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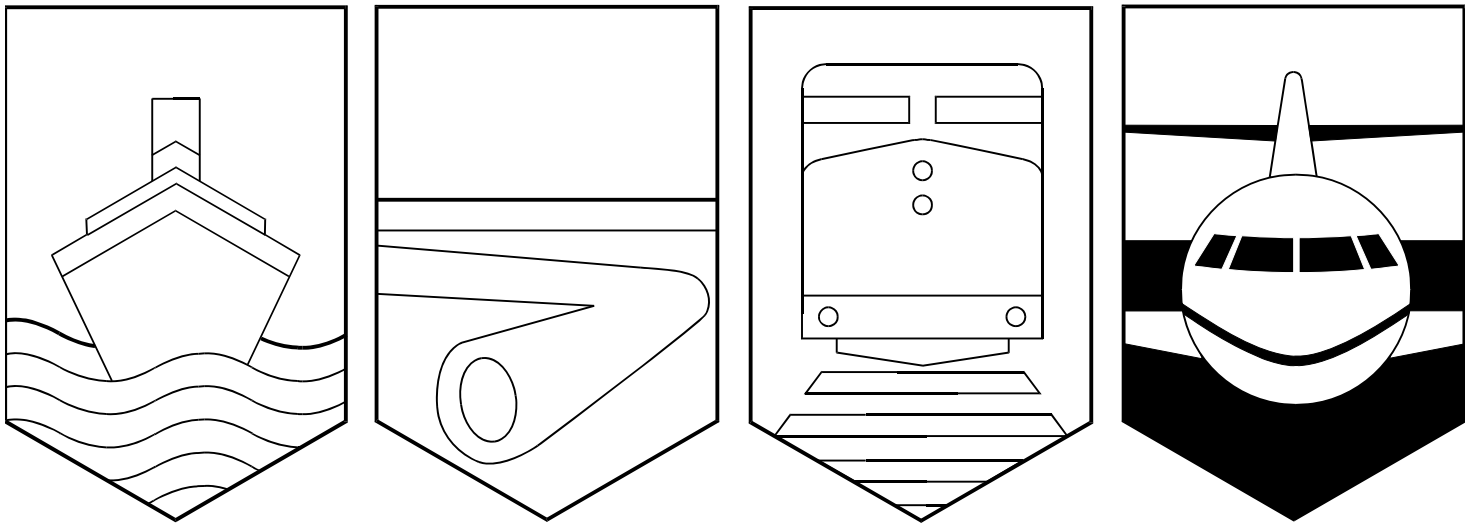

AVIATION OCCURRENCE REPORT

TAIL ROTOR DRIVE SHAFT FAILURE DURING HOVER

GREAT SLAVE HELICOPTERS LTD.
BELL 206B JETRANGER III (HELICOPTER) C-FPQS
WALMSLEY LAKE, NORTHWEST TERRITORIES
02 SEPTEMBER 1994

REPORT NUMBER A94W0162

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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Aviation Occurrence Report

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Great Slave Helicopters Ltd.
Bell 206B JetRanger III (Helicopter) C-FPQS
Walmsley Lake, Northwest Territories
02 September 1994

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Synopsis

The Bell 206B helicopter was being utilized to sling barrels of fuel at a remote tent camp. As the pilot was about to place two barrels near the camp generator shed, he lost tail rotor authority. The helicopter rotated rapidly to the right through approximately three revolutions, struck the ground upright, and rolled onto the right side. The pilot received minor injuries and the helicopter was substantially damaged.

The Board determined that the aft short tail rotor drive shaft failed in an area weakened by intergranular cracking which initiated from corrosive attack on the interior wall of the shaft. The drive shaft failure resulted in a loss of tail rotor thrust. The failure occurred when the helicopter was hovering at an altitude which precluded a successful autorotation.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The Bell 206B helicopter was being utilized to sling barrels of fuel from a beach to a nearby tent camp, with barrel clamps and a 20-foot lanyard. After transporting several barrels to the helicopter pad, the pilot slung two barrels to the camp generator. As the helicopter approached the generator shed, the pilot transitioned to a hover and began a vertical descent to set the barrels on the ground. When the barrels were approximately two feet above the ground, the helicopter departed from controlled flight and rotated violently to the right through three rotations. A ground assistant, who had positioned himself under the helicopter to stabilize the barrels and release the barrel clamps, realized the helicopter was out of control and ran toward the generator shed to escape. Immediately thereafter, the helicopter struck the ground and rolled onto the right side. The ground assistant was uninjured. The pilot sustained minor injuries, and the helicopter was substantially damaged.

