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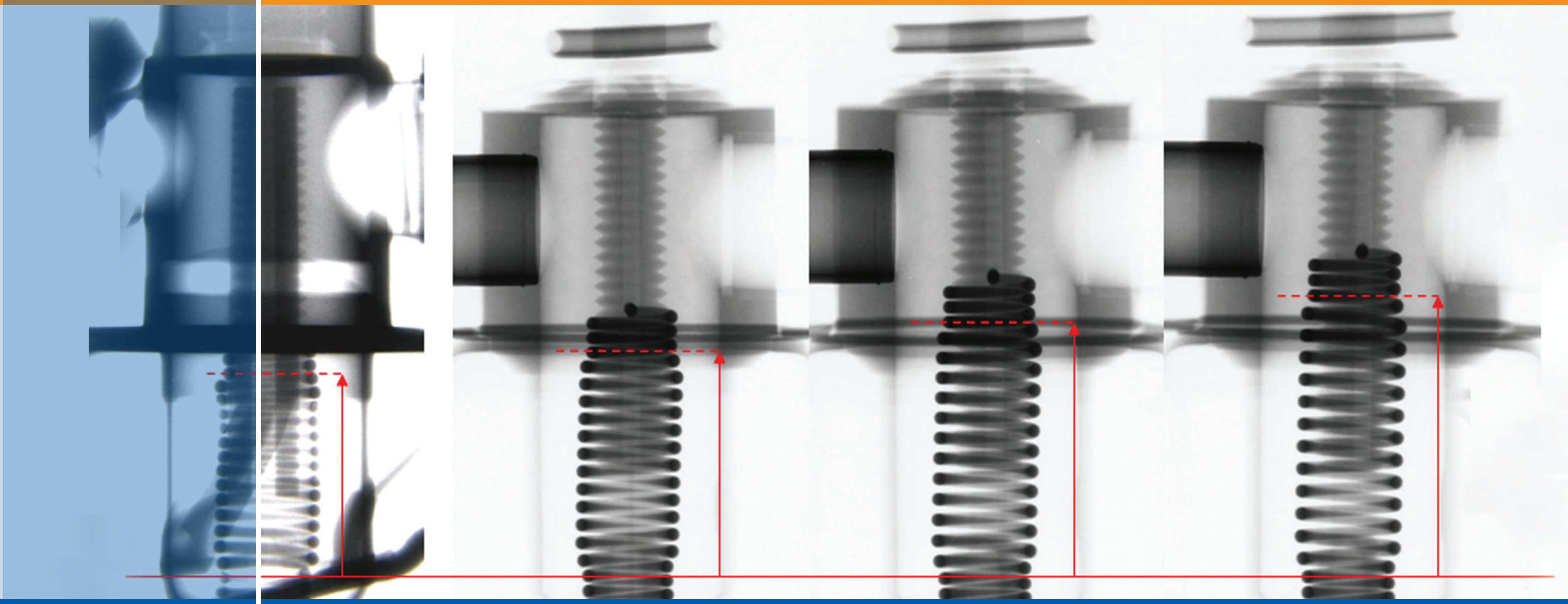

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2007-047
Final

Aircraft loss of control
255 km SW of Warburton, Western Australia
17 October 2007
VH-WXC
Cessna Aircraft Company 210M

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Figure 1: Reproduced from the Cessna Aircraft Company 210M Aircraft Flight Manual

Abstract

During the early evening of 17 October 2007, the pilot of a Cessna Aircraft Company C210M, registration VH-WXC, was fatally injured when his aircraft impacted terrain during a flight from Warburton to Kalgoorlie, Western Australia. That flight was being conducted at night under the visual flight rules and the pilot was the sole aircraft occupant.

The aircraft was seriously damaged by impact forces. There was evidence that the engine was producing significant power at that time. The aircraft was inverted when it collided with terrain, which was consistent with an in-flight loss of control. The accident was not survivable.

Examination of the aircraft wreckage found evidence that the aircraft's suction-powered gyroscopic flight instruments were in a low energy state. That was most probably because the vacuum relief valve was at a low suction setting. There was no lockwire fitted to the associated lock nut that would have ensured the security of the vacuum relief valve's adjustment spindle. The design of the valve was such that any in-service loss of friction on the lock nut could allow the spindle to move to a lower suction setting. In consequence, the aircraft's suction-powered gyroscopic flight instruments may not have been providing reliable indications to the pilot.

The pilot was appropriately qualified to conduct the flight. However, dark night conditions probably prevailed in the vicinity of the accident site which meant that the pilot would have had few external visual cues. In such conditions, the pilot was reliant on the indications from the aircraft's flight instruments to maintain control of the aircraft. The pilot would have had limited time to identify and react to any unreliable indications from the suction-powered flight instruments.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB’s investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: The ATSB’s assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

History of the flight

Shortly before 1800 Western Standard Time[1] on 17 October 2007, a Cessna Aircraft Company C210M (C210), registered VH-WXC (WXC), departed Warburton Aerodrome on a flight to Kalgoorlie, Western Australia (WA). The pilot was operating the aircraft at night under the visual flight rules (VFR) and was the sole aircraft occupant.

The aircraft had previously departed Kalgoorlie at about 1440 that afternoon to deliver an item of general freight to Warburton. The delivery was arranged at short notice and the pilot was called in to work to undertake the flight. The outbound flight to Warburton appeared to have proceeded normally. The pilot called Flightwatch[2] on high frequency (HF) radio at 1716 and cancelled his SARTIME[3] for arrival at Warburton.

The freight was offloaded at Warburton and the aircraft was refuelled. The pilot was reported to have asked the refueller to fill each tank to 'tabs'[4], an intermediate filling point, which provided 249 L of useable fuel on board the aircraft. Local fuel company records indicated that 79 L of aviation gasoline (AVGAS) 100/130 was added to the aircraft's fuel tanks at Warburton.

A series of HF radio transmissions on a Flightwatch frequency between 1750 and 1752 were identified as originating from the pilot. Although two-way communication was not established, a review of the recorded transmissions was consistent with the pilot attempting to nominate a SARTIME for his arrival at Kalgoorlie. That was the last transmission recorded from the pilot.

The pilot's house mate contacted the aircraft operator when the pilot didn't arrive home as expected that evening. A check of the aerodrome confirmed that the aircraft was overdue; AusSAR[5] was notified and a search commenced. A search aircraft subsequently located the aircraft wreckage, approximately 255 km (138 NM) along the direct track[6] from Warburton to Kalgoorlie. The aircraft was seriously damaged[7] by impact forces and the pilot was fatally injured.

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[1] The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) +8 hours.

[2] Flightwatch is the generic radio call-sign of the on-request flight information service, and responds to pilot requests for operational information.

[3] The time nominated by a pilot for initiation of Search and Rescue action if a report has not been received by the nominated unit.

[4] Metallic tabs inside each tank's filler neck that provided a visual indication of a reduced fuel tank capacity.

[5] AusSAR is the Australian agency responsible for coordinating search and rescue activities.

