Australian Government

Australian Transport Safety Bureau

Safe Transport

AVIATION SAFETY INVESTIGATION REPORT
200204328

Hamilton Island Aerodrome

Piper PA-32-300, VH-MAR

26 September 2002

When the ATSB makes recommendations as a result of its investigations or research, safety (in accordance with its charter) is its primary consideration. However, the Bureau fully recognises that the implementation of recommendations arising from its investigations will in some cases incur a cost to the industry.

Readers should note that the information in ATSB reports is provided to promote safety: in no case is it intended to imply blame or liability.

Cover photo: Earlier photo of occurrence aircraft

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This report was produced by the Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608.

Readers are advised that the ATSB investigates for the sole purpose of enhancing safety. Consequently, reports are confined to matters of safety significance and may be misleading if used for any other purpose.

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INTRODUCTION

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government's Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

In terms of aviation, the ATSB is responsible for investigating accidents, serious incidents, incidents and safety deficiencies involving civil aircraft operations in Australia, as well as participating in overseas investigations of accidents and serious incidents involving Australian registered aircraft. The ATSB also conducts investigations and studies of the aviation system to identify underlying factors and trends that have the potential to adversely affect safety. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations.

Prior to 1 July 2003, the ATSB performed its aviation functions in accordance with the provisions of the *Air Navigation Act 1920*, Part 2A. This investigation was conducted under the provisions of that *Act* because it was the relevant legislation at the time of the occurrence. Section 19CA of the *Act* states that the object of an investigation is to determine the circumstances surrounding any accident, serious incident, incident or safety deficiency to prevent the occurrence of other similar events. The results of these determinations form the basis for safety recommendations and advisory notices, statistical analyses, research, safety studies and ultimately accident prevention programs. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

Under the *Air Navigation Act 1920*, it is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will, at times, contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. 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.

The 24-hour clock is used in this report to describe the Hamilton Island local time of day, Eastern Standard Time (EST), as particular events occurred. EST was Coordinated Universal Time (UTC) + 10 hours.

ABBREVIATIONS

AEP	Airport Emergency Plan
AFM	Aircraft Flight Manual
AOC	Air Operator Certificate
AMSL	Above Mean Sea Level
ATS	Air Traffic Services
ATSB	Australian Transport Safety Bureau
AVR	Automatic Voice Recording
AWI	Airworthiness Inspector
AWS	Automatic Weather Service
BAC	Blood Alcohol Concentration
BOM	Bureau of Meteorology
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	Civil Aviation Regulation
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulations
CEO	Chief Executive Officer
CFR	Code of Federal Regulations
COA	Certificate of Approval
C of R	Certificate of Registration
CPL(A)	Commercial Pilot Licence (Aeroplane)
CSU	Constant Speed Unit
EAP	Employee Assistance Program
EFATO	Engine Failure After Takeoff
ELT	Emergency Locator Transmitter
ENG	Engine
ERT	Emergency Response Team
EST	Eastern Standard Time
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCU	Fuel Control Unit
FO	Average fundamental frequency
FOI	Flying Operations Inspector
ft	Feet
G	Stress imposed on a body or item resulting from an applied force causing acceleration.
gal	Gallon
+Gz	G, which forces aircraft occupants in the direction down into their seats
HIFD	Hamilton Island Fire Department
hPa	Hectopascal
hr	Hour
Hz	Hertz
ICAO	International Civil Aviation Organization
ICUS	In command under supervision
JAA	Joint Airworthiness Authorities
JAR	Joint Airworthiness Regulation
km	Kilometre

kt	Knot
L	Litre
lb	Pound
LYC	Textron Lycoming
m	Metre
M	(Degrees) Magnetic
MBZ	Mandatory Broadcast Zone
MHz	Megahertz
MRO	Medical Review Officer
MOS	Manual of Standards
mph	Miles per hour
NCN	Non-compliance Notice
nm	Nautical Mile
NPRM	Notice of Proposed Rule Making
NSW	New South Wales
OPS	Operations
PAI	Post-alcohol Impairment
PCP	Phencyclidine
PFL	Practice Forced Landing
Prop	Propeller
QNH	Altimeter sub-scale pressure setting
REM	Rapid Eye Movement
RPM	Revolutions Per Minute
SAP	Substance Abuse Professional
SARPs	Standards and Recommended Practices
SB	Service Bulletin
STC	Supplementary Type Certificate
STI	Safety Trend Indicator
TCDS	Type Certificate Data Sheet
THC-COOH	11-nor-Δ^9-THC-9-carboxylic acid
Δ^9-THC	Δ^9-tetrahydrocannibol
Ts&Ps	Temperatures and Pressures
TTIS	Total Time in Service
UK	United Kingdom
US	United States
USA	United States of America
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
WA	Western Australia

EXECUTIVE SUMMARY

At about 1708 Eastern Standard Time (EST) on 26 September 2002, the pilot of a Piper PA-32-300 (Cherokee Six) aircraft, registered VH-MAR, reported taxiing for departure from runway 14 at Hamilton Island, Queensland. The charter flight was to Lindeman Island, a distance of about 15 km to the southeast. On board the aircraft were the pilot and five passengers.

Witnesses to the east of runway 14 at Hamilton Island reported that, shortly after the aircraft became airborne, the engine began ‘coughing’ and ‘misfiring’, before ‘cutting out’ and then ‘starting again’. Shortly after, the aircraft commenced a right turn, and the engine was heard ‘spluttering’ and ‘misfiring’. Witnesses reported that, when part way around the turn, the engine again ‘cut out’, and the aircraft descended and impacted the ground.

The aircraft came to rest upright, aligned in an east-north-easterly direction, approximately 300 m to the west of the runway centreline and approximately 100 m south of the departure end of the runway. A severe post-impact fire consumed the majority of the aircraft’s fuselage. The six occupants of the aircraft were fatally injured.

The pilot was qualified, appropriately endorsed and authorised for the operation. The pilot’s condition and demeanour on the day of the occurrence were reported to be normal.

There was no evidence that fuel contamination, amount of fuel carried, structural failure or meteorological conditions were factors in the occurrence.

The engine installed in the aircraft was different from that specified in the aircraft Type Certificate Data Sheet. Notwithstanding, the Civil Aviation Safety Authority (CASA) and the engine manufacturer reported that the installed engine should have been capable of producing the power output expected from the engine certified for installation in the Cherokee Six. Furthermore, the engine had been in service in the aircraft for 126.2 flight hours with no reported power abnormalities, suggesting that, provided there were no defects, the engine should have been capable of producing the required power throughout its operating range.

The extensive damage caused by the impact forces and post-impact fire prevented functional testing of a significant number of aircraft and engine components. On the available evidence, there was nothing found to suggest what may have degraded the engine performance to the extent reported by the witnesses to the occurrence.

Post-mortem toxicological examination of the pilot’s blood revealed a blood alcohol concentration (BAC) of 0.081%, the presence of an inactive metabolite of cannabis, and an analgesic preparation consistent with a therapeutic dosage. The possibility that the pilot’s BAC reading resulted at least in part from post-mortem alcohol production could not be discounted.

There was insufficient evidence to definitively link the pilot’s prior intake of alcohol and/or cannabis with the occurrence. However, the adverse effects on pilot performance of post-alcohol impairment, recent cannabis use and fatigue could not be discounted as contributory factors to the occurrence. In particular, the possibility that the pilot experienced some degree of spatial disorientation during the turn as a combined result

of the manoeuvre, associated head movements and alcohol-induced balance dysfunction could not be discounted.

The following factors were considered to have significantly contributed to the occurrence.

1. Based on witness reports, the aircraft's engine commenced to operate abnormally shortly after lift off from the runway.

2. The pilot initiated a steepening right turn at low level.

3. The aircraft stalled at a height from which the pilot was unable to effect recovery.

The operator has initiated a number of safety actions in order to mitigate some of the issues identified in the report. Those actions include the areas of: company pilot training, fatigue management, documentation, and aircraft operations.

The ATSB has issued four recommendations concurrent with the release of this report. The first three recommendations address the potential use of alcohol and drugs by safety-sensitive personnel in the Australian aviation industry, and options to manage the safety risk to the travelling public of that potential use. The fourth recommendation addresses the CASA Air Operator Certificate Safety Trend Indicator surveillance methodology. In addition, two Safety Advisory Notices have been issued to CASA relating to pilot manipulation of the Cherokee Six fuel selector and development by operators of pilot induction training programs.

1. FACTUAL INFORMATION

1.1. History of the flight

On 26 September 2002, at about 1708 Eastern Standard Time (EST), the pilot of a Piper PA-32-300 (Cherokee Six) aircraft, registered VH-MAR, reported taxiing for departure from runway 14 at Hamilton Island, Queensland. The charter flight was to Lindeman Island, a distance of about 15 km to the southeast. On board the aircraft were the pilot and five passengers. An indication of the proposed flight path is at Figure 1.

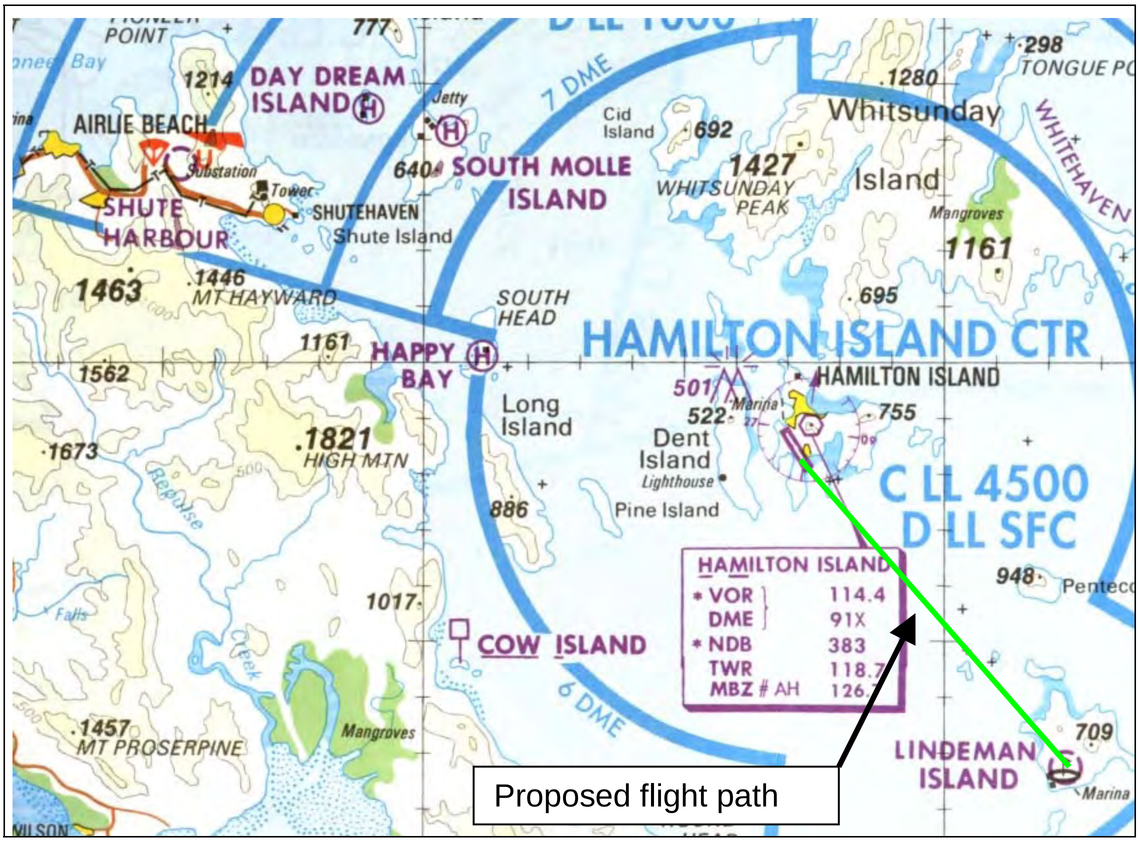

Figure 1: Hamilton Island and environs

Witnesses reported that the pilot backtracked along runway 14 to a position abeam taxiway A, prior to turning the aircraft and commencing its take-off run. The aircraft was reported to have become airborne at a point about 1,000 ft before the end of the runway.

Reports from witnesses to the east of the runway indicated that, shortly after take off, the engine was heard 'coughing' and 'misfiring', before 'cutting out' and then 'starting again'. Shortly after, the aircraft was seen to commence a right turn, and the engine was heard 'spluttering' and 'misfiring'. It was reported that the aircraft's wings progressed from an angle of about 60 degrees to the horizon early in the turn, to a 'steep' angle at which the wings approached being '…vertical to the ground'.

A number of witnesses reported that, when part way around the turn, the engine again 'cut out', and the aircraft descended '…like a dart' before impacting the sloping ground of the hillside. There was no report of any object falling from the aircraft, or of any vapour or smoke emanating from the aircraft. The maximum height achieved by the aircraft was reported as approximating the 98 m (322ft) elevated ground to the southwest of the runway end and in the background of the witnesses field of vision. An indication of the probable aircraft flight path is at Figure 2.