1 All times are MDT (Coordinated Universal Time [UTC] minus six hours unless otherwise stated.

2 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

3 See Glossary for all abbreviations and acronyms.

The accident occurred at latitude 63°32'N and longitude 108°07'W, at approximately 1800 mountain daylight saving time (MDT)[1], during the hours of daylight, at an elevation of approximately 1,250 feet[2] above sea level (asl)[3].

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	1	-	-	1
Total	1	-	-	1

1.3 Damage to Aircraft

The helicopter sustained substantial damage due to the impact and roll-over. The skid cross tubes detached from the fuselage, and the main rotor struck and severed the tail boom. The cockpit and cabin remained intact.

1.4 Other Damage

No significant property damage occurred.

1.5 Personnel Information

	Captain
Age	32
Pilot Licence	CPL
Medical Expiry Date	01 March 1995
Total Flying Hours	2,300
Hours on Type	2,000
Hours Last 90 Days	180
Hours on Type Last 90 Days	180
Hours on Duty Prior to Occurrence	9
Hours off Duty Prior to Work Period	16

The pilot was licensed in accordance with existing regulations, and qualified on Bell 206B helicopters. He had flown C-FPQS approximately 60 hours since being assigned to the helicopter on 17 August 1994. He had not experienced any mechanical problem with the

helicopter during that time. The pilot did not report any physiological or psychological factors which may have affected his performance.

1.5.1 Pilot Action

The pilot was aware that the ground assistant was under the helicopter when the loss of tail rotor thrust occurred. The pilot immediately lifted the collective and attempted to manoeuvre away from the generator shed and the ground assistant. The helicopter travelled approximately 50 feet before impact. The pilot did not release the sling load to avoid the risk of dropping the load on the ground assistant. The pilot did not attempt to enter autorotation due to the altitude, the low airspeed, and the perilous location of the ground assistant.

1.6 Aircraft Information

Manufacturer	Bell Helicopter Textron Inc.
Type and Model	206B JetRanger III
Year of Manufacture	1981
Serial Number	3231
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	10,407 hr
Engine Type (number of)	Allison 250-C20B (1)
Propeller/Rotor Type (number of)	Semi-Rigid (1)
Maximum Allowable Take-off Weight	3,200 lb
Recommended Fuel Type(s)	Jet A, Jet A-1, Jet B
Fuel Type Used	Jet B

The helicopter had been imported to Canada in May 1993, and was registered to the operator in June 1993. It had previously been American-registered as N825H, and had been utilized for off-shore oil platform work in the Arabian Gulf for approximately 11 years. The Arabian Gulf is a highly corrosive, salt water operating environment, and the summer days are extremely hot and humid.

The Canadian log-books indicated that the helicopter had been maintained in accordance with applicable requirements since import. The weight of the helicopter and sling load was estimated to be 3,150 pounds. The normal category maximum gross weight is 3,200 pounds. The Bell 206B is permitted to operate at 3,350 pounds gross weight for slinging operations. The centre of gravity was within the prescribed limits.

1.7 Meteorological Information

Good visual meteorological conditions existed at the time of the occurrence, and weather was not considered to be a factor. The pilot and ground assistant reported that the sky was clear with unlimited visibility. The winds were reported as light and variable, and the temperature was estimated to be 5 to 10 degrees Celsius.

1.8 The Bell 206B Tail Rotor Drive System

The Bell 206B JetRanger III tail rotor drive system consists of a forward short shaft, an oil cooler fan drive shaft, an aft short shaft, and five aft tail rotor drive shaft segments. The forward short shaft and the

oil cooling fan drive shaft are steel. The aft short shaft and the tail rotor drive shaft segments are aluminum. Steel-laminated flexible couplings are used to connect the shaft sections.

Bell 206B helicopters serial numbered 4004 and earlier, such as the accident helicopter, are fitted with a hollow aft short tail rotor drive shaft which is open at both ends. Bell 206B helicopters serial numbered 4005 and subsequent are fitted with a 206-040-369-1 drive shaft which is sightly larger in diameter, and is plugged at both ends.

Figure 1 - Bell 206 Power Train System

1.9 Wreckage and Impact Information

The accident occurred on open, flat tundra. The ground surface was shallow, grass-covered hummocks. Examination of the wreckage by the operator revealed that the tail rotor drive train aft of the oil cooler blower assembly was discontinuous, and that the oil cooler blower impeller had sustained extensive separation from the vane. The tail rotor drive shaft assembly, the oil cooler impeller assembly, the tail rotor gear box, and the tail rotor were forwarded to the TSB Regional Wreckage Facility for examination.

