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

AVIATION OCCURRENCE REPORT

LOSS OF ALTITUDE CONTROL DURING CIRCLING APPROACH

MILLAR WESTERN INDUSTRIES LIMITED
IAI 1124A, WESTWIND II C-FMWW
MEADOW LAKE, SASKATCHEWAN
27 JANUARY 1994

REPORT NUMBER A94C0014

Canada

MANDATE OF THE TSB

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

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

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

INDEPENDENCE

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

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Synopsis

The privately owned, Israel Aircraft Industries (IAI) Westwind II aircraft was en route from Edmonton Municipal Airport, Alberta, to the Meadow Lake aerodrome, Saskatchewan. Low ceilings and reduced visibility were reported in the vicinity of the destination aerodrome. As the aircraft was circling to land, it was observed to enter a number of steep-banked rolling manoeuvres. Immediately following these manoeuvres, the aircraft descended and struck the ground in a nose-high, slightly right-wing-low attitude. The initial impact with the ground produced very high deceleration forces. Internal fuel tanks ruptured and the aircraft was consumed by fire. Both pilots sustained fatal injuries.

The Board determined that, while circling to land on runway 26, the aircraft performed a non-typical circling procedure at a lower than published circling altitude, leading to loss of control consistent with an accelerated stall, and descended into terrain before recovery could be completed. Whiteout conditions may have contributed to this occurrence.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The privately owned Israel Aircraft Industries (IAI) Westwind II aircraft was en route from the Edmonton Municipal Airport, Alberta, to the Meadow Lake aerodrome, Saskatchewan. Low ceilings and reduced visibility were reported in the vicinity of the destination aerodrome. The crew completed a straight-in instrument approach to runway 08 at Meadow Lake, and began a circling procedure to the south of the aerodrome in order to set up to land on runway 26.

The aircraft passed overhead the aerodrome at an altitude of approximately 400 feet above ground level (agl). It then turned and proceeded in level flight towards the southeast. Approximately two and one-half miles from the aerodrome, the aircraft entered a number of steep-banked rolling manoeuvres. Immediately following these manoeuvres, the aircraft descended and struck the ground in a nose-high, slightly right-wing-low attitude. The ground-strike produced very high deceleration forces. The aircraft broke into several sections, internal fuel tanks ruptured, and fuel was sprayed forward and outward from the initial impact point. A severe post-crash fire erupted and engulfed the entire wreckage trail.

Emergency medical service and fire-fighting crews responded from the town of Meadow Lake and were on the scene within minutes of the accident. Both pilots died in the crash.

The accident occurred at 0855 central standard time (CST), at lat 54°07'N and long 108°31'W, during daylight hours.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	2	-	-	2
Serious	-	-	-	-
Minor/None	-	-	-	-
Total	2	-	-	2

1.3 Damage to Aircraft

The aircraft was destroyed by high deceleration forces. The cockpit and main cabin areas were consumed by the post-crash fire.

1.4 Other Damage

During the crash sequence, the aircraft bounced across a secondary road and struck the bottom two cables of a three-wire, rural powerline. The damage to this electrical transmission line caused a temporary power outage for Meadow Lake's northwest sector. The power outage occurred at 0855 hours CST.

Aviation fuel and aircraft debris spread along the wreckage trail and caused damage to an agricultural field.

1.5 Personnel Information

	Pilot-in-command	Co-Pilot
Age	46	33
Pilot Licence	ATPL	ATPL
Medical Expiry Date	01-May-94	01-Apr-94
Total Flying Time	15,650 hr	3,200 hr
Total on Type	1,000 hr	1,500 hr
Total Last 90 Days	60 hr	60 hr
Total on Type Last 90 Days	60 hr	60 hr
Hours on Duty Prior to Occurrence	2 hr	2 hr
Hours off Duty Prior to Work Period	15 hr	12 hr

1.5.1 Crew Flight Experience and Training

Each of the two crew members held a valid Airline Transport Pilot licence (ATPL), a valid instrument endorsement, and a current pilot proficiency check (PPC). In addition, each of the crew was up-to-date with respect to all requirements of the company-approved training plan. That training plan requires that company pilots complete an initial ground and flight training session for each aircraft type they are going to operate. In addition, recurrent ground and flight training sessions are required at least once per calendar year. This crew had just completed their most recent recurrent-training session in October 1993 at the Simuflite training facility in Dallas-Fort Worth, Texas. That particular training session emphasized circling approach procedures and provided an opportunity for the crew to practice these procedures in the flight simulator.

The aircraft captain was a veteran pilot with over 15,000 hours of flight experience. That experience spanned a career of more than 26 years in aviation during which he had worked as a flight instructor, a charter pilot, and then as chief pilot for several regional airlines before joining Millar Western's flight operations in 1988.

The first officer had approximately 3,200 hours of flight experience. The majority of that experience was obtained on the Westwind II aircraft and was in high-density flying operations.