[6] The track, Warburton to Kalgoorlie was 222° magnetic.

[7] The Transport Safety Investigation Regulations 2003 define 'serious damage'. That definition is used to also describe damage which results in the 'destruction of the transport vehicle'.

Personnel information

The pilot held an Australian Commercial Pilot (Aeroplane) Licence, a Command Multi-Engine Instrument Rating and a Grade 3 Instructor Rating.[8] He had completed the requirements for the issue of those ratings during May and June 2007 respectively.

The pilot held a Class 1 Civil Aviation Medical Certificate with nil restrictions.

Although called in at short notice for the flight, the pilot was reported to have been fit and well rested prior to commencing duty, and in normal spirits before departing Kalgoorlie. The pilot was observed to eat lunch before departing for Warburton, during which time he was seen to undertake flight planning activities.

A review of the pilot's logbook indicated that he had accrued 1,340.8 hours total aeronautical experience, of which 29.3 hours had been flown at night. In addition, the pilot had 102.1 hours flying the C210, including 5.3 hours at night. The pilot's logbook recorded:

- 2.0 hours instrument flying by day in the 90-day period preceding the accident
- 5.7 hours night flying during the previous 90 days and 11 hours night flying in the previous 6 months
- a total of 42.3 hours aircraft instrument flight time and 29.4 hours simulator/synthetic trainer instrument flight time.

Records maintained by the operator included the satisfactory completion by the pilot of an aircraft type check (Cessna 402) during August 2007, and a proficiency check that was flown in WXC during May 2007.

The pilot last flew on 16 October 2007 and had been free of duty from about 1800 that evening.

Aircraft information

The aircraft was manufactured in the United States in 1978 and was a six-seat, single piston-engined aircraft with retractable landing gear. The aircraft was maintained by the operator in accordance with the aircraft manufacturer's system of maintenance. The operator conducted maintenance on the aircraft in-house and held a Civil Aviation Safety Authority (CASA)-issued workshop approval.

A scheduled maintenance inspection of the aircraft was completed on 10 September 2007 and an aircraft maintenance release was issued. The maintenance release was issued at 11,111.9 hours total time in service and was valid for operations in the charter operational category, conducted by day or night under the VFR. The maintenance release was not recovered at the accident site, but was reported to be with documentation carried on board the aircraft when it departed Kalgoorlie. Records maintained by the operator indicated that, at the time of the accident, the aircraft had flown about 40 hours since the last scheduled maintenance.

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[8] The pilot had previously held equivalent qualifications on his New Zealand-issued commercial pilot licence.

The aircraft's engine had completed about 1,625 hours since last overhaul[9] and, the propeller, about 1,325 hours since new.[10]

Aircraft instrumentation

The aircraft was equipped with conventional flight instruments. Information derived from the aircraft's pitot/static system was displayed to the pilot on the airspeed indicator, the altimeter and the vertical speed indicator.

Gyroscopically-referenced flight instruments displayed information to the pilot in respect of the aircraft's attitude and heading. The attitude indicator provided information on the aircraft's pitch[11] and roll[12], the directional indicator provided information about the aircraft's heading[13], and the turn coordinator provided information about the rate and coordination of any turns.

The gyroscopes within the aircraft's attitude and directional indicator flight instruments were suction powered. The gyroscope within the turn coordinator was electrically powered. Each individual suction-powered gyroscopic flight instrument did not incorporate any warning flag or other indicator to verify their correct operation during flight.

Suction-powered gyroscopic instruments and system

An engine-driven rotating vane-type vacuum pump provided a single source of suction for the aircraft's attitude and directional indicator flight instruments. The vacuum pump was physically connected to the engine's accessory drive by a frangible nylon-torque-drive coupling. In the event of a malfunction restricting the normal rotation of the vacuum pump, that coupling was designed to shear and disconnect the vacuum pump from the engine's accessory drive. That allowed for the continued operation of the aircraft's engine and any other accessories should that occur.

The vacuum system was equipped with a vacuum relief valve to regulate the suction provided to the aircraft flight instruments (Figure 1). The setting of the relief valve could be adjusted by maintenance personnel. The relief valve could be adjusted via a splined spindle shaft that, once adjusted to provide the desired vacuum, was locked by a lock nut. A small hole in the lock nut facilitated its lockwiring[14] during normal operation. There was no handle on the spindle shaft of that model of vacuum relief valve and consequently, no direct mechanism by which the spindle

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[9] The engine manufacturer specified 2,000 hours engine operation between overhaul.

[10] The propeller manufacturer specified 1,500 hours operation between overhaul.

[11] The aircraft's angular displacement (rotation) about its lateral axis. Measured as degrees nose-up, or nose-down.

[12] The aircraft's angular displacement (rotation) about its longitudinal axis. Measured as degrees left and right roll (or wing low).

[13] The angle between a horizontal reference datum and the longitudinal axis of the aircraft. Expressed as a three-figure group from 000° to 359°, the reference datum can include compass, magnetic or true north.

[14] The threading of a fatigue-free wire through affected nuts or bolts to apply a torque that opposed their rotation once set.

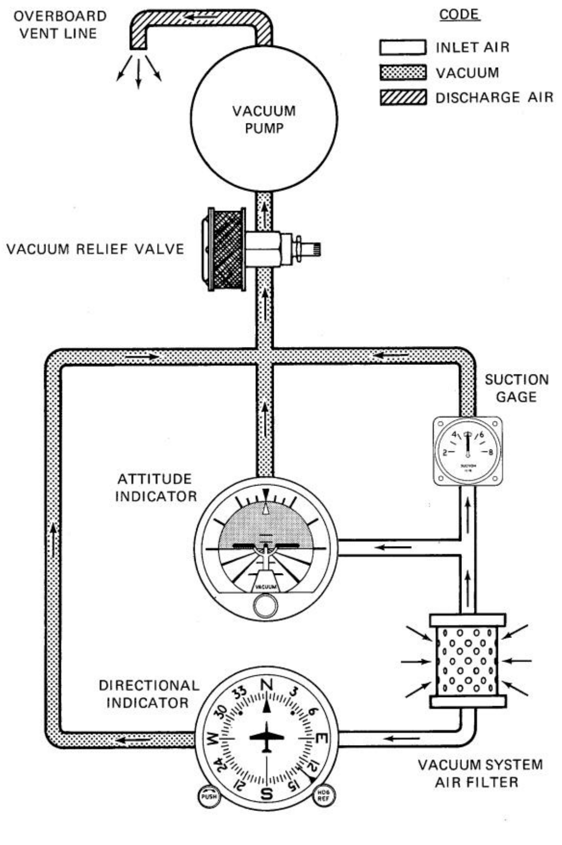
shaft could be immobilised against unwanted movement during flight. In that case, the lockwiring of the lock nut was critical to its security.

The relief valve operated by regulating the movement of a vacuum-modulated diaphragm valve that allowed the controlled ingress of atmospheric air - thus establishing the overall system suction levels. Balanced by an internal spring, the vacuum regulation levels could be set by adjusting the tension of the spring (via the spindle shaft), with lower spring tension levels corresponding with lower system vacuum levels.

