Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A05A0059

STALL AND LOSS OF CONTROL DURING CLIMB

PROVINCIAL AIRLINES LIMITED
DE HAVILLAND DHC-8-100 C-GZKH
ST. JOHN'S, NEWFOUNDLAND AND LABRADOR
27 MAY 2005

Canada

Aviation Investigation Report

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Summary

A de Havilland DHC-8-100 (Dash 8) aircraft (registration C-GZKH, serial number 117) operated by Provincial Airlines Limited was a passenger revenue flight from St. John's to Deer Lake, Newfoundland and Labrador, with 36 passengers and 3 crew on board. During the climb-out from St. John's, the indicated airspeed gradually decreased to the point that the aircraft entered an aerodynamic stall. The aircraft descended rapidly, out of control, losing 4200 feet before recovery was effected approximately 40 seconds later. The incident occurred during daylight hours in instrument meteorological conditions. There were no injuries and the aircraft was not damaged.

Ce rapport est également disponible en français.

Other Factual Information

Weather

Before departure, the flight crew checked the en route weather. The graphic area forecasts (GFA) for icing, turbulence, and freezing level, issued at 0911 Newfoundland daylight time[1] and valid for 1530 on 27 May 2005, depicted the freezing level at 10 000 feet. The comments section of the GFA indicated the possibility of nil to light icing during the climb above the freezing level. The GFA forecast light to nil turbulence in the area of flight. There were no pilot reports or significant meteorological reports (SIGMETS) issued advising of icing conditions or turbulence on the planned route.

Incident

The aircraft took off uneventfully from St. John’s at 1739. Aircraft weight at take-off was calculated to be 34 096 pounds, about 400 pounds below the maximum take-off weight. After take-off, the aircraft entered a right climbing turn. During the turn, the captain (pilot flying) engaged the autopilot. Flight data recorder (FDR) data show that, when the autopilot was engaged, the indicated airspeed (KIAS) was 162 and the rate of climb was 1190 feet per minute (fpm). After autopilot engagement, the rate of climb remained constant, while the IAS fluctuated slowly between 160 and 170 KIAS. During the climb, the captain’s primary task was to monitor the performance of the aircraft as it flew under the control of the autopilot and to make the necessary adjustments to engine power settings during the climb. After the aircraft was established in the climb on the outbound heading, the first officer commenced the paperwork necessary for the departure report.

FDR data show that there was little to no turbulence throughout the climb. FDR data also show that the outside air temperature was 5°C at 7000 feet; the air temperature decreased to below the freezing level at about 11 000 feet. At around 7000 feet, the crew selected the engine anti-ice systems ON and the ignition switches to manual; however, they elected to leave the pneumatic de-ice system OFF. The aircraft was not equipped with an electronic ice detector, so crews must detect ice visually. Ice forms primarily on the wing leading edges and on an ice probe located in front of the cockpit window. The crew was looking for ice accumulation during the climb above 7000 feet, but none was detected.

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[1] All times are Newfoundland daylight time (Coordinated Universal Time minus two and one-half hours) unless otherwise noted.

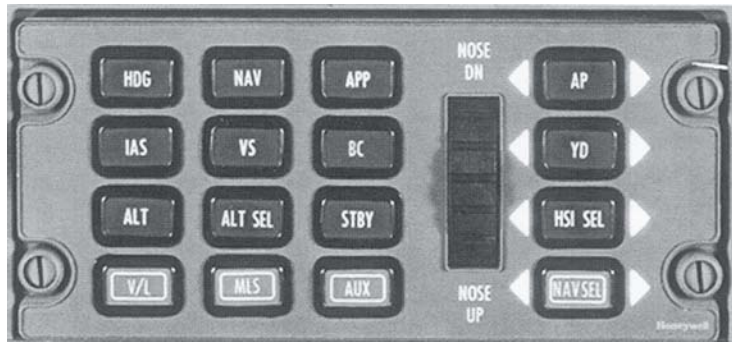

Figure 1. Flight guidance controller

Through about 8000 feet, the airspeed started a gradual decrease from 170 KIAS over a period of five minutes. During this time, the vertical speed continued at a constant 1190 fpm up. The gradual decrease in airspeed was detected when the first officer looked up from his paperwork, noted the decreased airspeed, and advised the captain. The captain then rotated the pitch control wheel on the flight guidance controller toward nose down (see Figure 1) to increase the airspeed. While attempting the adjustment, the captain saw the aircraft's stick shaker activate, causing the autopilot to disengage. This occurred at 14 800 feet above sea level, at 104 KIAS. The captain then began to manually fly the aircraft.