Both crew members had performed at consistently high levels during training exercises and during formal Transport Canada flight examinations. In addition, it was noted that the in-flight crew coordination and cockpit resource management principles that had been adopted by the company were being effectively used.

1.6 *Aircraft Information*

Manufacturer	Israel Aircraft Industries
Type	IAI 1124A (Westwind II)
Year of Manufacture	1982
Serial Number	380
Certificate of Airworthiness (Flight Permit)	Standard Category - Issued 21 February, 1989. Valid
Total Airframe Time	4,810 hours
Engine Type (number of)	TFE731-3-1G (2)
Propeller/Rotor Type (number of)	N/A
Maximum Allowable Take-off Weight	23,501 pounds
Recommended Fuel Type(s)	Jet A, Jet A1, Jet B, JP 5
Fuel Type Used	Jet A

1.6.1 *Aircraft Description*

The IAI 1124A (Westwind II) is a twin-engined turbo-fan business transport. It was originally

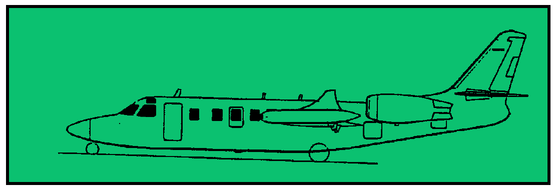

Figure 1- Westwind II

certificated by the Israeli Civil Aviation Authority in 1979 and subsequently by the United States Federal Aviation Administration in 1980. The aircraft design was based on the Westwind I, but incorporated a newly modified wing and NASA-type winglets above the tip tanks. These modifications were made to improve the aircraft flight performance in elevated temperature and altitude conditions.

The aircraft is powered by two fuselage-mounted, Garrett TFE731-3-1G turbo-fan engines, each of which is capable of producing 3,700 pounds of static thrust. The aircraft has a relatively high power-to-weight ratio and pilots indicate that the aircraft responds quickly and is capable of climbing rapidly with full power application, especially under conditions of low weight and low outside air temperature.

The Westwind II is controlled conventionally using manually operated all-metal ailerons, elevators, and rudder. The aircraft is equipped with double-slotted, electrically operated Fowler flaps, electrically operated trim tabs, and hydraulically operated speed brakes and lift-dumpers which are located above each wing and forward of the flaps. In addition, the entire tailplane is a cantilever, variable-incidence structure that is operated electrically.

The Westwind II is equipped with an FCS-80 automatic flight control system (AFCS). The autopilot processes signals from a flight guidance computer as well as manual inputs from the aircrew to automatically drive primary servo motors which position the aircraft control surfaces. The autopilot is normally engaged during flight but can be disengaged at will by the pilots. The aircraft's yaw damper system senses the yaw acceleration, combines the signal with the turn coordination signal and amplifies the resultant rudder command to drive the rudder servo motor. The yaw damper is normally engaged during flight.

The Westwind II is equipped with a number of anti-ice and de-icing systems and is approved for operation in icing conditions. The aircraft's flight manual indicates that, in conditions of visible moisture and freezing temperatures, ice will form on unheated parts of the windshield, windshield wipers, wing and empennage leading edges, air inlets, and engine nacelles.

1.6.2 Aircraft Operational Procedures

The company uses a pilot self-dispatch system. The system authorizes the pilot-in-command to make appropriate decisions related to the dispatch and control of assigned flight operations. Overall direction and supervision of the company's flight operations is the responsibility of the chief pilot.

The flight from the Edmonton Municipal Airport to Meadow Lake had been filed under instrument flight rules (IFR) and was flown by a direct route, and at an altitude of 27,000 feet above standard sea level pressure (FL 270). The intent of the flight was to re-position the aircraft to pick up and transport seven company personnel from Meadow Lake, Saskatchewan, to a second company facility in Whitecourt, Alberta. The flight plan indicated that the estimated time en route for the re-positioning flight between Edmonton Municipal and Meadow Lake was 35 minutes. The aircraft departed Edmonton at 0815 CST.

Prior to its departure from Edmonton, the aircraft was loaded with 5,300 pounds of jet fuel (Jet A). This fuel-load would allow the aircraft to complete the entire round-trip flight from Edmonton to Meadow Lake, then on to Whitecourt, and back to Edmonton without having to make any en route fuelling stops. The flight to Meadow Lake would require about 1,000 pounds of fuel, leaving about 4,300 pounds on board at the time the accident occurred.

1.6.3 Aircraft Weight and Balance

Because of the Westwind II design, a small change to the aircraft's load can result in a relatively large shift to the aircraft's centre-of-gravity (C of G) position. The aircraft's C of G envelope is published in Section VIII-21 of the *Westwind II Airplane Flight Manual*. The lower portion of that envelope identifies two separate zones. The manual indicates that, if the aircraft's zero fuel weight falls within zone 1, then fuel may be loaded up to the maximum ramp weight without exceeding the C of G limits. However, in order to maximize the aircraft's payload, the aircraft's C of G at its zero fuel weight is normally adjusted to the aft-most limit of zone 1. As passengers, baggage, and fuel are then added, the C of G will move progressively ahead, toward the forward limit of the operating C of G range. This adjustment to the zero fuel weight C of G position is accomplished through the use of removable ballast.