Visual examination confirmed that the aluminum aft short tail rotor drive shaft (Part No. 206-040-330-003) had failed in the vicinity of the forward bonded coupling. An approximately one-inch-long, irregular-shaped section of the shaft was missing between the forward and aft fracture surfaces, and was not recovered. The tail rotor gear box components, the laminated flexible couplings, and the tail rotor blades displayed no evidence of a pre-occurrence tail rotor strike.

1.10 The History of the Aft Short Tail Rotor Drive Shaft

The Bell 206B aft short tail rotor drive shaft is not a serialized item, and there is no requirement to maintain an applicable component history card. Seven boxes of maintenance records, which had accompanied the helicopter at import, were reviewed to determine the history of the drive shaft. Relevant documents indicated that the drive shaft had been replaced in February of 1988 at 6,262:10 airframe hours, and that the replacement drive shaft had been removed in serviceable condition from another helicopter, registered as N719H. Consultation with the company which previously owned both helicopters determined that N719H was an older Bell 206 which had been retired from service due to voids in the roof shell assembly. The retired helicopter had accumulated 15,006:10 airframe hours at the time it was withdrawn from service, and no evidence was found to indicate that the original aft short tail rotor drive shaft had ever been replaced.

N719H had been operated in the Arabian Gulf for approximately 10 years, and had been operated in the Gulf of Mexico prior to that. The Gulf of Mexico is also considered a highly corrosive, salt water operating environment.

1.11 TSB Engineering Branch Laboratory Examination

The aft short tail rotor drive shaft and the oil cooler impeller assembly were submitted to the TSB Engineering Branch Laboratory for detailed examination. The operator voluntarily submitted a second Bell 206B aft short drive shaft for use as a comparison. The exemplar drive shaft had been removed from a company sister ship due to external mechanical damage. The sister ship, C-FPRB, was one serial number subsequent to C-FPQS, and had a nearly identical time-in-service and operating history in the Arabian Gulf.

No corrosion was visible on the exterior of the failed drive shaft. However, the external wall had been reworked at some time in the past. The anodizing had been removed and the abraded metal surface had been coated with clear lacquer. Alodine chemical film material had not been applied to the exterior wall, as required, following removal of the original protective coating. The part number, vendor identification, and date of manufacture, which are normally present as inked markings on the tube surface, were not visible.

The failed drive shaft was manufactured from 2024 T3 aluminum and had a wall thickness of .060 inches, as specified in the engineering drawing for the Bell Part No. 206-040-330 assembly. The interior tube wall exhibited a number of fine scratches which had penetrated the anodized and lacquered surface, and several areas of corrosion. Scanning electron microscope examination of the forward and aft fracture surfaces identified an area of environmentally assisted cracking (EAC) and an

area of final overload fracture, indicating two distinct failure modes. The EAC fracture zone occupied greater than 35 per cent of the cross sectional area of the forward end fracture. The fracture surfaces displayed wholly intergranular features accompanied by corrosion product deposits. The tube wall showed evidence of exfoliation action. Analysis of the corrosion product deposits disclosed the presence of elements such as sodium, sulphur, chlorine, potassium, and calcium, which are the major constituents of sea water.

The exemplar drive shaft assembly showed a single incomplete inked marking (....9?23-80-1) on the shaft surface, and an inked date marking (9-19-80) on both the fore and aft attachment flanges. The original grey-coloured surface protection finish on the shaft and adaptor ends was intact, although only small patches of the lacquer coating remained. The exemplar shaft did not appear to have been reworked, and there was no evidence of corrosion on the outer or inner walls.

1.12 Aft Short Tail Rotor Drive Shaft Inspection Requirements

The *Bell 206B JetRanger III Component Repair and Overhaul Manual* provides the overhaul and repair instructions applicable to the tail rotor drive shaft system. It also identifies the mechanical and corrosion damage limits for the component. The damage limits pertain to externally visible defects, and there is no stated procedure to examine the bore of the drive shaft for corrosion.

The *Bell 206B III Maintenance Manual* identifies the scheduled inspection requirements for the helicopter. The 100-hour inspection tasks include a requirement to check the segmented drive shaft for condition and security. However, there is no specific reference to the aft short tail rotor drive shaft, nor is scheduled non-destructive testing (NDT) or overhaul of the component required.

1.13 The Service Difficulty Reporting Data Base

The Transport Canada Service Difficulty Data Base was searched to locate similar reports of Bell 206B aft short tail rotor drive shaft discrepancies and failures. There was no record of drive shaft replacement or failure due to internal corrosion.

