AVIATION INVESTIGATION REPORT

A99P0075

POWER LOSS—FUEL STARVATION

EAST WEST HELICOPTERS LTD.

BELL 214B HELICOPTER C-GEWT

KASLO, BRITISH COLUMBIA 35 NM NW

4 JULY 1999

Transportation Safety Board of Canada

Bureau de la scurit des transports du Canada

Aviation Investigation Report

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East West Helicopters Ltd.
Bell 214B Helicopter C-GEWT
Kaslo, British Columbia 35 nm NW
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Report Number A99P0075

Synopsis

The Bell 214B helicopter, serial number 28025, departed a staging area near Kaslo, British Columbia, at about 0645 Pacific daylight time on a local visual flight rules flight. The pilot and three crew members were on board. The helicopter was observed flying uneventfully in the area for about 10 minutes before the engine noise suddenly stopped. The helicopter, about 400 feet above ground level at the time, descended, made a 180-degree left turn, and landed heavily in a shallow, rapidly flowing river. The helicopter broke apart on impact and came to rest on the rocks in the middle of the river. Three of the occupants were fatally injured at impact; the pilot succumbed to his injuries about 45 minutes later. The aircraft was destroyed. There was no fire.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 History of the Flight

The Bell 214B helicopter was being used for heli-logging operations out of a staging area on the Glacier Creek forest service road, about 65 nautical miles (nm)[1] northwest of Cranbrook, British Columbia. East West Helicopters Ltd., owners and operators of the helicopter, had contracted North American Helitech, an aircraft maintenance organization (AMO), to maintain the helicopter. The night before the accident, an aircraft maintenance engineer (AME) and an apprentice AME (both from the AMO) had worked on the helicopter in the staging area until midnight. It is not known what maintenance may have been performed at that time.

The next morning, at about 0600 Pacific daylight time,[2] the company operations manager, who was also acting as the maintenance manager, drove the pilot, co-pilot, AME, and apprentice AME to the helicopter. After dropping off the helicopter crew, he then drove about 0.25 nm back down the valley from the helicopter and parked in a log landing area, where he remained in his vehicle.

The helicopter was started about 30 minutes later and was run on the ground for 10 to 15 minutes. The helicopter then took off and ascended briefly into the cloud base at about 500 feet above ground level (agl) before descending below the cloud. The company operations manager communicated by radio at that time with the pilot aboard the helicopter. The pilot indicated that he was doing a power check and that the conditions were too foggy for heli-logging. The helicopter then flew down the valley at about 400 agl, staying closer to the northwest side of the valley, and passed nearly overhead the operations manager. The helicopter continued down the valley, then made a 180-degree left turn and flew up the southeast side of the valley.

A short time later, the helicopter was heard coming from the same direction it had on the previous circuit from up the valley. As the helicopter neared the log landing area, the sound of the approaching helicopter stopped. The helicopter was then seen flying down the valley at about 400 feet agl, trailing white vapour from the exhaust. The main-rotor blades were heard and seen slowing. The helicopter then made a descending 180-degree left turn toward Glacier Creek, with the main rotor continuing to slow. Immediately before the helicopter disappeared from sight behind trees, the main rotor appeared to have stopped turning.

1 See Appendix B for abbreviations and acronyms.

2 All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	4	-	-	4
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	4	-	-	4

The pilot-in-command (PIC) was the only occupant to survive the initial impact. He survived for about 45 minutes before succumbing to injuries sustained at impact.

1.3 Damage to Aircraft

The helicopter was destroyed by impact forces.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

The 48-year-old PIC had been employed by the company as a pilot since June 1998, flying Bell 206 and Bell 214 helicopters. He held a valid Canadian commercial pilot licence (helicopter) and a medical certificate and was endorsed to fly several types of medium and light helicopters, including the accident helicopter. He had accumulated a total of about 14 000 hours' flying experience, of which about 300 hours were in the Bell 214B. His flying experience included about 2750 hours in heli-logging operations. Records indicate that the pilot had no recurrent flight training on the Bell 214B. His endorsement flight training was conducted more than two years before the accident flight. Several pilot proficiency check (PPC) reports contained comments that the pilot's handling of emergency procedures needed improvement; however, there is nothing in the pilot's file to indicate that extra training was received. A PPC report for a flight in January 1993 noted that the pilot needed to be briefed on autorotation procedures, both straight-in and 180-degree turns. There was no record found of the pilot having flown a PPC on the Bell 206 or Bell 214 helicopters.

