AVIATION OCCURRENCE REPORT

REJECTED TAKE-OFF - RUNWAY OVERRUN

MINISTIC AIR LTD.
BEECH 1900D C-FYSJ
ISLAND LAKE, MANITOBA
29 NOVEMBER 1997

REPORT NUMBER A97C0229

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.

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Summary

Ministic Flight 303, a Beech 1900D, serial number UE-233, was departing runway 12 at the Island Lake airport, en route to Winnipeg, Manitoba. The aircraft was carrying a crew of two, and 17 passengers. Take-off acceleration was described as normal. As the aircraft was rotated for take-off, the stall warning horn activated. The take-off was rejected, reverse thrust was selected, and both pilots applied the aircraft's brakes. The aircraft did not stop within the confines of the runway or the stopway area and departed off the end of the prepared surface. The aircraft came to rest straddling a ploughed bank of snow and sustained substantial damage. The engines were shut down, and the passengers and the crew evacuated the aircraft. One minor injury was reported. The occurrence took place during daylight hours, at 1410 central standard time (CST).

Ce rapport est également disponible en français.

[1] All times are CST (Coordinated Universal Time minus six hours) unless otherwise noted.

Other Factual Information

Both the captain and the first officer were certified and qualified for the flight in accordance with existing regulation. The captain had a total flight time of 5 200 hours, 704 hours of which were on type. The first officer had a total time of 1 250 hours, 200 of which were on type. The captain had received most of his training on the Beech 1900D type at an outside facility which made extensive use of a flight simulator. The first officer had received his type training
in-house, most of which was undertaken by a contract instructor. Neither pilot reported receiving instruction on faults related to the stall warning system which could result in a false stall warning.

The flight was a continuation of a series of flights originating at Winnipeg as Ministic Flight 302, with scheduled station stops at St. Theresa Point and Island Lake. The aircraft entered snow conditions at the start of the descent into St. Theresa Point, and visibility was observed to be about one-half mile in snow during the approach. The station stop at St. Theresa Point lasted about 25 minutes, during which time several passengers and some freight items were deplaned, and other passengers embarked. Snow continued to fall during the station stop, and the crew used brooms to remove snow from the aircraft's wings before departure. Snow was falling throughout the flight to Island Lake and the station stop of about 30 minutes at Island Lake. Observers noted some loose snow on the wings as the aircraft taxied from the ramp to the runway. Both crew members reported that this snow was not adhering to the wings, and that it blew off of the wings with the movement of the aircraft after it taxied from the ramp at Island Lake.

The first officer was at the controls during the take-off from Island Lake, and the captain performed the non-flying duties. These duties included monitoring the engine instruments and calling out the reference speeds during the take-off roll. The crew used a cockpit quick-reference chart, with speeds as follows: V1 (take-off decision speed), 103 knots, VR (rotation speed),
106 knots, and, V2 (single engine climb speed), 111 knots. A take-off is not normally rejected after V1 unless the aircraft's ability to fly is in doubt. The chart was produced by another operator and the figures in it were derived from the performance section of the Transport Canada approved aircraft flight manual (AFM). The figures in the quick-reference chart vary for every 1 000 pounds of gross weight and were calculated for an outside air temperature (OAT) of 25 degrees Celsius. For the take-off from Island Lake, the crew selected take-off speeds from the quick reference chart for a take-off weight from 16 001 pounds to 16 950 pounds. The take-off speeds listed in the AFM vary for every five degrees Celsius change in the OAT and every 1 000 pounds of gross weight. For paved, dry runway conditions, the AFM designated take-off speeds for an aircraft at a take-off weight of 16 000 pounds and an outside air temperature of minus five degrees Celsius were: V1, 100 knots, VR, 102 knots, and V2, 108 knots. The aircraft's balanced field length under these conditions is listed as 3 328 feet. The AFM contains a gravel supplement with performance information for aircraft using firm, dry, gravel surfaces. The

ravel supplement portions of the AFM list the following take-off speeds for the occurrence aircraft's weight and an outside air temperature of zero degree celsius: V1, 101 knots, VR,
101 knots, and V2, 108 knots. The balanced field length for these conditions is listed as
3 484 feet.