Prior to departing from the Edmonton Municipal Airport, the flight crew had positioned 100 pounds of removable ballast (four 25-pound bags of lead shot) into the aft baggage compartment in order to configure the aircraft's C of G to allow for the loading of eight passengers at Meadow Lake.

The aircraft's weight and balance for the re-positioning flight to Meadow Lake were within prescribed limits. Its weight for the time of the accident was estimated to be 18,138 pounds, and the distribution of that load would have placed the aircraft's C of G at the aft limit of the aircraft's C of G operating range.

1.6.4 *Aircraft Performance with Aft Centre of Gravity*

An aircraft's flight characteristics and control responses will vary depending upon the position of the C of G. These variations are well known in the aviation community and are published in numerous generally accepted aerodynamics reference texts. In general terms, the following effects can be expected with an aft C of G:

a) there is an increased probability that the aircraft may over-rotate with the application of an aft-elevator control input;

b) the aircraft will have reduced pitch stability, and increased susceptibility to aerodynamic stall; and

c) the aircraft's natural tendency to drop its nose at the stall is reduced.

1.6.5 *Aircraft Maintenance*

Company maintenance personnel are employed by Millar-Western on either a full-time or contract basis and are responsible to the chief pilot for the maintenance of company aircraft in accordance with the operations manual. Major maintenance work and inspections were carried out by Innotech Aviation Ltd. in Vancouver, British Columbia.

The aircraft was being maintained on a 50-hour, phased-inspection program in accordance with the Israel Aircraft Industries Westwind II maintenance manual. A phase 10 inspection was carried out on 07 December 1993, approximately 33 hours prior to the accident, at a total airframe time of 4,779.2 hours. The aircraft had also undergone a 4,800-hour structural inspection as per the Israel Aircraft Industries Westwind II Structural Inspection Program on 15 October 1993, at a total airframe time of 4,717.7 hours. Technical records indicate that all maintenance items had been properly carried out and that the aircraft was certified as being airworthy prior to the flight.

1.7 *Meteorological Information*

1.7.1 *Local Area Forecast*

The area forecast issued by Winnipeg for the Meadow Lake region and valid for the time of the accident (FACN5 CWWG 271130) indicated that the area would be under the influence of a moist low-level air mass and a light variable flow. Local stratus ceilings could be expected between 600 and 1,200 feet agl with isolated fog patches giving visibilities between one-half and three statute miles in snow grains and fog. Obscured ceilings could be as low as ground level and up to approximately 300 feet agl.

1.7.2 *Atmospheric Environment Service (AES) Weather Observations*

The hourly weather observations for the period leading up to the accident indicated a fairly constant balloon ceiling of 500 feet agl. An AES weather report taken immediately following the accident reported a thin obscured condition, with a balloon ceiling at 400 feet agl. The visibility was reported to be three statute miles in ice crystals. The temperature was -9 degrees Celsius (°C), dew point -11°C. The wind was from 280 degrees at 9 mph, and the altimeter was 30.10 inches of mercury. Subsequent weather reports indicate that the ceiling and visibility gradually reduced over the next few hours to as low as 200 feet agl and 1 1/2 miles visibility in very light snow and fog.

Balloon measurements are most reliable under conditions of low ceilings and low wind, and would likely be accurate to within 50 feet under the conditions that were present on the morning of the accident.

1.7.3 *Whiteout Conditions*

The *Aeronautical Information Publication Canada* (AIP - section AIR 2.12.7) describes whiteout as being an atmospheric optical phenomenon in which neither shadows, horizon, nor clouds are discernible. Whiteout is a phenomenon which generally occurs over an unbroken snow cover and beneath a uniform overcast sky, when the light from the sky is about equal to that from the snow surface. Because the light is so diffused, the sky and terrain tend to blend imperceptibly into each other, obliterating the horizon. The absence of a clearly definable horizon will adversely affect a pilot's ability to perceive visual cues even if the aircraft is operating below the cloud base and in visual meteorological conditions (VMC).

Video and still photographs taken immediately following the accident show a low, ragged cloud deck, snow-covered terrain, subdued lighting conditions, and an absence of a clearly definable visual horizon. All of these factors are conducive to whiteout conditions, which could have reduced flight visibility and adversely affected the crew's ability to judge altitude and flight path angle by visual reference with the horizon.

1.7.4 *Icing Conditions*

A pilot who landed at Meadow Lake approximately 45 minutes after the accident reported descending through a thin layer of fog and picking up a trace of ice on his approach to the aerodrome. In addition, several witnesses on the ground, at the time of the accident, noted that their vehicles' radio antennas were contaminated with ice and that trees in the local area were covered with hoar-frost. These ground reports originated from the region southeast of the accident site.

Investigators could find no direct evidence of ice at the accident site. Additionally, photographs taken by local media approximately fifteen minutes after the accident do not show ice contamination on any of the aircraft's airfoil sections.