The person occupying the right-hand pilot seat was an AME for the AMO that the company had contracted to maintain the helicopter. The co-pilot was seated in the passenger cabin, along with an apprentice AME. On this flight the co-pilot was not acting in that capacity, but, for convenience, he is referred to in this report as the co-pilot.

1.6 Aircraft Information

Manufacturer	Bell Helicopter Textron
Type and Model	Helicopter model 214B
Year of Manufacture	1978
Serial Number	28025
Certificate of Airworthiness	Valid
Total Airframe Time	8575 hours
Engine Type (Number of)	Allied Signal (Lycoming) T55-08D (1)
Rotor Type (Number of Rotor Blades)	Semi-rigid (2)
Maximum Allowable Take-off Weight	13 800 pounds
Recommended Fuel Type	JP-4, JP-5, JP-8 (Jet A / Jet A-1 / Jet B)
Fuel Type Used	Jet A-1

The Bell 214B helicopter is certificated to be operated with a minimum flight crew consisting of one pilot who shall operate the helicopter from the right crew seat. For external load flying, a supplement to the aircraft's type certificate can be issued by Transport Canada (TC) for a specific aircraft. This supplement allows a single pilot to fly that aircraft from the left seat, provided that certain modifications—including installation of dual controls, a left-door bubble window, and critical instruments added to the left-door window sill—have been made to the aircraft. The accident aircraft had been modified to be flown from the left seat, but a supplemental type certificate had not been issued for this aircraft.

Using information from documents recovered after the accident, the aircraft's weight and centre of gravity at take-off from the staging area were calculated to have been within certificated limits, regardless of the amount of fuel on board.

The aircraft journey log could not be located following the accident. It was reported that the journey log may have been aboard the helicopter at the time of the accident. The technical logs (airframe, engine, modifications, and installations) for the helicopter were recovered but do not contain information for the last month of the aircraft's operation. The airframe technical log entries indicate that a "surging" problem with the engine had been reoccurring for about a year.

The aircraft was to be operated in accordance with the *Canadian Aviation Regulations*, Part VII—Commercial Air Services, subpart 702—Aerial Work Operations, and in accordance with the Air Operating Certificate issued to the company by TC.

1.7 Meteorological Information

There is no Atmospheric Environment Service weather observation site in the immediate area of the crash. It was observed that the logging area, about 1000 feet above the crash site, was fogged in at the time of the accident. The cloud base was estimated to have been about 500 feet above the crash site and valley floor. The pilot of the accident aircraft had communicated by radio during the accident flight that the ceiling was low and that the fog was not going to clear for the day. Royal Canadian Mounted Police (RCMP) photographs, taken about one hour after the accident, show the clouds to be about 500 feet above the valley floor, with some clouds as low as 100 feet.

At Meadow Creek, 10 nm to the southwest and 900 feet lower than the accident site, the wind was calm at the time of the accident, the temperature was about 10 degrees Celsius, and the sky was overcast, with a cloud base at about 1500 feet agl.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Direct communication between the crew in the helicopter and the company operations manager on the ground was conducted using very high frequency radios. The pilot had communicated with the operations manager shortly after take-off. There were no further communications from the helicopter.

1.10 Helipad Information

The helicopter staging area is a wide section of the Glacier Creek forest service road, about 11 nm northeast of Meadow Creek. The staging area is 2660 feet above sea level (asl) and is about 0.25 nm up (northeast) the Glacier Creek valley from the accident site. It is at this location that the helicopter was normally refuelled and field maintenance performed.

1.11 Flight Recorders

Not applicable.

1.12 Wreckage and Impact Information

The wreckage was near the middle of Glacier Creek at 2620 feet asl. The helicopter had broken into four main pieces, all found within a few feet of each other. The cockpit/cabin section of the fuselage separated from the rest of the fuselage forward of the main-rotor gearbox pylon and came to rest upright at about a 30-degree angle to level, with the right side low. The main-rotor gearbox and pylon separated from the fuselage but remained attached to the mast and main-rotor blades. The aft fuselage separated from the main-rotor gearbox pylon but remained attached to the engine. The tailboom separated from the helicopter about three feet aft of the tailboom-to-fuselage attachment point.

The main- and tail-rotor blades exhibited very little rotational impact damage. The fuselage exhibited indications of high-speed, near-vertical impact damage with a low-speed forward component.