1.14 The Oil Cooler Impeller Fan

Examination of the oil cooler impeller determined that all 36 vanes had separated from the forward end plate, while a small number had remained partially attached to the aft end plate of the impeller assembly. Examination of the surfaces of the vanes failed to disclose any evidence of massive impact with foreign or ingested objects. The fracture surfaces were found to show ductile overload features, with no evidence of a progressive failure. Although the precise cause of failure was not determined, the destruction of the oil cooler impeller was considered secondary to the aft short tail rotor drive shaft failure.

1.15 Tail Rotor Thrust Failure

The *Bell 206B JetRanger III Flight Manual* states that, in the event of a complete loss of tail rotor thrust, the pilot is to "Reduce throttle to flight idle, immediately enter autorotation and maintain a minimum airspeed of 58 MPH IAS (50 knots) during descent."

The helicopter was hovering at approximately 25 feet above ground when the loss of tail rotor thrust occurred. The height/velocity diagram in the *Bell 206B JetRanger III Flight Manual* identifies the airspeed versus altitude limitations for safe autorotation landings. The helicopter was operating within the designated "avoid operation" area when the failure occurred, which indicates that an autorotational landing without damage would be unlikely.

Standard operating procedure dictates that an external sling load be released in the event of an in-flight emergency.

1.16 Survival Aspects

The fuselage structure remained rigid during the accident, and the occupiable cockpit survival space was not compromised. The pilot sustained a bruised right leg. He was not wearing the available shoulder harness; he was, however, wearing a protective helmet. Scars on the outside of the shell indicated that the helmet had effectively prevented serious head injury. The pilot was able to shut down the engine, fuel boost pumps, and electrical system, and evacuate the helicopter quickly without assistance. There was no evidence of a post-impact fire. A bystander observed smoke rising from the engine exhaust stack, and immediately discharged a fire extinguisher into the engine compartment as a precaution.

2.0 Analysis

2.1 Introduction

The weather and terrain were not considered factors in this occurrence. The analysis will address the failure of the aft short tail rotor drive shaft, and the effect of the loss of tail rotor thrust in a hover.

2.2 The Aft Short Tail Rotor Drive Shaft Failure

Available maintenance records indicated that the aft short tail rotor drive shaft had accumulated approximately 19,000 hours of time-in-service. Most of that time was accrued in a highly corrosive, salt water operating environment. The drive shaft had been improperly reworked at some time in the past, and the anodizing and lacquer surface protection on the interior wall had been scratched and penetrated. It is probable that the scratches allowed the initiation of the corrosion, and that the prolonged exposure to an extremely corrosive operating environment hastened the spread of the corrosion within the bore of the drive shaft. The corrosion went undetected, as it was not visible on the outer wall and there is no scheduled requirement for an internal visual or NDT examination. The aft short tail rotor drive shaft eventually failed under normal loading, after being weakened by the presence of intergranular cracking which extended from the corrosive attack of the interior wall.

The failure may be an isolated occurrence as no record of a similar aft short tail rotor drive shaft discrepancy or failure was found.

2.3 The Loss of Tail Rotor Thrust

The altitude and low airspeed at which the helicopter was operated when the loss of tail rotor thrust occurred were within the "avoid operation" area of the height/velocity specified by the manufacturer, and precluded a successful autorotation. The emergency was compounded by the perilous location of the ground assistant, who was standing under the helicopter as it began to rotate uncontrollably. The pilot successfully manoeuvred the gyrating helicopter away from the ground assistant and the generator shed before impact; however, it is probable that this procedure aggravated and prolonged the uncontrolled flight, and may have contributed to the roll-over which occurred at impact. The dragging of the unreleased sling load may also have aggravated the loss of control, and contributed to the roll-over event.

It is probable that the pilot's use of a protective helmet prevented serious head injury.

3.0 Conclusions

3.1 Findings

1. The aft short tail rotor drive shaft failed in an area weakened by intergranular cracking which had progressed from corrosion on the interior wall of the drive shaft.

2. Analysis of the corrosion product deposits disclosed the presence of elements such as sodium, sulphur, chlorine, potassium, and calcium, which are the major constituents of sea water.

3. Historical records indicated that the drive shaft had operated for many years in a warm, humid, and highly corrosive salt water environment.

4. The corrosion which existed in the bore of the drive shaft was not visible with the drive shaft installed.

5. The failure of the aft short tail rotor drive shaft resulted in a loss of tail rotor thrust.

6. The failure occurred while the helicopter was hovering at an altitude which precluded a successful autorotation.

7. The aft short tail rotor drive shaft had been improperly reworked at some time in the past.

8. The aft short tail rotor drive shaft is not a serialized item, and there is no requirement to maintain an applicable component history record.