The aircraft was equipped with both a flight data recorder (FDR) and a cockpit voice recorder (CVR). Both units were removed from the aircraft and their data were analysed. The FDR indicated that, during the start of the take-off roll, both engines were producing rated torque and both propellers were turning at maximum rated rpm. The FDR indicated that the aircraft was rotated at an indicated airspeed of about 106 knots. On hearing the stall warning horn, the first officer suspected that the aircraft may have been over-rotated and lowered the nose. The stall warning stopped, but recurred when the nose was raised again. The first officer then believed that a malfunction had occurred which would compromise the aircraft's flight capability. He called for a rejected take-off, and the captain concurred. The captain moved the engine power levers to idle and applied reverse thrust. FDR data indicate that engine power reduced to idle about four seconds after the aircraft was rotated. The aircraft's indicated airspeed reached a maximum of 126 knots and then declined sharply. The indicated airspeed was about 40 knots as the aircraft travelled past the end of the runway, and 20 knots as it departed the prepared surface of the stopway. FDR data indicate that the elapsed time to accelerate from 101 knots to 106 knots during the take-off roll was about one second, and a similar time was required for the deceleration through those speeds. The FDR data do not indicate with certainty whether or how far the aircraft lifted from the ground, and witness reports were inconclusive.

When the aircraft was examined after the occurrence, some ice was observed on the engine cowlings and on both wing sections, inboard of the engines; however, no ice or snow was found on the tail surfaces or the wings outboard of the engines. The design of the aircraft incorporates an engine bleed air system, heat exchanger and air cycle machine, much of which is located in the wing roots. When these systems are in operation, they generate heat, which has the effect of warming the skin of the inboard wing sections.

The runway at Island Lake is 4 000 feet long, composed of crushed stone. In addition to the runway length, there is a stopway area of about 300 feet on each end of the runway. The stopway is cleared of snow in winter, and is used by flight crews to turn their aircraft around before take-off and after landing. The area beyond the stopway area of runway 12 is an unprepared surface sloping down toward the lake. On the day of the occurrence, this area contained several banks of hard snow of various heights, and the runway and stopway surfaces were covered with graded, hard-packed snow. About one to two inches of loose snow was observed on the surface of the runway at the time the aircraft taxied for take-off. The runway surface was described as slippery at the time of the occurrence. Loose snow increases tire rolling resistance, delays acceleration, and results in longer take-off runs. Snow-covered or slippery runways provide decreased traction, which results in longer aircraft stopping distances, as compared to bare runways.

The calculated weight of the aircraft at take-off from Island Lake was 16 015 pounds, 935 pounds less than the aircraft's maximum gross take-off weight of 16 950 pounds. Its centre of gravity was within approved limits. The aircraft's maintenance records indicate that it was equipped and maintained in accordance with existing regulations. Transport Canada approved the Beech 1900D aircraft type for operation in Canada under section 704 of the Canadian Air Regulations. Section 704 provides that no person shall conduct a take-off in an aircraft if the weight of the aircraft exceeds the maximum take-off weight specified in the AFM for the pressure altitude and the ambient temperature at the aerodrome where the take-off is to be made. In the determination of the maximum take-off weight, the required accelerate-stop distance shall not exceed the accelerate-stop distance available, and the required take-off distance shall not exceed the take-off distance available. For the purposes of determining the accelerate-stop distance and take-off distance, the following factors shall be taken into account: the pressure altitude at the aerodrome, the ambient temperature, the runway slope in the direction of take-off, and headwind and tailwind components. The manufacturer was, as a condition of the aircraft type approval, required to determine and supply certain aircraft performance data including the balanced field lengths at various take-off weights, temperatures, and altitudes. The stopping performance of the aircraft for the accelerate-stop distance is calculated with engine power at idle, without the use of reverse thrust.

The James Brake Index (JBI) published in the Canada Flight Supplement contains a table which may be used to adjust calculated landing distances to compensate for slippery braking conditions. JBI correction factors for compacted snow or snow-covered runways range from 80% to 250% higher than hard dry surfaces. Transport Canada did not require the manufacturer to provide data on the effects of soft or wet runways, slippery runways, or runways containing loose snow on the aircraft's accelerate-stop distances or take-off distances. Slippery and
snow-covered runways are commonly encountered by flight crews operating in Canada during cold weather. The operator did not have performance charts for use for such conditions, nor were such charts available from the manufacturer.