The engine was found on its side, partially submerged in the creek. The starter-generator assembly had broken free of the accessory gearbox, and the exhaust tailpipe was deformed. Sand, gravel, and floating debris from the creek had washed into the engine intake and exhaust.

1.13 Medical Information

There was no sign that incapacitation or physiological factors had affected the pilot's performance.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The injuries to the occupants and the damage to the aircraft are consistent with high vertical-impact forces that characterize an unsurvivable accident. The two pilot seats were fitted with four-point lap belts and shoulder straps, and the cabin seats had conventional, two-point lap belts. Details about the cabin occupants' restraint or ejection are not known. The co-pilot, who had been seated in the cabin, was found out of his seat, about 10 feet away from the cabin. The other cabin occupant was found under the wreckage.

The PIC (seated in the left pilot seat) and the AME (seated in the right pilot seat) remained secured in their seats during the impact. They both sustained serious injuries from the disruption and break-up of the cockpit around them. Medical information revealed that the occupants of the front seats had been wearing the seat belt lap portion. They did not use the shoulder harnesses of their seat restraints; the shoulder straps were found rerouted behind the backs of the seats. The PIC was wearing a flight helmet.

1.16 Tests and Research

Following a preliminary examination of the wreckage at the site, the airframe, engine, and ancillary systems were transported to secure facilities and examined in greater detail. Attention was focused on the engine, main-rotor gearbox, fuel system, flight controls, and drive train.

The available records indicate that the total time on the engine as of 1 July 1999 (three days before the accident) was 5348.4 hours. The total time since overhaul of the engine as of 1 July 1999 was 3073.1 hours. The engine manufacturer's time between overhaul for this engine was 4000 hours.

The maintenance records show that the accident helicopter had been "surging" for more than a year, since the aircraft was imported from Japan. The records, however, do not give details of any symptoms exhibited by the aircraft. Many components—including the engine, fuel control unit (FCU), bleed band, and bleed band actuator—had been replaced in separate attempts to rectify this problem.

The Lycoming T55-08D gas turbine engine, serial number 31981, could not be run following the accident because of the damage. The engine was transported to an engine overhaul facility where it was disassembled and examined. Some of the critical components were removed from the accident engine and tested.

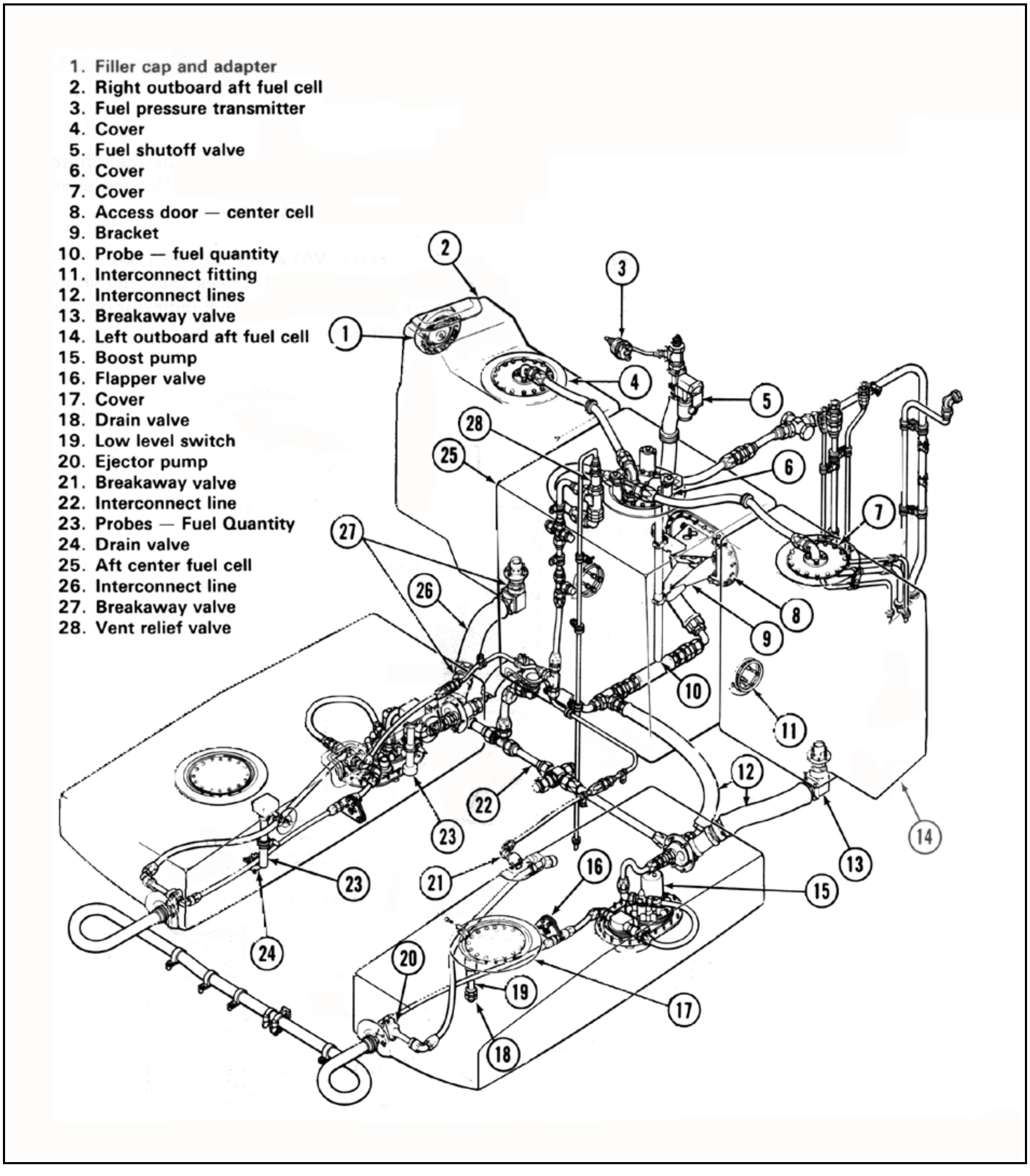
Disassembly of the engine revealed no indication of rotational damage. Several components of the engine were worn to or beyond service limits, including the axial compressor (tip clearance near limits), worn diffuser curl seal, cracked first- and second-stage turbine nozzles, and worn fuel nozzles.

