines.

Annex G: Rotor Brake Advisory Light

Rotor Brake Advisory Light ON

1. ***Rotor Brake . . . In detent and zero pressure**
2. ***If no suitable landing area available in immediate vicinity, establish a hover. Check for smoke, fumes, fire or other indications that the rotor brake is on.**
3. ***If Rotor Brake is ON . LAND IMMEDIATELY**
4. If Rotor Brake is OFF –
   LAND AS SOON AS POSSIBLE

5-8-1/5-8-2 Ch 2 – 2000-09-18

Sequence of Indications

(Based on Crew Interviews and Pilot Checklist)