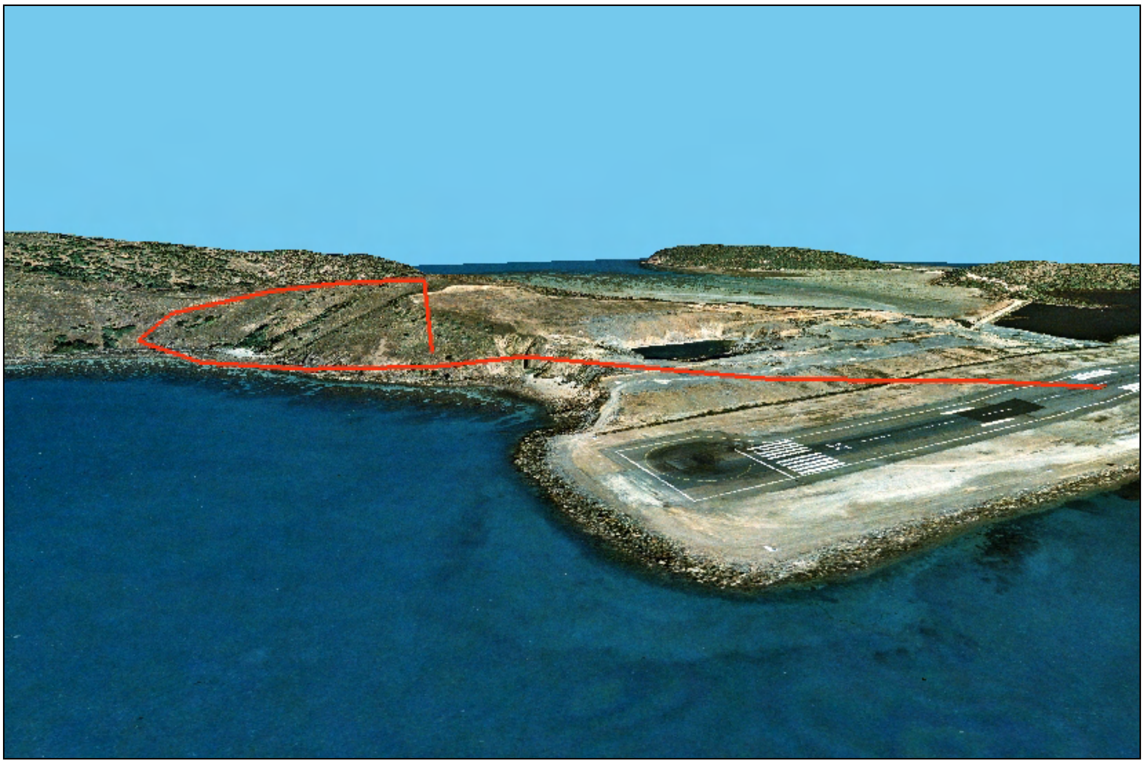

Figure 2: Probable aircraft flight path

The aircraft came to rest upright, aligned in an east-north-easterly direction (see figure 7), approximately 300 m to the west of the runway centreline and approximately 100 m south of the departure end of the runway. A severe post-impact fire consumed the majority of the aircraft's fuselage.

1.2. Injuries to persons

Injuries	Crew	Passengers	Others	Total
Fatal	1	5	-	6
Serious	-	-	-	-
Minor	-	-	-	-
None	-	-	-	-

Post-mortem results indicated that the aircraft occupants were fatally injured as a direct result of injuries from impact forces.

1.3. Damage to aircraft

The aircraft was destroyed by impact forces and post-impact fire.

1.4. Other damage

There was no injury to persons other than the aircraft occupants, or damage to property or the environment as a result of the aircraft impact with the ground or subsequent fire.

1.5. Personnel information

1.5.1. General information

Type of licence	Commercial Pilot (Aeroplane) Licence
Medical certificate	Class One (Nil restrictions)
Flying experience (total hours)	1,300.4
Hours on the type	19.2
Hours flown in the last 24 hours	3.9
Hours flown in the last 7 days	19.2
Hours flown in the last 90 days	189.8

The pilot commenced flying training in Sydney, NSW in March 1998. He obtained his Commercial Pilot (Aeroplane) Licence in July 1999, and a Grade Three (Aeroplane) flight instructor rating in November 1999 at the same flying school. The pilot accrued about 780 instructional hours working at that school and achieved his initial multi-engine endorsement on 14 November 1998.

Between 24 May and 12 September 2002, the pilot was employed by a charter operator based in Kununurra, in the north of WA. During that time, the pilot flew Cessna 206, Cessna 207 and Gippsland Aeronautics GA8 Airvan aircraft; the largest portion of that flying being in the Cessna 207. The pilot was reported to have departed the company on amicable terms, having flown more than 400 hours.

The pilot commenced employment with the Hamilton Island operator on 19 September 2002, and held the relevant aircraft class and special design feature endorsements to allow operation of the Cherokee Six. He also satisfied the recent experience requirements of the Civil Aviation Regulations (CAR), and was certified competent in the execution of flight crew emergency procedures in accordance with Civil Aviation Order (CAO) 20.11.

1.5.2. Pilot 72-hour history

The occurrence flight occurred within the pilot's first week of employment with the operator. During that week, a friend that the pilot had initially met during his previous employment in the north of WA, arrived in the Whitsunday area. The pilot socialised with the friend and phoned and communicated via text message with a number of family members, friends and recent acquaintances and work colleagues during that period. When interviewed, those individuals indicated that the pilot was not experiencing any degree of personal distress and that he was happy with his new position.

A witness reported that, on 23 September 2002, the pilot retired for bed sometime after 2345. The pilot was free from flying duties on 24 and 25 September and moved into alternative accommodation on 25 September. While the pilot's eating and sleeping patterns could not be fully determined for those days, the pilot was reported to have consumed several alcoholic drinks on the night prior to the occurrence, before retiring to his hotel room at about 2300.

Telephone records revealed that the pilot made two calls and sent four text messages to the visiting friend that night, the last being at 0042 on the day of the occurrence. Subsequently, the pilot spoke to that friend on the day of the occurrence at 1406 for 1 minute 30 seconds. The pilot informed the caller that everything was alright.

On the day of the occurrence, the pilot arrived at work at about 0725. That was 10 minutes after the planned take-off time of a positioning flight in which he was a passenger. Witnesses reported that, although appearing rushed, there was nothing unusual about the pilot's observed physical condition or mental state throughout the day of the occurrence.

On the afternoon of the occurrence, a company pilot reported confronting the occurrence pilot after he saw him perform a downwind landing at Shute Harbour at about 1610. The company pilot reported that he became very irate with the occurrence pilot and spoke to him in a forceful manner. The occurrence pilot replied that he was aware of the downwind conditions but that, in his previous employment, downwind landings were conducted to save time. The impact of that interaction upon the pilot's subsequent performance could not be established.

The pilot's physiological status, including fatigue, is discussed further in sections 1.13 and 1.18.9 and 10 of this report.

1.6. Aircraft information

1.6.1. General information

Manufacturer	Piper Aircraft Company
Model	PA-32-300 Cherokee Six
Serial number	32-40920
Registration	VH-MAR
Year of manufacture	1970
Certificate of airworthiness	Issued 18 August 1975
Certificate of registration	Issued 30 July 2002
Maintenance release	Valid to 11,288.6 hours / 16 September 2003
Total airframe hours	11,219

Based on the available evidence, the aircraft was calculated to have been within weight and balance limitations at the time of the occurrence.

1.6.2. Aircraft history

The aircraft's maintenance release was recovered from the accident site. It revealed that there were no recorded unserviceabilities, and that a daily inspection had been carried out on the aircraft on the day of the occurrence. However, damage to the maintenance release precluded identification of the person certifying completion of that inspection.

The most recent scheduled maintenance on the aircraft was a 100 hour inspection completed on 16 September 2002, 10 days before the occurrence. At that time, the aircraft had completed 11,188.6 hours total time in service (TTIS). The aircraft subsequently accrued 30.4 hours time in service before the occurrence.

1.6.3. Engine

The engine installed in the occurrence aircraft was a Textron Lycoming IO-540 series six cylinder, normally aspirated, piston engine. The engine was installed in the occurrence aircraft on 24 May 2002 after accruing 979.6 hours in a different aircraft type. At the time of the occurrence, the engine had accrued 126.2 hours in the occurrence aircraft, 1,105.8 hours since overhaul and 12,305 hours TTIS.

The aircraft's maintenance records indicated that, prior to installation in the occurrence aircraft, and subsequent purchase of the aircraft by the operator, the engine had been converted from a 'K1C5' specification engine to one considered by the responsible engineering organisation to be suitable for installation in a Cherokee Six. However, the lack of documentation required to legitimise the conversion meant that, for regulatory purposes, the engine remained a 'K1C5'. Additionally, there was no evidence that the engine data plate[1] had been changed to reflect the conversion.

The Type Certification Data Sheet[2] (TCDS) for the Cherokee Six specified that the aircraft should be fitted with a Textron Lycoming IO-540-K1A5 specification engine rated at 300 HP. The occurrence aircraft - engine combination was not consistent with the aircraft's certification standard.

A CASA powerplant specialist reported that, aside from the regulatory issues, the recorded engine hardware change should have had no practical effect on engine operation. The engine manufacturer advised that if the engine was converted to an IO-540-K1A5, and the governor was correctly set, it should have produced 300 horsepower at the rated 2,700 RPM.

1.6.4. Fuel system

Two main fuel tanks were located in the inboard leading edge section of the aircraft's wings. There were also two fibreglass tip tanks. Approximately 1 US pint (0.5 L) in each of the four tanks was unusable. The Cherokee Six Owner's Handbook included the following operating tips:

> The shape of the wing fuel tanks is such that in certain maneuvers the fuel may move away from the tank outlet. If the outlet is uncovered, the fuel flow may be interrupted and a temporary loss of power may result. Pilots can prevent inadvertent uncovering of the outlet by avoiding maneuvers which could result in uncovering the outlet.
>
> Prolonged slips or skids in any pitch attitude or other unusual maneuvers which could cause uncovering of the fuel outlet must be avoided when the tank selected is not full.

Fuel lines connected each tank to an underfloor fuel selector valve. The fuel selector control was located on the floor beneath the centre of the aircraft's instrument panel. It had five positions, corresponding to: an OFF selection; followed by left tip; left main; right main; and right tip tanks when moving the selector from left to right. Those fuel selector control positions are indicated at Figure 3. The in-cockpit location of the fuel selector control is indicated in the occurrence aircraft cockpit photograph at Figure 4.

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[1] A data plate is a fireproof plate that identifies the basic specifications of the unit to which it is attached.
[2] The Type Certification Data Sheet documents the compliance of an aircraft design with the applicable design standards.

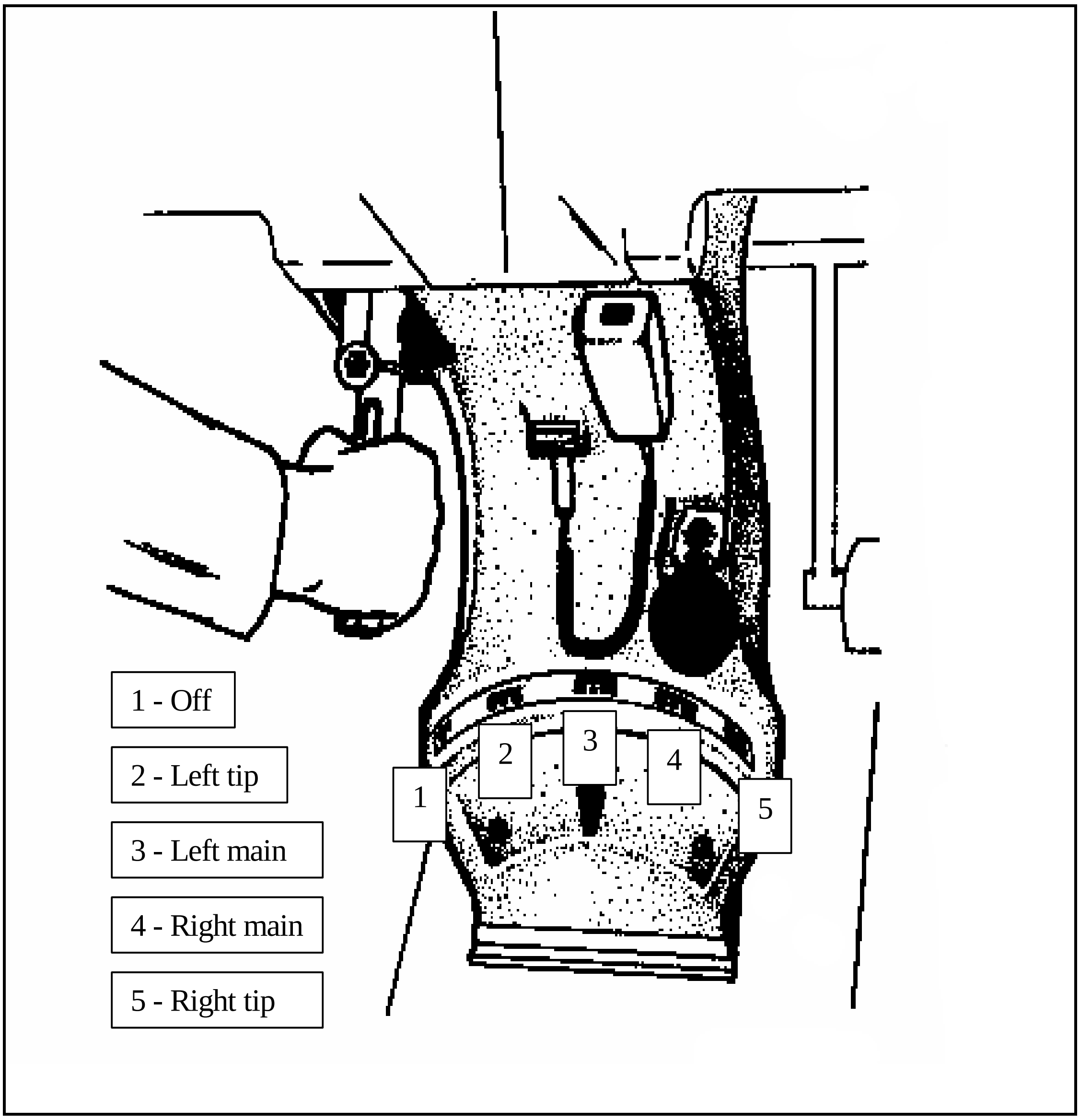

Figure 3: Fuel selector control positions

Figure 4: Occurrence aircraft cockpit photograph

Fuel tank selection was to be checked '…on the proper tank' as part of the Cherokee Six Owner's Handbook Takeoff Checks and was indicated by the position of the fuel selector control and by detent 'feel'. Tank selection ported fuel through a corresponding hole in the fuel selector plate valve and into the fuel bowl. The aircraft manufacturer's service manual stated that:

> When the fuel selector is not in a positive selector detent position, more than one port will be open at the same time.