The FCU, bleed band, bleed band actuator, and fuel flow divider were removed from the accident engine, tested individually, then installed on a serviceable engine where a run-up was performed. When tested individually, each of the components was functional and performed within the manufacturer's specified limits. When the components were installed on a serviceable engine and tested together, overall performance was acceptable, with no surging or flame-out.

Disassembly and inspection of the main-rotor gearbox, serial number AME 52004, found all components to be operable, including the free-wheel device (Sprag clutch). No mechanical defects were found that would have contributed to an unsuccessful autorotation.

The TSB Engineering facility analyzed the light bulbs in the cockpit annunciator panel, the warning and caution lights, and the three instruments in the left pilot's door (engine/rotor dual tachometer, engine torquemeter, and hook load gauge). The bulb analysis indicated that several warning lights were on at the time of impact, including the right boost pump, low fuel, and low rotor rpm (revolutions per minute) lights. An illuminated boost pump light indicates that fuel flow from the related fuel boost pump has dropped to the point where the flow-activated switch operates, indicating an inoperable fuel boost pump or a lack of fuel. The instrument analysis indicated that the engine rpm was at 3 per cent and that the rotor rpm was at 16 per cent at the time of impact.

The Bell 214B helicopter is equipped with five fuel cells interconnected to feed into the two forward fuel cells, which are the lowest cells in the system (see Figure 1). Each of the forward cells has a partition with a small one-way flapper valve, which divides the cell into a forward and an aft section. The aft section of each forward cell contains an electrically driven boost pump, part number 164A213, which supplies fuel to the engine. Each boost pump also operates a jet pump, located in the forward section of each cell, to supply fuel from the forward section of the cell to the aft section. A fuel cell interconnect line runs between the left and right forward fuel cells, normally ensuring that the fuel level in the two forward cells remains equal. The fuel quantity gauge is operated by probes located in the centre cell and the right forward fuel cell. If the centre fuel cell does not contain any fuel, the fuel quantity gauge is operated solely by the probes in the right forward cell. The fuel quantity gauge does not directly register fuel in the left forward cell. The left forward fuel cell contains a float-switch used to activate the low-fuel warning light. The Bell 205 has similar fuel storage, fuel transfer, and fuel indicating systems.



