CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-12404 (DFS 2-4-2)
DATE OF REPORT: 1 MARCH 2001

AIRCRAFT TYPE: CH124A SEA KING
DATE/TIME: 191415Z JUL 99
LOCATION: SHEARWATER, NS
CATEGORY: "B" CATEGORY

SYNOPSIS

The crew of aircraft CH124A404 had just returned from a crew operational readiness exercise (COREX) and was in the process of shutting down on the Shearwater ramp. After rotor disengagement, three crewmembers deplaned, leaving the Co-pilot and the Navigator to conduct the remainder of the shutdown procedure. After attempting to cycle the rotor brake in accordance with the checklist procedure, smoke and flame developed in the forward part of the main gearbox. The ground crew advised the co-pilot of the fire and an emergency shutdown was performed. The co-pilot was unable to reselect the manual rotor brake. The ground crew commenced fighting the fire using four 50 lbs. dry chemical extinguishers retrieved from the surrounding area. The 12 Wing fire fighters arrived shortly thereafter with the foam truck and quickly extinguished the blaze. The aircraft suffered "B" category damage to the engine compartments and main gearbox area. There were no injuries in this occurrence.

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1. FACTUAL INFORMATION

1.1. History of Flight

The crew of aircraft CH124A404 had just returned from a Crew Operational Readiness Exercise (COREX) and was in the process of shutting down on the Shearwater ramp. Three of the five crewmembers exited the aircraft once the rotor blades had stopped turning, leaving the co-pilot and navigator onboard to complete the shutdown procedure. Following the engine wash, the co-pilot shut down #2 engine and commenced the blade fold sequence. After attempting to cycle the rotor brake in accordance with the checklist procedure, smoke and flame developed in the forward part of the main gearbox. The marshaller advised the aircrew of the fire and the co-pilot shut down engine #1 using the speed selector lever, but was unable to reselect the manual rotor brake because it was unusually stiff. He subsequently noticed the cockpit indication of a dual engine fire and pulled both ‘T’ handles, activating the fuel shut-off valves. The co-pilot decided against actuating the fire extinguisher switch and both crewmembers safely evacuated the helicopter. The ground crew commenced fighting the fire using four 50 lbs. dry chemical extinguishers and was able to contain, but not extinguish the fire. The 12 Wing fire fighters arrived shortly thereafter and extinguished the blaze using Aqueous Fire Fighting Foam (AFFF).

1.2. Injuries to Personnel

There were no injuries in this occurrence.

1.3. Damage to Aircraft

The damage was localized to the upper part of the aircraft between the engines and the transmission (station 202 to station 260). The rear half of both engine access doors were moderately damaged by heat (Figure 1). The fuselage around the right side exhaust area was extensively burned. The aluminium panel directly below the exhaust was burned through. The right side transmission access door was severely sooted (Figure 2). The left side had minimal heat damage in these same areas. The transmission cowling (doghouse) had extensive heat damage. The fibreglass panel on the right side was heated to the point where the resin was burned off and the cloth lost some of its shape. The aluminium mesh on the top forward section of the doghouse was burned through. The aluminium panel on the right side below this mesh was completely consumed. The left side of the doghouse was sooted but received considerably less exposure to heat and flames. All utility hydraulic stainless steel lines in the area of the rotor brake were extensively sooted and electrical wire bundles were sufficiently heated to melt the insulation. Some MGB lines from the Quick Change Unit (QCU) were burned through or loosened by extreme heat and there was evidence of MGB oil in the post fire residue. A section of the engine fire extinguisher lines, where they are routed past the rotor brake assembly, were completely melted. The cabin roof directly below the forward area of the transmission was exposed to sufficient levels of heat to burn off the paint, discolour the fuselage skin and deform at least one stringer in the area of station 243.5. The damage was assessed as B Category.