The Island Lake weather observation at 1400 was as follows: winds 080 degrees true at eight knots, visibility one-half statute mile in snow, an overcast cloud ceiling at 500 feet above ground level, and a temperature of minus four degrees Celsius. The observations at 1450 and 1443 noted visibilities of one mile and two miles in light snow, respectively. As the crew was taxiing the aircraft to the runway for takeoff, they requested updated weather information from the Winnipeg Flight Service Station. They were advised that the current ceiling was 700 feet above ground level, and the visibility was one statute mile. Snow continued to fall throughout the afternoon on the day of the occurrence.

The aircraft's stall warning system consists of a lift transducer vane and a backing plate located on the left wing leading edge, a sensor unit, and several resistors. The vane is able to move up or down within a range of motion afforded by a gap in the backing plate in which it is mounted. Aerodynamic pressure on the lift transducer vane varies with the wing's angle of attack. When an angle of attack approaches that of an imminent stall, the vane changes position, and the sensor unit produces a signal which activates the stall warning horn in the cockpit. Rigging tolerances allow the vane to be in the up, "wing stalled", position or the down, "wing unstalled" position on the ground. In unstalled flight, dynamic air pressure holds the vane in the down, or "wing unstalled" position. The system is disabled on the ground by the operation of the landing gear safety switch, located on the left main landing gear. The system has a preflight test capability through the use of a switch placarded STALL

WARNING TEST on the copilot's left hand subpanel. The stall warning test is incorporated into the "originating" check, which is performed before the first flight of the day, but not at station stops. The stall warning system was tested before the initial flight on the day of the occurrence and found to be serviceable. This switch, when held in the TEST position, bypasses the landing gear safety switch, and, if the system is functional, activates the stall warning horn. The test system does not detect a system malfunction which would generate a false stall warning in flight. The Beech 1900 series stall warning system differs from some other stall warning systems in that the lift transducer vane in
the Beech 1900 may be in the "stalled" or "unstalled" position while the aircraft is at rest on the ground. In the Beech 200 system, for example, the vane is normally in the "unstalled" position on the ground.

The stall warning heat is switched on and checked along with other ice protection items as part of the "BEFORE TAKE-OFF (FINAL ITEMS)" check in the Transport Canada approved check list, which was in effect at the time of the occurrence. The stall warning heat is switched off as part of the "AFTER LANDING" check. The crew reported that the stall warning heat was switched on at Island Lake as they taxied the aircraft from the ramp to the runway for take-off. The aircraft taxied away from the ramp about two minutes before the start of the take-off roll. The stall warning system is equipped with anti-icing capability on both the mounting plate and the vane. The heat is controlled by a switch in the ICE PROTECTION group located on the pilot's right subpanel placarded STALL WARN - OFF. Electrical voltage is supplied to the stall warning heat system at 28 volts in the air, and is reduced to 10 volts for ground operation by the operation of the left landing gear safety switch. The manufacturer's information does not quantify the temperatures attained by the system during ground or air operation; such temperatures would depend on ambient temperature, atmospheric moisture, and relative wind. The AFM states that the level of stall warning heat is minimal for ground operation. A STALL HEAT annunciator in the Caution/Advisory panel illuminates if there is insufficient current to heat the vane and the faceplate heaters. No STALL HEAT indication was observed by the crew on the day of the occurrence.

Several hours after the occurrence, the stall warning transducer vane was checked by the crew, and found to be stuck. The ambient air temperature did not rise above freezing from the time of the occurrence until the aircraft was examined the following day by TSB investigators. During that examination, the vane was found to be frozen in the "wing stalled" position. Power was supplied to the stall warning heat system with the landing gear safety switch in the "ground" position. The lift transducer vane and its backing plate gradually became warm to the touch, but remained frozen for several minutes after heat was applied. When the landing gear safety switch was moved to the "flight" position, the temperature of the vane and backing plate increased rapidly, and the vane became free to move. After the stall warning vane was freed, it remained in the "wing stalled" position with the aircraft at rest.