Within a second of autopilot disengagement, the aircraft began to roll right and pitch down (see Appendix A – Flight Data Recorder Plot and Appendix B – Flight Data Recorder Plot – Engines). Immediately after the aircraft began to roll, it was noticed that there was ice on the left engine inlet. The roll angle increased to 64°, the pitch angle went from 15° nose up to 5° nose up, and the aircraft vertical acceleration dropped to approximately 0.5 g. The aircraft pitch then increased to 30° nose up briefly before decreasing to 40° nose down. These conditions are indications that the aircraft wing had fully stalled. However, the captain interpreted the indications as severe turbulence.

The FDR data show that the aircraft underwent three distinct stalls during the loss-of-control event, with the third stall being the most severe. The data show that the control column position cycled rapidly back and forth as the stall developed, but was moved generally aft, remaining aft during all three stalls. There was significant aileron and rudder pedal movement during the event, but these controls were ineffective in regaining control and were in response to the aircraft's movement, rather than the cause of it. The data indicated that aircraft control was regained when the control column was moved forward.

An aircraft's stall airspeed increases as a result of ice contamination. Also, stall warning devices may not be accurate when ice is present and may not provide a normal warning of stall. The aircraft's stick shaker will normally activate six to nine per cent above the stall speed, providing ample opportunity for the pilot to initiate stall recovery procedures. According to the flight manual, the stall speed for the aircraft's configuration and weight was 94.5 KIAS. However, the aircraft stalled very shortly after stick shaker activation, at about 103 KIAS.

During the loss of control, there were heavy control column forces and severe buffeting. The aircraft descended rapidly, losing 4200 feet before recovery was effected. Minimum IAS recorded by the FDR during the loss of control was 0 KIAS. The actual minimum airspeed would have been higher, because airflow to the pitot tube was most likely disrupted due to excessively high angles of attack and side-slip. The maximum airspeed was 210 KIAS; this was recorded during the stall recovery. The g load peaked at 2.24 g during the recovery.

The standard technique for a stall recovery is to immediately and simultaneously advance the control column to reduce the angle of attack, apply maximum power, and then level the wings when the aircraft has exited the stall. An ice-induced stall requires a recovery technique in which the control column is moved forward aggressively (altitude permitting) to reduce the angle of attack and trade altitude for airspeed. FDR data show that, after the stall, power remained unchanged and the control column moved aft of its pre-stall position for about 22 seconds. The aircraft exited the stall when the control column was subsequently moved forward.

Immediately after recovery, the crew observed that ice was building up rapidly on the aircraft fuselage. Airframe de-ice equipment was then selected ON. The pneumatic boots functioned when selected, and were effective in removing the ice. The crew requested a lower altitude to remain clear of icing conditions and continued to Deer Lake. After landing, the pilot reported a severe turbulence encounter to company personnel. A heavy turbulence check was subsequently carried out, and no damage was found.

Company Information

Provincial Airlines Limited had an approved Air Operator Certificate (AOC) to operate two Dash 8 aircraft under Section 705 of the *Canadian Aviation Regulations* (CARs). The company had been operating the aircraft since January 2004.

The captain held a valid airline transport pilot licence (ATPL) and was certified and qualified for the flight in accordance with existing regulations. He had accumulated over 10 000 hours of flight experience, 131 hours of which was on the Dash 8. The captain attended Dash 8 training at Flight Safety Canada and received a Dash 8 rating on 14 April 2005 after 36 hours of simulator and 2 hours of flight training. The captain had five days of time off before the occurrence flight, and considered himself to be rested before the flight.

The first officer held a valid ATPL and was qualified for the flight in accordance with existing regulations. He had 112 hours of flight experience on this type of aircraft. He attended Dash 8 training with the captain, and received a Dash 8 rating on 14 April 2005 after 28 hours of simulator and 1 hour of flight training. The first officer had two days of time off before the occurrence flight, and considered himself to be rested before the flight.