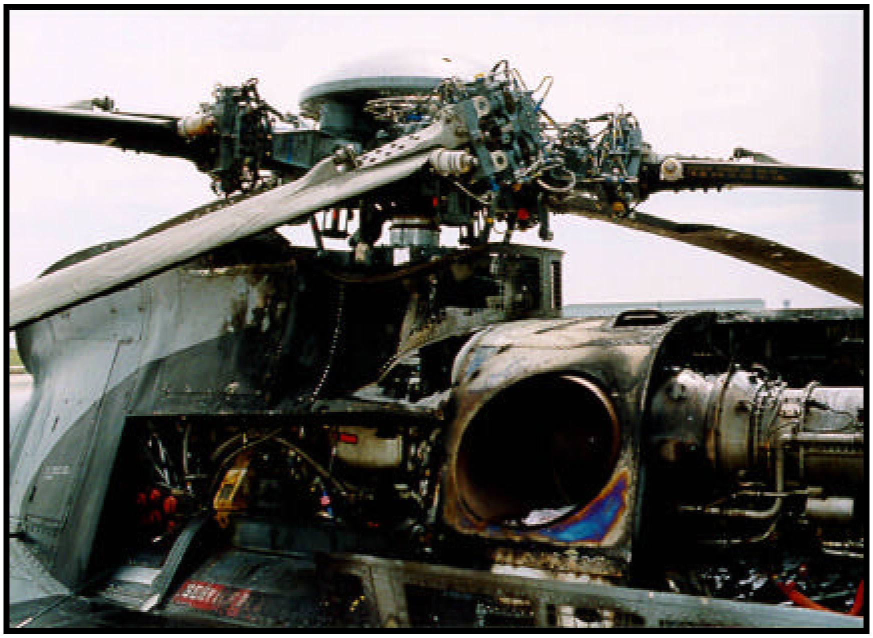

Figure 1 - Burn Damage

Figure 2 - Right Side Damage

1.4. Collateral Damage

Nil

1.5. Personnel

	Co-pilot	Nav.
Rank	Capt.	Capt.
Age	38	25
Category Valid	MHCC YES	TACCO B YES
Medical Category valid	YES	YES
Total flying time	3100	420
Flying hours on type	1800	235
Flying hours last 30 days	15	13
Duty time last 24 hrs	4	4

1.6. Aircraft Information

A review of the aircraft log set indicated that the helicopter was serviceable prior to the flight and no discrepancies were noted during the mission. There were no anomalies found in the documentation. The MGB had been installed approximately 129 hours prior to the occurrence. It had successfully passed the independent inspection associated with the MGB installation and Numbers 15 through to 20 supplementary inspections. In addition, the left hand (LH) engine had been replaced 105 hours prior to the occurrence.

1.7. Meteorological Information

Wind was 270 degrees at 5 knots (the aircraft 11 o'clock position). Weather was not a factor in this occurrence.

1.8. Aid to Navigation

N/A

1.9. Communications

Due to the rapid crew evacuation, an emergency was not declared over the UHF radio. Quick thinking maintenance personnel ensured that the tower was immediately informed by telephone.

1.10. Aerodrome Information

N/A

1.11. Flight Recorders

The aircraft is not equipped with any onboard recording devices.

1.12. Wreckage and Impact Information

N/A

1.13. Medical

The two occurrence crewmembers remaining on board at the time of the occurrence provided samples for toxicological analysis. All tests were normal.

1.14. Fire, Explosives Devices, and Munitions

1.14.1 Fire

Ground crew initiated fire-fighting actions with four 50 lbs. dry chemical extinguishers. 12 Wing Standard Operating Procedures (SOP) do not require extinguishers to be immediately available to the recovery crew; therefore, ground crew had to retrieve the extinguishers from the surrounding area.

Three of the four extinguishers functioned properly. The fourth extinguisher could not be made to dispense extinguishing agent, even with back-up activation. Furthermore, the ground crew had difficulty directing the extinguishing agent of the functioning portable extinguishers into the area of the engines and gearbox due to the lack of reach of the portable extinguisher's nozzle. Maintenance personnel were only able to contain the fire; it was only brought under control when the fire fighters applied AFFF agent to the blaze.

One member of the ground crew response team climbed up on the left sponson to better direct the dry chemical extinguisher stream into the base of the fire. Once the extinguishing agent was exhausted from the portable extinguisher, the member entered the helicopter to close the doors and windows prior to the arrival of the foam truck with the intention to limit the damage to electronic equipment inside the aircraft. After securing the personnel door, the member noted the intensity of smoke and fumes in the cabin area. The member realised the danger of the situation and quickly exited the aircraft via the cargo door, just as the fire truck arrived on scene.