Fuel then passed through a filter, before being conveyed to a fuel control unit (FCU) via a manually selectable electric fuel pump and then engine driven fuel pump. The electric fuel pump was provided in case of failure of the engine driven pump, and was required to be in the ON position for all takeoffs and landings.

1.6.5. Stall warning

The aircraft's stall warning system provided the pilot with an indication of impending stall by activation of a red light located on the left side of the instrument panel. The aircraft was not equipped with an aural stall warning device.

1.7. Meteorological information

The aviation forecasts prepared by the Bureau of Meteorology described the weather conditions for the day of the accident. Hamilton Island was located in aviation forecast area 44. The forecast prepared at 1326 EST, and valid from 1500 to 0300 EST the next morning, indicated 'mostly good conditions' would exist throughout the area, with 'isolated areas of smoke'. The 2,000 ft wind was forecast to be 048° magnetic (M) at 10 kts. Scattered cumulus and stratocumulus cloud was forecast over the 'sea, coast [and] ranges' with a base of 2,500 ft. Visibility was forecast to be 8 km in smoke, reducing to 1,000 m in thick smoke. The freezing level was forecast at 12,500 ft.

The aerodrome forecast for Hamilton Island, issued at 1102 EST and valid from 1200 EST until 2359 EST indicated a wind of 078° M at 12 kts and visibility greater than 10 kms. Scattered cloud was forecast with a base of 2,500 ft. The temperature was forecast to be 24 degrees and the sea-level altimeter sub-scale pressure setting (QNH) 1018.

The 1700 EST readout from the Hamilton Island Automatic Weather Service indicated a wind of 100° M at 13 kts, with gusts to 15 kts. The observed temperature was 23 degrees, the dew point 19 degrees and the sea-level QNH was 1017.4 hPa.

Witnesses to the eastern side of the upwind end of runway 14 reported that conditions were clear, and that the wind was '…blowing about 5 kts south-easterly'.

1.8. Aids to navigation

There were no navigation aids, landing aids, or visual ground aids that were relevant to the planned flight, which was operated under the Visual Flight Rules.

1.9. Communications

At the time of the occurrence, Hamilton Island Air Traffic Services (ATS) were not available, having ceased operations for the day, and Mandatory Broadcast Zone (MBZ) procedures were in place. The Whitsunday MBZ radio frequency of 126.7 MHz was not monitored or recorded by Hamilton Island ATS.

The airfield owner/operator utilised an audio cassette recorder in the airfield control tower in order to record the MBZ frequency as a history of arrivals and departures at Hamilton Island. That audio cassette recording apparatus did not include the capability to annotate time or other indicators on the audio cassette tape.

Transmissions made by the pilot on the MBZ frequency, and recorded by the airport owner/operator's audio cassette recorder were recovered and examined. The transmissions included those required by the Aeronautical Information Publication for operations in an MBZ and indicated compliance with procedures for such operations. The transmissions provided no evidence that the pilot was experiencing abnormal aircraft operations.

1.10. Aerodrome information

Hamilton Island airfield elevation was 15 ft (4.6 m) above mean sea level. The airfield had a sealed runway with a Take-off Run Available and Accelerate-stop Distance Available of 1,764 m or 5,787 ft. The runway was aligned southeast (runway 14) to northwest (runway 32). There was no gradient promulgated for either runway. A windsock was located abeam each runway threshold. Right circuits were promulgated in the Enroute Supplement (Australia)[3] for operations on runway 14.

The majority of the airfield services, the passenger terminal and the aircraft operator's facility and tarmac were located on the eastern side of the runway. Four taxiway inverts allowed entrance to the runway from the eastern side of the runway:

- Taxiway C, from abeam the operator's tarmac and allowing approximately 1,075 m (3,527 ft) take-off distance available
- Taxiway B, allowing approximately 1,200 m (3,937 ft) take-off distance available
- Taxiway A, allowing approximately 1,480 m (4,856 ft) take-off distance available
- Taxiway E, allowing approximately 1,560 m (5,118 ft) take-off distance available.

The runway 14 extended centreline was over water. Elevated ground was located to the right of the extended centreline and a sheltered, sweeping bay was to the left. Departure from runway 14 on the majority of standard company routes normally involved a right turn after takeoff. An aerial photograph of Hamilton Island is at Figure 5.

[3] The Enroute Supplement (Australia) is published by Airservices Australia and includes aerodrome and facilities information, route flight planning requirements, conversion tables.

Figure 5: Aerial photograph – Hamilton Island

1.11. Flight recorders

The aircraft was not fitted with a flight data recorder or cockpit voice recorder, nor was either required by the relevant aviation regulations.

1.12. Wreckage information

1.12.1. Overview of wreckage

The accident site was located approximately 300 m to the west of the take-off runway centreline and approximately 100 m south of the departure end of that runway. The terrain at the accident site was inclined at an average of 19 degrees down to the horizon, with light scrub and numerous small groups of palm trees. Numerous large rocks were found in the vicinity of the impact point. A photograph of the location of the accident site is at Figure 6.

Figure 6: Accident site location

The aircraft wreckage was substantially intact, upright and in the immediate proximity of the impact point. The nose of the aircraft was oriented in an east-north-easterly direction. All structural components and flight control surfaces were located in the immediate vicinity of the wreckage. That was consistent with the aircraft being intact upon impact with the ground. A severe post-impact fire consumed the majority of the aircraft's fuselage. A photograph of the aircraft at the accident site is at Figure 7.

Figure 7: Accident site aircraft photograph

The aircraft struck the ground with minimal forward speed over the ground. Indications were that the right wing of the aircraft contacted the ground first, while slightly banked to the right and in a nose low attitude. That was estimated to have been about 70 degrees nose down to the horizon. There was evidence of aircraft rotation to the right at ground impact.

1.12.2. Wreckage examination

Impact forces fully compressed the cockpit-to-engine firewall space. There was no evidence of aircraft impact with the ground prior to it coming to rest at the accident site.

The right wing exhibited impact damage to the lower leading edge and the main fuel tank was ruptured and protruded forward of the wing leading edge. The wing tip tank was dislodged from the wing, but remained largely intact. Damage to the wing was consistent with impact with the ground and adjacent rocks.

Impact forces distorted the left wing leading edge and breached the main fuel tank. The leading edge wing tip exhibited crush damage. The post-impact fire consumed the underside of the left wing and tip tank.

Impact forces disrupted the left and right underwing fuel tank vents. The fuel tank caps were secured in place and visual inspection revealed no abnormalities.

Due to the extensive impact damage and post-impact fire, no fuel samples could be recovered from the wreckage.

Damage to the propeller assembly indicated propeller rotation at the time of impact. Two of the three propeller tips were found at about 52 m and 79 m to the south of the point of impact.

The propeller spinner was wedged against a large rock and the propeller was found loosely attached to the engine crankshaft. The crankshaft was bent to the right and down from its normal position. The engine was largely intact, but the post-impact fire had consumed the sump. There was extensive damage to the induction and exhaust system piping.

Most of the cabin fittings and the aircraft fuselage were consumed down to the level of the floor pan by the post-impact fire. That fire damage continued aft to the stabilator assembly. The stabilator assembly was complete and the vertical stabiliser was intact. There was impact damage to the outboard under surface of the left stabilator, consistent with its having struck surrounding rocks. Fire had consumed all three aircraft tyres.

Due to extensive impact and fire related damage, on-site examination of the remnants of the cockpit controls and the aircraft flight instruments did not provide any conclusive information about pre-impact instrument indications and control positions. The position of the park brake handle was unable to be determined.

Pre-impact flight control continuity was evident for all flight controls. Damage to both of the flap actuating rods indicated some degree of flap extension at impact. However, due to the substantial impact and fire damage, the investigation could not determine the pre-impact position of the flaps. The stabilator trim was found in the neutral position.

1.12.3. Examination of components recovered from the wreckage

Fire damage precluded functional testing of the recovered components and limited the extent of their examination.

1.12.3.1. Engine and propeller

The aircraft engine and propeller were recovered from the accident site and inspected at an authorised overhaul facility under the supervision of the ATSB.

The engine inspection revealed that the only anomalous observation attributed to pre-impact engine operation was a tight fitting number-2 cylinder exhaust valve. There was no sign of the collateral damage normally associated with a valve that had stuck during engine operation. Data published by the engine manufacturer indicated that sticking valves would almost always cause an engine to run very rough at engine start, and that a sticking valve condition is often identified by an intermittent hesitation or miss in engine speed.

The propeller inspection revealed significant damage to the propeller, consistent with ground impact, with no evidence of any pre-impact defects. Witness marks were evident on the butt and pre-load plates of two of the three blades. Those marks indicated that the two blades had been at fine pitch at ground impact. Damage to the butt and pre-load plate of the remaining blade prevented an assessment of its pitch angle at impact. Damage to all pitch change knobs was consistent with the turning moment generated by rearward bending of the blades during propeller rotation. Expert advice was that the nature of the damage to the blades indicated that the propeller had been powered by at least 50% engine power when the blades contacted the ground.

1.12.3.2. Fuel system

The following fuel system components were recovered from the wreckage and were subsequently examined to determine their pre-impact functionality:

- fuel selector valve
- electric fuel pump
- engine driven fuel pump
- FCU
- flow distributor
- injector lines
- fuel nozzles.

The fuel selector valve was in a beyond the OFF position consistent with being driven beyond the off detent by impact forces. The absence of witness marks on the fuel selector housing and plate prevented determination of the position of the fuel selector mechanism prior to impact. There was no evidence of any pre-existing defects. Although the fuel selector valve detent mechanism was intact and showed minimal wear, it was not possible to determine its pre-impact effectiveness.

One of the two motor brushes in the electric fuel pump was badly worn. There was no evidence of any arcing or other damage normally associated with a brush malfunction. It was not possible to determine if the pump was operating at the time of occurrence.

Examination of the engine driven fuel pump, FCU, flow distributor and injector lines did not reveal any anomalies or defects consistent with pre-impact unserviceability. The FCU inlet filter was intact, with no evidence of contaminants or other residue.

The fuel nozzles were subjected to visual, radiographic and pneumatic examination. While three of the six injectors were obstructed, the evidence indicated that those contaminants were a product of the post-impact disruption and fire. Overall, there was no conclusive evidence of pre-occurrence contamination of one or more fuel injector nozzles.

1.12.3.3. Ignition system

The following ignition system components were recovered from the wreckage and were subsequently examined to determine their pre-impact functionality:

- ignition switch
- left and right magnetos
- spark plug leads
- spark plugs.

The ignition switch mechanism was found in the BOTH (magnetos ON) position. There was no evidence of any pre-existing defects in the switch mechanism.

The internal condition of both magnetos was severely compromised as a result of intense heat. As a result, the investigation was unable to determine the pre-impact serviceability of the internal components of either magneto. The impulse coupling fitted to the left magneto showed no sign of mechanical damage. Data published by the engine manufacturer indicated that failure of one magneto would result in a 3% engine power loss.

Extensive impact and fire damage to all spark plug leads precluded their examination and test.

All 12 spark plugs displayed minimal wear, and all but the number-4 cylinder lower spark plug exhibited residue consistent with normal combustion. That plug exhibited a contaminant bridging the electrodes and an oily residue consistent with pre-impact accumulation, and was the only plug that would not fire when tested. Data published by the engine manufacturer indicated that failure of one spark plug would degrade engine take-off power output by less than 1%.

1.12.4. Induction and exhaust

The air box assembly and air filter were destroyed. The post-impact fire consumed the sump containing the induction plenum and disrupted the induction pipes.

Impact forces destroyed the exhaust system precluding its examination. Data published by the engine manufacturer indicated that loose muffler baffles may result in a loss of power and that a blocked exhaust system could result in engine power loss due to the excessive back pressure.

1.12.5. Stall warning system

The wing-mounted stall warning actuator was functionally examined and tested. There was no evidence of any pre-existing defects.

1.13. Medical and pathological information

1.13.1. Autopsy and toxicology

A review of the pilot's medical records, and the results of post-mortem examinations and toxicological testing, found no evidence of any pre-existing medical disease that may have influenced the pilot's performance.

Toxicological testing revealed the presence of alcohol, cannabis metabolites,[4] opiates and paracetamol in the pilot's blood. The pilot's blood carbon monoxide level could not be assessed because of the blood sample's unsuitability for such analysis. It could not be determined whether the pilot had eaten or consumed any fluids during the eight to 12 hours preceding the occurrence.

The pilot's blood alcohol concentration (BAC) was found to be 0.081%. However, the examining toxicologist stated that, due to the possibility for post-mortem production of alcohol, that result should be interpreted with caution. The nature of the pilot's injuries precluded examination of other body fluids in order to determine the source of the pilot's BAC or confirm recent use of cannabis. While it was reported that the pilot consumed a quantity of alcohol during the evening prior to the day of the occurrence, the rate of alcohol consumption, whether the pilot had concurrently consumed food, or the time of the last drink could not be established.

Post-mortem toxicological analysis of the pilot's blood identified the presence of 11-nor-Δ^9-THC-9-carboxylic acid (THC-COOH), an inactive metabolite of cannabis. The presence of Δ^9-tetrahydrocannabinol (Δ^9-THC), the most potent and psychoactive constituent of cannabis, could not be confirmed or excluded in the toxicological analysis due to decomposition interferences.

The detection of THC-COOH in the pilot's blood indicated the use of cannabis within the previous few weeks, but did not necessarily indicate that the pilot was under the influence of cannabis at the time of the occurrence. The pilot was reported to be a user of cannabis and police advice was that smoking implements found in the pilot's personal effects indicated recent use.[5] Those implements were sent by the police to a forensic laboratory for DNA testing. That testing indicated that there was no difference between the DNA identified on one of the smoking implements and that obtained from the occurrence pilot. While the toxicological evidence was inconclusive, the possibility that the pilot had recently used cannabis could not be discounted.