The right and left fuel boost pump assemblies were disassembled and inspected. Both pump assemblies were extensively damaged during the crash; the left boost pump was broken from its base, and the right boost pump was cracked along its base. Disassembly showed that the component parts (brushes, impellers, bearings, etc.) were within wear limits, although the brushes on the left boost pump motor were worn nearly to limits. During testing, neither pump motor operated when power was initially applied. On the right boost pump motor, one of the brushes was stuck and would not contact the commutator. When the brush was pushed in, to contact the commutator, and electrical power was reapplied, the motor operated. On the left boost pump motor, one of the

wires to the brush assembly was broken internally, although the wire insulation was intact. Because there were no indications that this pump was not functioning in flight, it is concluded that the wire broke during the impact. When power was applied directly to the relay on the motor, bypassing the broken wire, the motor operated. No records could be found to indicate the pumps' time in service on the accident aircraft or the time since overhaul or repair for either pump.
Information gathered from several sources—including Bell 214B operators, maintenance facilities, and a component repair-and-overhaul facility—indicates that the average time between replacement or repair of Bell 214B boost pumps is 100 to 300 hours. The component repair-and-overhaul facility reported that if grease is added to the pump motor bearings during repair, the boost pumps are able to operate for about twice as long (600 hours) before requiring servicing. The boost pump is a condition-monitored item,[3] but the pump manufacturer reports that the design goal of the pump is 1000 hours. Records could not be found to indicate when the boost pumps had been installed on the accident helicopter or how many hours of operation had accumulated on the boost pumps. No record could be found in TC's service difficulty report database of any submissions for boost pumps with this part number.

Globe Motors, the manufacturer of the boost pumps, contends that both right and left boost pumps had been repaired since new and that these repairs were not carried out by Globe Motors. Globe Motors does not provide any facility with parts, drawings, manuals or revisions that are required for overhaul or repairs to be carried out on these pumps.

The Bell 214B flight manual states that, with both the right and left fuel boost pumps operating, the unusable fuel during normal flight operations is 23 pounds. The manual also states that with one boost pump inoperative, the unusable fuel increases to 103 pounds. The forward fuel cell interconnect is unable to flow fuel between the cells as rapidly as the engine can consume fuel from the cell with the operable boost pump.[4] The fuel quantity gauge is designed to retain its last indicated pointer position when power is cut off; the fuel quantity gauge indicated 500 pounds of fuel when it was recovered from the wreckage.

During the crash, virtually all of the remaining fuel was lost because of damage to the aircraft and the rupturing of the fuel system. A small amount of fuel was found in the FCU and in the hoses connected to the FCU. Analysis showed that the fuel was similar to Jet A and free of contaminates.

The engineer who was on the accident flight would normally refuel the helicopter each morning before the helicopter began logging, rather than each evening after the helicopter finished logging for the day. Because the helicopter was taken on a maintenance test flight, rather than the usual heli-logging flight, it is possible that the

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3 *Condition monitoring* is a maintenance process under which data on the whole population of specified items in service is analyzed to indicate whether technical resources need to be allocated. Condition monitoring is not a preventive maintenance process. Rather, this type of maintenance allows failures to occur and relies upon analysis of operating experience information to indicate the need for appropriate action.

4 TSB Engineering Laboratory Report LP 14/00.

helicopter was not refuelled before the flight or that it was refuelled with less fuel than normal.

1.17 Other Information

1.17.1 Pilot Procedures

In heli-logging operations using the Bell 214B helicopter, it is a standard practice for the pilot flying to occupy the left seat and for the pilot not flying to be in the right seat. The pilot flying manoeuvres the helicopter for all phases of flight, while the pilot not flying monitors the engines and the ancillary systems and records the loads picked up during the cycle. This division of work load allows the pilot flying to concentrate solely on manoeuvring the helicopter.

On helicopters used in vertical-reference flying,[5] such as the Bell 214B helicopter, cockpit dimensions and fuselage width require the pilot flying to lean markedly to the side to be able to see clearly the long line and load suspended below the helicopter. Because such a body position is difficult to achieve by a pilot wearing a shoulder harness, it is a widespread practice for the pilot manoeuvring the helicopter to use the lap belt portion only.[6] In helicopters dedicated to vertical-reference flying, the shoulder straps are commonly stowed behind the seat back to prevent them from interfering with the pilot's movements. In the accident helicopter, the upper-body support of the left pilot's seat had also been modified to allow the pilot to lean toward the side window without interference.

Emergency procedures following a power loss in the Bell 214B require timely and correct pilot response. If the emergency procedures are not implemented correctly and quickly, rotor rpm can rapidly decay to a point where it cannot be regained regardless of pilot response. Once that point is reached, the rotor will continue to slow until it stops, making a successful autorotation impossible.

