Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A00Q0133

RUNWAY EXCURSION

HYDRO-QUÉBEC
CONVAIR LINER 340 (580) C-GFHH
LA GRANDE 4, QUEBEC
27 SEPTEMBER 2000

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Summary

The Hydro-Québec Convair 340 (580), registration C-GFHH, serial number 109, with 18 passengers and 4 crew members on board, made an instrument flight rules flight from La Grande 3 to La Grande 4, Quebec. The aircraft touched down on the snow-covered runway at La Grande 4 approximately 800 feet beyond the runway threshold. Shortly after the nose wheel touched down and the pilot set the propellers to reverse pitch, the aircraft drifted to the right. Despite the attempts of the pilot flying (the captain) to correct, the aircraft continued its course and exited the south side of Runway 09 at approximately 50 knots. The aircraft travelled 350 feet over soft, rocky ground and came to rest about 120 feet outside the runway edge, about 2500 feet from the runway threshold. The flight crew followed the procedure to shut down the engines, but the left engine would not stop. On the captain's order, the first officer went into the passenger cabin and ordered an evacuation. All passengers exited the aircraft via the window emergency exits over the right wing. The left engine eventually shut down on its own after about 15 minutes. Five persons sustained minor injuries. The aircraft sustained substantial damage but did not catch fire.

Ce rapport est également disponible en français.

Other Factual Information

History of the Flight

Hydro-Québec is a producer and distributor of electricity. Its operations involve frequent travel by employees, particularly workers assigned to maintain the dams in the James Bay region. Around 0730 eastern daylight time[1] on 27 September 2000, the Convair 340 (580) operated by Hydro-Québec took off from Dorval / Montréal International Airport, Quebec. That day the aircraft, flight number Ampères 180, was to fly to Rouyn, La Grande Rivière, La Grande 3 (LG-3), and La Grande 4 (LG-4), then return to Dorval via the same route in reverse.

When taxiing at Dorval, the captain found it harder than usual to turn the nose-gear steering wheel to the left. However, by turning the wheel harder and intermittently and using differential braking, he was able to steer the aircraft on the ground. The flight crew therefore decided to continue the flight. The problem was present at each stop, but the technique used to steer the aircraft on the ground enabled the pilot flying (PF) to manoeuvre the aircraft. On one stop, the first officer visually inspected the nose wheel well and found nothing wrong. The flight crew decided to continue their route as planned and agreed to report the problem to company maintenance on returning to Dorval.

On the approach to LG-4, the sky was obscured at 800 feet, visibility was 1 statute mile in light snow showers, and surface wind was from the west at 5 to 7 knots. Landing on Runway 09 would decrease the flight time, and the maximum allowable tailwind on landing specified in the *Prop-jet Convair Flight Manual* would not be exceeded, so the flight crew elected to make a downwind landing on Runway 09.

The approach for Runway 09 was normal, and the aircraft touched down approximately 800 feet beyond the runway threshold. As soon as the nose wheel touched down, the PF set the propellers to reverse pitch. Shortly afterward, the aircraft started to drift to the right. The PF tried to correct by braking and applying full left rudder while setting the propellers to reverse pitch asymmetrically, but the aircraft continued its course and exited the south side of Runway 09. The aircraft exited the runway at approximately 50 knots and about 25° to the runway centreline. The aircraft went down a slope to a point about seven feet below the level of the runway surface. The aircraft continued for 350 feet over very soft and rocky ground before coming to rest.

Before the aircraft came to a stop, the captain pulled the two emergency handles (E-handles). Pulling the handles cuts the fuel supply to the engines to shut them down. However, the left E-handle could not be pulled all the way out. When the aircraft stopped, the captain immediately lowered the gang bar and closed the battery switch. The flight crew then heard an unusual noise that they could not identify. On the captain's order, the first officer went to the passenger cabin to order an evacuation. Four window emergency exits, two on each side over the wings, and the rear service door were opened. One passenger exited the left side and walked out onto the wing near the engine that was still running. Since the engine was running and there was a risk of fire or explosion, he was ordered to get back inside the aircraft and exit via the right side with the other passengers. When the window emergency exits were opened,

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[1] All times are eastern daylight time (Coordinated Universal Time minus four hours).

the first officer realized that the unusual noise heard by the crew was coming from the left engine. He advised the captain, who had just then entered the cabin. The captain went back to the cockpit to try again to pull the left E-handle, but it was stuck. He tried to shut down the engine using the normal method, that is, selecting the fuel ignition switch OFF, but the engine kept running. The 18 passengers and the 4 crew members exited onto the right wing and walked to the edge of the runway, from where they were taken to the terminal. Five passengers were treated for minor injuries.