Morphine and codeine were also detected in the blood of the occurrence pilot. The autopsy report noted that the levels of those two drugs, and the ratio between them suggested that the morphine was a metabolic by-product of the codeine. The co-existence of paracetamol, according to the report, suggested that those drugs reflected

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[4] 11-nor-Δ^9-THC-9-carboxylic acid

[5] Police defined recent use as estimated as having been used within 14 days.

the use of an analgesic preparation containing paracetamol and codeine (such as Panadeine), and that the levels were consistent with therapeutic use.

A second toxicological analysis of the pilot's blood samples was conducted on the advice of the responsible forensic laboratory. That independent second analysis restricted its analytical comment to the presence of cannabis metabolites. The second toxicologist's report confirmed the presence of THC-COOH and commented that an analysis for Δ^9-THC could not provide any results because of degradation of the pilot's blood specimens.

In support of the investigation, an aviation medicine specialist was commissioned by the ATSB to conduct research into the effects of alcohol and cannabis on human performance from an aviation perspective. That research has recently been released by the ATSB in the form of two discussion papers that are available on the ATSB website at www.atsb.gov.au.[6, 7]

1.13.2. Civil Aviation Safety Authority pilot medical questionnaires

A pre-requisite for renewal of the pilot's Medical Certificate was completion of the Civil Aviation Safety Authority form, *Medical Questionnaire and Examination Form for Revalidation of a Medical Certificate which is Current or has Lapsed for Less than Five Years.* Section 4 of that form was a Health Questionnaire. The Health Questionnaire sought a 'Yes' or 'No' response from the applicant to the following item:

> Since the last aviation medical examination, or in the last two years has the applicant:
>
> 7A. EVER, or is he/she NOW using any of the following substances: opiates, cannabinoids, sedatives and hypnotics, cocaine, other psychostimulants, hallucinogens or volatile solvents?

Item 7A did not appear in Section 4 of the medical questionnaire forms completed annually by the occurrence pilot until his medical examination on 24 March 2000. The occurrence pilot had, when renewing that, and the following two Medical Certificates answered 'No' to item 7A. The issues associated with self-disclosure of information during medical examinations are discussed in section 2.5.2.2.

1.14. Fire

There was no report or evidence of an in-flight aircraft fire. A severe post-impact fire was confined to the aircraft wreckage and consumed the majority of the aircraft fuselage and cabin area.

The source of the intense fire was from fuel that had spilled from the ruptured wings. The ignition source of the fire could not be positively identified, but was likely from fuel spillage from the ruptured right wing coming into contact with the hot engine.

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[6] Newman, D. G. (2004). *Alcohol and human performance from an aviation perspective: A review*. Canberra, ACT: Australian Transport Safety Bureau.

[7] Newman, D. G. (2004). *Cannabis and its effects on pilot performance and flight safety: A review*. Canberra, ACT: Australian Transport Safety Bureau.

It was reported that a handheld fire extinguisher was carried to the accident site by one of the group of people first on the scene. That person expended the portable extinguisher on the aircraft fire, but without effect.

An Aerodrome Rescue and Fire-Fighting Service was not in place at Hamilton Island at the time of the occurrence, neither was there any regulatory requirement for that level of service.

The Hamilton Island Fire Department (HIFD) consisted of one permanent Fire Chief and 10 other volunteer fire fighters. The Department base was located in the eastern, built-up area of Hamilton Island. The Fire Chief was reported to be immediately available for regular public transport passenger carrying operations. All fire fighters were reported to be contactable via the fire member pager group for all other airport response and other requirements.

At about 1715, the HIFD fire member pager group was activated with a message indicating ‘Plane down at end of runway, on fire…’ and the general location of the fire. Access to the scene of the accident was through an abandoned quarry via a four-wheel drive track, which included a number of steep grades that prevented rapid access to the accident site. The HIFD arrived at the scene of the accident by about 1727, and commenced efforts to extinguish the fire.

The HIFD fire-fighting equipment included an 1,800 L, two-wheel drive pumper fire tender that included an integral 200 L aqueous foam tank, and a back-up 5,000 L water tanker. On arrival at the scene of the accident, the HIFD fire crew commenced managing the post-impact fire under the direction of the Fire Chief. They were unsuccessful in their initial attempts to extinguish the aircraft fire using two portable dry chemical fire extinguishers, and they then used the aqueous foam to extinguish the fire amongst the aircraft wreckage and surrounding grass, and to cool a number of ‘hot spots’.

The fire was contained within 18 m downwind of the aircraft. It was reported that the fire-fighting effort did not expend all of the fire-fighting liquid available at the accident site.

1.15. Survival aspects

The aircraft was not fitted with a fixed emergency locator transmitter (ELT). The aircraft maintenance release was annotated with the requirement for the carriage of a portable ELT when required. CAR 252A did not require the carriage of an ELT during the occurrence flight.

The six occupants were located within the aircraft cockpit and cabin wreckage area. The destruction of the aircraft cockpit and passenger cabin from the combined effects of the impact forces and post-impact fire rendered the accident non-survivable.

1.16. Tests and research

1.16.1. Examination of fuel samples taken from the fuel supplier

Examination of the aircraft’s Flight Record and local fuel suppliers’ documents indicated that, on the day of the occurrence, the pilot conducted three refuelling operations. Those refuels were from the same mainland fuel supplier. That supplier quarantined a fuel sample for test by the fuel manufacturer.

The investigation team also quarantined 20 L of that fuel for subsequent independent examination.

The fuel manufacturer and independent laboratory tests of the fuel samples were consistent and indicated that the fuel:

- was Aviation Gasoline 100/130 Green
- contained no visible water or sediment
- was clear and bright
- complied with relevant industry standards.

Examination of the mainland fuel supplier’s records confirmed that, on the day of the occurrence, nine other aircraft refuelled from the same fuel source as the occurrence aircraft on a total of 15 occasions between 0925 and the time of the occurrence. There were no reports from the pilots of those aircraft of any fuel-related problems that day.

1.16.2. Radio transmission audio analysis

The investigation team conducted an audio analysis of the pilot’s radio transmissions made from the occurrence aircraft. Those transmissions were recorded on the airport owner’s audio cassette and the ATS automatic voice recording (AVR). The audio cassette recordings were of the occurrence flight, and the AVR recordings were of the 1600 sector from Hamilton Island to Shute Harbour, where passengers reported significant vibration during the takeoff (see section 1.18.3.5). The analysis provided no evidence of any predominant frequencies that could be attributed to abnormal aircraft engine operation.

1.16.3. Analysis of pilot’s speech

Speech analysis holds promise as a technique for detecting changes in the psychological and/or physiological state of a speaker that may be associated with: fatigue; hypoxia; alcohol intoxication; drug impairment; physical exertion; workload demand; emotional stress; and fear (see attachment A). An independent forensic phonetician was commissioned to conduct an analysis of the pilot’s speech. The analysis was conducted to help provide additional insight into the pilot’s physiological status and its possible impact on the pilot’s fitness for duty on the day of the occurrence.

The analysis included two components: *auditory* analysis, which provided a qualitative assessment of observations of the pilot’s voice; and *acoustic* analysis, which provided a quantitative assessment of the pilot’s voice.

The independent analysis reported that there were observed changes in the pilot’s voice quality and pitch, and speech and articulation rates recorded on the day of the occurrence, when compared with his recorded voice on previous flying days. The phonetician stated that those changes were consistent with the hypothesis that the pilot may have been experiencing some form of physiological irregularity on the day of the occurrence. However, the observable differences in the pilot’s speech were not statistically significant.

1.17. Organisational and management information

1.17.1. Operating organisation

1.17.1.1. Organisational structure

The company had evolved as part of a widely dispersed aircraft and helicopter operation. That included a mustering division, a tourism division that incorporated elements in Sydney and at Hamilton Island, and a commercial division located at Bankstown, NSW.

An Air Operator Certificate (AOC) authorised the operator to conduct aeroplane operations, including charter operations utilising the Cherokee Six aircraft. Two additional AOCs authorised the company helicopter operations. Three Chief Pilots provided management support for those AOCs. The Chief Pilot for the aeroplane operation, which included the air taxi element, was based at and living on Hamilton Island and was in the midst of establishing himself on the mainland.

Day to day operational control of the air taxi operation was administered from Shute Harbour, on the mainland. The remainder of the company, including the engineering and support elements, was operated and administered from the company's base at Hamilton Island.

1.17.1.2. Organisational change

The Managing Director reported that the financial viability of the company was the key concern upon assuming control of the tourism division. He reported rationalising the air taxi aircraft type mix from seven to three types. Benefits of that management initiative were reported to include easier management of the pilot roster and endorsements, a diminished inventory of aircraft spare parts and a reduction in the number of aircraft manufacturer publications held by the company.

Over the period 23 February 2000 to 19 April 2002, the operator experienced ongoing turnover of Chief Pilots for the aeroplane operation. That included an established Chief Pilot, selection of a prospective replacement Chief Pilot that unexpectedly discontinued the appointment process, an interim Chief Pilot and the incumbent Chief Pilot.

The CASA approval process for appointment of the incumbent Chief Pilot spanned a period of over 6 months. During that period, and in order that the operator remained able to satisfy the requirements of CAO 82.1, an extension to the employment of the interim Chief Pilot was agreed between CASA, the operator and the interim Chief Pilot. During that extension, agreement was reached with CASA for the interim Chief Pilot to work remote from Hamilton Island, but with another senior company pilot acting in-locality as Deputy Chief Pilot. That pilot held responsibility for the day to day management of the aeroplane operation.

1.17.1.3. Operational management

Company management reported avoiding influencing day to day operational matters in the air taxi business. Rather, management fulfilled a support role for the company operation. Management focus was reported to include: the business overall; the nature of the client base; the seasonal nature of the tourism business; the optimal company aircraft mix; aircraft investment scenarios; and other higher level considerations.

The position of Chief Pilot was considered by management to be an executive position, with responsibility for: managing a team of people; ensuring operations complied with regulatory requirements; and flying company aircraft. Although not a company directive, management believed that a Chief Pilot should fly an average of three days each week. Management estimated that the incumbent Chief Pilot probably flew more hours than any other of the company pilots.

The air taxi operation was reported by management to be more difficult to control than either of the company helicopter operations. Additional guidance was reported to be necessary for the air taxi operation, being in response to the number of recent changes of Chief Pilot, and the impact of those changes on the operation.

1.17.2. Pilot induction and check to line

The company's Operations Manual stated that 'pilot induction training, route and line checks and where applicable, instrument rating flight tests will serve to meet the requirements of CAR 219'. That regulation required a pilot to have:

> '…adequate knowledge of the route to be flown, the aerodromes to be used and the designated alternate aerodromes. That was to include a knowledge of:
>
> (i) the terrain;
> (ii) the seasonal meteorological conditions;
> (iii) the meteorological, communication and air traffic facilities, services and procedures;
> (iv) the search and rescue procedures; and
> (v) the navigational facilities associated with the route to be flown…'

Based on the documentation provided by the operator, the investigation was unable to confirm whether all elements of CAR 219 had been satisfied during the occurrence pilot's induction training and check to line.

CAO 40.1.0 defined the conditions for flight as pilot in command of an aeroplane within an aeroplane class. Those conditions placed responsibilities upon the pilot in command and aircraft owner and operator and included the requirement for the pilot to:

- be familiar with the systems, normal and emergency flight manoeuvres and aircraft performance, flight planning procedures, weight and balance requirements and the practical application of take-off and landing charts of the aeroplane to be flown
- have sufficient recent experience or training on the aeroplane type, or in a comparable type, to safely complete the proposed flight
- hold an endorsement for any relevant aircraft design feature.

CAO 82.0 placed responsibility for monitoring operational standards, maintaining training records and supervising the training and checking of flight crew of an operator with the Chief Pilot. That responsibility was reflected in the company Operations Manual. A pilot's training was administered via an Induction Training Checklist, and included the requirement for the inducted pilot to carry out a check flight. The company

Operations Manual did not include a requirement for a newly appointed pilot to complete a period of supervised operations, either prior to, or after, the check flight.

Reported company management understanding was that the company induction and training requirement was of one week's duration. Management expectation was that, in that time, a newly employed pilot:

- went through the company Operations Manual, spent time with company personnel and got a feel for the company's operations
- flew in command under supervision (ICUS). Management reported that, in the case of the occurrence pilot, the flying component was thought to have been of two day's duration, and to have included six hours flight ICUS.

That management understanding was not reflected in the company Operations Manual.

The occurrence pilot was reported to have observed the air taxi operation on 17 September 2002, and accompanied the Chief Pilot on a flight from Hamilton Island to Mackay and return. That flight was in a twin-engine Partenavia aircraft, and was recorded by the Chief Pilot as a 'flight assessment'. The flight was of 1.1 hours duration and included the practise of an engine failure after takeoff (EFATO) The pilot's performance during the EFATO was recorded by the Chief Pilot as being '…a bit rusty – needs more work on that'.

The Chief Pilot reported supplying copies of the company Operations Manual and Cherokee Six Owner's Handbook to the occurrence pilot on the 17 September 2002. The intention was that the pilot would read those manuals on the Chief Pilot's rostered day off on 18 September 2002.

On the evening of 17 September 2002, the pilot attended a company CAO 20.11 Emergency Procedures Competency Check and briefing session. That check was conducted with several other company pilots and was reported to have included a guided discussion by the Chief Pilot. That discussion included an emergency scenario that was based on an EFATO in a single-engine aircraft shortly after takeoff at one of the island airfields used by the company. It was reported that the overall consensus amongst those pilots present was that the best option in the scenario given was to ditch the aircraft straight ahead. The power loss scenario was reported to not include the discussion of partial power loss after takeoff.

Experienced company Cherokee Six pilots reported that the options available for a pilot confronted with a partial engine failure depended on: the degree of power loss; the weight of the aircraft; and the ambient conditions. Options were reported to include: the conduct of a low-level procedural turn and low-level circuit in order to maintain height and airspeed prior to landing on the runway; and flight to an alternate landing area or to an appropriate area in which to ditch the aircraft.