There have been a number of similar occurrences both in Canada and United States where the stall warning horn activated during the take-off sequence, and in some cases after the aircraft had been de-iced.

Analysis

During the approach to St. Theresa Point and the flight and approach to Island Lake, the aircraft flew in snow that was heavy enough to reduce visibility to one-half mile. During this time, the gap between the lift transducer vane and the backing plate was exposed to the ambient airflow, and to the snow which was falling during these flights. At the existing ambient temperatures, snow entering the stall warning system would probably have melted on contact, leaving the resulting water in the stall warning system.

The stall warning heat was turned off as part of the after landing checks. After the system was turned off, no heat was provided to the system; thereafter, the ambient airflow over the wing during the taxi from the runway to the ramp, and the ambient temperature, would have had the effect of cooling the stall warning system, allowing the water in the system to freeze during the station stop at Island Lake. The Beech 1900 stall warning system tolerances are such that the lift transducer vanes, in some individual aircraft, may normally be in the "wing stalled" position while in others, the vane may normally be in the "wing unstalled" position with the aircraft at rest. Because the lift transducer vane tolerances in this particular aircraft resulted in a vane position normally in the "wing stalled" position when the aircraft was at rest, the vane would have frozen in that position during the station stop.

The pilots, in accordance with the aircraft checklist, tested the stall warning system on the initial flight of the day, but did not test it after start-up at Island Lake. In any event, the design of the test circuit is such that it would not detect a false warning, and had the pilots tested the system, it would not have helped them avoid the false stall warning after take-off. Although the pilots turned on the stall warning heat during the taxi to the runway, the system did not have sufficient capacity, at its reduced operating voltage, to thaw the frozen lift transducer vane. The vane remained frozen in the "wing stalled" position during take-off.

Although snow was observed on the aircraft's wings while the aircraft was on the ramp at Island Lake, the snow probably blew off before or during the take-off roll. Most of the snow observed after the occurrence on the inboard wing sections likely resulted from the warming effect of the aircraft's engine and systems, combined with the snow which fell after the occurrence. The aircraft's speed, gross weight, relatively clean wings, and configuration indicate that the wings were producing lift and were not stalled at take-off.

During the take-off roll, when the first officer rotated the aircraft and weight came off of the landing gear, the landing gear safety switch closed, which completed the stall warning circuit and generated an inappropriate stall warning signal. Because the first officer believed that the aircraft might not be capable of flight, he called for a reject, even though the airspeed was beyond V1, and the captain concurred.
The information about the other occurrences, where the stall warning horn activated during the take-off sequence, does not appear to have been disseminated to other Beech 1900 operators.

A number of factors present during the occurrence changed the aircraft's accelerate-stop performance from that listed in the AFM:

a. The quick-reference speeds for V1 of 103 knots, and VR of 106 knots used by the crew, were slightly higher than those (101 knots and 101 knots respectively) listed in the more-detailed reference in the AFM;

b. Because of the time required for recognition, decision, and reaction, engine power was reduced four seconds after rotation, and the aircraft reached a speed of 126 knots before starting to decelerate;

c. The snow-covered, slippery condition of the occurrence runway differed from the bare, dry surfaces on which the AFM data is based. The snow on the runway increased both the aircraft's acceleration distance by increasing the rolling resistance, and increased the stopping distance by decreasing tire traction, thereby increasing the accelerate-stop distance of the aircraft by an undetermined amount; and

d. Partially mitigating the effects of the factors listed above, the crew used reverse thrust on both engines.

Although Transport Canada required the manufacturer to provide performance charts containing correction factors for density-altitude, temperature, runway gradient, and wind conditions, the manufacturer was not required to provide charts for corrections to the accelerate-stop or take-off distances resulting from soft or wet runways, slippery runways, or runways containing loose snow. Because performance data were not available, the crew was not able to determine how much snow on the runway was acceptable for continued operation of the aircraft, or to what extent such snow and a slippery runway would affect the take-off and rejected take-off performance of the aircraft.

The following TSB Engineering Branch Report was completed:

LP 183/97 Flight Recorder Report.

Findings

1. Maintenance records indicate that the aircraft was equipped and maintained in accordance with existing regulations.

2. Both the captain and the first officer were certified and qualified for the flight in accordance with existing regulation.