The aircraft sustained substantial damage but did not catch fire. After the aircraft exited the runway, the landing gear dug into the soft ground, causing the propellers to contact the ground. The propellers, with their reduction gear assemblies, separated from the engines. After separating from the engine, the left propeller blades entered the fuselage and damaged an unoccupied seat. The landing gear of the aircraft collapsed rearward, and the aircraft came to rest about 2500 feet from the runway threshold, almost 120 feet south of Runway 09. The left engine overheated and stopped from a lack of oil about 15 minutes after the occurrence.

Flight Crew Information

The flight crew was certified and qualified for the flight in accordance with existing regulations. The captain had approximately 15 500 flying hours, including just over 6000 hours as captain on the Convair. The first officer had just over 11 000 flying hours, including nearly 4000 hours on the Convair.

In spite of the difficulty of turning the steering wheel to the left, the flight crew elected to make the flight from Dorval, but did not advise maintenance. This decision was based on the fact that it was still possible to steer the aircraft on the ground. The flight crew did not anticipate steering problems with the aircraft take-off or landing, because on those phases the aircraft is normally steered only with the rudder. The flight crew had encountered similar situations in the past but had had no difficulty on take-offs and landings. In addition, it is common to note different levels of resistance on Convair's steering wheels.

Aerodrome Information

LG-4 is a registered aerodrome owned by Hydro-Québec. It has one gravel runway 5000 feet long and 150 feet wide. Snow is cleared from the runway by snowplows and snowblowers operated by Hydro-Québec. According to the aerodrome maintenance manual, the depth of snow tolerated on the runway is 5 centimetres (approximately 2 inches), but this can vary depending on the weather and the aircraft type.

Runway snow clearing had been completed about 30 minutes before the aircraft landed. At the time of landing, a width of 130 feet in the centre of the runway was cleared and snow accumulation was under 5 centimetres. However, the snowplow had left ridges of snow 6 to 10 inches high on each side of the runway, 10 feet in from the runway edge lights. The ridges did not affect aircraft steering, since the aircraft tire tracks showed a turn to 25° from the centreline before reaching the ridges. After the occurrence, the Canadian runway friction index (CRFI) was measured using a decelerometer mounted on a vehicle. This device measures the braking force acting on the vehicle when the brakes are applied. The indicator scale on the device is graduated from 0 to 1; a reading of 1 indicates maximum vehicle deceleration. At the time of the occurrence, the CRFI was 0.45; this reading meets the CRFI minimum requirement

of 0.35 specified in the aerodrome maintenance manual. According to the specifications manual, a CRFI of 0.45 would allow the aircraft to land in a 90° crosswind of 20 knots without affecting directional control.

Firefighting services at the LG-4 aerodrome are provided by a crew of firefighters who work part-time for Hydro-Québec. The fire hall is housed in the same building as the air terminal. Since firefighting services are available when there are air operations at the LG-4 aerodrome, the firefighters were on duty and arrived at the occurrence site very quickly to assist the passengers and stand by to respond in the event of a fire or an explosion.

Evacuation

The flight manual indicates that, in case of emergency, the engines must be shut down by pulling the E-handles. It also specifies that, if a hard landing is imminent, all electric power sources must be selected OFF to reduce the risk of fire. In this case, the pilot must lower the gang bar and select the battery switch OFF, thereby cutting all electrical power.

The passenger cabin has six emergency exits: four window emergency exits over the wings; a fifth window emergency exit aft of the right wing; and one service door with evacuation slide in the left rear. When an evacuation is necessary, the captain normally gives the evacuation order over the public address system, or by sounding an alarm when the public address system is out of service. Depending on the circumstances, the captain notifies the flight attendants and the passengers whether they must evacuate via one or more specific emergency exits or if all exits can be used.