9. The pilot successfully manoeuvred the gyrating helicopter away from the ground assistant and the generator shed before impact.

10 The pilot was not wearing the available shoulder harness.

11. It is probable that the pilot's use of a protective helmet effectively prevented serious head injury.

12. The pilot did not release the sling load prior to impact.

13. It was not determined why the oil cooler impeller vanes detached from the supporting end plates.

3.2 Causes

The aft short tail rotor drive shaft failed in an area weakened by intergranular cracking which initiated from corrosive attack on the interior wall of the shaft. The drive shaft failure resulted in a loss of tail rotor thrust. The failure occurred when the helicopter was hovering at an altitude which precluded a successful autorotation.

4.0 Safety Action

The Board has no aviation safety recommendations to issue at this time.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 05 July 1995.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Laboratory Report was completed:

LP 140/94 - Tail Rotor Drive Shaft Analysis.

This report is available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

asl	above sea level
CPL	Commercial Pilot Licence
EAC	environmentally assisted cracking
hr	hour(s)
IAS	indicated airspeed
lb	pound(s)
MDT	mountain daylight saving time
mph	miles per hour
NDT	non-destructive testing
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
'	minute(s)
"	second(s)
°	degree(s)

TSB OFFICES

HEAD OFFICE

HULL, QUEBEC*
Place du Centre
4th Floor
200 Promenade du Portage
Hull, Quebec
K1A 1K8
Phone (819) 994-3741
Facsimile (819) 997-2239

ENGINEERING
Engineering Laboratory
1901 Research Road
Gloucester, Ontario
K1A 1K8
Phone (613) 998-8230
24 Hours (613) 998-3425
Facsimile (613) 998-5572

*Services available in both official languages

REGIONAL OFFICES

ST. JOHN'S, NEWFOUNDLAND
Marine
Centre Baine Johnston
10 Place Fort William
1st Floor
St. John's, Newfoundland
A1C 1K4
Phone (709) 772-4008
Facsimile (709) 772-5806

GREATER HALIFAX, NOVA SCOTIA*
Marine
Metropolitain Place
11th Floor
99 Wyse Road
Dartmouth, Nova Scotia
B3A 4S5
Phone (902) 426-2348
24 Hours (902) 426-8043
Facsimile (902) 426-5143

MONCTON, NEW BRUNSWICK
Pipeline, Rail and Air
310 Baig Boulevard
Moncton, New Brunswick
E1E 1C8
Phone (506) 851-7141
24 Hours (506) 851-7381
Facsimile (506) 851-7467

GREATER MONTREAL, QUEBEC*
Pipeline, Rail and Air
185 Dorval Avenue
Suite 403
Dorval, Quebec
H9S 5J9
Phone (514) 633-3246
24 Hours (514) 633-3246
Facsimile (514) 633-2944

GREATER QUÉBEC, QUEBEC*
Marine, Pipeline and Rail
1091 Chemin St. Louis
Room 100
Sillery, Quebec
G1S 1E2
Phone (418) 648-3576
24 Hours (418) 648-3576
Facsimile (418) 648-3656

GREATER TORONTO, ONTARIO
Marine, Pipeline, Rail and Air
23 East Wilmot Street
Richmond Hill, Ontario
L4B 1A3
Phone (905) 771-7676
24 Hours (905) 771-7676
Facsimile (905) 771-7709

PETROLIA, ONTARIO
Pipeline and Rail
4495 Petrolia Street
P.O. Box 1599
Petrolia, Ontario
N0N 1R0
Phone (519) 882-3703
Facsimile (519) 882-3705

WINNIPEG, MANITOBA
Pipeline, Rail and Air
335 - 550 Century Street
Winnipeg, Manitoba
R3H 0Y1
Phone (204) 983-5991
24 Hours (204) 983-5548
Facsimile (204) 983-8026

EDMONTON, ALBERTA
Pipeline, Rail and Air
17803 - 106 A Avenue
Edmonton, Alberta
T5S 1V8
Phone (403) 495-3865
24 Hours (403) 495-3999
Facsimile (403) 495-2079

CALGARY, ALBERTA
Pipeline and Rail
Sam Livingstone Building
510 - 12th Avenue SW
Room 210, P.O. Box 222
Calgary, Alberta
T2R 0X5
Phone (403) 299-3911
24 Hours (403) 299-3912
Facsimile (403) 299-3913

GREATER VANCOUVER, BRITISH COLUMBIA
Marine, Pipeline, Rail and Air
4 - 3071 Number Five Road
Richmond, British Columbia
V6X 2T4
Phone (604) 666-5826
24 Hours (604) 666-5826
Facsimile (604) 666-7230