On 19 September 2002, the pilot signed as having read and understood the company Operations Manual and all quoted references therein. By so doing, the pilot agreed to apply the procedures within the manual. It was reported that the pilot returned the Cherokee Six Owner's Handbook to the Chief Pilot some time prior to the occurrence.

The pilot completed a 1.8 hour, eight sector Cherokee Six Line Check with the Chief Pilot on 19 September 2002. During that check, the occurrence pilot flew the aircraft, and conducted the passenger briefings and liaison duties normally undertaken by company air taxi pilots. Average sector length was about 12 minutes, with passengers onboard the aircraft on five of the eight sectors. CAR 249 precluded the practice of emergency procedures while carrying passengers. Total time not carrying passengers was less than 0.7 hours. Apart from a break at around 1230 of about 1.5 hours duration, average time between sectors was about 9 minutes.

The check to line did not include the practice of recovery from the stall or the simulation of engine power loss after takeoff. However, the Chief Pilot reported retarding the engine power during cruise at height, in order to show the occurrence pilot the sink rate at 90 kts in the Cherokee Six. The flight included operations to four of the 'regular ports of call' and resulted in the pilot being certified '…checked to line for PA32 air taxi'. The occurrence pilot then carried out the three remaining revenue-raising sectors in that aircraft as pilot in command.

Company staff reported that, over the period that the pilot was employed with the company, ongoing assistance and direction was afforded the pilot to assist his assimilation into the company operation. That assistance included, but was not limited to explanation of the end-of-day administration required at the Air Taxi Base at Shute Harbour, sourcing a replacement fuel card, options available for obtaining a meal at Hamilton Island, and the implications of the repeat nature of air taxi passengers in the Whitsunday area. An experienced air taxi pilot reported being surprised at how quickly the pilot had been released to line.

Part 121B of the Civil Aviation Safety Regulations (CASR) is a proposal to retain the operational flexibility presently enjoyed by charter operations in small aeroplanes,[8] while increasing the level of safety of those operations. That is considered possible as a result of raising the standard of flight crew performance through better training and supervision.

If adopted, CASR Part 121B will affect air taxi operations in the Cherokee Six, and may, depending on a newly appointed pilot's previous experience, require additional induction training requirements to be provided by the operator. That training would be likely to be in excess of that provided to the occurrence pilot, and possibly in excess of that understood by management to have been provided to the pilot. The content of the proposed CASR Part 121B, as it might have affected the occurrence pilot's induction training for employment as a Cherokee Six air taxi pilot, is discussed at attachment B.

1.18. Additional information

1.18.1. Occurrence pilot transition to the air taxi operation

Whilst employed in the north of WA, the pilot flew on an average of 20 days per month, and averaged less than two transit or scenic flights per day. Average sector length for those flights was about 2.5 hours. Total flight time averaged 70.5 hours per month, or about 3.5 hours per flying day. Around 80% of the hours flown had been in the form of scenic flights in and around two remote locations, and included the potential for operations in Class G airspace, Common Traffic Advisory Frequency areas and MBZs.

In contrast, during his time as an air taxi pilot at Hamilton Island, the pilot flew the Cherokee Six on five of his eight-days employment with the company, and averaged

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[8] Aeroplanes were described as 'small' when their authorised maximum take-off weight was not above 5,700 kg.

more than 15 sectors per day. Average sector length for those flights was less than 15 minutes. The pilot conducted 20 takeoffs from Hamilton Island, in various passenger configurations and environmental conditions. Total flight time was estimated at 19.2 hours, or about 3.8 hours per flying day. That included the potential for operations at up to 11 locations; and for operations in Classes C, D and G Airspace and MBZs.

1.18.2. Operational tempo and the air taxi environment

Management reported that air taxi aircraft travelled everywhere and everyway between the islands, with the resulting potential for higher levels of fatigue and the need for regular adjustments to planned operations. Air taxi aircraft were employed in a mix of taxi, scenic and commuting flights that required landings at differing airstrips and in different environments each day. The fleet of eight air taxi aircraft was reported to log 50-100 takeoffs and landings per day.

Company management reported that, during ‘normal’ air taxi operations, there was no issue with the tempo of those operations. Management reported that air taxi pilots knew that they could step down due to fatigue at any time without penalty, but that there were some days that the pilots had to work ‘…really hard’. It was reported that, on those days, pilots ‘…endured a lot of pressure’. Management recognised that it was not always easy for a pilot to step down for a rest, because a replacement pilot, generally the Chief Pilot, might not be available at that time.

When comparing the risk of the air taxi operation with that of other charter operators, management reported that the only elevated risk was the number of air taxi flights per day. Management estimated that the air taxi business resulted in 500 takeoffs and landings in any 100 flying hours, whereas most other charter operators probably averaged one takeoff and landing per flying hour. Management felt that the primarily over water nature of the company’s air taxi operation heightened any risk associated with the high number of takeoffs and landings.

The company Operations Manual listed the pilot in command responsibilities for flight. Included among those responsibilities were: aircraft refuelling and completion of fuel records, accurate completion of the passenger manifest, determination of aircraft weight and balance, checking and loading passenger baggage, and ensuring that passengers received safety and other flight briefs. Company management reported that guest liaison officers were, at times, available to assist air taxi pilots to escort passengers onto the aircraft tarmac, load and secure the aircraft and conduct passenger emergency and other briefing and safety requirements. It was reported that a guest liaison officer did not assist the occurrence pilot to load the aircraft for the occurrence flight.

Experienced company air taxi pilots reported that they had to closely monitor their duty times because of the hectic nature of the air taxi business. Air taxi pilots also reported that they had to do much more forward contingency planning than for other charter operations, and that there was increased opportunity for error by air taxi pilots.

Pilots commented that, whereas the air taxi day might commence with a manifest indicating a total of two flight hours, by the time of the first arrival at the main company base, the pilot ‘…might as well throw the manifest into the bin’ due to frequent changes in planned sectors. The pilots reported that, throughout the air taxi flying day, there was progressively less time available for aircraft turnarounds. That was reported as being particularly the case in the late afternoon, when the air taxi pilots often needed to do their checks ‘…on the run’.

1.18.3. Operational information relating to flights conducted by VH-MAR on the day of the occurrence

1.18.3.1. Aircraft performance

The Owner's Handbook for the Cherokee Six included performance charts that allowed aircraft performance planning by the pilot. The Altitude Conversion Chart allowed application of the observed meteorological conditions to derive density altitude. The density altitude at the time of the occurrence was estimated to be approximately 960 ft.

The company Operations Manual stated that detailed aircraft climb, cruise and descent data was found in the relevant Owner's Handbook. The handbook for the Cherokee Six described the take-off technique for the aircraft as:

> Allow the airplane to accelerate to 65 to 70 mph [56.5 to 60.8 kts], then ease back on the wheel enough to let the airplane fly itself off the ground.

The Cherokee Six Owner's Handbook included the requirement for the pilot to set flaps at 10 degrees (first notch) just before takeoff. The requirement to set flaps prior to takeoff was also listed in the in-cockpit flip-type pilot's checklist that had been installed by the operator.

A Takeoff Distance versus Density Altitude chart was included in the Cherokee Six Owner's Handbook for a take-off speed of 1.2 times the aircraft stall speed, and flaps setting of 10 degrees. That chart allowed derivation of the ground run take-off distance. At the estimated aircraft weight of 2,994 lbs (1,358 kg), predicted take-off distance in the published take-off configuration was about 900 ft (274.3 m). There were no witnesses to the aircraft's take-off run. However, a witness who had regularly observed aircraft lifting off from the upwind end of runway 14 commented that the occurrence aircraft lifted off from the runway really late, and that '…he [had] never seen a little plane take off that late'. The investigation could not confirm the take-off technique or aircraft configuration established for takeoff by the occurrence pilot.

Based on the information provided by the available witnesses, the published runway data and the predicted take-off performance, the investigation calculated that the aircraft lifted off from the runway from a position 2,950 ft (899.2 m) later than that derived from the manufacturer's data.

Trigonometry was applied to each witness position and estimated aircraft height combination to derive an estimated maximum height achieved by the aircraft during the takeoff and right turn. The estimated maximum height was 250-300 ft AMSL.

The Cherokee Six Owner's Handbook included a Glide Distance versus Altitude diagram that allowed calculation of the glide range at: an aircraft weight of 2,900 lbs (1,315.4 kg); speed of 90 mph (78 kts); and with the propeller windmilling, zero degrees flap setting, and in zero wind conditions. The glide distance related to aircraft angle of bank, published take-off configuration, and at the estimated take-off weight of the occurrence aircraft was unable to be derived from the Glide Distance versus Altitude diagram.

The aircraft landing distance versus density altitude could be calculated via the Landing Distance versus Density Altitude diagram within the Cherokee Six Owner's Handbook.

Aircraft parameters for application of that chart were: power off; flaps set at 40 degrees; no wind; maximum braking; and landing to a paved, level and dry runway. At those parameters, and an estimated aircraft all up weight of 2,994 lbs (1,358 kg), the estimated landing distance ground roll was about 585 ft (178.3 m). Predicted landing distance at alternative aircraft configurations was not published.

The Owner's Handbook indicated that the Cherokee Six stall characteristics were 'conventional'. While a stall recovery technique was not promulgated in either the Aircraft Flight Manual (AFM) or Cherokee Six Owner's Handbook, the AFM stated that:

> Loss of altitude during stalls can be as great as 350 feet, depending on configuration and power.

1.18.3.2. Fuel management

The AFM included the requirement for a sample of fuel to be drawn from the fuel system daily, prior to the first flight, and after each refuelling, to avoid the accumulation of water or sediment. That required each tank to be drained through its individual quick drain, and the fuel strainer to be drained while moving the fuel selector control through the OFF and left tip, left main, right main and right tip tank positions. Senior pilots indicated that all pilots were in the habit of draining the aircraft tip tanks as part of their aircraft daily inspections, and that there had been no known problems with the use of aircraft tip tanks at the company.

Company pilots reported that it was company policy that the tip tanks should not normally be used and that 5 – 10 L residual fuel was generally left in those tanks. The Chief Pilot reported having passed that policy on to the occurrence pilot during the pilot's induction training. However, the tip tank usage policy was not formalised in company operational documents or pilot directives, and some pilots reported having routinely used the aircraft tip tanks and preferring larger amounts of residual fuel in the tip tanks. The occurrence aircraft Flight Record indicated addition of fuel to the main tanks only throughout the day of the occurrence. There was no indication in that record, or other documentation, of the quantity of any residual fuel in the aircraft tip tanks.

The company Operations Manual nominated a planned normal cruise fuel flow for the Cherokee Six of 60 L/h. The manual also promulgated standard routes and time intervals for application by pilots. The standard flight interval from Lindeman Island to Hamilton Island was 5 minutes. Throughout the occurrence day's operation, the pilot had consistently annotated 4 minutes taxi time on the aircraft Flight Record for each sector. That was, 2 minutes taxi for takeoff, and 2 minutes for taxi after landing. The pilot summed the taxi and airborne times to arrive at the sector flight time.

Examination of the aircraft fuel swipe card record for the occurrence day confirmed that the pilot conducted the last of the day's three refuelling operations at Shute Harbour at 1358. That record indicated that the pilot added 25.88 L of aviation gasoline to the aircraft. The corresponding annotation on the aircraft Flight Record indicated 90 L in each of the left and right main tanks. That was, a total of 180 L carried on taxi for the next sector.

The aircraft Flight Record indicated a total of 85 minutes flight time between the 1358 refuel at Shute Harbour and the aircraft's arrival at Lindeman Island at 1642. At the planned normal cruise fuel flow for the Cherokee Six, that meant that 95 L of fuel remained in the aircraft at Lindeman Island. The investigation could not explain why the pilot had, instead, annotated a total of 105 L remaining in the aircraft main fuel tanks for the sector to Hamilton Island immediately preceding the occurrence flight.

Application of the standard sector time intervals, and taxi times allowed by the pilot throughout the day to the 95 L of fuel calculated as remaining in the aircraft at Lindeman Island, meant that the pilot arrived at the Hamilton Island company terminal with an estimated total of about 86 L of fuel. The investigation concluded that, after allowing for the standard 2 minutes taxi time to the departure point, the pilot commenced his takeoff for the occurrence flight with a total of about 84 L of fuel onboard the aircraft.

1.18.3.3. Engine management

A senior company pilot reported that the normal air taxi protocol was to conduct thorough engine run-ups on the first flight of the day and, for the remainder of the day's sectors, to carry out abbreviated checks. The investigation could not determine if the occurrence pilot conducted a pre-flight engine run-up prior to the occurrence flight.

Senior company pilots reported that, if taxiing for an extended period of time, they would lean the aircraft fuel mixture setting. That procedure was not formalised in company documentation. A senior company pilot indicated that, by the end of the day, an engine could suffer slight 'rich-fouling' of the spark plugs if the pilot did not lean the fuel mixture while taxiing. The investigation could not determine the management of the mixture setting during taxi by the occurrence pilot during the day of the occurrence.

1.18.3.4. Pace of operations

Two additional sectors to those expected by the pilot, and listed in the Bookings Sheet, were annotated in the aircraft Flight Record as having been flown early in the afternoon on the day of the occurrence. All subsequent planned sectors prior to the occurrence flight failed to meet the planned departure times.

A passenger on the 1600 sector from Hamilton Island to Shute Harbour, who was also a licensed pilot, reported that the pilot taxied at Hamilton Island without completing a pre-flight passenger safety brief. The pilot in command was reported to then backtrack on the runway:

> … very quickly, to the extent that [it was] thought that it may have been the take off.

The engine run-up check was reported done '…on the run…', and it was reported that the taxi from the runway in to the terminal at Shute Harbour was '…very quick'.

A passenger, also a senior company pilot, reported that the return flight to Hamilton Island immediately prior to the occurrence flight departed about 20-25 minutes later than planned. That passenger reported that, although running late, the pilot in command completed his passenger seat allocation, safety briefing and other responsibilities on each sector.