The captain could not use the public address system or the alarm to order the evacuation because he had shut off the electrical power required to operate them. He instructed the first officer to go into the cabin and order the evacuation. The first officer had difficulty opening the door between the cockpit and the passenger cabin because it was blocked by an object that likely shifted during the runway excursion. When he arrived in the cabin, the first officer ordered the evacuation but did not specify which side to use, leading the flight attendants to believe that both sides of the aircraft were available for evacuation.

The flight attendant seated at the rear of the aircraft opened the left service door. However, she inadvertently deactivated the evacuation slide automatic deployment system, thereby preventing the slide from deploying automatically when the door was opened. On opening the door, the flight attendant noticed that the left engine was still running. Realizing there was a risk of fire or explosion, she decided not to use that exit and directed the passengers toward the window emergency exits on the right side. Meanwhile, the other flight attendant, who was seated near one of the emergency exits over the left wing, opened the window emergency exit and saw that a passenger had already gone out onto the left wing via the other left window exit. Noting that the left engine was still running, she ordered the passenger to get back in the aircraft and evacuate with the other passengers via the two window emergency exits leading onto the right wing. The evacuation was conducted rapidly and calmly. The captain exited the aircraft last.

Different Methods for Shutting Down Engines

There are three ways to shut down the engines on the Convair; one method is to pull the E-handles, which the PF did. However, the mechanical linkages between the E-handle and the left engine were damaged in the occurrence, preventing the engine from being shut down.

The two other methods are selecting the fuel ignition switches OFF or closing the fuel shut-off valves. However, these two methods require electrical power.

The essential circuits powered by the aircraft batteries were serviceable. The PF therefore had the option of shutting down the engine using the fuel ignition switch or closing the fuel shut-off valve. However, after the PF lowered the gang bar and selected the battery switch OFF, as required by the hard-landing procedure, it was impossible to shut down the engine using either of these two methods.

Carrier Information

The Air Transport Unit of Hydro-Québec operates and exercises the privileges of an air carrier in accordance with certificate number 9243, in addition to holding private operator certificate number P-8958. The unit is also an approved maintenance organization (AMO) and performs aircraft maintenance in accordance with the *Maintenance Policy Manual* approved by Transport Canada in February 2000.

Aircraft Information

The type certificate for the aircraft was issued in 1952 by the Federal Aviation Administration. Over the years, the type certificate has been owned by various companies; its current owner is Tracor Flight Systems Inc. Although this company holds the type certificate, it does not provide operators with the technical support normally provided by aircraft manufacturers. The Convair 340 and 440 aircraft, during the course of their service, have undergone several modifications, including replacement of the piston engines with prop-jets. After this modification, the aircraft were designated Convair 340 (580) or 440 (580). Convair production ceased in 1969.

The aircraft C-GFHH was built in 1953 and had accumulated 78 438 flying hours since new. The aircraft was certified and equipped in accordance with existing regulations and approved procedures. The latest inspection of the aircraft was on 16 September 2000. The aircraft logbook showed no outstanding deficiencies related to the circumstances of the occurrence. However, on 19 September 2000 the flight crew of this flight reported a deficiency related to the nose wheel: the steering wheel was hard to turn. Hydro-Québec maintenance personnel corrected the deficiency by cleaning and lubricating the nose-gear steering system. The aircraft was put back in service.

Directional Control of Aircraft on Ground

The factors that could have caused the aircraft to swerve were examined, including the nose-gear steering system, propeller pitch, brakes, tire condition, rudder, pilot technique, weather, and runway surface condition. Preliminary information suggested that nose-gear steering could be the cause. Consequently, the TSB analyzed specifically the aircraft steering system, while not ignoring the other factors mentioned above, although no indication was found that they could have contributed to the occurrence.

To steer the aircraft on the ground, the pilot in the left seat uses the nose-gear steering wheel on the console to the pilot's left. During take-off and landing, directional control of the aircraft is maintained solely by the rudder.

The aircraft's ground steering system (Figure 1) comprises several components, including the nose-gear steering wheel, a system of cables and pulleys, and a steering control valve fitted to a nose-wheel steering cylinder, which is attached to the nose-wheel strut.