The aircraft manufacturer's Aircraft Flight Manual (AFM) indicated that a suction of 4.6 to 5.4 inches of mercury (inHg) was required to operate the suction-powered gyroscopic flight instruments. The AFM indicated that a suction reading outside of that range may indicate a system malfunction or improper adjustment, and that in such a case, the attitude and directional indicators should not be considered reliable.

A suction gauge was mounted on the right side of the cockpit instrument panel and could be used by the pilot to monitor the suction being supplied to operate the attitude and directional indicator gyroscopes.

Figure 1: Schematic of aircraft instrument vacuum system (Cessna Aircraft Company)



The aircraft was not equipped with a secondary vacuum pump or a standby source of suction. In addition, there was no warning light[15] or other warning system to

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[15] Service kit SK210-11 was available from the aircraft manufacturer to fit a 'low suction' warning light to that model of aircraft.

indicate to the pilot that the suction being supplied to the suction-powered instruments was outside the range required for their correct instrument operation.

A number of pilots who had recently flown the aircraft recalled that the suction gauge had always read high, and most recalled that the suction was consistently above the 'green arc'[16].

Aircraft maintenance documentation indicated that the engine-driven vacuum pump was replaced on 02 August 2007; approximately 70 hours of operation prior to the accident. The maintenance documentation recorded no other work being carried out on the aircraft's vacuum system since that date.

The aircraft manufacturer's maintenance manual specified the replacement of the vacuum relief valve air filter every 100 hours of operation. The vacuum system air filter was required to be visually inspected for dirt and damage every 200 operating hours. Replacement of that air filter was required every 500 hours of operation. It was also required to be replaced if found to be damaged during periodic inspection, or if it became sufficiently clogged to cause a reduction in suction to below 4.6 inHg.

The maintenance manual stipulated that the engine-driven vacuum pump be replaced every 500 hours of operation. The replacement of the engine-driven vacuum pump drive coupling was mandated every 6 years, or concurrent with the replacement of the vacuum pump.

The maintenance manual did not specify a service life on the vacuum relief valve. A review of the aircraft maintenance documentation recorded the last replacement of that valve in 1997.

The maintenance manual specified replacement of the vacuum system hoses every 10 years. The aircraft's maintenance documentation recorded the replacement of the attitude indicator and directional gyroscope hoses during 1995.

There was no discrete record in the aircraft's maintenance documentation of any later replacement of the vacuum system hoses and system air filters. There was, however, certification of maintenance being completed in compliance with the system of maintenance. For such certification to be properly made, such a replacement should have occurred. It can therefore be reasonably assumed that the vacuum system hoses and air filters were replaced around 2005.

Electrically-powered gyroscopic instruments and system

The turn coordinator utilised an electrically-powered gyroscope to provide the pilot with information about the aircraft's direction and rate of turn. This instrument also provided limited redundancy in the event the suction-powered instruments failed. A number of pilots recalled that the turn coordinator was serviceable during their flights, and routinely checking it when completing their instrument checks during taxi.

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[16] The green arc was depicted on the face of the suction gauge and indicated a desired suction range of 4.6 to 5.4 inHg.

Additional aircraft equipment

The aircraft was equipped with an electrically-powered, two-axis (aileron and elevator control) autopilot that was designed to provide automatic pitch and roll stability as commanded by the selected mode of operation. Pilots who had recently flown the aircraft reported that the autopilot was not serviceable. Consequently, it was unlikely that the pilot used the autopilot during the occurrence flight.

The aircraft operator published a Minimum Equipment List (MEL) that stipulated the minimum equipment required to operate the aircraft. That document indicated that a serviceable autopilot was not required for VFR charter or IFR freight operations. An autopilot was not stipulated by the relevant regulations as equipment required for flight at night under the VFR.

The aircraft was equipped with a global positioning system (GPS) that was suitable for use under the VFR, two very high frequency omnidirectional radio range (VOR) receivers, and an automatic direction finding (ADF) receiver.

Aircraft operational information

The stipulated fuel for the aircraft was 100LL/100 minimum grade aviation gasoline. Two fuel tanks provided a total useable fuel of 336 L. Analysis of refuelling records was consistent with the aircraft departing Kalgoorlie fully fuelled. Based on the quantity of fuel that was added at Warburton, the investigation determined that about 166 L was consumed during the outbound flight, at a consumption rate of about 60 L/hour. It was estimated that, at the time of the accident, the aircraft’s fuel tanks contained about 190 L of fuel.

The maximum take-off weight stipulated by the aircraft manufacturer was 1,723 kg. At the time of the accident, the operating weight of the aircraft was estimated to be about 1,260 kg, and the longitudinal centre of gravity was within the manufacturer’s specified limits.

Meteorological information

Last light at Warburton was 1805 on the evening of the accident and 1814 in the vicinity of the accident site. At the time of the accident, the moon was a waxing crescent[17], with 29% of its visible disk illuminated; and its elevation was about 60° above the western horizon.

The Bureau of Meteorology (BoM) conducted a post-accident analysis of the weather conditions during the afternoon and evening of the accident. That analysis indicated that a cold front and middle-level trough were moving through the south-western parts of WA during the afternoon and were approaching the Western Goldfields. Ahead of the front, a well-developed surface trough extended from the southern Pilbara to the Eucla regions. That surface trough was estimated to have intersected the aircraft’s planned track, about halfway from Warburton to Kalgoorlie.

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[17] A waxing crescent describes a moon that is partly, but less than one half illuminated by direct sunlight, and the illuminated fraction of the moon's disk is increasing. This occurs between the new and first quarter moon, where half of the visible disk is illuminated by direct sunlight.

The BoM analysis indicated that, although not directly observed in the region,[18] it was probable that a band of thunderstorms was associated with, and orientated along the surface trough, and that their development was aided by weak, mid-level atmospheric instability. Due to relatively low surface humidity, the thunderstorms were likely to have had a relatively high base (around 11,000 ft above mean sea level (AMSL)), and were unlikely to produce heavy rainfall or to reduce horizontal visibility below 5,000 m. The BoM indicated that the dry air beneath any thunderstorms was likely to evaporate any rain, and could have contributed to the development of strong downbursts in the vicinity of those thunderstorms. That would have resulted in strong wind gusts or squalls with blowing dust.

The aircraft's planned track from Warburton to Kalgoorlie was through aviation forecast Areas 64 and 61.[19] The relevant forecasts for those areas were consistent with the BoM post-accident analysis and predicted generally north-westerly winds at 25 to 30 kts, isolated[20] cumulonimbus cloud at 10,000 to 35,000 ft, and scattered[21] altostratus cloud above 12,000 ft.