1.17.2 Audits and Records

A TC audit of East West Helicopters Ltd. had not been conducted in the three years preceding the accident. Following the accident, TC audited the company on 14 July 1999.

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5 *Vertical-reference flying* describes helicopter operations where a load is slung on a line below the helicopter.

6 The TSB investigation into a heli-logging accident at Stave Lake, British Columbia, (TSB Report No. A97P0094) determined that it is common practice for the pilot to wear only the lap belt portion of the seat restraints.

TC found the flight crew training program was lacking in several areas, including the following:

- The training program (as reflected in the company operations manual, reissued in early 1999) had not been implemented fully.
- Flight crew training records were incomplete and in need of restructuring.
- Essential information with regard to pilot licence(s), medical validation certificate(s), type endorsement(s), competency check status, aerial work training received, etc. was not available.
- Pilots had not undergone the required competency checks, and one pilot was neither trained nor endorsed on type.
- Although the company had a system to record and track pilot flight duty times, flight times, and rest periods, the system was not being used.

The audit reviewed the operational control system and concluded that East West Helicopters suffers from a lack of operational control because of the significant workload placed on the operations manager. Besides overseeing the aerial operations, the operations manager was responsible for the day-to-day running of a parent trucking company. Also, the company's chief pilot was on active flight status, making it difficult to implement the required program in full. TC staff have indicated that the company corrected all of the items noted in the audit and that the company has been put on a one-year audit cycle.

An examination by TSB investigators of the aircraft technical logbooks recovered after the accident revealed that they had not been updated (records transcribed) in over one month.[7] Other records show that several major components had been replaced during that time, including the main transmission, FCU, engine reduction gearbox, and tail-rotor gearbox.

Company work sheets associated with maintenance functions were kept by the operations manager (who was also acting as the maintenance manager) to oversee the contracted AMO. These records were current to 1 July 1999, three days before the occurrence. "Serviceable" tags for various component changes and replacements performed shortly before the occurrence were incomplete and loosely stored in a binder and did not accompany the journey log.

[7] Records are required to be transcribed to technical logs within 30 days.

2.0 Analysis

2.1 General

It was reported that the engine noise had stopped and that the main rotor was slowing as the helicopter passed over the log landing area. An examination of the helicopter after the accident identified negligible rotational damage to the engine, drive train components, main-rotor blades, and tail-rotor blades. Subsequently, a more detailed inspection of the wreckage revealed that all component breakage and damage in the flight controls, drive train, and main-rotor gearbox were overload in nature and were attributable to the impact forces of the accident. Based on this information, it was determined that the helicopter had lost power before impact.

A detailed examination of the engine and its accessories revealed several anomalies. While these anomalies may explain the need for a pre-flight compressor wash and for the in-flight power check, they would not have caused a complete power loss.

The light bulb analysis showed that the low-fuel light and the right boost pump annunciator light might have been illuminated at the time of the crash. The fuel level sensor is in the left forward cell; therefore, the low-fuel light would indicate that the left forward cell was virtually empty. Assuming the right boost pump became inoperative, the fuel from the left forward cell was consumed at a faster rate than the fuel could transfer from the right forward cell to the left forward cell. The fuel in the left forward cell eventually reached an unusable level, and the engine stopped. The fuel gauge indicator retains its last position when power is cut off. The gauge indication after the crash was 500 pounds. Assuming that power was lost at impact, the gauge was indicating 500 pounds of fuel just before the crash. Relying on the principle that the fuel in the forward cells will remain equal because of the cell interconnect line, the system measures the amount of fuel in the right forward cell, and doubles that amount for the fuel quantity indicator. Therefore, at the moment of the crash, there was approximately 250 pounds of fuel in the right cell and virtually none in the left cell. The boost pump light would indicate that the right boost pump was not operating or that there was no useable fuel in the right fuel cell. In light of the following, it is likely that the pump was not operating (failed): the engine stopped in flight; nothing mechanically wrong was found with the engine; there was useable fuel in the right cell; and the boost pump light might have been on.