The cable and pulley system links the steering wheel to the control valve. When the pilot turns the steering wheel to the left or right, tension is applied to the cables connected to the pulley on the steering control valve. This action determines the direction and the deflection rate of the nose wheel by allowing hydraulic fluid to enter one side or the other side of the nose-wheel steering cylinder; the steering cylinder then deflects the nose wheel through a system of gears.

Hydraulic pressure is regulated by the nose-gear steering wheel, allowing the nose gear to turn through an arc of 62.5° to either side. When the nose-wheel steering cylinder moves, tension on the cables is relieved, allowing the selector valve in the steering control valve to return to the centre point when the desired deflection rate is achieved. If the pilot wants to decrease or increase the turn radius, s/he simply turns the steering wheel in the desired direction, and the selector valve moves again to allow hydraulic fluid to flow to the cylinder, which then deflects the nose wheel. When no input is applied to the steering wheel, the selector valve returns to the null point and allows the nose wheel to pivot freely as differential braking is applied or to be centred by the centring cam.

The centring cam on the nose-gear damper centres the nose wheel when the damper is not compressed. This ensures that the nose wheel is properly centred when the landing gear is lowered for the landing or before being retracted. A graduated scale from 0° to 62° on the steering wheel indicates to the pilot the deflection angle of the nose wheel. Based on the information gathered, the graduated scale indicated that the nose wheel was centred before landing and that the centring cam was working properly.

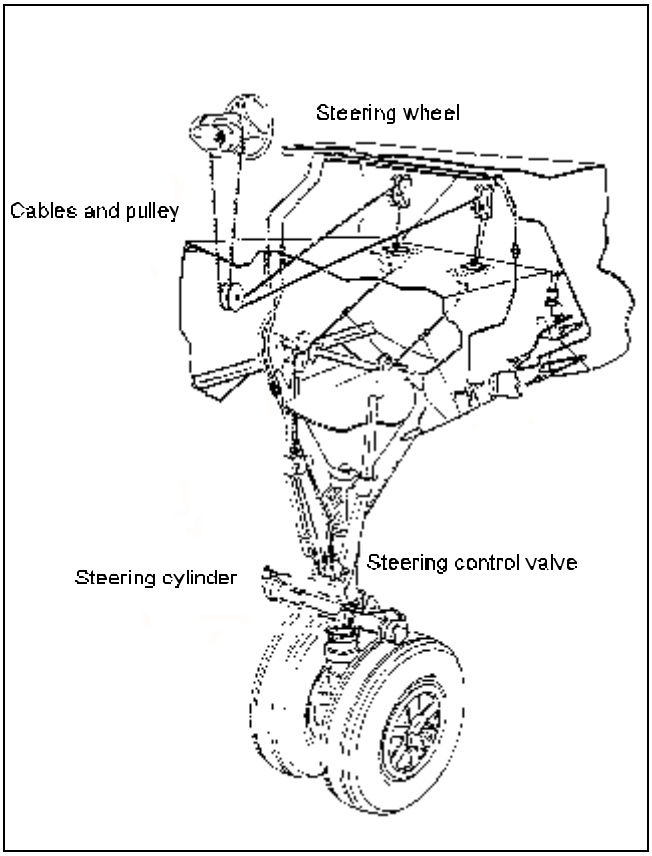

Figure 1 - Directional control on the ground

Maintenance of Steering Control Valve

Hydro-Québec maintenance personnel are not authorized to repair or overhaul certain parts, such as the steering control valve and the steering cylinder. These parts must be sent to a specialized organization when they require repair or overhaul. The steering control valve bearing part number 10156 and serial number 93291A, which was on the aircraft at the time of the occurrence, was manufactured by Weston Hydraulics Ltd. The information gathered indicates that this part must be overhauled every 6000 flying hours. In August 1997, the valve was sent to Precision Aero Components Inc. for overhaul.

Precision Aero Components Inc. has been an AMO for about eight years and has approximately 10 employees. It specializes in the maintenance, repair, and overhaul of aircraft components. Only three of the employees can service hydraulic components like the steering control valve. No formal training on the overhaul or repair of the valve is provided by the valve manufacturer. The training is in-house and on-the-job. Since it was founded, Precision Aero Components Inc. has serviced only two other steering control valves.