1.8 *Aids to Navigation*

The aircraft was properly equipped for IFR flight. All on-board navigational equipment was serviceable prior to the flight.

1.8.1 *Departure and En Route Facilities*

The aircraft was given an air traffic control (ATC) clearance for a direct route of flight from Edmonton Municipal to the Meadow Lake aerodrome at FL 270. The en route portion of the flight was monitored and controlled by ATC facilities at the Edmonton Area Control Centre (ACC) and by the Department of National Defence Terminal Control facilities at Cold Lake, Alberta. Recorded communication tapes and radar data related to these portions of the flight were secured following the accident and were used in the investigation.

1.8.2 *Destination Facilities*

The Meadow Lake aerodrome is served by a company-approved instrument approach procedure which is based on the low frequency "YLJ" non-directional beacon (NDB) situated approximately 4.6 nautical miles west of the aerodrome. When the wind is out of the west (favouring runway 26), the Meadow Lake approach requires the pilot to complete a circling procedure to align the aircraft with the active runway.

"Circling" is the term used to describe the visual manoeuvring required after completing an instrument approach to bring an aircraft into position for landing on a runway which is not suitably located for a straight-in landing. The AIP (section RAC 9.25) states that "the basic requirements [of a circling approach] are to keep the runway in sight after initial visual contact, and remain at the circling MDA [minimum descent altitude] until a normal landing is assured."

Aircraft performance differences have an effect on the airspace and visibility needed to perform a circling manoeuvre safely. The Westwind II normally manoeuvres in the category D speed range of 141 to 165 knots indicated airspeed (KIAS); its estimated approach speed under the existing weight conditions would have been approximately 150 KIAS. The category D obstacle clearance area extends 2.3 miles outwards from the end of the runway and provides a minimum 300-foot clearance above all obstacles within the visual manoeuvring area.

In Meadow Lake, the controlling obstacle for a category D circling approach is a 250-foot television transmission tower situated approximately two miles east of runway 26. Obstacle clearance from that tower has been established for IFR flights through the publication of a 604-foot minimum descent altitude for category D aircraft. A 200-foot radio broadcast tower is located three miles southeast of the aerodrome, and is approximately one-half mile south of the accident aircraft's circling track. That tower is 0.7 miles outside the category D obstacle clearance area and does not present a risk to aircraft that are manoeuvring within the published circling airspace. The aircraft captain was aware of the presence of this tower and routinely commented on its location when flying into Meadow Lake.

The circling approach procedure that the crew had practiced during the latest simulator training session is similar to the one depicted by the solid flight-path-line in figure 2. That procedure is consistent with standard circling procedures depicted in the AIP and the Transport Canada *Instrument Flight Procedures Manual* (TP 2076E). However, on the day of the accident, the aircraft began the circling procedure overhead the aerodrome and followed the flight path indicated by the dotted line on figure 2. That flight path took the aircraft outside the category D obstacle clearance area and into the vicinity of the 200-foot high radio tower. The abrupt rolling manoeuvres that were observed by ground witnesses occurred as the aircraft was approaching

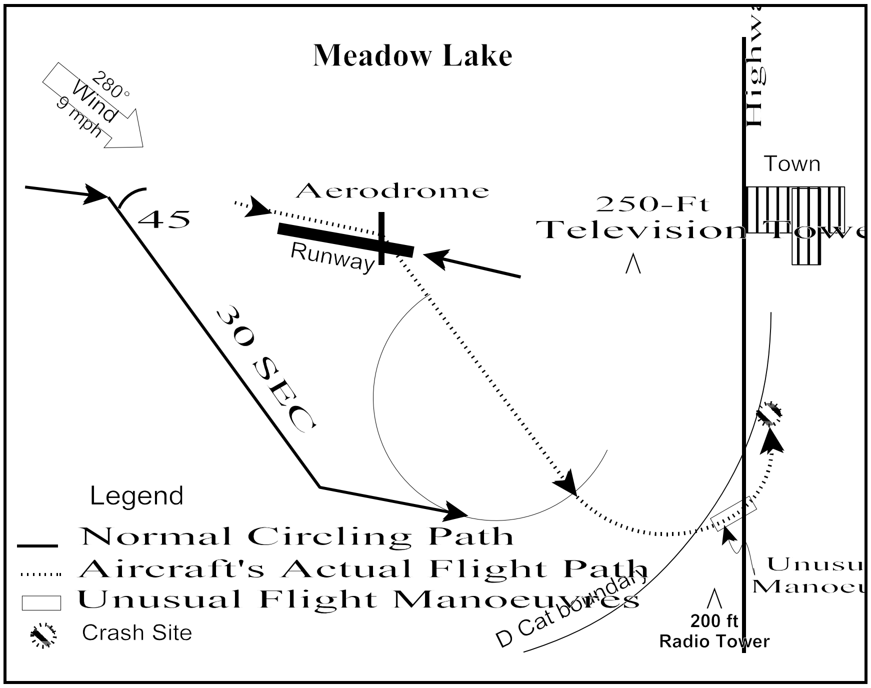

Figure 2 - Circling Approach

the northbound highway which leads into the town of Meadow Lake. These witness accounts indicate that the event was of short duration and involved several steep-banked attitudes in both directions. Based on one witness's description of the aircraft's nose movement to the left while it was established in a steep right-banked attitude, it is possible that the aircraft was also subjected to a negative g force.