Proprietary ground-based equipment recorded lightning activity in a band that ran generally north-west to south-east, and intersected the pilot's track about halfway between Warburton and Kalgoorlie. That was consistent with the estimated position of the surface trough. No lightning activity was recorded in the vicinity of the accident site; although several strikes were recorded 60 to 85 km (32 to 46 NM) west-south-west of the accident site between 1820 and 1838.[22]

Aids to navigation

There was a non-directional beacon (NDB) ground-based navigation aid at Warburton.[23] Kalgoorlie was equipped with an NDB[24], a VOR transmitter[25] and distance measuring equipment (DME). An off-track NDB[26] was available at Laverton.

Navigating at night under the VFR required either visual navigation; fixing the aircraft's position with reference to ground features at least every 30 minutes or, as

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[18] The remoteness of the accident site, and paucity of regional surface observations in that area, meant that direct observations were not possible.

[19] For the purposes of providing aviation weather forecasts to pilots, Australia is sub-divided into a number of forecast areas.

[20] 'Isolated' in the context of a meteorological forecast refers to the presence of individual cumulonimbus cloud.

[21] Cloud amounts are reported in oktas. An okta is a unit of sky area equal to one-eighth of total sky visible to the celestial horizon. Few = 1 to 2 oktas, scattered = 3 to 4 oktas, broken = 5 to 7 oktas and overcast = 8 oktas.

[22] The investigation estimated that, during that period, the aircraft would not have been closer than 100 km (54 NM) to that recorded activity.

[23] Rated coverage 167 km (90 NM) day/night.

[24] Rated coverage 259 km (140 NM) day/148 km (80 NM) night.

[25] Rated coverage 111 km (60 NM) below 5,000 ft and 167 km (90 NM) from 5,000 ft to below 10,000 ft.

[26] Rated coverage 83 km (45 NM) day/night.

the pilot was qualified to use the relevant radio navigation aids, establishing a positive radio fix[27] at least every 2 hours.

The rated coverage of the available ground-based radio navigation aids along the direct track from Warburton to Kalgoorlie placed the aircraft outside the 2-hour position fixing requirement at some time during the flight. However, it would have been possible to plan the route sector via the Laverton NDB should the requirement to visually fix position have not been possible.[28]

The location of the accident site on the direct track from Warburton to Kalgoorlie suggested that the navigation of the aircraft was not a factor in the accident.

Communications

The examination of communications that were recorded at Kalgoorlie for the purpose of administering aerodrome usage charges confirmed that the pilot departed Kalgoorlie Aerodrome at about 1440. The Warburton Common Traffic Advisory Frequency was not recorded.

A review of the Air Traffic Services (ATS) Flight Information Services (FIS) frequencies along the route recorded no transmissions by the pilot on the relevant Flight Information Area (FIA) frequencies.

Although the pilot successfully cancelled his SARWATCH via HF radio on arrival at Warburton, he was unable to establish two-way HF communication with Flightwatch on departure from Warburton. The HF transmissions between 1750 and 1752 were most probably made as the pilot was taxiing for departure at Warburton.

For flights conducted at night under the VFR and proceeding beyond 222 km (120 NM) from the aerodrome of departure, the pilot in command was required to submit a SARTIME flight notification to ATS or, as an alternative, to leave a Flight Note with a responsible person.

There was an ATS FIA very high frequency (VHF) transmitter on frequency 130.9 MHz at Warburton, and the pilot could have submitted a SARTIME on that frequency. That frequency also provided an en route traffic control service for aircraft operating at high altitude inside controlled airspace. It was unable to be determined why the pilot did not attempt to submit his SARTIME on the FIA VHF frequency.

The operator was not holding a Flight Note for the aircraft's arrival back at Kalgoorlie.

Kalgoorlie and Warburton aerodromes were each equipped with VHF pilot-activated lighting. Those systems required the use of the aircraft's VHF communication radio to activate the runway lighting.

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[27] A positive radio fix constituted: station passage of a NDB, VOR or DME ground station; the appropriate use of an approved Global Positioning System (GPS) installation; or the intersection of two or more position lines, intersecting at angles on not less than 45°.

[28] The distance from Warburton to Laverton was 267 NM. Flying that track, the pilot would have been able to comply with the relevant radio navigation position fixing requirements, provided that the aircraft achieved a groundspeed of at least 133 kts.

Medical and pathological information

A post-mortem examination and toxicological testing was conducted on the pilot by the relevant state authorities. Those examinations did not identify the existence of any pre-existing medical condition or factors with the potential to have affected the pilot's performance, or to have incapacitated the pilot.

The examining pathologist commented that 'Minimal toxicology could be done but no common drugs were found.' Testing for the presence of carbon monoxide was not reported.

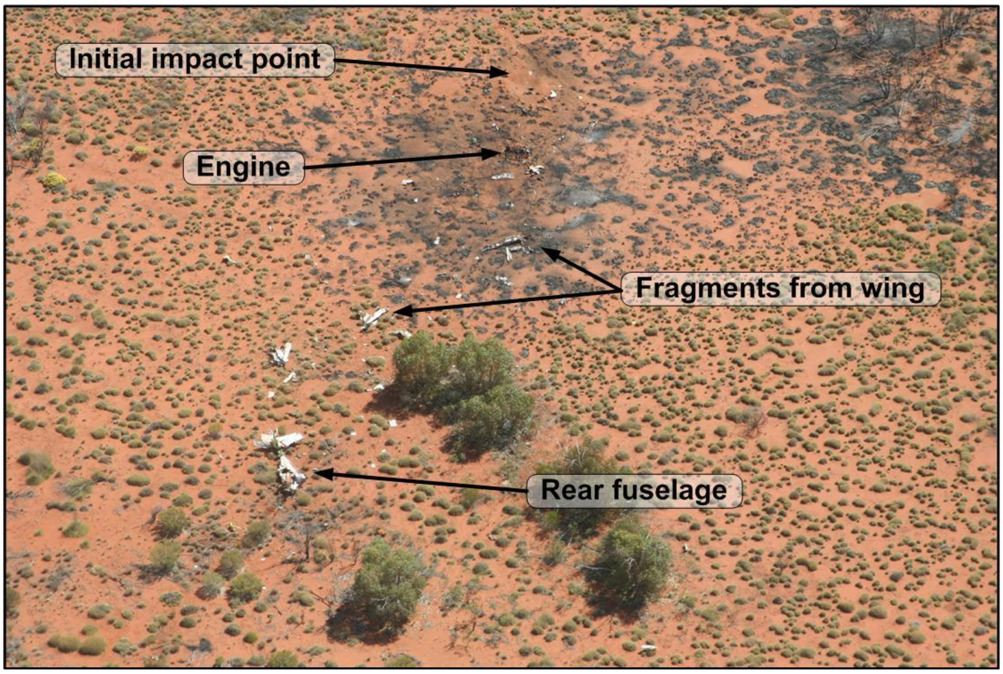
Wreckage and impact information

On-site information

The investigation estimated that the aircraft would have been in the vicinity of the accident site between about 1846 and 1906, which would have been about 1 hour after departing Warburton.