Because of the difficulty of finding some components for the steering control valve, the overhaul of the valve installed on C-GFHH was only completed in June 1998. About six months after the overhaul, Hydro-Québec maintenance personnel reinstalled the steering control valve and the steering cylinder on one of its aircraft and found that the nose-gear steering system was not operating normally. Both components were then returned to Precision Aero Components Inc.

When the valve was received at Precision Aero Components Inc., it was found damaged. The cause of the damage could not be determined. To repair it, the nylon locknuts (item 24, Appendix A) had to be removed and were reinstalled during the repair.[2] This type of nut is designed with a nylon locking device to prevent it from coming loose in service. When it is first used, the nylon ring inside the nut conforms to the shape of the threads on the metal bolt, thereby serving as a locking device for the nut. Using this type of nut more than once is not recommended, because the nylon locking system loses its effectiveness and the nut can come loose. When overhauling and repairing the steering control valve, the company referred to the Convair maintenance manual, which, like the overhaul manual (*Kelowna Flightcraft Convair 580 Overhaul Manual*), provides instructions for reassembly. However, the maintenance manual does not go into sufficient detail to overhaul or repair the steering control valve.

After the steering control valve and cylinder were repaired in January 1999, they were returned to Hydro-Québec. They were installed on C-GFHH on 20 July 2000 in accordance with the instructions contained in the maintenance manual. The investigation revealed that these two components had accumulated 250 flying hours since being put back in service.

Testing of Steering Control Valve

After the occurrence, the nose-wheel steering control valve (Appendix A) was sent to Kelowna Flightcraft Inc. for testing. Kelowna Flightcraft Inc. is the largest operator of Convairs in Canada, with a fleet of 13, and is an AMO. Its expertise in servicing and overhauling certain aircraft components is often utilized by other operators, since the current holder of the type certificate for this aircraft provides no technical support.

The valve exhibited no damage, corrosion, or friction wear. Under the supervision of a TSB investigator, the test was conducted using a steering cylinder used on Convairs and a jig designed especially for this type of test. During the test, as soon as hydraulic pressure was applied, the steering cylinder moved to the right, corresponding to a steering wheel input for a right turn.

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[2] A diagram showing all item numbers appears in Appendix A—Diagram of Steering Control Valve.

The investigation revealed that the steering control valve lever (item 13) had no grease fitting and that there was no groove on the outside of the bushing (item 7) to ensure adequate lubrication, unlike other steering control valve levers on Convairs.

Weston Hydraulics Ltd., the manufacturer of the steering control valve, modified the valve lever by installing a grease fitting and by grooving the outside of the bushing. This modification was made at the request of Consolidated Vultee Aircraft Ltd. after several reports from Convair 340 and 440 operators of the bushing corroding and seizing inside the lever. Consolidated Vultee Aircraft Ltd. published information about this modification in 1957, in its Newsletter No. 413. In the same newsletter, the company advised that this modification would be incorporated into future Convair 440 production, that is, around 1958. The newsletter does not state that the modification is mandatory. It is therefore quite possible that the steering control valve installed on C-GFHH is the model that was originally installed on Convairs and that it was not modified.

Newsletters are normally distributed to all operators of the aircraft type and to all AMOs concerned. Newsletters serve to advise them of modifications to an aviation product but do not oblige them to comply with the modification. When a modification is mandatory for all operators or all AMOs, an airworthiness directive (AD) or a manufacturer's service bulletin is issued to all operators and AMOs concerned. There was no indication that an AD or a service bulletin was issued to that effect.

Despite the modification to the valve lever by the manufacturer, there was apparently no amendment to the maintenance manual or the overhaul manual to reflect this modification. Drawings of the steering control valve in the maintenance manual and the overhaul manual do not show the location of the grease fitting on the lever. The grease fitting is shown only on the drawing included in Newsletter No. 413. Also, neither manual had written instructions for servicing the grease fitting.

Four of the five Convairs operated by Hydro-Québec had a grease fitting on the steering control valve lever. Hydro-Québec maintenance personnel never noticed that the steering control valve lever on C-GFHH was different from those on the four other aircraft. Also, the inspection forms used by Hydro-Québec maintenance staff contain no references to the location or the servicing of the grease fitting. Although there were no specific instructions on servicing the lever grease fitting, the maintenance staff lubricated the aircraft that were fitted with one, since the presence of the grease fitting automatically prompted them to do so.