1.9 Communications

All recorded radio communications were reviewed following the accident. From that review it was determined that:

a) radio communications during the departure from the Edmonton Municipal Airport were routine; and

b) en route radio communications with Edmonton ACC and with the Department of National Defence facilities at Cold Lake were routine and gave no indication of an in-flight difficulty.

In addition to the recorded data, the following information was obtained from other sources:

a) radio communication with the AES observer and airport manager at Meadow Lake appeared normal;

b) in-flight radio communications were being accomplished by the first officer; and,

c) no radio transmissions were heard from the aircraft during its circling procedure.

1.10 Aerodrome Information

Meadow Lake is a privately owned, registered aerodrome operated by the Saskatchewan Government's Department of Highways and Transport. Aerodrome information is listed in Transport Canada's *Canada Flight Supplement* (CFS). This information is provided by the operator and is verified by Transport Canada on a three- to five-year inspection cycle.

The Meadow Lake aerodrome is uncontrolled. Weather and current aerodrome information is available through a Universal Communications (UNICOM) facility which operates during limited hours. An AES weather observer provides local weather reports (hourly reports and/or special reports) and maintains a limited self-service aviation weather information system for use by aircraft operators.

The aerodrome has two runways. The main runway is a 5,000-foot by 100-foot asphalt surface oriented on a 080°/260° magnetic (M) heading. The runway had just been swept and was bare and dry at the time of the occurrence.

The Meadow Lake aerodrome is not equipped with crash fire rescue facilities and relies on the town of Meadow Lake to provide this service.

The CFS indicates that Jet B aviation fuel is available from drums. However, this fuel type is not maintained at the aerodrome, and is only available at limited hours from the bulk dealer in the town of Meadow Lake. Because of the considerable difficulty and expense that would be incurred to transport and use this fuel, the Millar-Western flight operations procedure was to carry sufficient fuel on board the aircraft when flying into Meadow Lake in order to meet the flight requirements for the next leg of their itinerary.

1.11 Flight Recorders

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was either required by regulation.

1.12 Wreckage and Impact Information

1.12.1 Ground Scars and Wreckage Dispersion

The aircraft crashed about 2.5 nm east-southeast of the runway threshold. Examination and measurement of impact scars indicated that the aircraft struck the ground with an approximately 15° nose-up, slightly right-wing-low attitude. Wreckage scatter was linear from the point of initial impact, and was symmetrical around a nominal track of 004°M. The total length of the wreckage trail was 1,035 feet.

1.12.2 Aircraft Structures

The aircraft had been subjected to severe impact damage. The wing section, the empennage, and the cabin/cockpit areas detached during the crash sequence, and had come to rest as separate segments near the north end of the wreckage trail. The forward fuselage had separated from the centre-section at the aft-cabin pressure bulkhead and was resting upright at the northernmost end of the crash site. The entire cabin and cockpit interiors, along with the right-forward fuselage and windshield sections had been consumed by a post-crash fire.

The cabin door and the left emergency exit panel were detached from the fuselage and were located on the wreckage trail. Both main-door locking pins were extended and in their LOCKED position. The emergency exit window was resting, interior-side-down, on the snow, near the north end of the wreckage trail. There was no evidence of soot or fire on the inside of the emergency exit window. The right emergency exit remained secure to the fuselage and was fire damaged.

The main landing gear actuators were extended 12 inches. This measurement is consistent with the gear being DOWN AND LOCKED at impact.

1.12.3 Instrument/Electrical Systems

The cockpit area had been severely damaged by fire and, for that reason, the flight instruments and navigation components were removed from the cockpit and shipped to the TSB Engineering Branch Laboratory in Ottawa for further disassembly and analysis. The following information was determined, based on that examination:

a) the aircraft's indicated airspeed at impact was 175 KIAS;

b) the vertical velocity at impact was 2,200 feet per minute (fpm) DOWN; and,

c) the autopilot was DISENGAGED and the yaw damper was ENGAGED at impact.

1.12.4 Engines

Both engines sustained heavy impact damage, but escaped the post-crash fire. Damage caused by the ingestion of debris was evident on the fan blades on both engines. Several fan blades were detached on the right engine and the right fan shroud was bulged. All fan blades on the left engine were attached. Several displayed leading edge mechanical damage.

The engines, complete with the electronic engine controls (EECs), were removed from the site and taken to the manufacturer's facility, Allied Signal in Phoenix, Arizona, for teardown examination and analysis. From that analysis it was determined that both engines were producing power at impact; however, the extent of engine power could not be established.