2.2 Fuel Delivery System

The average length of time that the fuel boost pumps on the Bell 214B were found to operate before requiring repair or overhaul is much lower than the design life goal set by the pump manufacturer. Depending on the attitude of the helicopter, failure of a boost pump in one cell could result in a significant amount of fuel remaining in that cell, while the fuel in the cell with the operable boost pump is consumed to exhaustion. This is because the forward fuel cell interconnect is unable to flow fuel from the cell with the inoperable boost pump to the cell with the operable pump as rapidly as the engine can consume fuel from the cell with the operable boost pump. Exhaustion of the fuel in the cell with the operable boost pump will cause the engine to flame out.

2.3 Fuel Indicating System

Because the fuel quantity indicating system does not directly measure the amount of fuel in the left forward cell, unless the fuel level in both forward cells is equal, the gauge will indicate an incorrect amount of fuel remaining. For the same reason, the fuel low-level warning system, which does not directly measure the fuel in the right forward cell, can read incorrectly. Either of these indications could lead the pilot to believe that there is more fuel than is actually available and to continue flight operations until fuel exhaustion.

2.4 Emergency Procedures

Pilots may not be aware of the significance of a boost pump failure. The Bell 214B flight manual does not list boost pump failure under "Emergency Procedures" (Section 3); it is listed under "Malfunction Procedures" (Section 4). Of the three possible categories of seriousness (land immediately, land as soon as possible, and land as soon as practical), boost pump failure is categorized as the least serious (land as soon as practical). Because the flight manual does not refer to the possibility of incorrect fuel quantity indications following a boost pump failure, the accident pilot may not have regarded the boost pump failure as critical.

The low cloud base limited the height above the ground that the helicopter was able to fly. Thus, the helicopter may not have been high enough to carry out a successful autorotation.

Because no mechanical malfunction was found that would have contributed to an unsuccessful autorotation and because procedures following a power loss in the Bell 214B require timely and correct pilot response, it is possible that the accident pilot's lack of recent training on Bell 214B emergency procedures contributed to the unsuccessful autorotation.

2.5 Safety Management

An occurrence can often be traced back to identifiable organizational and management factors. An examination of whether the company's policies, procedures and practices are in concert and accurately reflect a sound safety philosophy is key to understanding the role of such factors in an occurrence. East West Helicopters had policies and procedures in place to ensure operational compliance and safety. However, as shown in this occurrence, deficiencies uncovered by both the TC post-accident audit and the TSB investigation indicated that the workload of the operations manager compromised operational control and led to operational practices being at odds with safety policies. The nature of the deficiencies identified was such that they could have been identified through a more effective company safety management system.

2.6 Survivability

Neither front-seat occupant was wearing his available shoulder harness. Because of the severity and high vertical component of the impact forces in this accident, it is unlikely that the use of the shoulder harness would have prevented fatalities.

Given that vertical-reference flying necessitates upper-body freedom of movement, dismissal of the shoulder harness is almost inevitable. It is not known if the crew's rejection of the shoulder harness was deliberate or a continuation of a habit they had developed while heli-logging. It is likely that a crew's regular rejection of shoulder harnesses will diminish their awareness of the safety advantages of shoulder harnesses and, at the same time, reinforce a less-than-ideal safety practice. Accident investigations and research conducted by the TSB have consistently shown that the use of the shoulder harness portion of the seat restraint system is effective in reducing or preventing injury during moderate-impact forces.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The helicopter engine lost power in flight (engine flame-out) because of fuel starvation.

2. The usable fuel in the left cell was exhausted. Although there was fuel in the right cell, it was not available at a usable rate because the right boost pump was inoperative and the fuel transfer was slower than engine fuel usage.

3. When the right boost pump is inoperative, the fuel quantity gauge indicates more fuel than is actually on board. The actual amount of usable fuel would be difficult to determine in flight.

3.2 Findings Related to Risk

1. The model of electric fuel boost pumps used on the Bell 214B helicopter has a history of requiring repair or overhaul well before its expected service life.

2. The pilot did not have a current pilot proficiency check and had not received any recurrent training on type, possibly affecting his ability to conduct an effective autorotation.

3. The Bell 214B flight manual does not adequately describe the consequences of a boost pump failure or emphasize its seriousness.

3.3 Other Findings

1. Neither of the front-seat occupants was wearing the available shoulder harness.

2. The helicopter's weight and centre of gravity were calculated to have been within certificated limits.

3. The certification for this helicopter requires the pilot to be seated in the right front seat during flight with passengers. The pilot was flying from the co-pilot (left front) seat.

4. The helicopter had been modified to be flown from the left seat, but a supplemental type certificate had not been issued by Transport Canada.