The aircraft impacted sandy, desert-type terrain at high speed (Figure 2). Ground markings in the vicinity of the initial impact were consistent with the aircraft's nose, engine and forward fuselage; the leading edge of the aircraft's wing; and the aircraft's vertical stabiliser striking the ground at that point.

Figure 2: Photograph overhead the accident site



Fragments of red and green coloured lens material from each of the aircraft's wingtip-mounted navigation lights, and of the red lens, tail-mounted anti-collision beacon were found in the immediate vicinity of the initial impact point. The location of those fragments relative to the impact point indicated that the aircraft was in an inverted attitude when it collided with terrain. The orientation of the ground marks that were made by the leading edge of the wing and the vertical stabiliser was consistent with the aircraft being in a banked, left wing-low attitude of about 30° from the horizontal, and a nose-down attitude of about 20°.

The fuel tanks ruptured on impact and there was a post-impact fire. All major aircraft components were located at the accident site and the aircraft was assessed as being intact prior to its collision with terrain.

The elevation of the terrain in the vicinity of the accident site was about 1,450 ft. The aircraft's ground track immediately prior to the impact was about 217° magnetic (M)[29], and the rear fuselage came to rest in the direction of flight, approximately 50 m beyond the initial impact point.

The aircraft's engine and propeller were located a short distance from the point of the initial impact. Damage to the propeller blades and hub mounting flange was consistent with the propeller being under engine power at the time of the collision with terrain.

The aircraft's fuel caps were found secured and there was no evidence of an in-flight fuel leakage. Due to the: breakup of the aircraft; the disruption to the aircraft's fuel tanks and lines; and the post-impact fire, it was not possible to obtain a fuel sample from the wreckage.

At impact, the wing flaps were in the UP position and the landing gear was retracted.

The frangible nylon-torque-drive coupling between the vacuum pump and the engine accessory drive was intact. That was consistent with the vacuum pump being connected to the engine's accessory drive at the time of the accident. The carbon impeller body from the engine-driven vacuum pump was found to have shattered.

The vacuum relief valve sustained damage during the impact sequence, but had remained attached to the engine firewall and was affected by a low-intensity, post-impact fire. The flexible (suction) hose that connected the vacuum relief valve to the engine-driven pump remained attached to the body of the relief valve, but the hose had torn away outboard of the hose clamp. Due to the post-impact fire it was not possible to determine the serviceability of the suction hoses.

Although badly disrupted, the instrument panel remained mostly attached to the engine firewall.

A number of instruments and components were recovered by the Australian Transport Safety Bureau (ATSB) for technical examination, including:

- the engine tachometer
- the cylinder head and oil temperature gauges
- the suction gauge
- the attitude and directional indicators
- a number of components from the vacuum pump and system[30]
- the electrically-powered turn coordinator.

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[29] The track from Warburton to Kalgoorlie was 220° M.

[30] The vacuum relief valve was recovered from the aircraft wreckage in May 2008.

Examination of recovered components

Cockpit instrumentation

An examination of the engine tachometer gauge revealed witness marks that were made by the tachometer indicating needle striking the face of the gauge at impact. The marks were consistent with an indication of about 2,300 RPM at that time.

Witness marks on the faces of the cylinder head and oil temperature gauges were consistent with the indication of normal engine operation.

Witness marks on the face of the suction gauge were consistent with an indication of about 3.0 inHg at that time.

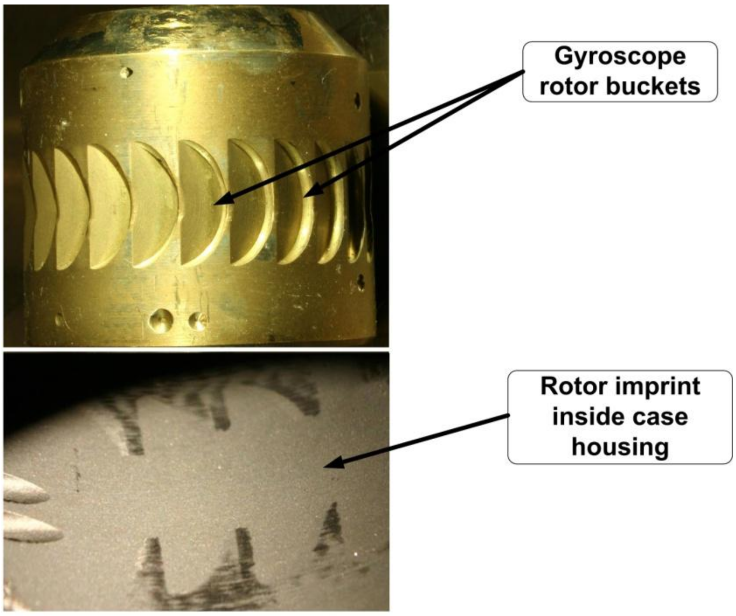
Suction-driven system and components

Although the cases of the attitude and directional indicators had been disrupted, each instrument's brass gyroscope rotor had remained within its respective case assembly (directional gyroscope shown at Figure 3). An examination of those rotors revealed damage that was consistent with their being in a low energy state at the time of the impact with terrain.

Figure 3: Directional indicator with gyroscope rotor and disrupted instrument case

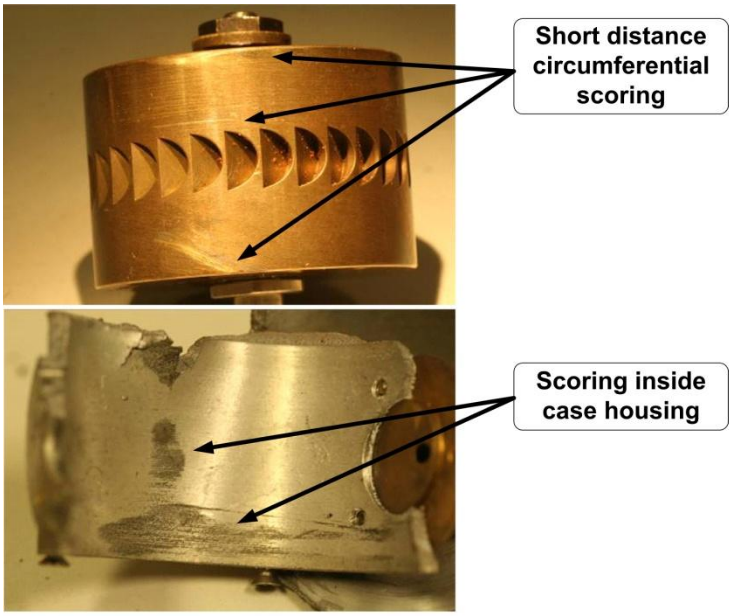
The gyroscope rotor from the attitude indicator had contacted the inside of its case housing. There was minor scuffing to the case assembly and an imprint of the gyroscope rotor buckets on the housing (Figure 4). That damage was consistent with the rotor impacting the case housing and stopping suddenly while in a relatively low energy state.

Figure 4: Disassembled attitude indicator and case imprint



The gyroscope rotor from the directional indicator had also contacted the inside of its case during the impact sequence, and exhibited short-distance rotational scoring (Figure 5). That was consistent with the rotor being in a relatively low energy state at that time, rotating only a short distance while in contact with the housing before being brought to a stop.