1.12.5 Flight Controls

The aircraft's primary flight control systems were examined at the accident site. No pre-impact system discontinuities were identified. All observed damage was overload in nature and was consistent with the high impact forces and the subsequent breakup of the airframe.

The secondary flight control systems were examined prior to wreckage removal. From this examination it was determined that the flap extension was symmetrical and that the flaps were in a 20° DOWN position at the time of impact. It was noted, however, that one of the attachment clamps for the right flap drive cable had been missing for some time prior to the accident. This missing clamp allowed the drive cable to contact the outer flange of the aileron servo-lever-arm. Over time, the movement of the lever arm against the drive cable had caused metal from the lever-arm to become abraded. Although the contact between these two components was sufficient to remove metal, it did not result in noticeable interference, or obstruction of movement within the aileron system.

Thrust reversers, lift-dumpers and speed brake systems were all STOWED at impact. The position of the horizontal stabilizer was determined to be near its full NOSE DOWN position at 29° Mean Aerodynamic Chord (MAC). This position is consistent with an approach speed range under the aircraft's estimated weight and C of G conditions. The rudder and the aileron trim tabs were found in their NEUTRAL positions.

1.13 Medical Information

The aircraft's captain held a valid category 1 medical in accordance with the requirements of his ATPL. Medical records and post-accident medical examinations revealed no evidence of any pre-existing medical conditions to indicate that the captain may have suffered a sudden incapacitation in flight. Additionally, there was no anatomical evidence to suggest that a myocardial ischemia or heart attack had occurred.

The co-pilot held a valid category 1 medical. A routine histology was done following the accident and no ante-mortem abnormalities were found to indicate any cause of sudden incapacitation. Tests did indicate that the first officer had a 10% carboxyhaemoglobin saturation level. The first officer was a smoker and it is possible that this may account for some of the carbon-monoxide found in the blood.

Drug and alcohol screening and histological examinations of both crew members were negative.

1.14 Fire

The aircraft's fuel tanks ruptured on impact with the ground and spread fuel, forward and outward, along the wreckage trail. The aircraft's cabin interior had been recently re-upholstered with fire blocking material. However, fuel invaded the cockpit and cabin sections and these areas sustained the worst of the fire damage. There was no evidence of an in-flight fire.

1.15 Survival Aspects

The accident was considered to be non-survivable because of the magnitude of the deceleration forces, and the subsequent thermal stress.

The four-point seat restraint system used by each of the crew members remained secured to the aircraft structure and the seat-belt webbing did not fail. The captain's left shoulder-harness strap was not attached to the centre buckle. It could not be determined why the strap was not properly secured. The crew seat sub-structures collapsed because of the high vertical deceleration and side loads at impact.

1.16 Tests and Research

Three separate witnesses were able to locate the aircraft's position in space at the time of the abrupt, steep-banked rolling manoeuvres. That position was approximately 3,000 feet southwest of the accident site. An aircraft performance analysis was conducted to determine whether the observed in-flight manoeuvring may have been associated with an aerodynamic stall. This mathematical analysis was based on evidence which indicated that, at the time of impact, the aircraft's speed was 175 KIAS, and that its descent velocity was 2,200 fpm. By using this data as a reference, it was possible to estimate the aircraft's flight path angle to impact. By projecting that angle, it was then possible to approximate the aircraft's altitude and speed at the point where the abrupt in-flight manoeuvring occurred. From that analysis it was determined that:

a) the aircraft's flight path angle from the point of the abrupt manoeuvres to the ground was approximately 7.8° DOWN;

b) the aircraft's altitude at the time of the manoeuvres was approximately 400 feet agl;

c) the total time from the observed manoeuvres to impact was approximately 10 seconds; and

d) the aircraft's speed at the time of the manoeuvres was estimated to be between 129 and 154 KIAS.

1.17 Additional Information

1.17.1 Aerodynamic Stall and Stall Warning

An airfoil is capable of producing lift throughout a limited range of angles of attack. If the angle of attack is increased beyond those limits, lift from the wings will be destroyed and the aircraft will stall.

A stall can be induced at a higher airspeed than normal when back-pressure is applied to the control column to maintain level flight while tightening the turn. The actual stall speed of the aircraft will increase proportionally with any increase in bank angle and back pressure. This form of "accelerated stall" is normally characterized by negligible warning and rapid onset.

As an airfoil approaches its critical angle of attack, a stall warning system will normally alert the pilot of the impending stall. The Westwind II is not equipped with an aural warning system but relies on an angle of attack indicator and aerodynamic buffet to warn the pilot of an approaching stall.

The aircraft flight manual indicates that, at the accident weight, the 1.0 g stall speed of the aircraft in landing configuration with 20 degrees of flaps and landing gear down will be 102 knots calibrated airspeed (CAS). The maximum permissible manoeuvring flight load limit, with the landing gear and flaps down, is published as +2.0 g. Based on that limit, the aircraft's accelerated stall speeds could reach as high as 144 knots.