1.14.2 Explosives

The Sea King is equipped with Mk 25 Smokes, Explosive Underwater Signalling devices (SUS), and explosive charges for cutting the SONAR and Hoist cables. The fire did not progress sufficiently to involve any of these items. They were removed and made safe by qualified ground crew immediately after the fire was extinguished.

1.15. Survival Aspects

Both crewmembers safely evacuated the aircraft without requiring the use of their survival equipment.

1.16. Test and Research Activities

The Main Rotor Gearbox in its entirety, engine compartment doors and the "Dog House" panels were delivered to QETE to determine the cause of the fire.

QETE also constructed a mock up of the suspect hydraulic line and rotor brake accumulator housing, to determine the time required for vibration and chafing to cause hose rupture.

1.17. Organisational and Management Information

N/A

1.18. Additional Information

N/A

1.19. Useful or Effective Investigation Techniques

N/A

2. ANALYSIS

2.1. General

The main thrust of this investigation was to determine the ignition source of the fire and the fuel involved. It was clear from early in the investigation that a hydraulic leak had occurred in a hydraulic line leading to the rotor brake. The affected hydraulic line, by design, is isolated from the hydraulic system as long as the blades are spread. In this instance, it was technically impossible for a leak to occur at any time other than during the blade-spread or blade-fold sequence.

2.2. The Aircraft

2.2.1. General

A review of the servicing documentation found no discrepancies prior to the occurrence.

Technical analysis by QETE (Project # D010099) indicated that the hydraulic line providing pressure to the automatic rotor brake (P/N AE24600500E0110) (Figure 3) had been chafing on the "rotor brake panel package accumulator housing" until the line ruptured under pressure. Atomised hydraulic fluid then sprayed on the "number-2 engine power turbine housing" (Figure 4), causing a fire. Actual QETE data demonstrated a minimum time to failure of 100 hours of chafing to rupture the braided steel line (under chafing conditions deemed by QETE to be more demanding than could be expected under normal Sea King flight conditions). From this, and the fact that the MGB had been installed 129 hours prior to the occurrence, it is concluded that the failed line was installed in such a way that it chafed on the rotor brake accumulator housing, eventually resulting in a failure of the pressurised hydraulic line.

The initial fire was fed by pressurised hydraulic fluid spraying onto the #2 engine Power Turbine Housing, but once the fire was fully established, there was sufficient heat to melt supply lines that allowed other combustible liquids into the area of the fire. The QETE analysis showed that transmission fluid fed the fire in later stages. This is consistent with the fact that the fire seemed to re-ignite after the dry chemical extinguishers were exhausted.