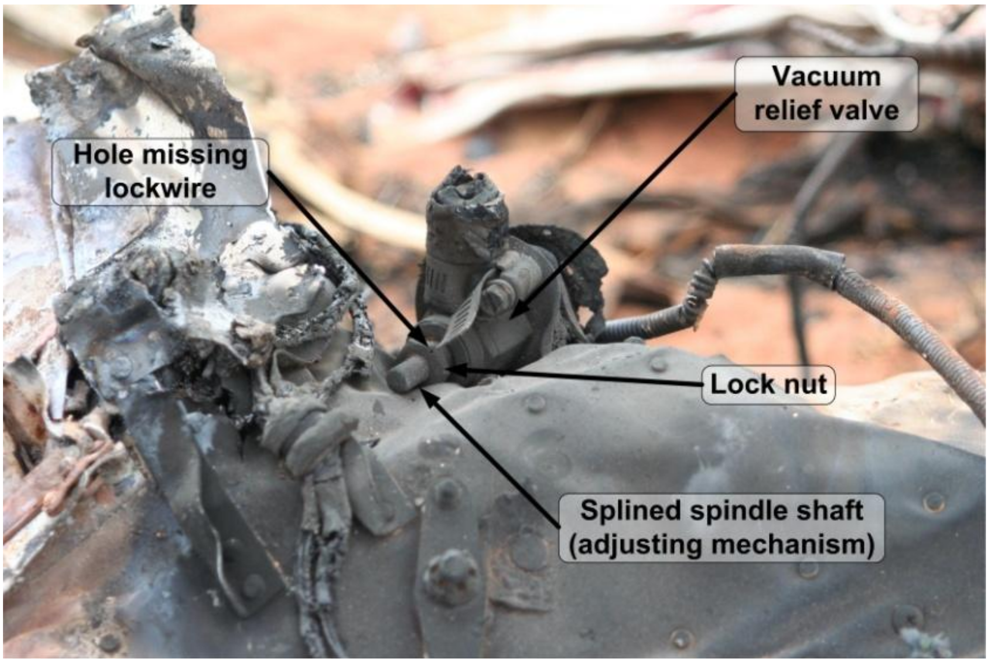
Figure 5: Disassembled directional indicator and case scoring



An examination of the recovered components from the vacuum pump found no defect with the pump assembly and the investigation concluded that the damage to the impeller vanes was consistent with a high energy impact and sudden stoppage of the components while rotating.

The end cover plate of the vacuum relief valve was dislodged during the impact and the diaphragm was heavily charred and embrittled as a consequence of the post-impact fire. The polyurethane foam garter filter within the valve had also been consumed by the fire. There was no lockwire attached to the valve's splined spindle shaft lock nut (Figure 6).

Figure 6: Vacuum relief valve mounted on the engine firewall



Prior to its disassembly, the vacuum relief valve was x-rayed and measurements taken of the internal settings of the valve assembly, including the physical position of the spindle shaft and of the diaphragm spring. The valve was then disassembled and examined.

The lock nut for the spindle shaft was found to be finger-tight, and was easily removed from the valve assembly. However, due to the effects of the post-impact fire and other post-accident thermal transients, it was not possible to assess the tightness of the lock nut at the time of the accident.

At the base of the regulator diaphragm (Figure 7), the bleed orifice was found partially covered with congealed, oily sand, which was also found around, and on both sides of the orifice plate (Figure 8). The regulating spring was free to move on the threaded portion of the spindle shaft and was securely attached to the orifice plate.

Figure 7: Fire damage to regulator diaphragm

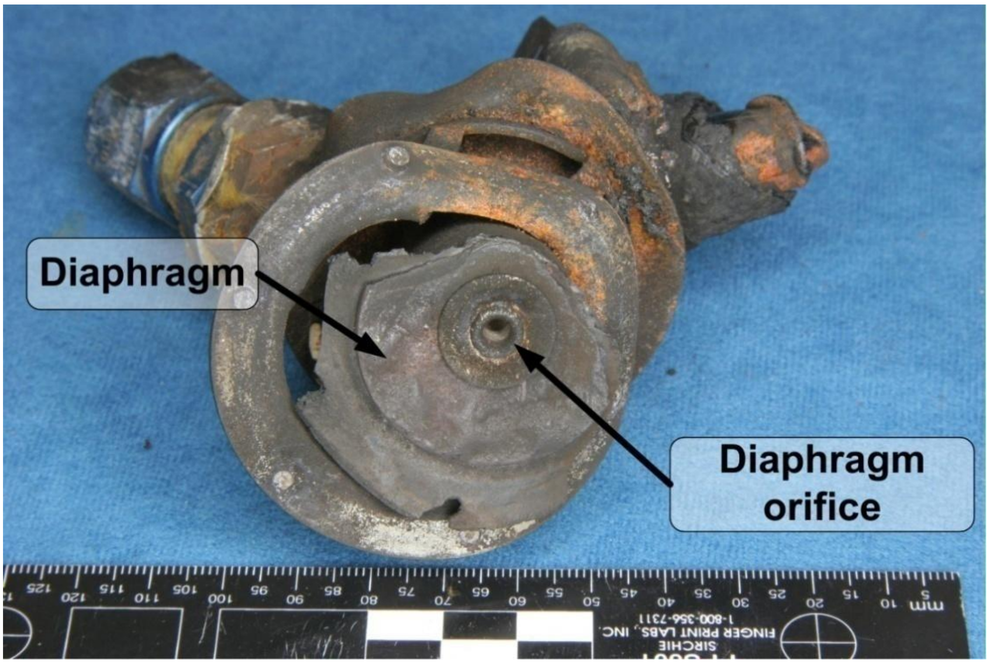
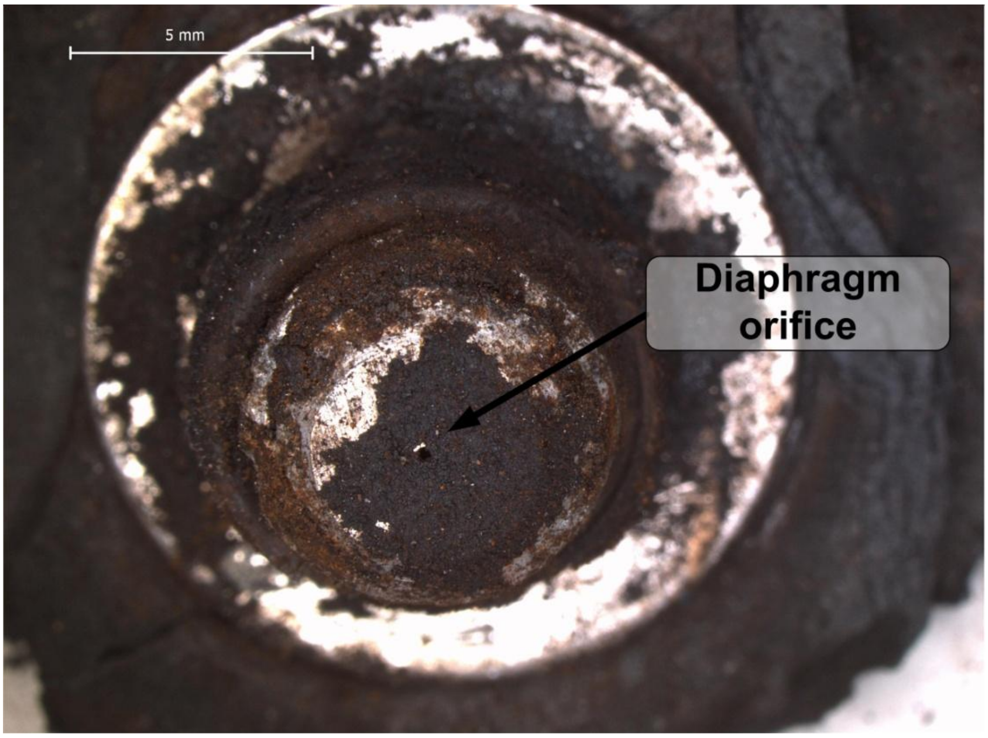