Company pilots receive training in aircraft "upsets" and unusual attitude recovery during initial and recurrent training. On 12 March 2005, both the captain and first officer completed a surface contamination and airborne icing course.

Aircraft Information

The aircraft's weight and centre of gravity were within the prescribed limits, and the aircraft was certified for flight in known icing conditions. There were no aircraft technical malfunctions that contributed to this occurrence.

The aircraft's de-ice system removes ice accumulations from the leading edges of the wings, the horizontal and vertical stabilizers, and the inlet lip of the engine nacelles by alternately inflating and deflating pneumatic boots. The anti-ice systems use electrical heating elements to prevent ice formation on the left and right pitot probes and static ports, the left and right stall warning transducer vanes, the left and right engine compressor intake flanges, the elevator horns, the leading edge of the propeller blades, and the windshield. All ice protection systems were serviceable.

The aircraft is configured with a Sperry SPZ-8000 digital automatic flight control system (AFCS). A single flight guidance controller (see Figure 1) is used to select modes of operation and engage/disengage the autopilot. Most of the controls on the AFCS controller are alternate-action push-button (push ON, push OFF). There are two vertical modes available. The IAS button captures and holds the aircraft's indicated airspeed at the time of selection. The vertical speed (VS) button captures and holds the aircraft's VS at the time of selection. When VS mode is engaged, the airspeed is not controlled by the AFCS.

If a change is required when either of these modes are engaged, the pitch wheel is used to dial in the new reference. The aircraft's trim is then adjusted automatically nose up or nose down to the new value. An ID-802 advisory display in front of both pilots shows, *inter alia*, the selected vertical mode (either IAS or VS), its value (in KIAS or hundreds of feet per minute), and the outside air temperature (in degrees Celsius). Flight Safety Canada standard operating procedures (SOPs) for the climb phase, page 10.4, state the following:

> The vertical speed (VS) mode should not be used for climb, since airspeed may decrease below that desired, as the FD increases pitch attitude to maintain climb rate to compensate for decreasing engine power at higher altitudes.

To help guard against inadvertent selection of VS mode and subsequent low airspeed, Flight Safety Canada SOPs require a verbal challenge and response when an AFCS mode is engaged. For example, upon engaging the IAS mode, the pilot flying calls out, "Set IAS," along with the captured airspeed. The pilot monitoring confirms the selection of IAS and reads back the captured IAS value.

At the time of the occurrence, Provincial Airlines Limited SOPs for the climb phase did not warn against the use of VS mode during the climb; however, it was common knowledge that VS was not to be used during the climb. There was no requirement in the Provincial Airlines Limited SOPs for a verbal challenge and response between crew members for an AFCS mode engagement.

The aircraft was equipped with a Fairchild F800 FDR (part number 17M800-261, serial number 03422). The recorder contained an expanded parameter data set that added pitch, roll, and yaw flight control position sensing, roll and pitch control disconnects, and propeller ground range beta. The FDR was shipped to the Transportation Safety Board of Canada (TSB) Engineering Laboratory for download and analysis of the data. The data quality on the tape was poor. Half of the data contained numerous drop-outs and data spikes. However, the data trend was still visible, and the data were vital to the investigation. In order to clean up the data, all the bad data from each parameter were deleted manually, allowing a linear interpolation between data points. The result was a clean trace on the plot, but a reduced resolution and frequency for each parameter. Only the data from the incident flight were corrected, due to the time required to clean up the data. The cockpit voice recorder did not have useful information relevant to the occurrence because it had been overwritten during post-occurrence flying.

Additional Information

Flight in Icing Conditions

According to the aircraft flight manual (AFM) and company SOPs, icing conditions exist when the aircraft is flying in visible moisture in temperatures below 5°C. When operating in icing conditions, or when ice is detected, engine intake bypass doors must be open and engine ignition switches are to be set at manual. The AFM requires that the airframe de-ice be selected to slow or fast on initial detection of ice. The aircraft is not equipped with an electronic ice detector. Crews detect ice visually, looking for evidence of ice accumulation on the wing leading edges and on an ice probe located in front of the cockpit window. The Flight Safety Canada SOPs advise that, even if ice is not detected visually, ice may be present on portions of the aircraft that cannot be seen.