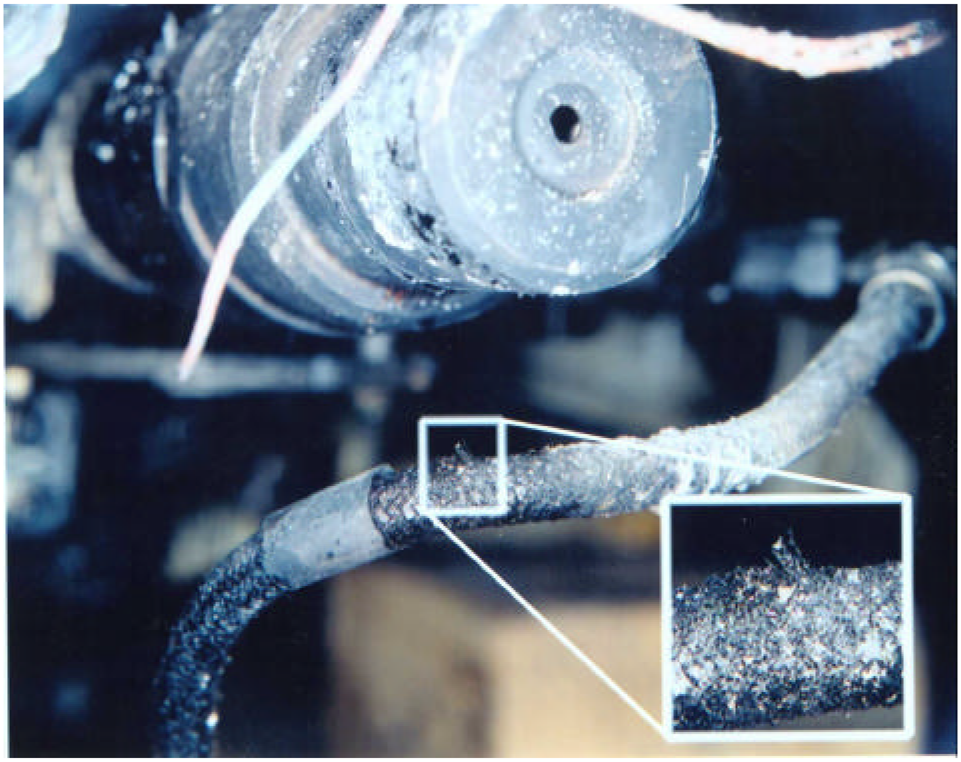

Figure 3 - Ruptured Hydraulic Line

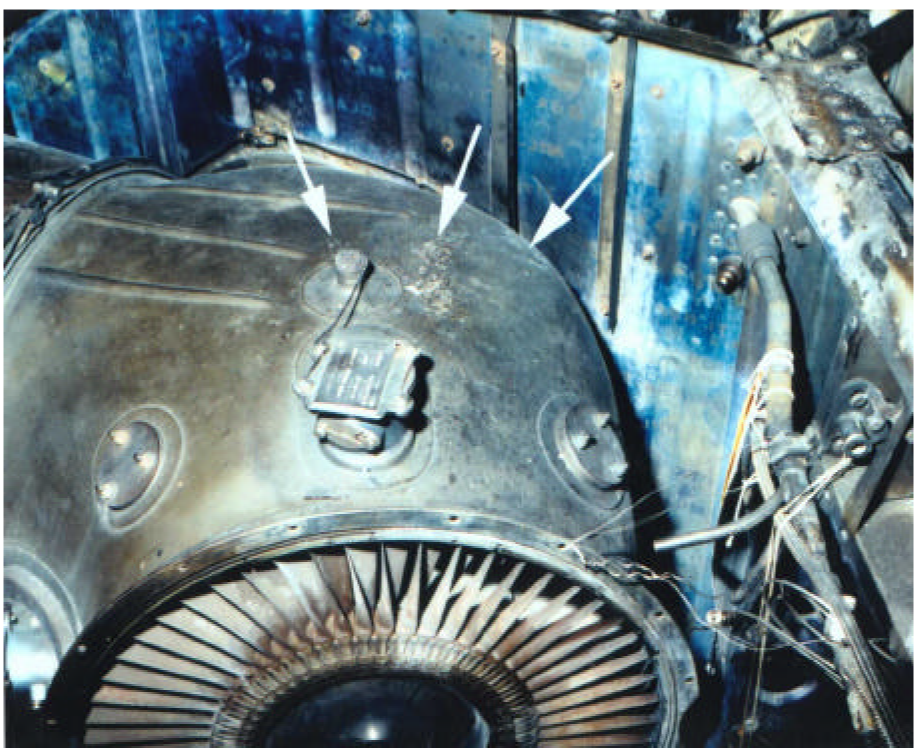

Figure 4 - Ignition Evidence on PT Housing

2.3. The Aircrew

The aircrew were qualified and authorised to conduct the mission. The weather was suitable and crew rest was determined not to be a factor.

2.3.1. Crew Manning Requirements

A review of 1 CAD orders with respect to aircraft manning while both engines are running produced an undetected ambiguity. The orders are specific concerning crew requirements for starting the Sea King, but there is no direct statement concerning the manning requirements during shutdown.

In the start sequence the #1 engine is mechanically disconnected from the MGB and rotor system, through the use of the accessory drive system, until after the #2 engine has been started and the main rotor (referred to as the “Head”) has been engaged. Once the #2 engine is running, there is a direct link between the MGB, the rotor system and the #2 engine. Even at idle, the head will turn if the rotor brake is not engaged, or fails for any reason. On shutdown, the # 1 engine is again placed in “Accessory Drive” before disengaging the “head”. The lack of orders on manning requirements on shutdown imply that only one pilot is required to operate the aircraft in accessory drive because there is no chance of engaging the head.