1.17.2 Aerodynamic Effects of Ice on the Wing

An increase in surface roughness caused by the accumulation of ice on a wing can cause the wing to stall at higher than normal speeds. In addition, ice contamination on the lifting surfaces will increase the aircraft's total weight, decrease the lift-generating capacity of the wing, and increase the aerodynamic drag of the wing.

2.0 Analysis

2.1 Flight Crew Training and Qualifications

The flight crew was properly qualified, trained, and experienced, and had consistently demonstrated high levels of performance during Transport Canada flight evaluations. There was no evidence of pre-existing medical conditions which would have incapacitated either crew member.

2.2 Meadow Lake Circling Approach

Both crew members were familiar with the Meadow Lake aerodrome and with the company-approved circling approach. The crew had received a weather briefing prior to the flight, as well as radio updates from Cold Lake and from the AES observer at Meadow Lake, and they were aware that the reported ceiling at the Meadow Lake aerodrome was 500 feet agl, and was below the category D circling limits. Although weather conditions in the vicinity of Meadow Lake were conducive to the formation of airframe and airfoil icing, no evidence of ice was found on the aircraft. The crew reportedly had no overriding pressure to complete this flight under unsuitable weather conditions. The reason why they initiated the flight, and why they attempted the approach under the reported weather conditions was not determined.

The aircraft was visible to observers on the ground as it passed over the Meadow Lake terminal building, and therefore must have been at or below the measured cloud base of 400 feet agl at the time of the accident; the aircraft appeared to be circling to land on runway 26. No definitive reason could be found to explain why the aircraft was manoeuvring below the category D MDA of 604 feet agl during the circling manoeuvre. Even if the crew had obtained visual contact with the ground at the category D MDA, the recommended practice is to remain at the circling MDA until a normal landing is assured.

The aircraft's speed at the time of the abrupt in-flight manoeuvring was calculated to be between 129 and 154 KIAS. Based on these calculations, it appears that the aircraft may have been manoeuvring at or below its normal circling approach speed. The risk inherent in flying at a lower airspeed is that the buffer between the aircraft's actual manoeuvring speed and its stall speed will be reduced. Extra precautions will then be necessary to limit the flight loading during any turning manoeuvres and to prevent a stall.

2.3 Abrupt In-Flight Manoeuvres

The aircraft was executing a left-hand turn to line up with runway 26 when it completed a number of rapid-onset, steep-banked, rolling manoeuvres. The event was of short duration, lasting only a few seconds. Based on the witnesses' descriptions, it is possible that the aircraft was also subjected to a negative g force while it was established in a steep right-banked attitude. The cause of these manoeuvres could not be determined, but the manoeuvres were likely associated with an accelerated stall.

2.3.1 Aircraft Position at the time of the Manoeuvres

At the time of the observed manoeuvres, the aircraft was turning back toward the runway and would have normally been established in a left-hand, 30°-banked turn. However, the circling procedure had been initiated overhead the aerodrome, and a westerly wind would have caused the aircraft to drift even further toward the east, to a point approximately 2.5 nm away from the aerodrome's runway environment and outside the obstacle clearance areas for the circling approach. This placed the aircraft in the vicinity of a 200-foot radio broadcast tower. Since the captain was familiar with this tower's location, it is likely that the crew recognized they were in its vicinity; this may have prompted the crew to tighten the turn back toward the aerodrome.

2.4 Possible Explanations for the Abrupt Manoeuvres

2.4.1 Possibility of an Accelerated Stall

With the aircraft's C of G at the aft limit, there would be an increased probability that the aircraft might over-rotate with the application of up-elevator. The aft C of G would have reduced the aircraft's pitch stability, and increased the probability of an accelerated stall.

Based on one witness's description of the abrupt manoeuvres that were observed prior to impact, it is possible that the aircraft may have been subjected to a negative g force while in a steep, right-banked attitude. If that were the case, then the rolling manoeuvre may have been caused by a high-speed stall, and the nose movement to the left, as observed by the witness, may have been the result of the crew's control input to recover from that stall.

2.4.2 *Possibility of a Planned and Intentional Manoeuvre*

It is possible, however, that the in-flight manoeuvres observed by the witnesses may have been planned and intentionally actioned by the crew in order to situate the aircraft with respect to both the radio tower and the airport. However, it is unlikely that a professional flight crew would undertake such abrupt manoeuvres at low altitude and with degraded visual references, as the risk would increase significantly.

2.4.3 *Possibility of an Undetermined System Malfunction*

There was no indication of any pre-impact aircraft failure or system malfunction that would have caused the abrupt in-flight manoeuvring, nor was there any indication of an in-flight fire. At impact, the aircraft configuration was consistent with the circling approach. All airfoil sections were accounted for and were in their appropriate positions for the phase of flight. The speed brakes, lift dumpers, and thrust reversers were all STOWED at impact, and the flaps were extended symmetrically at 20°. Based on the observed flight dynamics, it is unlikely that a transient deployment of any of these ancillary control systems occurred prior to or during the abrupt in-flight manoeuvring.