Examination of the steering control valve revealed the following deficiencies:

- Two washers (item 6) were installed, whereas the overhaul manual and the maintenance manual showed one washer. Thus, greater resistance was applied on the bushing (item 7) and on the lever (item 13). This incorrect assembly impeded the lever from pivoting freely on the bushing.

- Normally, when 30 to 60 pounds of tension is applied to the cables, the lever must be able to pivot freely on the bushing. During the test, it was not possible to make the lever pivot on the bushing, even when 150 pounds of tension was applied. According to the overhaul manual, the clearance between the bushing and the lever must be 0.001 to 0.003 inch. Measurements with a vernier caliper revealed that the circumference of the bushing was 0.0005 inch greater than the circumference of the hole in the lever. This shows that the bushing was a tighter fit inside the lever than

specified, preventing the lever from pivoting freely.

- The nylon locknuts (item 24) at either end of the shuttle (item 30) showed signs of wear and were loose enough to turn with the fingers. The resulting play affected the response of the shuttle to movements by the yoke bracket (item 12).

Any of these deficiencies impeded the operation of the steering control valve and adversely affected directional control of the aircraft on the ground.

Analysis

The flight crew's decision to make the flight from Dorval despite being aware of a problem with directional control of the nose gear on the ground is questionable. Since the nose-gear steering wheel is used only at very low speeds while taxiing, the crew did not anticipate steering problems on landing or take-off. Directional control of the aircraft during these two phases is normally maintained solely with the rudder. Also, taxiing could be done exclusively with differential braking. Nevertheless, there must not be any mechanical deficiencies in the aircraft steering system.

A pilot confronted with a problem must assess the risks inherent in all available solutions to make the right decision. In this occurrence, the flight crew were aware of the problem even before taking off from Dorval. They decided to make the flight without reporting the deficiency to maintenance. Since the maintenance base for Hydro-Québec aircraft is at Dorval, it would have been preferable for the crew to report the deficiency before departing. This would have allowed maintenance personnel to examine the situation and take action to correct the deficiency or find an acceptable alternative. It was impossible for the flight crew to detect the deficiencies observed on the steering control valve. This fact, combined with the previous experience regarding the difficulty of using the nose-gear steering wheel, prevented the flight crew from making an informed analysis of the problem and the associated risks.

Communication between flight crew and cabin personnel in an emergency situation is essential for the exchange of crucial safety information. The captain can order passengers to remain seated or evacuate the aircraft. On the other hand, the cabin crew may be in a position to detect an emergency situation that may not be noticed by the flight crew. The cabin crew must be able to apprise the flight crew of the situation and of the need to evacuate the aircraft. In accordance with the hard landing procedure, the crew lowered the gang bar before ordering the evacuation. Thus, the public address and alarm systems could no longer be used, which delayed the flight attendants' initiation of the evacuation. The inadvertent deactivation of the evacuation slide automatic deployment system, in different circumstances, could have delayed the evacuation and compromised passenger safety.

The left engine was running without a propeller. It was producing an unusual noise, which created some confusion during the evacuation. Only after the left-side emergency exits were opened did the crew notice that the engine was still running and that evacuation could be dangerous on that side. Despite the completion of the emergency engine shutdown procedure provided in the flight manual, the left engine could not be stopped by pulling the E-handle because the mechanism had been damaged on impact. When the PF realized that the left engine was still running, the attempt to shut it down with the fuel ignition switch was unsuccessful because electrical power had been switched off.

The maintenance personnel at Precision Aero Components Inc. did not notice that the steering control valve lever had no grease fitting. Given the small number of overhauls and repairs performed previously by the company on this type of valve, its employees had few opportunities to make comparisons with other valves. In addition, there were no drawings of the valve in the overhaul manual or the maintenance manual that showed the location of a grease fitting. Because Newsletter No. 413 was issued more than 40 years ago, it is possible that it did not reach all Convair operators and AMOs over the years. Frequent changes in the ownership of the type certificate, in addition to the lack of technical support from the current holder of the type certificate, prevented AMOs, particularly recently established AMOs, from being brought up to date on modifications, some of which were made many years ago.