It is clear from the 1 CAD orders that two pilots are normally required to start the #2 engine, as indicated by the following extract:

> *“Two qualified pilots are required to do a number two engine and/or head run. In addition, a MHC is authorized to do a number two engine and/or head run with the following personnel occupying the left seat:*
>
> *a. a UT pilot;*
> *b. Aircraft technicians – 514;*
> *c. an AES OP; and*
> *d. an Air Navigator.”*

From this order, one can conclude that two pilots (or acceptable designates, as per above) are also required any time that the rotors are running and / or the #2 engine is in operation. This interpretation would include the shutdown phase of operation. That said, the squadron practise is to permit the right seat pilot to complete the shutdown unassisted once the rotor head has been stopped. Although there was a navigator in the aircraft at the time of the occurrence, he was not occupying the left seat. (Note 1)

Although there is a conflict between the requirements implied in 1 CAD Orders and the accepted squadron practise, it must be clearly stated that the lack of a left seat occupant (in this case at least) had little if any bearing on the occurrence, either in cause or effect. The investigation team noted, however, that not all squadrons share MH 423's practices of single pilot water washes. In fact, both of the other squadrons believe that the 1 CAD order for minimum manning applies any time the number 2 engine is in operation. Nevertheless, the ambiguity of the 1 CAD order does foster differing interpretations of the manning requirement on shutdown.

Note 1: *In the past, the #2 engine was secured prior to stopping the rotor and the waterwash was conducted with both engines secured. The issue of single pilot shutdown was therefore moot, because the rotor would be stopped and the #2 engine shutdown before the left seat pilot could depart. This procedure was universally accepted and practised by the MH community. Subsequent changes to the waterwash procedure required that the #2 engine remain at idle after disengagement of the Main rotor. Since that time, the practise of single pilot waterwashes has been maintained in the operational squadrons despite the contradiction implied in the 1CAD order.*

2.4. Active Factors

2.4.1. Routing and Clamping

The chafed line in this occurrence is routed directly between the fuselage and the QCU, without clamping. It is connected to a "T" junction, the orientation of which dictates the routing of the hose. Upon installation, line clearance from other aircraft parts must be assured by inspection. Post-installation inspection failed to detect the line-to-accumulator contact.

Upon return to service, the hydraulic line supplying high-pressure fluid to the automatic rotor brake began chafing against the brake housing itself. The location of the affected line made inspection (figure 5 and 6) very difficult, as evidenced by the fact that multiple opportunities for detection (Supplementary Inspections 15 through 20 and a LH engine change) did not result in detection of this routing deficiency. It should be noted, however, that installation of the LH engine requires removal of several panels covering the chafed line, during which time technicians would have had a clearer view of the affected area.

A post-occurrence survey of other aircraft in the fleet yielded no further cases of wear on that line. However, Flight Safety Occurrence number 96262 dated 14 August 1999 (one month later), identified a similar occurrence of chafing on a "rotor blade positioner" hydraulic line. This occurrence, although in a slightly different area, further highlights the challenges in detecting routing and clamping deficiencies.

Strict adherence to installation and inspection procedures would have prevented this occurrence. Failing that, experience indicates that effective and timely detection of routing and clamping occurrences requires maintenance personnel to take advantage of every opportunity to visually and tactilely inspect exposed lines and clamps. Nevertheless, no special requirement to inspect for routing and clamping is published in the supplementary card deck or in the maintenance procedures for routine servicing. It is concluded that the lack of "opportunistic Inspections" permitted the chafing to remain undetected.

Routing and clamping is a CF-wide concern that has particularly affected the Sea King community. There have been over 75 occurrences with routing and clamping as one of the cause factors reported between January 1990 and July 1999 for the Sea King fleet alone; including one "A" category fatal accident. The complexity of the electrical, hydraulic and fuel systems within the Sea King (and other helicopters of its generation), in concert with constant vibration typical of helicopter operations, pose a great challenge to maintenance staff.