The investigation determined that, on the day of the occurrence, the pilot completed 17 sectors, and accumulated an estimated 3.9 flying hours. Average sector length was about 14 minutes.

The pilot spent a total of about 5 hours on the ground that day; including a 70-minute break commencing at about 1105. The pilot's activities during that break could not be established. Excluding the 70-minute break, the average period between segments was just over 14 minutes. The shortest break recorded throughout the day was of 1-minute duration.

Whereas the number of planned passengers for the day totalled 37 on the Bookings Sheet, the aircraft Flight Record indicated that the actual number of passengers carried was more than 45.

An experienced air taxi pilot reported that, on the day of the occurrence, the occurrence pilot '…would have been run ragged that day, as there was lots of work'.

1.18.3.5. In-flight observations

There were several passenger reports that the aircraft had been difficult to start on several occasions during the week preceding, and on the morning of the occurrence. That contrasted with reports from a number of experienced senior company pilots that had flown the aircraft since its most recent routine 100-hourly maintenance service. Those pilots reported that the aircraft had displayed no recent problems of that nature, and that it had '…flown like a dream'. A senior company pilot who flew as a passenger in the occurrence aircraft on the two sectors immediately preceding the occurrence flight reported that, during those sectors, he '…heard, saw and perceived no funny or indicative noises or other things during [those] flights…', and '…saw no fluctuations in the gauges, etc'. The cylinder head gauge was reported by the senior pilot to be '…back from the yellow line'.[9] The senior company pilot made no reference to the presence of any in-flight vibrations during those sectors.

Two holidaying passengers, who were also licensed pilots, reported that, as the pilot in command set full power for takeoff for the 1600 sector from Hamilton Island to Shute Harbour, a severe vibration was felt throughout the aircraft. One of those passengers, seated in the aircraft right pilot's seat, reported that the severity of the vibration meant that, in his opinion, a rejected takeoff would have been appropriate. That passenger, while having more than 850 hours instructional experience, had not previously acted as pilot in command of a Cherokee Six aircraft. The passenger pilot was not wearing a headset.

The second passenger, who was also a licensed pilot, was seated in the extreme right rear of the aircraft and was also not wearing a headset. That passenger reported an opinion that, if acting as pilot in command, the most prudent action in response to the perceived level of vibration would have been to return to Hamilton Island for an immediate landing. The passenger reported minimum experience acting as pilot in command of a Cherokee Six-type aircraft.

[9] Considered by the senior pilot to indicate operation within the normal operating range.

Both passengers reported that the pilot in command seemed unperturbed by the aircraft vibration, and continued the takeoff. The vibration was reported to have diminished when the pilot in command reduced power after takeoff to set climb power. The investigation could not determine the reasons for, or nature of that reported vibration.

A senior company pilot reported that, while travelling as a passenger on the sector to Hamilton Island immediately prior to the occurrence flight, the aircraft right cabin door latch 'popped' open during the cruise. The Cherokee Six Owner's Handbook stated that an insecure door might spring partially open and that:

> This will usually happen at takeoff or soon afterward. A partially open door will not affect normal flight characteristics, and a normal landing can be made with the door open.

It was reported that the pilot in command requested the senior company pilot to take hold of the door and continued the flight to Hamilton Island. The senior company pilot reported that the pilot in command intended to have the door latch examined on arrival at Hamilton Island. The occurrence pilot's temperament was described as calm when the forward cabin door came ajar.

A company maintenance engineer reported examining the right cabin door latch after the aircraft's arrival at Hamilton Island. The engineer reported that the minor nature of the work carried out to adjust the door latch meant that no entry was made in the aircraft maintenance log. The occurrence pilot was reported to have been satisfied with the maintenance work carried out on the latch, and to have stated that the aircraft '…was fine'.

1.18.4. Aeronautical knowledge and experience

As noted in section 1.17.2, the induction training and check to line undertaken by the occurrence pilot on appointment to the operator did not include the practice of actions in response to power loss, or abnormal engine operation after takeoff in the Cherokee Six. In that case, the pilot could be expected to react to such emergencies in accordance with previously assimilated competencies, standards and training.

The occurrence pilot completed his student, private and commercial pilot training in accordance with the Day VFR Syllabus Aeroplane – Student, Private and Commercial Pilot Licences. In accordance with government policy, national competency standards for private and commercial aeroplane pilot licences were developed by the aviation industry in conjunction with CASA and the Australian National Training Authority. The Private and Commercial Aeroplane Pilot Competency Standards revised, but did not change the Day VFR Syllabus Aeroplanes standards.

The Aeroplane Pilot Competency Standards became mandatory on 1 September 1999, and required each training organisation to ensure that its curriculum provided for the training and assessment of all units of competency relevant to a particular qualification. The pilot provided flying instruction in accordance with those units of competency while employed at the Sydney flying school.

The flying school used the publication *Flight Instructor's Manual*[10] as the primary reference for its flying instructor training. Subsequently, when employed as a flying instructor with that school, the occurrence pilot was required to use that publication as his primary reference.

Content from the Day VFR Syllabus Aeroplane – Student, Private and Commercial Pilot Licences, the *Flight Instructor's Manual* and Private and Commercial Aeroplane Pilot Competency Standards relevant to the development of the occurrence is included in attachment C.

1.18.5. Practice of engine power loss after take off and other abnormal situations

There was no specifically mandated requirement for the practice by pilots of engine power loss after takeoff or other abnormal situations during proficiency checks, checks to line or biennial flight reviews. Although CAO 40.1.0 required familiarity with normal and emergency flight manoeuvres when acting as a pilot in command of an aeroplane, the term 'familiar' was not defined.

The investigation was unable to examine the pilot's student pilot training notes, and was therefore unable to establish the extent of the practice of power loss after takeoff during the pilot's student pilot training. Once qualified as a flying instructor, the pilot logged extensive practise of engine power loss after takeoff and flights involving practice forced landings (PFL). The last instance of such training recorded by the pilot was as an instructor in a flight in March 2002 that included the practice of PFLs.

1.18.5.1. Recent practice of emergency and other abnormal situations

The pilot signed the WA operator's Operations Manual on 13 June 2002. That manual included the requirement that, following loss of engine power after take off, where sufficient height and airspeed were not available to complete troubleshooting checks, pilots should, amongst other checks:

- 'lower the nose [of the aircraft] immediately to maintain airspeed above stall speed'
- 'Keep straight ahead. Change direction only to avoid obstacles. Use rudder only. Keep wings level.' The instruction included a note to 'Always maintain enough airspeed to ensure full control of aircraft to point of touch-down. Coarse use of ailerons near the stall airspeeds precipitates wing dropping'.

The pilot's induction training notes at that company indicated that steep turns, stalls, forced landings and circuits were '…flown [by the pilot] with no problem areas'. That flight was conducted in a Cessna 207 that was equipped with an aural stall warning device.[11]

A pilot from the WA company reported that, as part of his induction training at that company, the occurrence pilot would probably have experienced practice engine power loss in the Cessna 206, Cessna 207 and Airvan from in the cruise, at height. It was reported that company policy was that engine power loss in single-engine aircraft, after takeoff, was not practised.

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[10] Campbell, R.D. (1994). *Flight Instructor's Manual* (Amended and reprinted). Surrey, England: The Campbell Partnership.

[11] The pilot's flight training and instructional experience had also been predominantly conducted in aircraft equipped with aural stall warning devices.

1.18.5.2. Operator required engine power loss procedures and training

The air taxi company Operations Manual directed that operation and handling of company aircraft was to be in accordance with the AFM, manufacturer's Operating Handbook and the Operations Manual. The AFM had precedence where any conflict existed with other publications. In regard to the handling of engine power loss failures after takeoff:

- The AFM included no directed actions in the event of a power loss after takeoff
- The Cherokee Six Owner's Handbook listed the following actions should an Engine Power Loss During Takeoff occur:[12,13]
  - If sufficient runway remained for a normal landing, land straight ahead
  - If insufficient runway remained, maintain a safe airspeed and make only a shallow turn if necessary to avoid obstructions. Use of flaps depended on circumstances. Normally, flaps should be fully extended for touchdown
  - Procedures in order to attempt to restart the engine should the aircraft have achieved sufficient altitude included the note that, if engine power was not regained, the pilot should proceed with promulgated Power Off Landing procedures
- The company Operations Manual stated that pilots should use the normal and emergency checklist that was located in the aircraft map pocket. That checklist was derived from the AFM and [Cherokee Six] Owner's Handbook. The Chief Pilot reported that the occurrence aircraft on board checklist did not include actions in the event of an EFATO.

The Chief Pilot reported that his last employment had been as a flying instructor based at Moorabbin, Victoria and that he was unable to simulate power loss after takeoff at that location. That was reflected in the Moorabbin entry to the facilities section to the Enroute Supplement (Australia). The Chief Pilot reported reluctance to the practice of EFATOs around the Hamilton Island area, because of the over water nature of the company operation and, at Shute Harbour, due to the extensive numbers of trees surrounding the airfield. Senior company pilots reported undertaking EFATO training with an earlier Chief Pilot, and that the previous interim Chief Pilot had conducted EFATO training for company pilots at the inland location of Proserpine.

1.18.6. Effect of angle of bank on aircraft load factor and stall speed

The publication *Aerodynamics for Naval Aviators*[14] stated that no appreciable increase in an aircraft's load factor or stall speed occurred at bank angles less than 30 degrees. Above 45 degrees angle of bank, the increase in aircraft load factor and stall speed was quite rapid. The author emphasised that pilots should avoid steep turns at low airspeeds, labelling that flight condition as being common to stall-spin accidents. The effect of angle of bank on stall speed and aircraft load factor is discussed in the following sections.

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[12] The manufacturer did not indicate whether the pilot actions also applied in the case of a partial engine power loss during takeoff.

[13] The manufacturer included a note that 'If engine failure was caused by fuel exhaustion, power will not be regained after tanks are switched until empty lines are filled, which may require up to ten seconds'.

[14] Hurt, H. H. Jr. (1965). *Aerodynamics for Naval Aviators* (Revised edition). Basin, Wyoming: Aviation Maintenance Publishers.

1.18.6.1. Aircraft load factor

Aerodynamics for Naval Aviators stated that, for an aircraft in a steady, coordinated turn, the vertical component of lift must equal the weight of the aircraft and the horizontal component of lift must equal the centrifugal force experienced by the aircraft. That requirement lead to the following relationship:

$$n = \frac{1}{\cos \phi}$$

where

n = load factor or “G”

ϕ (phi) = angle of bank (in degrees)

The relationship between angle of bank and load factor (or “G”) is summarised at Table 1.

Angle of Bank, ϕ (degrees)	0	15	30	45	60	75	80	84
Load Factor, *n* (or “G”)	1.000	1.036	1.154	1.414	2.000	3.864	5.757	9.569

Table 1: Increase in Load Factor Relative to Angle of Bank

1.18.6.2. Aircraft stall speed

Stall speed with full (40 degrees) flaps was promulgated in the AFM as 63 mph (54.7 kts) at a weight of 3,400 lbs (1542.2 kg). The Cherokee Six Owner’s Handbook promulgated a stall speed of 58 mph (50.4 kts) in that configuration and at 2,900 lbs (1315.4 kg). Stall speed with no flaps was promulgated in the AFM as 71 mph (61.7 kts) at a weight of 3,400 lbs (1542.2 kg). The Cherokee Six Owner’s Handbook promulgated a stall speed of 66 mph (57.4 kts) in that configuration and at 2,900 lbs (1315.4 kg). Neither the AFM nor Cherokee Six Owner’s Handbook included a stall speed for the recommended take-off configuration.

Aerodynamics for Naval Aviators allowed derivation of aircraft stall speed at varying angles of bank via the formula:

$$v_s\phi = v_s\sqrt{n},$$ where

$v_s\phi$ = stall speed at some bank angle ϕ

v_s = stall speed for wing level, lift-equal-weight flight

n = load factor corresponding to the angle of bank

The effect of increasing angle of bank on those stall speeds published in the Cherokee Six Owner's Handbook is summarised at Table 2.

AOB in degrees / Config	Wings Level	30	40	45	50	60	70	75	80	90
2900 lbs (1315.4 kg) Full Flap	50.4	54.4	57.5	60.0	63	70.6	85.7	99.3	121.0	∞
2900 lbs (1315.4 kg) No Flap	57.4	62.0	65.4	68.3	71.8	80.4	97.6	113.1	137.8	
Gross Weight Full Flap	54.7	59.1	62.4	65.1	68.4	76.6	93	107.8	131.3	
Gross Weight No Flap	61.7	66.6	70.3	73.4	77.1	86.4	104.9	121.6	148.1	

Table 2: Increase in Aircraft Stall Speed (in kts) Relative to Angle of Bank

1.18.7. Chief Pilot issues

CAO 82.1 required charter operators to establish the position of Chief Pilot, and to appoint a person to that position. CAO 82.0 mandated that a person could not be appointed as, or act as a Chief Pilot unless that person's appointment had been approved in writing by CASA. Included amongst the responsibilities of a Chief Pilot listed at Appendix 1 to that CAO was that a Chief Pilot:

> …[has] control of all flight crew training and operational matters affecting the safety of the flying operations of the operator.

Section 7.11 of the CASA *Air Operator Certification Manual* emphasised the critical importance of the quality of a Chief Pilot to the safety of the flying operations of an operator. The manual also stressed the need for a Chief Pilot to be able to manage 'the system', and that approval of a Chief Pilot candidate should only occur when:

> …the nominee shows the capability to manage the operator's objectives within the boundaries imposed by aviation safety legislation.

On 11 September 2001, the company's Executive Officer made application to CASA for approval of the Chief Pilot candidate. In response, CASA commenced its normal Chief Pilot approval process, which included:

- A desk-top audit, in order to confirm the candidate's qualifications, experience, record of any misdemeanours and that the approval request proforma was compiled correctly
- An interview, which was conducted on 9 October 2001. It was reported that the interview included assessment of flight planning and operational knowledge and the review of the candidate's approach to several management scenarios. The interview was suspended early by the Flying Operations Inspector (FOI), in order to allow the Chief Pilot candidate a 2-week period in which to gain a better understanding of the Hamilton Island air taxi operation.