3. The aircraft's weight and centre of gravity were within allowable limits for the departure from Island Lake.

4. The crew tested the stall warning system on the first flight of the day in accordance with the aircraft checklist and found it to be serviceable.

5. The Beech 1900 stall warning test function does not detect a condition in the stall warning system that will lead to a false stall warning on take-off.

6. Neither pilot received instruction on faults related to the stall warning system which could result in a false stall warning.

7. The rigging of the lift transducer vane of the Beech 1900 differs from that of some other aircraft types in that the vane may be in the “stalled” or “unstalled” position when the aircraft is at rest.

8. The aircraft flew in snow which was heavy enough to reduce visibility to one-half mile during the approach to St. Theresa Point and during the subsequent flight to Island Lake.

9. The moisture in the stall warning system froze the lift transducer vane in the “stalled” position during the station stop at Island Lake.

10. The reduced heat provided to the stall warning system during the short taxi time was not sufficient to melt the ice after the stall warning heat was turned on during the “Before Take-off” check.

11. The aircraft’s engines were developing normal rated power at take-off, and both propellers were turning at maximum rated rpm.

12. The aircraft’s stall warning system activated as the aircraft was rotated at 106 knots.

13. The pilots were not aware of previous occurrences of false stall warnings in the Beech 1900 aircraft type.

14. The pilots rejected the take-off about four seconds after rotation and reached a maximum speed of 126 knots.

15. The runway was snow covered and slippery at the time of the occurrence.

16. There were no performance data available to the pilots to determine the aircraft’s accelerate-stop distance under snowy and slippery runway conditions.

17. The pilots' use of the cockpit quick reference take-off speed chart lead to slightly increased aircraft’s accelerate-stop distance.

18. The higher-than-V1 speed from which engine power was reduced, together with the snow-covered runway conditions, increased the aircraft’s accelerate-stop distance.

Causes and Contributing Factors

The stall warning activated at take-off because the lift transducer vane had frozen in the "stalled" position, and a rejected take-off was initiated at a speed and position from which the aircraft could not be stopped within the cleared runway and stopway surfaces remaining. Contributing to the occurrence were insufficient heat to melt the frozen stall warning system and the lack of performance data for the prevailing runway conditions.

Safety Action

During training, neither pilot had received instruction on the differences in the design of the Beech 1900 stall warning system from that of other aircraft types. Neither pilot was aware that such differences could lead to a false stall warning on take-off in the event of a malfunction of the system, as it did in this occurrence. Ministic Air Ltd. has added a segment to its initial and recurrent pilot training explaining the design of this system and the effects of some system malfunctions. In addition, the company standard operating procedures will be changed to include this information.

The approved aircraft flight manual requires the pilots to complete a pre-flight inspection of various interior and exterior components of the aircraft before engine start. Some of these items are required to be checked before the first flight of the day and need not be checked before the subsequent flights undertaken that day. Some items, marked "+", must be checked before every flight. Item number 14 on the "Preflight Inspection, Left Wing and Nacelle" check is "Stall Warning Vane ---- CHECK FOR FREEDOM OF MOVEMENT". After the occurrence, the manufacturer amended the checklist by designating this as an item to be checked before every flight. Because of the rigging of the stall warning vane, its freedom of movement cannot be checked from inside the cockpit. The change was made in order to ensure that pilots would be made aware, before any flight, of a condition which would render the vane unserviceable.

At the time of the occurrence, item number 5 on the "BEFORE TAKE-OFF (FINAL ITEMS)" check was "Stall Warn Heat ---- ON." The manufacturer amended the checklist in December, 1997, and moved this item to the "BEFORE TAXI" check, which is completed after engine start and before the "BEFORE TAKE-OFF" check. The change was made in order to allow the stall warning heat to operate for a longer period of time on the ground before flight so as to ensure that the system would be functional after take-off.

No recurrences of false stall warnings were reported to the manufacturer during the first winter operating season after the date of these changes. However, the stall warning heat system is affected by many variables, including ambient temperature, humidity, precipitation, wind, stage length, taxi distance, and ground turn-around time. The situation will continue to be monitored by the TSB.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 16 November 1998.