5. The helicopter was not maintained in accordance with existing regulations and approved procedures: information was not transcribed to the technical logbook within the required 30 days.

4.0 Safety Action

4.1 Action Taken

Transport Canada (TC) audited the company on 14 July 1999 and found the flight crew training program was lacking in several areas. TC staff have indicated that the company corrected all the items noted in the audit and that the company has been put on a one-year audit cycle. See Section 1.17.2 of this report.

4.2 Action Required

While the findings in this investigation relate to the Bell 214B, some of the findings are valid for the Bell 205, though to a lesser extent because of the reduced fuel flow requirements of the Bell 205. Of the 34 Bell 214Bs operating commercially around the world, 8 are in Canada or under Canadian registration. Of the 200 Bell 205s operating commercially around the world, 68 are in Canada or under Canadian registration.

The fuel quantity gauges in these helicopters are operated by probes located in the centre cell and the right forward fuel cell. If the centre fuel cell does not contain any fuel, the fuel quantity gauge is operated solely by the probes in the right forward cell. The fuel quantity gauge does not directly register fuel in the left forward cell. The left forward fuel cell contains a float-switch used to activate the low-fuel warning light.

The fuel quantity indicating system does not directly measure the amount of fuel in the left forward cell. Therefore, unless the fuel level in both forward cells is equal, the gauge will indicate an incorrect amount of fuel remaining. For the same reason, the fuel low-level warning system, which does not directly measure the fuel in the right forward cell, can read incorrectly. Either of these indications could lead pilots to believe that there is more fuel than is actually available and to continue flight operations until fuel exhaustion.

When the right boost pump is inoperative, some fuel in the right cell is not available because fuel transfer via the fuel cell interconnects is slower than engine fuel usage. At the same time, the fuel quantity gauge indicates more fuel than is actually on board because the fuel quantity indicator is only getting information from the right fuel cell, which has fuel trapped in it. From the moment the right boost pump becomes inoperative, the quantity of fuel indicated on the gauge would decrease slowly; the system measures the amount of fuel in the right forward fuel cell, and doubles that amount for the fuel quantity indicator. However, the fuel in the right forward cell is being depleted only by the amount of fuel that flows through the interconnect line to the left cell. The actual amount of usable fuel remaining would be difficult for the pilot to determine in flight. The low-fuel light, which gets its information from the left fuel cell, will illuminate as the fuel level in the left cell decreases below a set level. This information could easily be misinterpreted by pilots. The actual flying time remaining before fuel starvation following a loss of a right boost pump would be somewhat more than half of what it would be with both boost pumps operating.

The flight manuals for the Bell 214B or the Bell 205 do not explain these symptoms. There are notes that the unusable fuel is 103 pounds in the event of a boost pump failure on the 214B and 59 pounds unusable in the same situation in the Bell 205. The manuals do not contain information explaining that the fuel quantity indicating system may provide incorrect information.

Boost pump failures are common in Bell 214B and Bell 205 helicopters. The boost pumps have no time limit before overhaul and are normally kept in service until they fail.

The consequences of fuel starvation in flight are serious. There is insufficient information readily available to pilots operating Bell 214B and Bell 205 helicopters to reasonably expect that they would take appropriate action in the event of a boost pump malfunction or a loss of fuel pressure for any other reason. Therefore, the Board recommends, for the consideration of Bell Helicopter Textron and the Minister of Transport, that:

> The Bell 214B and Bell 205 flight manuals be modified to provide information regarding the inaccuracy of fuel quantity indications, thereby allowing pilots to make informed decisions in the event of a loss of fuel boost pump pressure.

A01-05

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 6 June 2001.

Appendix A – List of Laboratory Reports

The following TSB Engineering Laboratory reports were completed:

LP 77/99—ELT Analysis
LP 78/99—Fuel & Oil Sample Analysis
LP 92/99—Instrument Examination
LP 14/00—Fuel Transfer Calculation
LP 130/00—Fuel Quantity Gauge Examination

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix B – Glossary

agl	above ground level
AME	aircraft maintenance engineer
AMO	aircraft maintenance organization
asl	above sea level
FCU	fuel control unit
nm	nautical mile(s)
NW	northwest
PIC	pilot-in-command
PPC	pilot proficiency check
RCMP	Royal Canadian Mounted Police
rpm	revolutions per minute
TC	Transport Canada
TSB	Transportation Safety Board of Canada