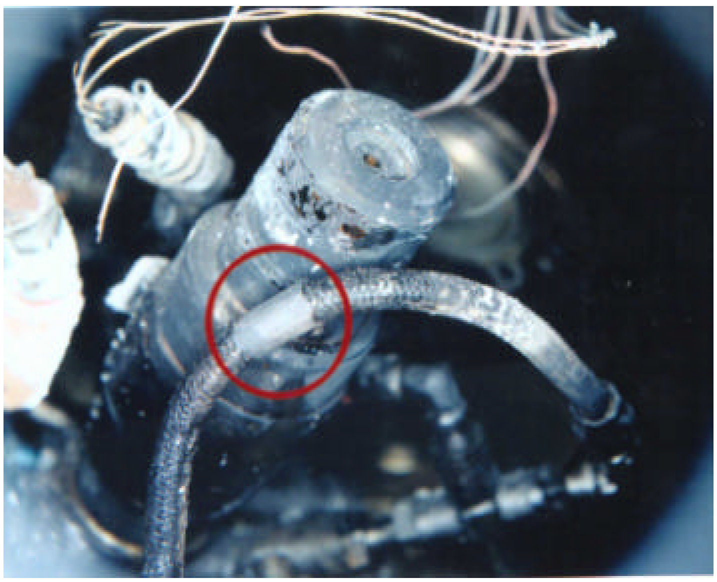

Figure 5 - Line Repositioned to show chafing

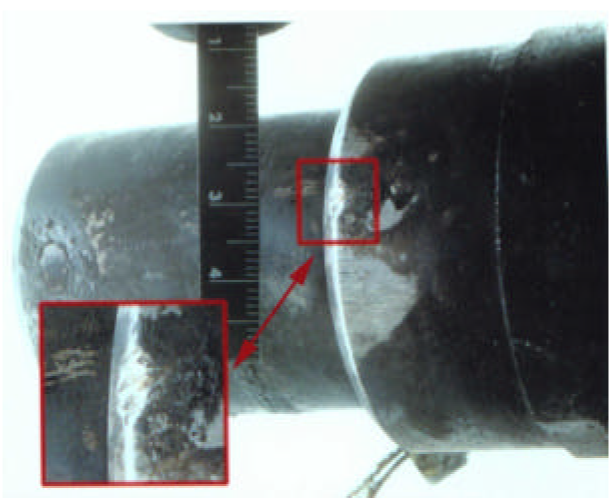

Figure 6 - Accumulator Housing Showing Chafing Damage

2.4.2. Pilot Emergency Response

Upon noticing the illumination of the engine fire warning lights, the pilot pulled the "T" handles, but did not activate the fire bottles. The Pilot Check list indicates the proper response to an "Engine Fire Light on the Ground", as follows:

a. Illuminated "T" Handle…Pull
b. Both SSL (Speed Selector Levers)… Shut Off
c. All Boost Pumps… Off
d. Fire Light On…Visually Confirm
e. Fire Extinguisher Switch… Main
f. Fire Extinguisher Circuit Breaker (CB)…In
g. Fire Extinguisher Switch (If Necessary)… Reserve
h. Emergency Shut down

All of these actions are required immediate responses (committed to memory without reference to the checklist). Evidence indicates that the pilot completed items "a","b" and "h" and then abandoned the aircraft.

Post-fire analysis indicated that although the source of the fire was not restricted to the engine compartment (figure 7), the fire extinguishing agent supply lines which are routed through the area of the fire, were, at some point in time, completely consumed by fire. Thus, activation of the engine fire bottles might have caused fire-fighting agent to be delivered directly onto the source of the fire through the burned holes in the fire extinguishing agent supply lines.

It is assessed that the decision not to complete the check list procedure allowed a slightly more rapid egress (perhaps 5 seconds). Completion of the check list procedure, however, may have resulted in earlier and more effective suppression of the fire.

Figure 7 - Fire damage to Engine and Transmission Area

2.5. Latent Factors

2.5.1. 50 Lbs Portable Fire Extinguisher Effectiveness

Ground crew personnel believed that they had extinguished the fire at least twice, and therefore paused in the delivery of dry chemical agent. Each time the fire re-ignited almost immediately and it was necessary to use AFFF agent before the fire could be completely extinguished.

Dry chemical agent works by denying oxygen to a fire, but does not affect residual heat. It is believed that the ground crew had in fact extinguished the fire at least twice, but combustibles in the form of hydraulic fluid and transmission fluid, continued to flood by gravity onto the fire-heated metals around the main gearbox, permitting re-ignition. A safe condition could not be achieved until aqueous foam was applied to aircraft, thereby reducing heat sources below ignition temperatures, dispersing the flammable fluids and providing a contiguous aqueous layer to deny oxygen to the fire.