2.5 *Loss of Altitude Control*

Regardless of the underlying cause, the steep-banked attitude and abrupt manoeuvres resulted in a loss of altitude control and the aircraft began an approximately 8° descent path to impact. During the descent, it appears that the flight path was directionally stable. The aircraft hit the ground with a velocity of 175 KIAS and with a vertical velocity of approximately 2,200 fpm. The aircraft was in an approximately 15° nose-up, slightly right-wing-low attitude at impact, which suggests that one or both of the crew members had recognized the altitude loss and was attempting to initiate an overshoot procedure.

Because the time between the observed manoeuvres and the impact was of short duration, it is unlikely that the crew had sufficient time to recognize the situation, initiate the appropriate response, and complete the recovery before striking the ground.

The crew's ability to judge altitude and flight path angle by visual means may have been adversely affected by the whiteout conditions that were present, which would likely have slowed their recovery response.

3.0 Conclusions

3.1 Findings

1. Both crew members held valid Airline Transport Pilot Licences, valid instrument endorsements, and current pilot proficiency checks.

2. The aircraft was maintained in accordance with the approved maintenance schedule and was certified as being airworthy prior to the flight.

3. The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

4. Although the aircraft's weight and balance were within the prescribed limits, the aircraft's C of G was at the aft limit of the C of G operating range.

5. The aft C of G condition would have reduced the aircraft's pitch stability, increased its susceptibility to aerodynamic stall, and aggravated its stall characteristics.

6. Wind conditions at Meadow Lake required the crew to complete the NDB approach to runway 08, then perform a circling procedure to land on runway 26.

7. The normal approach speed of 150 KIAS required that the crew carry the circling procedure down to the category D MDA of 604 feet agl.

8. The measured ceiling of 400 feet did not allow the circling procedure to be conducted at category D minima.

9. The aircraft passed over the Meadow Lake terminal building at or below the cloud base of 400 feet agl and appeared to be circling to land on runway 26 at an altitude lower than the published category D circling minima.

10. The aircraft manoeuvred approximately 2.5 miles from the runway environment, and was outside the category D obstacle clearance area for the final portion of the flight.

11. It is likely that the crew recognized they were outside the normal manoeuvring area and tightened the turn while turning back toward the aerodrome.

12. The aircraft entered a number of steep-banked rolling manoeuvres while turning to line up with runway 26 at Meadow Lake.

13. Following the abrupt in-flight manoeuvring, pitch and roll control were re-established prior to impact; the aircraft struck the ground in a nose-high, slightly right-wing-low attitude, suggesting that recovery was initiated.

14. Both engines were producing power at impact; however, the extent of engine power could not be established.

15. It is unlikely that the crew had sufficient time to complete the recovery.

16. Although weather conditions in the vicinity of Meadow Lake were conducive to the formation of airframe and airfoil icing, no evidence of ice was found on the aircraft.

17. The crew's ability to judge altitude and flight path angle by visual means may have been adversely affected by the whiteout conditions that were present, and this would likely have slowed their recovery response.

18. There was no evidence of pre-existing medical conditions which could have incapacitated either crew member.

19. There was no evidence of any pre-impact aircraft system failures that could have caused the abrupt in-flight manoeuvring, nor was there any evidence of an in-flight fire.

20. The accident was considered to be non-survivable because of the magnitude of the deceleration forces, and the subsequent thermal stress.

3.2 Causes

While circling to land on runway 26, the aircraft performed a non-typical circling procedure at a lower than published circling altitude, leading to loss of control consistent with an accelerated stall, and descended into terrain before recovery could be completed. Whiteout conditions may have contributed to this occurrence.

4.0 Safety Action

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

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, the Hon. Wilfred R. DuPont and Hugh MacNeil, authorized the release of this report on 08 February 1995.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch Laboratory reports were completed:

LP 34/94 - Cockpit Instrumentation IAI Westwind II;
LP 73/94 - Approach Speed Calculation, IAI 1124A.

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

Appendix B - Glossary

ACC	Area Control Centre
AES	Atmospheric Environment Service
AFCS	automatic flight control system
agl	above ground level
AIP	Aeronautical Information Publication
ATC	air traffic control
ATPL	Airline Transport Pilot Licence
C of G	centre of gravity
CAS	calibrated airspeed
CFS	Canada Flight Supplement
CST	central standard time
CVR	cockpit voice recorder
EEC	electronic engine controls
FDR	flight data recorder
FL	flight level
fpm	feet per minute
hr	hour(s)
IAI	Israel Aircraft Industries
IFR	instrument flight rules
KIAS	knots indicated airspeed
MAC	mean aerodynamic chord
MDA	minimum descent altitude
NDB	non-directional beacon
PIREP	pilot report of weather conditions in flight
PPC	pilot proficiency check
UNICOM	Universal Communications
VMC	visual meteorological conditions
°	degree(s)
°C	degrees Celsius
°M	degrees magnetic

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