Figure 8: Regulator diaphragm orifice – contaminated but clear



There was no evidence of internal mechanical failure or malfunction of the vacuum relief valve, although that assessment was significantly limited by the degree of damage sustained by the unit during the impact sequence and post-impact fire.

Survival aspects

An emergency locator transmitter (ELT) was installed in the aircraft's fuselage. However, the ELT was destroyed by impact forces and was incapable of transmitting a distress signal.

Due to the extent of the impact forces and the extent of the breakup of the aircraft, the accident was not survivable.

Tests and research

Fuel quality

A sample of fuel was obtained from the equipment at Warburton that was used to refuel the aircraft. An analysis of that fuel sample confirmed its compliance with the relevant standard for AVGAS 100/130.

Vacuum relief valve

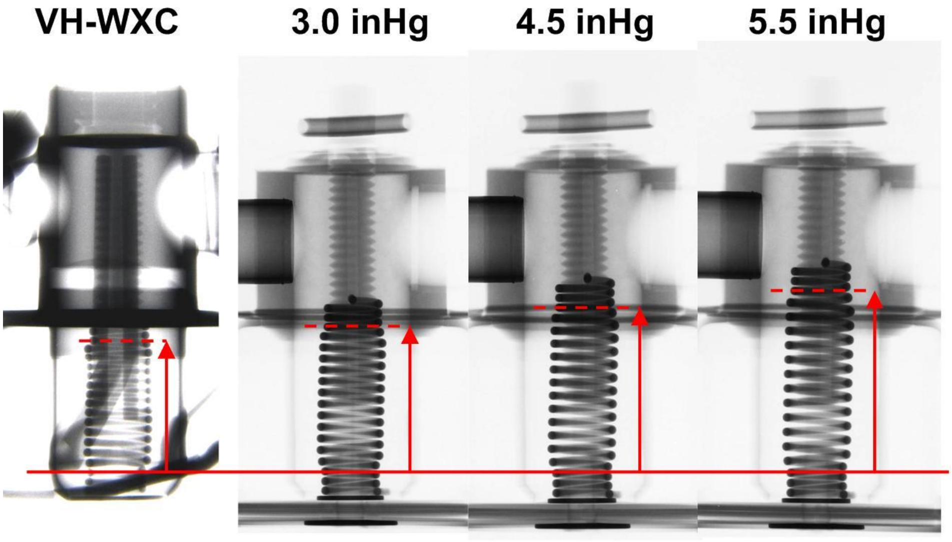
In order to evaluate the 'as-found' setting of the aircraft's vacuum relief valve, the investigation examined serviceable exemplar vacuum relief valves from a number of other light aircraft.

A series of set-points for the aircraft's vacuum relief valve was established using the exemplar valves at 3.0, 4.5, 5.0 and 5.5 inHg. A relatively large movement of the adjustment spindle was required between the set-points for the exemplar valves. Although the investigation was unable to source an identical valve to that installed in the aircraft at the time of the accident, the investigation identified an exemplar valve that had an identical spindle and diaphragm spring assembly.

The diaphragm spring tension (and hence the valve set-point) was indicated by the position of the spring end that engaged with the threaded spindle, and by the relative separation of the individual coils of the diaphragm spring. A comparison of the various set-points for the exemplar vacuum relief valve found that the lower vacuum settings corresponded with a lower diaphragm spring tension.

A comparison of the aircraft's vacuum relief valve with the exemplar unit showed that the diaphragm spring position corresponded most closely with the lowest set-point examined; 3.0 inHg (Figure 9).

Figure 9: Comparative diaphragm spring positions vs vacuum set points in comparison with the as-found regulator from WXC



Additional information

Civil Aviation Advisory Publication 5.13-2(0)

Civil Aviation Advisory Publication (CAAP) 5.13-2(0) was published by CASA in December 2006. That document provided information that was advisory in nature, providing the CASA-preferred method for complying with the relevant Civil Aviation Regulations for flight at night under the VFR.

The introduction to the CAAP stated:

> Loss of control by pilots of night visual flight rules (NVFR) aircraft in dark night conditions has been a factor a significant number of fatal accidents in this country and the purpose of this CAAP is to highlight the hazards of night flying and to provide advice to NVFR pilots and others on how to fly safe NVFR operations.

In addition to general information relevant to operating an aircraft at night under the VFR, the CAAP discussed a number of non-normal and emergency situations, including the possibility of a gyroscopic instrument (vacuum) failure. In respect of a gyroscopic instrument failure, the CAAP provided the following guidance:

> The attitude indicator will probably not fail instantaneously, but may give inaccurate indications for a time, which could be disorienting. Any loss of vacuum should be cause to use the attitude indicator with caution.
>
> If the attitude indicator is sluggish or topples, the performance of the indicator should be confirmed by reference to the turn coordinator or turn and balance indicator. If a fault is detected, it is advisable to cover the attitude indicator to avoid any distraction.

> Continued flight should still be possible using the turn indicator or a standby attitude indicator powered by an alternate power source, but current practice in instrument flying by reference to a limited panel is essential, as a number of fatal UFIT (uncontrolled flight into terrain) accidents attributable to vacuum pump failure have demonstrated.

The CAAP also included competency standards for night flying under the VFR as guidance for trainees, instructors, testing officers and holders of NVFR ratings. Those standards included performance standards for ‘Limited Instrument Panel Manoeuvres’.

Command instrument rating – partial panel proficiency

A pilot’s ability to control an aircraft without reference to the primary attitude indicator was tested during the initial issue and during subsequent renewals of a pilot’s command instrument rating. In those tests and renewals, the applicant was required to demonstrate proficiency in controlling the aircraft without reference to the primary attitude indicator during normal flight, within a specified tolerance of ± 5° heading and ± 200 ft altitude. Similarly, the applicant was required to demonstrate a recovery from an unusual attitude, without reference to the primary attitude indicator.