The steering control valve lever's lack of a grease fitting is not a deficiency in itself, since no AD or service bulletin was issued requiring its installation. However, the clearance between the bushing and the lever was not within the specifications in the overhaul manual. This deficiency and the absence of lubrication made it even harder for the lever to pivot on the bushing, thereby impeding the operation of the steering control valve. Since the holder of the type certificate for the Convair did not provide technical support, Precision Aero Components Inc. did not have specific information on the repairs and overhauls on the steering control valve such as that contained in the overhaul manual. The use of the maintenance manual instead of the overhaul manual for the overhaul and the repair did not allow the maintenance personnel at Precision Aero Components Inc. to obtain specific instructions, such as the clearance between the bushing and the lever, which was essential for its operation.

The deficiencies noted during the examination of the steering control valve show clearly that it was not reassembled as shown in the drawings in the overhaul manual or the maintenance manual. The maintenance personnel of Precision Aero Components Inc. have done very few repairs and overhauls of this particular part. The limited experience and the lack of formal training of the maintenance personnel concerning the repair and the overhaul on the steering control valve might have contributed to the incorrect reassembly of the steering control valve.

Each of the deficiencies revealed by the analysis of the steering control valve impeded its operation and had an adverse effect on directional control of the aircraft on the ground. The presence of two washers instead of one and the friction between the bushing and the lever prevented the lever from pivoting freely on the bushing, thereby impeding the operation of the steering control valve. In addition, re-use of the nylon locknuts during the repair degraded their effectiveness; they eventually came loose, creating play in the movement of the steering control valve.

The following Engineering Laboratory Report was completed:

LP 106/00—Nose-Gear Assembly Examination

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

Findings as to Causes and Contributing Factors

1. The steering control valve lever was not reassembled in accordance with the specifications and the drawings in the overhaul manual and the maintenance manual: the lever was assembled with two washers instead of one, and the circumference of the bushing was 0.0005 inch greater than the circumference of the

hole in the lever. These two deficiencies created additional resistance that impeded the pivoting of the aircraft steering wheel.

2. The nylon locknuts were reinstalled during the repair of the steering control valve, contrary to the recommendation that they be used only once. The locknuts then came loose in service, creating play in the parts of the valve.

3. Incorrect interpretation of the problem and the influence of previous experience using the nose-gear steering wheel led the crew to make the flight despite their concern about the aircraft's nose-gear steering system.

Findings as to Risk

1. The maintenance personnel of Precision Aero Components Inc. used the (incomplete) maintenance manual instead of the overhaul manual to overhaul and repair the steering control valve, contributing to the incorrect reassembly of the valve.

2. The steering control valve lever was not fitted with a grease fitting, and the outside of the bushing was not grooved to allow adequate lubrication, thereby risking corrosion and seizure of the bushing inside the lever.

3. The limited experience and the lack of formal training of the maintenance personnel concerning the repair and the overhaul on the steering control valve might have contributed to the incorrect reassembly of the steering control valve.

4. The pilot flying cut the electrical power, as required by the hard landing procedure. The left engine could therefore not be shut down, causing a risk of injury when the passengers evacuated.

5. The pilot flying cut the electrical power after the aircraft exited the runway, as required by the hard landing procedure. The electrical power required to operate the public address and alarm systems was thereby lost, and the evacuation could not be ordered promptly.

6. The evacuation slide automatic deployment system was inadvertently deactivated, which could have delayed the evacuation and compromised passenger safety.

7. After separating from the engine, the left propeller blades entered the fuselage and damaged an unoccupied seat.

Other Findings

1. The numerous changes in ownership of the Convair type certificate and the lack of technical support from the current holder caused maintenance problems for Convair operators and approved maintenance organizations (AMOs), particularly for recently established AMOs.

Safety Action

After the occurrence, Hydro-Québec removed from its aircraft all the steering cylinders and steering control valves to have them checked.

The type certificate was transferred to Kelowna Flightcraft Inc. in January 2001. Convair owners and/or operators will therefore be provided with technical support; they had not had any technical support in the last few years.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 12 February 2002.

Appendix A—Diagram of Steering Control Valve