Although ground crew experienced some difficulty attacking the base of the fire due to the lack of nozzle extensions for the portable extinguisher, post-occurrence analysis from Canadian Forces Fire Marshal (CFFM 4) indicated that the dry chemical extinguishers performed in accordance with the design envelope:

> *"… the fire extinguisher has operated within its intended use and that there is not a requirement to recommend anything over and above what is now in place in terms of equipment or procedures. The placement should be verified as being correct and the maintenance procedures should be examined."*
>
> *"The standard extinguisher for flight lines in the past has been Halon 1211. Due to the effects of this substance on the environment, the use of Halon has been outlawed" … "and we have implemented the replacement of halon throughout the Canadian Forces." "… through an extensive selection process have determined that the dry chemical is suitable for this purpose. We do realise that it is not perfect and are looking into alternate equipment such as a compressed air foam extinguisher…"*

From the CFFM analysis, it is concluded that the 50 Lbs. Dry Chemical extinguisher is the best equipment presently available and performed in accordance with its design specifications.

2.6. Additional Issues

2.6.1. Emergency Response Delays

Upon noticing the outbreak of fire, several technicians sprinted to the hangar and to adjacent start crews, to retrieve available fire extinguishers.

As previously noted, the fire re-ignited repeatedly when new fuel sources flowed onto the fire-heated areas. If an extinguisher had been immediately available, the fire could have been suppressed at an earlier stage and the surrounding metals might not have been heated to such an extent. It is therefore likely that, had an extinguisher been immediately available, the dry chemical agent alone would have been sufficient to extinguish the fire.

It was further observed that the fire had developed sufficient heat to melt the aluminium tubing for the fire extinguishing supply lines and to deform the stringer immediately under the MGB. This requires a temperature in excess of 1100 degrees Celsius. The ignition point of the magnesium alloy of the MGB is also approximately 1100 degrees C, but the heat dissipating properties of the magnesium alloy did not permit ignition. The use of dry chemical extinguishers served to control the spread of fire and therefore limited the generalised heating of the magnesium alloy MGB, preventing possible ignition.

Magnesium, once ignited, is difficult to extinguish because the flame is self-sustaining. Had the magnesium alloy ignited, there were no resources at Shearwater that would have prevented the total destruction of the aircraft. The active intervention of ground personnel using portable dry chemical extinguishers prior to the arrival of the fire vehicle, likely prevented an "A" category occurrence.

2.6.2. Fire Extinguisher Serviceability

A failure analysis of the non-functioning dry chemical extinguisher determined that after its last use in November 1998, caked dry chemical agent had remained in and blocked the hose. Activation of the extinguisher could not clear the blockage, rendering the extinguisher useless. Procedures are in place to ensure that purging is conducted prior to recharging a spent extinguisher, and yet this step of the maintenance procedure for this particular extinguisher was somehow missed. Random testing identified no similar malfunction, so this is considered an isolated incident.

2.6.3. Damage Control Efforts

While fighting the fire, one of the ground crew realised that the fire truck would spray liquid over the entire aircraft. Knowing that the aircrew had already evacuated and because the extinguisher was now empty, he decided to enter the burning aircraft to close all windows and doors in order to prevent water damage to the electronic equipment inside. Once inside, the member closed both upper and lower portions of the personnel door, and turned towards the cockpit with the intention of closing the right side pilot window. With the smoke and fumes dangerously thick, he instead quickly exited the aircraft via the rear cargo door.

Although training does not advocate this kind of risk taking, this member was highly motivated to take some positive action to protect the aircraft. While his devotion and bravery are commendable, it is felt that entering the burning aircraft constituted an unacceptably high level of risk.

3. CONCLUSIONS

3.1. Findings

3.1.1. The aircrew was current, qualified and authorised for the mission.

3.1.2. The aircraft was serviceable for the mission.

3.1.3. The weather was not a factor in the occurrence.

3.1.4. The crew was medically fit at the time of the occurrence.

3.1.5. 1CAD orders are not sufficiently precise to prevent varying interpretations of the manning requirements for shutdown.

3.1.6. Improper installation of the rotor brake hydraulic line caused it to make contact with the rotor brake accumulator housing.