Monitoring Errors

A past study[2] has noted that, when flight crews are monitoring automated systems, they may not be aware of the aircraft's energy state, particularly when approaching or trending toward a low-energy state. Monitoring errors occur more frequently if a pilot is engaged in some other manual task or where automation is highly reliable, leading to automation complacency. Monitoring errors can take place during both high and low workload situations.

While these types of errors are common, they are also easily detected, and the industry has recognized the steps that may most effectively mitigate the risk of these types of errors occurring. For example, given the ease with which incorrect automation modes may be selected, the importance of crew procedures to cross-check mode selections has been highlighted:

> Where systems are in place that are vulnerable to mode errors, procedural constraints (such as limiting the number of modes routinely used and requiring that mode changes be announced and confirmed by both pilots) can become effective tools to mitigate the potential for mode errors to arise.[3]

Pneumatic De-ice Boot Operating Procedures

For years, it was believed that, if the pneumatic boots were activated too soon, the ice would not break off, and the boots would subsequently inflate and deflate beneath an expanding ice bridge. However, research has shown that ice bridging does not occur with modern pneumatic

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2 1996 Federal Aviation Administration Human Factors team report titled *The Interfaces Between Flight Crews and Modern Flight Deck Systems*

3 Parasuraman and Byrne, 2003, p. 328

boots, and the Dash 8 flight manual reflects the current practice of "early and often" for pneumatic de-icing equipment. Transport Canada's (TC) Commercial and Business Aviation Advisory Circular (CBAAC) No. 0130R, issued on 15 June 1999, included information resulting from investigations into accidents in which airborne icing was determined to be a contributing factor. Air operators were informed that they must amend their training programs to include the new information prior to 01 October 1999. The section titled "10 - Operational Use of Pneumatic De-Icing Boots"[4] states:

> Unless specifically prohibited by the AFM, it is recommended that pilots of turbine-powered aeroplanes equipped with pneumatic de-icing boots with an automatic cycle, select the boots on automatic as soon as the aeroplane enters icing conditions. The boots should be left on until the aeroplane has departed the icing conditions. If the automatic boots have a FAST/SLOW option, the FAST option should be selected for moderate and severe icing conditions.

Provincial Airlines Limited manuals and programs were in compliance with TC's CBAAC No. 0130R. However, in the course of the investigation, it became apparent that a sizeable proportion of Dash 8 pilots may still hold to the traditional practice of waiting for ice to accumulate prior to activating the pneumatic boots, despite contrary instructions in guidance material. When contacted, Flight Safety Canada training personnel confirmed this, and estimated that 50 per cent of pilots, both Canadian and international, who attend their training sessions still hold to old practices despite directions to select de-icing equipment immediately upon entering icing conditions.

Throughout the aviation industry, flight crews receive mandatory ground training in airborne icing. However, the ability to train in a simulator for flight in actual icing conditions is limited. The changes to stall characteristics with ice accumulation typically are not duplicated in simulator training, including the increase in stall speed and the onset of the stall before the activation of the artificial stall warning. Also, it is difficult to account for changes to normal stall symptoms, such as buffet or an increased tendency for a wing drop. While it is possible to teach these characteristics and the associated recovery techniques during classroom ground training, without the benefit of having experienced these stall symptoms, pilots can be ill-prepared to recognize and recover from contaminated-wing stall symptoms.

The following Engineering Laboratory report was completed:

> LP 050/05 – Flight Data Recorder Analysis

This report is available from the TSB upon request.

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[4] www.tc.gc.ca/CivilAviation/commerce/circulars/AC0130r_att.htm, accessed 22 February 2006.

Analysis

The steady rate of climb after autopilot engagement indicates that the crew had inadvertently selected VS mode instead of IAS mode. This selection error was not detected, in part because there was no requirement in the SOPs for the crew to announce and confirm the IAS mode selection on the AFCS. The indicated airspeed then fluctuated near the value the crew intended, perhaps bolstering the crew's belief that the aircraft was operating in the intended IAS mode, and leading them to become complacent about monitoring the airspeed. Also contributing to the monitoring error was the co-pilot's preoccupation with paperwork during the climb. Because the crew had inadvertently selected an inappropriate AFCS mode and did not detect this error or adequately monitor the airspeed, the airspeed eventually decreased during the climb to the point of stall.