A second, successful Chief Pilot approval process was carried out at Hamilton Island on 17 April 2002. The resulting Chief Pilot Approval of Appointment instrument was issued on 19 April 2002, with a specified expiry date of 30 November 2002. The CASA intent was that surveillance already planned to be conducted in that period would include assessment of the Chief Pilot's performance against the Chief Pilot duties and responsibilities. Planned surveillance subsequent to a ramp check inspection and completion of an on-site Safety Trend Indicator (STI) risk assessment form on 23 April 2002 was for the completion of another STI in September 2002. While the STI risk assessment form did not include the capacity for direct assessment of the Chief Pilot's performance, the aim was that the September surveillance would include examination of the Chief Pilot's performance. The Chief Pilot approval was subject to review after consideration of that surveillance.

1.18.8. CASA surveillance

In February 2000, CASA commenced a program to better enable FOIs and Airworthiness Inspectors (AWI) to identify organisations that exhibited greater potential for presenting problems, and to quantify the stressors existing within an organisation. The program was not considered by CASA to represent a formal risk management tool, but was a supplement to other extant surveillance modalities, including: aircraft ramp checks; on-site and other audits; etc. As part of that program, CASA district offices were required to complete an STI questionnaire on each organisation in early 2000, and then every 6 months thereafter. Those STI forms reflected the new surveillance format, and were to be completed by:

> …the inspector or inspectors with the most detailed knowledge of the organisation as determined by the relevant Team Leader/Area Manager.

The STI forms[15] are divided into two sections, the first seeking general information about the organisation being examined by CASA. The second section contains Safety Indicator questions requiring 'Yes', 'No' or 'Don't Know' responses by the FOI or AWI. There are 30 indicator questions in the AOC STI, and 29 in the Certificate of Approval (COA) STI. Each of the indicator questions includes the possibility of annotation of a shaded box by the examining inspector. The shaded boxes indicate the '…potentially less safe options'. The 'Don't Know' option reflects the expectation by CASA that:

> …most inspectors [would] not be able to provide information on all indicators for all organisations, particularly if the organisation [had] not been audited recently.

The overall AOC or COA Safety Indicator score, indicating the potentially riskier organisations, is obtained by summing the shaded boxes.

Consolidated STI reports are distributed to district offices monthly, and include trending information and weighted data to take account of varying organisational factors, such as: the size of an operation; whether the operation involves the carriage of passengers; the number of 'Don't Knows'; and overall safety indicator score annotated by the examining inspector. In addition, CASA interrogates the raw STI data on a quarterly basis. There is no weighting given to the rate of increase of the indicator score, and 'Don't Know' responses are given less weight than definite risk factors.

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[15] CASA is currently progressing with the implementation of Mark II of the STI form. However, the revised STI will remain but one tool within a suite of safety management strategies employed by CASA.

The weighted STI scores are ranked by each CASA district office in preparation for their use as a management tool during surveillance planning, and when developing the scope and priority for audit scheduling. That process may also highlight the requirement for Special Audits and Spot Checks of an organisation, in order to take account of an operator's higher level of perceived risk. No objective criteria are provided in order to assist inspectors to consistently determine the requirement for such additional surveillance and there is the potential for other non-STI information to modify the priority for additional surveillance that might have been derived from weighted STI scores in isolation.

CASA surveillance of the operator was reported by the responsible district office to be carried out annually, and was risk-based. That surveillance was reviewed monthly and relied on intelligence on and from the local industry, inspector reports and completion of STI forms. CASA officers reported that, during the period '…March 2002 until the 26 September accident, there had been no out of the ordinary observations [arising from the monthly review of surveillance information] indicating that CASA should increase its surveillance of [the company]'.

1.18.8.1. Operations surveillance

A review of CASA files indicated that, during the year prior to the occurrence, the responsible CASA district office conducted AOC STI and other operations surveillance on the operator on four occasions. The STI component to that surveillance is summarised in Figure 9.

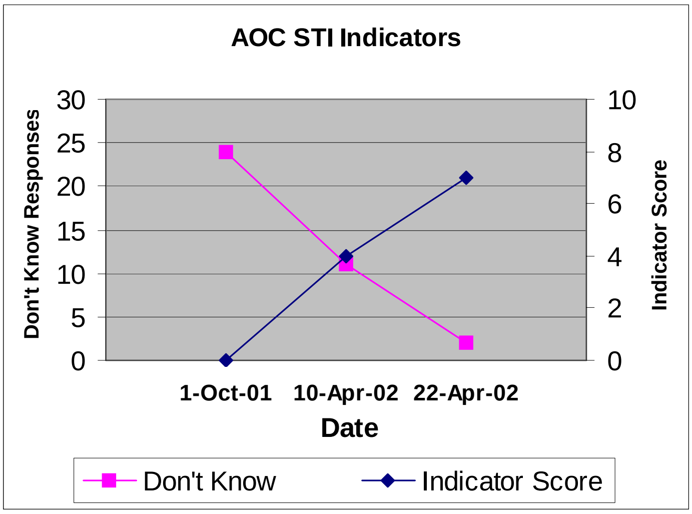

Figure 9: AOC STI risk indicators

Two STIs were conducted in April 2002. Both indicated CASA awareness of the changed organisational context, in terms of the recent Chief Pilot and company ownership and structural changes within the previous 12 months. The FOI that conducted the second STI in April indicated that plans were in already in place to address those issues. In addition, that FOI indicated awareness of a reportable incident within the past 12 months for which the operator was probably at least partially responsible. There was nothing to indicate what was planned by CASA to address the organisational changes and other issues affecting the company operation.

No operations surveillance of the company was carried out between April 2002 and the date of the accident.

1.18.8.2. Engineering surveillance

The responsible CASA district office AWIs conducted COA STI and other engineering surveillance of the operator on six occasions during the year prior to the occurrence.

The engineering risks remained relatively constant over the year prior to the occurrence, and the surveillance inspectors indicated a maximum of two 'Don't Know' responses to the safety indicators. Identified risks included primarily engineering management and personnel-related issues, and the non-acquittal of Non-compliance Notices (NCN) within the allocated response period. Included among those NCNs was the occurrence of continued aircraft operation beyond the flight time stipulated for compliance with the requirements of certain Airworthiness Directives. However, the inspectors noted a progressively improved result in the company engineering administration and documentary processes over that year.

1.18.8.3. CASR Part 119

In order to reduce the safety risks associated with aircraft flight and associated ground operations, CASA is presently introducing a Safety Management Systems (SMS) approach for passenger carrying operations. That approach will be formalised under the proposed CASR Part 119 regulatory requirements, and will affect air transport operators who engage in operations under the following proposed CASRs:

- Part 121A; or
- Parts 121B or 133, when operations under these Parts are undertaken:
  - wholly within Australia and, at any time, involve the operation of four or more aircraft under the operator's AOC; or
  - not wholly within Australia.

The proposed Part 119 regulations are estimated by CASA to commence having effect in the second quarter of 2005,[16] and will mandate the implementation of an SMS by affected AOC holders. Documented processes for risk management within an operator's organisation are also mandated under the Part 119 proposal.

CASA plans to transition AOC holders to the new regulatory requirements through a case management process. SMS training sessions have already commenced, and are attended by CASA officers and industry personnel. CASA estimates that transitional AOCs could be issued for up to six years.

In addition, CASA's new surveillance procedures require inspectors to undertake audits using the systems approach. That approach has resulted in the following significant changes to extant surveillance methodologies:

- Inspectors are required to carry out thorough pre-audit preparation, including consideration of safety intelligence, and the objectives and scope of the planned audit

[16] CASA Directive 3/2004 of 3 February 2004 delayed further development of CASR Part 119 until 30 June 2004.

- Recording and reporting of findings
- Follow-up and planning of subsequent action.

The changes proposed under CASR Part 119 are planned to underpin CASA's transition towards an industry surveillance/oversight program that places greater emphasis on the Authority auditing the operator's processes and procedures, rather than on end-product inspections. The intent is that application of a systems approach, and risk management method, will result in greater emphasis being placed on the notion of 'shared responsibility' for safe operations, between the regulator and individual operator.

1.18.9. Detection of drug and alcohol use in the aviation industry

The use of drugs and alcohol is common in modern Western society. Alcohol is the most widely used and misused drug in the Western world, with some reports indicating that alcoholism affects approximately 1% of adult users.[17] Cannabis is the most widely used illicit drug in the world. Chronic misuse of substances such as alcohol and illicit drugs can cause significant social, economic, legal and public health problems for the wider community.

Flying an aircraft is an activity requiring high levels of cognitive functioning and psychomotor skill. These areas of human performance are generally impaired following the use of substances such as alcohol and illicit drugs.[18, 19, 20, 21, 22, 23, 24] As such, the use of drugs and alcohol by pilots can compromise their ability to safely operate an aircraft. This can lead to reduced flight safety, with clear adverse implications for pilots, passengers and the entire air transport system.

CAR 256 places restrictions on the operation of aircraft by pilots that have consumed, used or absorbed alcoholic liquor, drug, pharmaceutical or medicinal or other substances (see attachment D). In recent years, there have been calls for these regulations to be made more prescriptive and stringent.

The company Operations Manual included a drug and alcohol policy reflecting the content of CAR 256. That policy stated:

> Flight crew shall not be in a state, which by reason of having consumed, used or absorbed any alcoholic liquor, drug, pharmaceutical or medical preparation or other substance, where his or her capacity to act is impaired. Flight crew shall not act as operating crew if, during the period of eight hours immediately preceding the commencement of duty, they have consumed any alcoholic liquor. Company flight crew shall not consume any alcoholic liquor during their tour of duty.

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17 International Civil Aviation Organization. (1995). *Manual on prevention of problematic use of substances in the aviation workplace* (Doc. 9654-AN/945). Montreal: ICAO.

[18] Billings, C. E., Wick, R. L, Gerke, R. J, & Chase, R. C. (1973). Effects of ethyl alcohol on pilot performance. *Aerospace Medicine, 44,* 379-82.

[19] Cook, C. C. H. (1997). Alcohol and aviation. *Addiction, 92,* 539-555.

[20] Gibbons, H. L. (1988). Alcohol, aviation and safety revisited: a historical review and a suggestion. *Aviation, Space, & Environmental Medicine, 59,* 657-660.

[21] Modell, J. G., & Mountz, J. M. (1990). Drinking and flying – the problem of alcohol use by pilots. *New England Journal of Medicine, 323,* 455-461.

[22] Reid, G. R. (1999). Aviation Psychiatry. In: J. Ernsting, A. N. Nicholson, & D. J. Rainford (Eds). *Aviation medicine* (3rd Ed) (pp. 397-416). Butterworth-Heinemann: Oxford.

[23] Yesavage, J. A, Dolhert, N., & Taylor, J. L. (1994). Flight simulator performance of younger and older aircraft pilots: Effects of age and alcohol. *Journal of the American Geriatric Society, 42,* 577-82.

[24] Yesavage, J. A, Leirer Von, O. (1986). Hangover effects on aircraft pilots 14 hours after alcohol ingestion: a preliminary report. *American Journal of Psychiatry, 143,* 1546-1550.

The Company Contract and Conditions of Employment referred to in the occurrence pilot's Letter of Appointment included instant dismissal in the case of an 'employee under the influence of drugs or alcohol while at work or in uniform'. There was no test regime or means of testing for those substances described in the employment contract or other company documentation examined by the investigation, nor was one required.

Attachment D examines the current situation with regard to international drug and alcohol regulations and testing programs for aircrew and others involved in the aviation industry. The analysis then considers the issue of whether a drug and alcohol testing program should be introduced into the Australian aviation industry.

1.18.10. Fatigue

Fatigue can arise from a number of different sources, including: time on task; time since awake; acute and chronic sleep debt; excessive physical and/or cognitive activity; emotional strain; circadian disruption (that is, factors which affect the normal 24-hour cycle of body functioning); or a combination thereof. A review of fatigue research relevant to flight operations noted that fatigue can have a range of influences, such as: increased anxiety; decreased short-term memory; slowed reaction time; decreased work efficiency; reduced motivation; increased variability in work performance; and increased errors of omission.[25] However, many of those symptoms generally only appeared after substantial levels of sleep deprivation had been imposed. The review of fatigue research relevant to flight operations also made the following observations:

- a common symptom of fatigue is a change in the level of acceptable risk that a person tolerates, or a tendency to accept lower levels of performance and not correct errors
- most people need eight hours sleep each day to achieve maximum levels of alertness and performance
- fatigue is cumulative
- there is a discrepancy between self-reports of fatigue and actual fatigue levels, with people generally underestimating their level of fatigue.

To minimise the likelihood of fatigue influencing pilot performance, regulatory authorities and companies place restrictions on the flight and duty times for pilots.

Details of the recent work and rest history for the occurrence pilot indicated that he had commenced duty about 9.5 hours before the occurrence. According to one witness statement, the occurrence pilot had a history of difficulty sleeping and would often be awake until 0300. The investigation could not clearly establish the time that the pilot rose on the day of the occurrence, and therefore how long the pilot had been awake prior to the occurrence.

A number of factors are known to exacerbate the effects of fatigue on human performance. For example, the adverse effects of alcohol on normal sleep architecture are well established. In particular, alcohol can detrimentally affect sleep quality.[26] The impact of alcohol on sleep patterns causes subjective feelings of tiredness and impaired concentration the following day. Additional cumulative factors that can compound the

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[25] Battelle Memorial Institute. (1998). *An overview of the scientific literature concerning fatigue, sleep, and the circadian cycle* (Report prepared for the Office of the Chief Scientific and Technical Advisor for Human Factors, Federal Aviation Administration). Washington, DC: Author.

[26] Graeber, R. C. (1988). Aircrew fatigue and circadian rhythmicity. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (305-344). San Diego, CA: Academic Press.

effects of fatigue include but are not limited to the type of work conducted, environmental conditions such as heat, and inadequate nutrition.