3.1.7. The automatic rotor brake pressure line chafed against the "rotor brake panel package accumulator housing" for a period in excess of 100 flight hours and probably for the 129 hours since MGB installation, ultimately causing the line to rupture under pressure.

3.1.8. The wear on the hydraulic line was undetected by routine inspection.

3.1.9. Atomised hydraulic fluid contacted the #2 engine exhaust cowling and ignited.

3.1.10. The heat from the fire was sufficient to consume transmission lines; thereafter, transmission fluid and hydraulic fluid, which leaked by gravity onto the heated surfaces, continued to feed the fire, even after the engines were secured.

3.1.11. The pilot did not complete the required checklist response to "fire on the ground".

3.1.12. The lack of immediately available fire fighting equipment probably contributed to the damage, in that the fire had time to intensify before fire fighting action could commence.

3.1.13. The lack of a nozzle extension for the 50 lbs. dry chemical extinguisher inhibited the ground crew’s ability to attack the base of the fire.

3.1.14. The properties of the dry chemical agent did not prevent re-ignition of the fire when additional fuel sources flooded onto the heat-soaked metal.

3.1.15. Containment of the fire with the portable extinguishers possibly averted “A” category damage to the aircraft.

3.1.16. The malfunction of one dry chemical extinguisher was caused by an isolated case of failure to purge lines during cleaning and recharging.

3.1.17. Entering the burning aircraft constituted an unacceptable level of risk.

3.1.18. Although the Portable Dry Chemical extinguisher is suitable for flight line operations, it is not optimal.

3.2. Cause(s)

3.2.1. Improper installation of the rotor brake hydraulic line during MGB installation was responsible for the hydraulic line being in contact with the rotor brake accumulator housing.

3.2.2. Chafing of the "automatic rotor brake pressure line" against the rotor brake accumulator housing caused the hydraulic line to rupture, which then sprayed atomised hydraulic fluid onto the #2 engine exhaust cowling, causing a fire.

3.3. Contributing Factor(s)

3.3.1. The location of the hydraulic line and the lack of mandated opportunistic inspections made timely detection through routine inspection extremely unlikely.

4. SAFETY MEASURES

4.1. Safety Measures Taken

4.1.1. All aircraft in the fleet were surveyed for routing and clamping issues on the main rotor brake hydraulic line, with no faults found.

4.1.2. Maintenance personnel were briefed by the WFSO on their responsibilities during an aircraft ground fire and the hazards of entering a burning aircraft were stressed.

4.1.3. The Canadian Forces Fire Marshal is investigating a possible replacement of the portable fire extinguisher, with a more effective type of agent.

4.1.4. 1 CAD Orders have been amended to allow a MHC or MHCC to conduct number 2 engine and/or head runs single Pilot.

4.2. Further Safety Measures Required

4.2.1. It is recommended that 12 Wing staff evaluate the benefits of equipping the local aircraft recovery crew with fire extinguishing equipment.

4.2.2. It is recommended that 1 CAD investigate the feasibility of replacing the 50 Lbs. Dry Chemical extinguisher with the compressed air foam type extinguisher presently under consideration by CFFM.

4.2.3 It is recommended that DGAEPM consider procedures and/or orders which would decrease the probability of improper routing and clamping and increase the probability of detecting errors in routing and clamping - with priority given to helicopters of the same vintage as the Sea King.

4.3. Other Safety Concerns

It is recommended that 1 CAD Orders be reviewed to identify regulations that may have been rendered confusing or impractical by changes to Sea King Operating procedures.

4.4. DFS Remarks

Improper routing and clamping as well as repeated failure to detect those errors has resulted in a significant number of occurrences over the years, including loss of life and valuable resources. This trend is not improving, and may even be getting worse. It is probably exacerbated by several factors: inaccessibility of technical manuals due primarily to a move to electronic publications, the relative difficulty of accessing all the locations where routing and clamping could be a problem, especially in older aircraft, and a decline in experience levels of our technicians. Ways need to be found to mitigate the effects of known or probable contributing factors individually, but more routing and clamping awareness is also in order. Supervisors need to remember that P03 does not obviate their responsibility to ensure jobs are properly done. Confirmation of proper routing and clamping should be part of every inspection or maintenance action. Both changed procedures and vigilance are required if we are to avoid costly accidents like this one.

R.E.K. Harder
Colonel
DFS