The stall occurred at about 14 000 feet. The aircraft was in cloud, the temperature was below freezing, and the pneumatic de-icing boots were not activated. Therefore, ice accumulation on critical flight surfaces was possible. The stall occurred at an airspeed higher than expected for a clean wing with very little pre-stall warning from the stick shaker. It is likely that ice had accumulated on the aircraft's critical surfaces before the stall.

In large transport category aircraft, it would be unsafe to purposely enter a fully developed stall. Therefore, current regulations only require that flight crews receive limited training in stall recognition and recovery, with recovery being initiated at the first indication of a stall. Such training does not allow pilots to become familiar with symptoms of a fully developed stall or allow for practise in recovering from a full aerodynamic stall. In this instance, because of ice contamination, the stall happened at a higher-than-usual airspeed, and the symptoms of the stall were not those that the pilot had been trained to expect. As a result, the captain did not recognize that the aircraft had stalled and, instead, interpreted the unusual movement of the aircraft as being due to turbulence. He therefore continued to try to lift the nose of the aircraft, deepening the stall and lengthening the period of time that the aircraft was out of his control. This led to excessive altitude loss before the aircraft was recovered.

Findings as to Causes and Contributing Factors

1. During the climb, the captain inadvertently selected vertical speed (VS) mode on the automatic flight control system (AFCS) instead of the intended IAS mode, and neither flight crew detected the selection error.

2. The operator's standard operating procedures (SOPs) did not have a prescribed method for ensuring the correct selection of AFCS climb modes.

3. The flight crew did not activate the pneumatic de-ice equipment while climbing in icing conditions.

4. The flight crew did not detect the decreased airspeed until the aircraft was near the stall.

5. The aircraft stalled at a higher-than-normal airspeed, with little advance warning, most likely due to accumulated ice on critical surfaces.

6. The captain, believing that they had encountered severe turbulence, did not recognize that the aircraft had stalled, and did not apply the standard stall recovery technique.

Findings as to Risk

1. Typically, flight crews receive only limited training in stall recognition and recovery, where recovery is initiated at the first indication of a stall. Such training does not allow pilots to become familiar with natural stall symptoms, such as buffet, or allow for practise in recovering from a full aerodynamic stall.

2. A significant proportion of Dash 8 pilots may hold outdated beliefs on the use of pneumatic de-icing equipment.

Safety Action Taken

The Transportation Safety Board of Canada (TSB) issued Safety Advisory A050019-1 on 22 July 2005 on the subject of inadvertent selection of inappropriate automatic flight control system (AFCS) modes of operation. The letter suggested that Transport Canada (TC) ensure that operators have incorporated measures into their procedures to ensure the correct selection and monitoring of AFCS climb modes. On 04 October 2005, TC responded, advising that a copy of the advisory had been passed on to all TC regions, and that the Department would take the necessary action, as required. Since the occurrence, the operator has revised its standard operating procedures (SOPs) to contain a challenge and response action whenever AFCS modes are engaged in the climb.

The TSB issued Safety Advisory A50018-1 on 22 July 2005 on the subject of timely selection of pneumatic de-icing equipment. The advisory suggested that TC consider additional action to ensure that pilots are conforming to published de-icing procedures and to dispel old beliefs about the proper use of pneumatic de-icing equipment. On 04 October 2005, TC responded, advising of additional efforts to move this information into the published guidance material in the near future. As well, TC is drafting an article for publication in an upcoming issue of the *Aviation Safety Letter*. This article will inform pilots of the need to conform to published de-icing procedures and attempt to dispel old beliefs about the use of pneumatic de-icing equipment. Since the occurrence, the operator has directed its trainers to re-emphasize procedures for activation of pneumatic boots as described in its SOPs and the aircraft flight manual.

To reduce the likelihood of monitoring errors, the operator has directed all crews to not conduct paperwork during critical phases of flight. These duties are to be performed during level flight only while en route.