Airworthiness advisory circulars

A number of Airworthiness Advisory Circulars (AAC) that were relevant to aircraft suction-driven gyroscopes and the testing of aircraft vacuum systems and engine-driven (dry) vacuum pumps, have been issued by CASA. Those circulars included:

- AAC 1-87, *Gyro Failures and How to Identify Early Failures*. This AAC included information on a number of potential gyroscopic failure modes, and sought to assist pilots to identify gyroscope bearing failure in a timely manner, and to highlight a number of precautions that would minimise the risk of preventable damage to the instruments.
- AAC 1-97, *Functional Testing Aircraft Vacuum/Pressure Systems*. Manufacturer-recommended maintenance requirements for vacuum manifold systems that were equipped with more than one vacuum pump were highlighted in this AAC. In addition, the AAC discussed the deterioration of vacuum hoses, and the recommended schedule for replacement of those components.
- AAC 1-98, *Dry Vacuum Pumps*. This AAC encouraged maintenance personnel to follow the relevant manufacturer’s instructions when inspecting an aircraft’s vacuum system, and to correctly identify the cause of any vacuum pump failure. The circular provided information on the factors that may contribute to the premature failure of a vacuum pump, and included a checklist for use during pump replacement.

ANALYSIS

The physical evidence was consistent, and indicated that there was no in-flight structural failure or breakup of the aircraft, and that the engine was producing significant power when the aircraft impacted the ground. The aircraft's attitude at ground impact was consistent with its departure from controlled flight at a height from which the pilot was unable to recover.

This analysis will examine the factors that may have contributed to that departure from controlled flight.

Weather conditions in the vicinity of the accident site

The presence of a strong surface trough along the track from Warburton to Kalgoorlie increased the risk of high altitude cloud associated with the trough obscuring the celestial horizon, resulting in dark night conditions in the vicinity of the accident site. In such conditions, the pilot's reliance on the aircraft's flight instruments to maintain control of the aircraft would have increased.

Suction provided by the aircraft's vacuum system

The probable 3.0 inHg of suction that was being provided to the aircraft's suction-powered flight instruments at the time the aircraft collided with terrain, was less than that required for the reliable operation of those instruments.

The low energy evident in the gyroscope rotors at ground impact was consistent with the indication of low suction on the suction gauge. In that case, the attitude and directional indications to the pilot from the aircraft's attitude and directional indicators would have been unreliable. The lack of a warning flag or annunciator to indicate to the pilot that the related instruments may not be providing reliable indications, increased the risk that he would not recognise the unreliable indications in a timely manner.

Vacuum relief valve

The missing lockwire that was necessary to secure the lock nut to the vacuum relief valve's spindle shaft adjusting mechanism, increased the risk of a reduction in the clamping pressure against that shaft. Any loss of lock nut security could allow the spring tension on the diaphragm to move the lock nut, and therefore the adjustment spindle, towards a setting where progressively lower suction was provided to the aircraft's suction-powered flight instruments. Any in-flight vibration increased the likelihood for that to have occurred.

The aircraft maintenance records did not record any adjustments to the aircraft's vacuum relief valve. The investigation was unable to determine when the vacuum relief valve was last adjusted, or when the required lockwiring may have been omitted. The pilot reports of the suction gauge having previously normally read in the high range contrasted with the valve's as-found low suction setting. That contrasting evidence suggested that any movement of the lock nut had either gone unnoticed, or that its movement had occurred over a comparatively short period of time. Given that the pilot would have completed checks of the engine instruments prior to takeoff from Warburton, it was more probable that the adjustment spindle had moved sometime after the aircraft departed Warburton.

Loss of aircraft control

The pilot’s Command Instrument Rating and instrument flying training and proficiency assessments meant that he ought to have been able to have controlled the aircraft without reference to the primary attitude indicator. However, the ability of a pilot to recover from the loss of an aircraft’s attitude indicator is predicated on the availability of sufficient cues for the pilot to identify the failure.

The suction gauge for the aircraft’s flight instruments was on the far right side of the instrument panel. Consequently, it was out of the normal pattern of a pilot’s instrument scan, which would have increased the difficulty for the pilot of detecting an abnormal indication from that system. In the absence of any other warning cues, and given the dark night environment affecting the flight, the pilot would have had difficulty identifying an unreliable or failing attitude indicator. The investigation concluded that the loss of aircraft control was more probably the consequence of the pilot not identifying and responding to the erroneous indications from the aircraft’s attitude indicator.

Delay in the commencement of the search and rescue

The unsuccessful attempt by the pilot to nominate a SARTIME using high frequency radio meant that the pilot departed Warburton without a SARTIME for the flight. Although it was the pilot’s apparent intention to submit a SARTIME, it was not established why the pilot did not attempt to submit his SARTIME on very high frequency (VHF) radio via the Air Traffic Services VHF Warburton frequency.

The lack of a SARTIME for the flight delayed the commencement of the search for the missing aircraft. Had the pilot’s house mate not reported him overdue at Kalgoorlie, there would have been a greater delay in the commencement of the search and rescue effort. While in this case, the accident was not considered survivable, the successful nomination and acknowledgement of a SARTIME would have increased the likelihood of a more expeditious search and rescue response and, in other circumstances, had the potential to save lives.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of control involving Cessna 210M, registered VH-WXC, which occurred approximately 255 km south-west of Warburton, Western Australia on 17 October 2007. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The aircraft departed controlled flight; most probably as a consequence of the pilot not detecting and responding appropriately to unreliable attitude and directional information in sufficient time to recover the aircraft before impacting the ground.
- The suction provided to the aircraft's attitude and directional indicators was below the level required for their normal operation, increasing the risk of the provision to the pilot of unreliable attitude and directional information.
- There was no evidence that the lock nut on the vacuum relief valve's spindle shaft was lockwired, increasing the risk of the spindle shaft moving to a lower suction setting.

Other safety factors

- High altitude cloud associated with the surface trough increased the risk of the obscuration of the celestial horizon, contributing to likely dark night conditions in the vicinity of the accident site.

Other key findings

- At the time of impact with terrain, the aircraft was intact and there was evidence that the engine was producing significant power.
- The delay in commencing the search for the aircraft occurred because the pilot did not nominate a SARTIME for his arrival at Kalgoorlie.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during this investigation included:

- the aircraft operator
- a number of the aircraft operator’s employees
- the Bureau of Meteorology (BoM)
- Airservices Australia
- the WA Police Service
- the Coroner’s Court of Western Australia
- the Civil Aviation Safety Authority (CASA)
- the aircraft manufacturer
- the owner/operator of Kalgoorlie Aerodrome
- a number of witnesses at Warburton
- recorded information from a proprietary lightning monitoring network.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the aircraft owner/operator, the BoM and CASA. No submissions were received from those parties.

Aircraft loss of control 255 km SW of Warburton, Western Australia
17 October 2007, VH-WXC, Cessna Aircraft Company 210M