As a result of recent stall and upset occurrences in turbojet aeroplanes, TC has reinforced the need for appropriate training for the prevention of an aeroplane stall and for stall recovery. TC released Commercial and Business Aviation Advisory Circular (CBAAC) No. 0247 entitled "Training and Checking Practices for Stall Recovery" on 24 August 2005.[5]

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 23 February 2006.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

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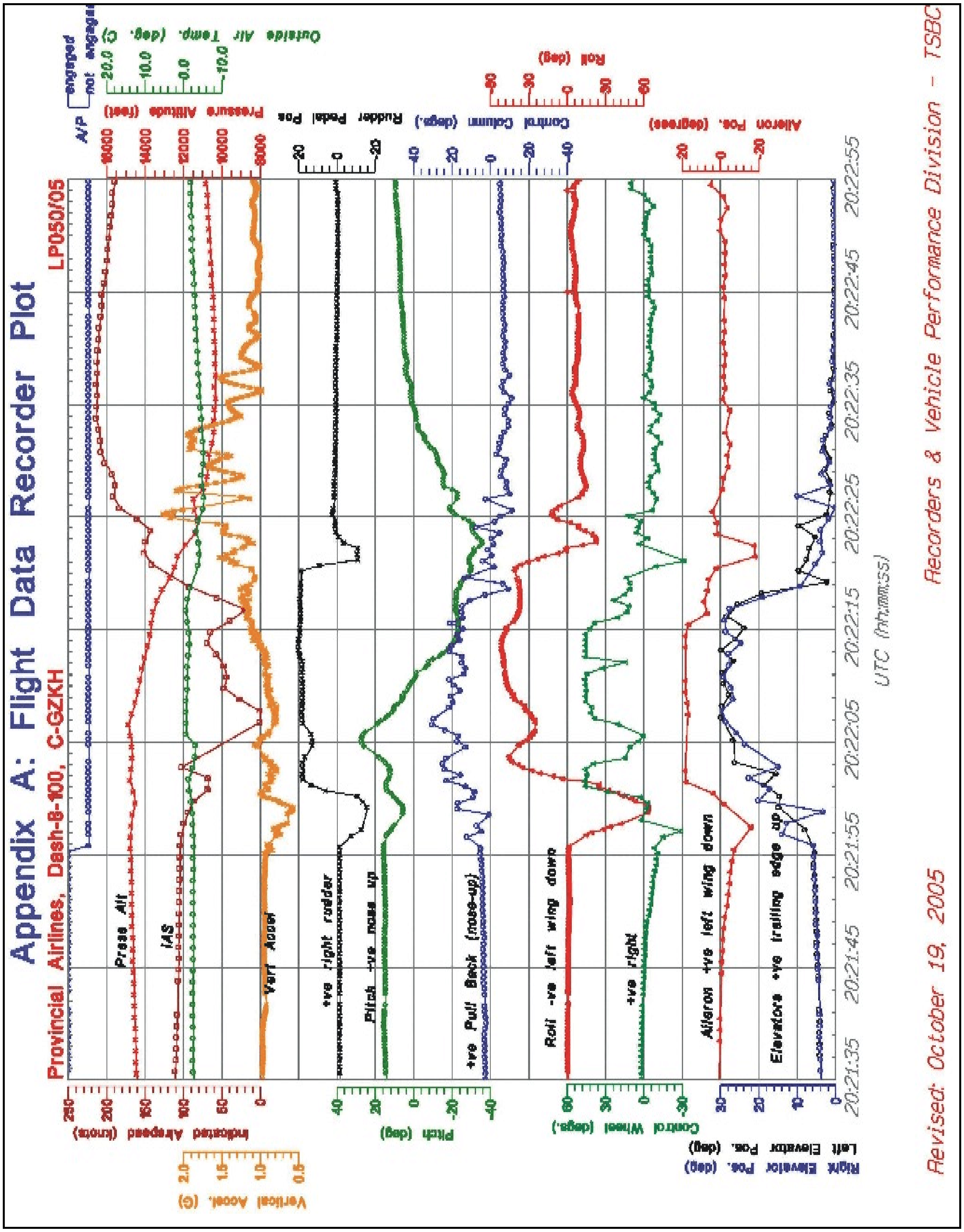
5 www.tc.gc.ca/CivilAviation/commerce/circulars/AC0247.htm, accessed 22 February 2006

Appendix A – Flight Data Recorder Plot



Appendix B – Flight Data Recorder Plot - Engines