1.18.11. Environmental conditions

Pilot performance, including reaction time and concentration, has been found to deteriorate under conditions of thermal or heat stress, which can be brought about above temperatures of 32 degrees Celsius.[27, 28] The maximum recorded temperature at Hamilton Island on the day of the occurrence did not exceed 26 degrees Celsius. However, aircraft cockpits can emulate the greenhouse effect by trapping radiation and raising the temperature of the cabin to levels well above the outside ambient temperature.[29]

The aircraft was operating in a tropical environment, with relatively high ambient temperatures and humidity levels. The aircraft was not air-conditioned. Thermal stress can accelerate the onset of dehydration and fatigue, which a pilot may or may not readily accept or recognise.[30, 31] Dehydration can produce significant problems with human performance, such as poor cognitive functioning and dizziness.

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[27] Cable, G. G. (1997). Thermal stress in the aviation environment. *Avmedia: Journal of the Aviation Medical Society of Australia and New Zealand, 17,* 29-40.

[28] Gordon, M., & Hirsch, I. (1986). New issues in agricultural spraying in Israel. *Aviation, Space, and Environmental Medicine, 51,* 56-60.

[29] Froom, P., Shochat, I., Strickman, L., Cohen, A., & Epstein, Y. (1991). Heat stress on helicopter pilots during ground standby. *Aviation, Space, and Environmental Medicine, 62,* 978-981.

[30] Froom, P., Shochat, I., Strickman, L., Cohen, A., & Epstein, Y. (1991). Heat stress on helicopter pilots during ground standby. *Aviation, Space, and Environmental Medicine, 62,* 978-981.

[31] Razmjou, S., & Kjellberg, A. (1992). Sustained attention and serial responding in heat: Mental effort in the control of performance. *Aviation, Space, and Environmental Medicine, 63,594*-601.

2. ANALYSIS

2.1. Introduction

The investigation established that the circumstances of the occurrence were consistent with a pilot decision to attempt a return for a landing in response to an engine abnormality. The execution of that decision resulted in a steepening turn, which led to the aircraft stalling at a height from which the pilot could not effect recovery. The origin of the engine abnormality could not be established due to the extensive disruption of the aircraft and its components by impact forces and the severe post-impact fire.

The force of the aircraft impact with the ground was not survivable. There was no evidence that fuel contamination, insufficient quantity of fuel or aircraft structural failure was a factor in the occurrence. The investigation could not discount the possibility of some impairment of pilot performance as a result of the combined effects of the previous night's reported alcohol consumption, fatigue, and recent cannabis use.

2.2. Background – the air taxi operation

It was reported that the Hamilton Island air taxi operation entailed higher levels of risk than for other charter operations. That heightened risk resulted from the number of air taxi flights and the resulting high number of takeoffs and landings conducted each day. Air taxi pilots experienced a mix of taxi, scenic and commuting flights, requiring operations to differing airstrips, and in differing environments each day. A comparison of the occurrence pilot's charter experience in the north of WA with that once in the air taxi environment supported that contention. Once in that environment, the average number of sectors flown by the pilot each air taxi day increased by a factor of seven, and average sector duration decreased by 90%.

2.3. Flight operations

2.3.1. Induction training

The requirements of CAO 40.1.0 meant that the induction training provided to the occurrence pilot by the operator was required to ensure familiarity with, amongst other requirements, emergency flight manoeuvres in the Cherokee Six and the flight planning and other issues affecting the air taxi operation in that aircraft.

In developing an induction program, some operators might rely on retention by the newly appointed pilot of the competencies previously assessed for the award of a particular pilot's licence. In addition, reliance might be placed on a pilot's previous employer(s) ensuring pilot proficiency in those skills when employed with that employer. The risk for the operator is that a pilot may, in fact, not retain the systems, normal and emergency flight manoeuvre, aircraft performance and other familiarity requirements of the CAO. In that case, an operator may develop an induction program not reflective of a newly appointed pilot's experience base.

The only specific after take-off emergency flight manoeuvre recorded during the occurrence pilot's induction and check and training procedure was the practice of an EFATO in a Partenavia aircraft. The investigation considered that the performance of the twin-engine Partenavia in an EFATO situation, and the resulting pilot flyaway emergency considerations and actions, bore little resemblance to those necessary in a single-engine aircraft such as the Cherokee Six.

In addition, the CAR 249 restrictions meant that the maximum time possible for the pilot to have specifically practised emergencies in the Cherokee Six prior to being ‘checked to line’ was less than 0.7 hours. The investigation concluded that the approach to the pilot’s induction training, while recognising the emergency flight manoeuvre familiarity requirements of the CAO, largely left responsibility for integrating that Cherokee Six training with existing competencies and experiences with the pilot.

However, the pilot’s ability to integrate Cherokee Six emergency actions with existing competencies and experiences on other aircraft types was limited by the absence of EFATO actions in the onboard company emergency checklist, and of actions within the Cherokee Six Owner’s Handbook in response to a temporary power loss. That, and the absence of any skills-based after take-off emergency training in the Cherokee Six, increased the likelihood of the pilot experiencing difficulty responding effectively to after take-off emergencies in that aircraft type.

Although not promulgated in company publications, provision of the management induction training expectation to the occurrence pilot would most likely have better prepared the pilot for the dynamic and demanding air taxi environment. The lack of comprehensive induction training and check to line actually provided, most likely prevented the occurrence pilot from developing a full appreciation of the nature, operational tempo and risks inherent in the air taxi operation. Given that company management considered risks in that operation ‘elevated’ when compared to other charter operations, the investigation concluded that the occurrence pilot was under prepared for the demands of air taxi operations.

Had the proposed CASR Part 121B (see attachment B) been in place at the time of the occurrence, the occurrence pilot would have been required to have regularly practised EFATO and other abnormal situations as part of the proposed Annual Proficiency Check requirement. In addition, the primarily over water nature of the air taxi operation, employing single-engine aircraft, could be expected to have included the conversion course syllabus requirement for the practise of engine power loss after takeoff. Given his previous flying experience, the occurrence pilot would also have required supervision by the operator for a minimum of 25 flying hours. That supervision could have improved the pilot’s understanding of the risks inherent in the air taxi operation, and reinforced the opportunistic guidance and advice provided by other company personnel. The investigation concluded that adoption of relevant elements of the proposed content of CASR Part 121B could be expected to better prepare pilots for the air taxi operation.

2.3.2. Operational procedures

2.3.2.1. Management-Chief Pilot interaction

The management focus on strategic and other planning issues affecting the company would have served to increase the pivotal importance of the Chief Pilot in satisfying management objectives applicable to the air taxi business element. It was likely that the dispersed nature of the air taxi operation and company assets, the primarily strategic management focus, and the Chief Pilot's flying rate, diminished the possibility for timely lines of communication between management and the Chief Pilot. That would have caused difficulty for the Chief Pilot when integrating management requirements within the air taxi operation, and may have explained the apparent disparity between the induction training provided to the occurrence pilot, and that thought by management to have been provided for that pilot.

In addition, the Chief Pilot's flying rate may have adversely impacted on his ability to formalise other directives and procedures within the company publications, and to adequately supervise the air taxi operation. That may have explained the varying application by company Cherokee Six pilots of: the informal tip tanks usage policy; the informal application by pilots of the 'lean while taxi' procedure; and the apparently inappropriate application of previously learned operational time management techniques by the occurrence pilot in the air taxi environment.

There was the potential for those factors to increase any organisational stress that may have already existed as a result of the organisational and other change being managed by company management. While there appeared to be no direct link between those factors and the development of the occurrence, the investigation considered that the risk of any organisation suffering an incident in circumstances similar to those existing in this air taxi operation was elevated.

2.3.2.2. Pace of operations

The increase in passenger demand above the Booking Sheet requirements and additional unplanned sectors early in the afternoon on the day of the occurrence, increased the pilot's workload and placed some time pressure on the pilot to regain 'schedule'. This was partially demonstrated when the pilot performed a downwind landing from the 1600 sector to Shute Harbour, and commented that he did that with his previous employer to make up time. However, there was insufficient information for the investigation to determine whether any perceived or actual time pressure on the occurrence pilot had adversely impacted upon his completion of pre-flight, pre-take-off and engine run-up checks, or on the conduct of the takeoff on the occurrence flight.

2.3.2.3. Initiation and direction of turn

The content of the various flying training syllabi, *Flight Instructor's Manual* and competency standards and assessments generally addressed the actions following an EFATO. That also appeared to be the case with the Engine Power Loss During Takeoff emergency procedures listed in the Cherokee Six Owner's Handbook. Each publication emphasised the need to restrict turns to a minimum. In addition, there was no evidence of the occurrence pilot's exposure to those conditions in recent competency assessments. In that case, it was not surprising that the occurrence was most probably the pilot's first exposure to such a difficult, overwater emergency.

Witness reports of the aircraft's engine performing abnormally shortly after lift off from the runway meant that the pilot was confronted with a very difficult, time-critical decision for which he was under prepared. His decision to commence a turn was in response to an ill-defined, unenviable, over water emergency situation to which it was likely that varying responses could be expected from individual pilots. In an instant, the pilot had to: assess and act on the likelihood of a successful ditching and egress for all aircraft occupants; and the possibility that engine power, although intermittent, may have initially appeared adequate for the pilot to attempt to manoeuvre the aircraft for a successful emergency landing on land.

The investigation considered that the pilot's decision to commence a right turn might have been in response to observing an expanse of water to the left and ahead of the aircraft shortly after lift off from the runway whereas, at that time, land was probably visible to the right. The pilot may also have been pre-disposed to the right turn by the promulgated runway circuit direction, and the fact that most air taxi destinations required a right turn after takeoff from runway 14 at Hamilton Island.

Based on the reported abnormal engine operation commencing shortly after lift off from the runway, the investigation considered it unlikely that the pilot achieved a climb speed much beyond the recommended take-off speed of about 60 kts.

The stall speed for the occurrence aircraft was unable to be determined. However, the investigation estimated that the stall speed for a turn at 60 degrees angle of bank would have been more than 70 kts and, at 80 degrees angle of bank, more than 121 kts.

The reported bank angle of the aircraft approached an estimated 90 degrees. There were a number of factors that could have led to the large angle of bank, however, the investigation was unable to positively determine which of those factors may have influenced the pilot in command to have applied that amount of bank. Given the pilot's experience, the investigation considered it unlikely that the pilot commenced the right turn with the intent of deliberately applying the observed angle of bank. It was possible that the pilot may have increased the angle of bank in response to having reacquired sight of the intended landing area once part way around the turn. Alternately, the increased angle of bank may have been a result of a conscious pilot decision to increase the rate of turn in order to reach an immediate landing area on land. It was also possible that the increased angle of bank may have been induced from the effects of the G-excess illusion (see section 2.5.1.1).

The reported angle of bank meant that the derived aircraft stall speed was more than 61 kts above the recommended take-off speed. About half way around the turn, the aircraft was reported to descend '…like a dart…' and impact the ground.

The investigation concluded that the aircraft stalled at a height from which it was not possible for the pilot to effect recovery before the aircraft impacted the ground.

2.3.2.4. Limitations of the visual stall warning

It is important to ensure that appropriate warning system information is presented in a form that pilots or crews can readily understand, and at the right time to facilitate making effective judgements and decisions.[32] In particular,

> …the alerting function for all important failures should be fulfilled by a [sic] audio warning for the obvious reason that even the most conspicuous visual warnings

32 Noyes, J. M., Starr, A. F., Frankish, C. R., & Rankin, J. A. (1995). Aircraft warning systems: application of model-based reasoning techniques. *Ergonomics, 38*, 2432-2445.

rely on head and gaze orientation. Accidents have occurred to aircraft such as the Jaguar, which has no audio warning for undercarriage, because the pilot has landed, gear up, with a large flashing light in the gear lever that has gone unnoticed.[33]

The location of the stall warning indicator on the far-left side of the occurrence aircraft's instrument panel would have made it difficult for the occurrence pilot to notice during the completion of the reported steep right turn. That was increasingly likely, given that the pilot's focus at that time was most probably maintaining, or reacquiring sight of the intended forced landing area to the right of the aircraft, and managing the aircraft's performance in order to reach that area.

Aural stall warning systems in general aviation aircraft have several human performance advantages compared with visual stall warning devices.[34] When designed correctly, auditory warning signals can improve operator performance.[35] Auditory warnings have several advantages over visual warnings. For example, auditory warnings have an immediacy that may not be apparent with visual warnings, and they may also produce higher levels of compliance.[36,37] In addition, auditory warnings reduce the need to continuously monitor visual displays, they reduce clutter and visual workload, and they can reduce response time.[38,39] Furthermore, auditory warnings can alert the pilot to dangerous conditions regardless of head position and direction of gaze, as well as provide sensory inputs that are less disrupted by hypoxia and positive G-forces than are visual inputs.[40, 41] That was possibly of particular relevance during the steepening, low-level right turn, when, as previously discussed, the primary concern of the occurrence pilot may have been external to the aircraft.

Given the pilot's previous experience on aircraft equipped with an aural stall warning device, it was possible that the pilot may have assessed the absence of an aural warning during the steep turn as an indication that the aircraft was not at immediate risk of stalling.

The aircraft manufacturer was unable to advise the reason for the installation of an aural stall warning device in later Cherokee Six aircraft, rather than the visual device installed on earlier models such as the occurrence aircraft. The incorporation of an aural stall warning device in all Cherokee Six aircraft would provide a more effective means to alert pilots of an impending stall in flight.

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33 Green, R. G., Muir, H., James, M., Gradwell, D., & Green, R. L. (1991). *Human factors for pilots*. Aldershot, UK: Ashgate.

34 Stanton, N. A., & Edworthy, J. (Eds.) (1999). *Human factors in auditory warnings*. Aldershot, UK: Ashgate.

35 Edworthy, J., Loxley, S., & Dennis, I. (1991). Improving auditory warning design: Relationship between warning sound parameters and perceived urgency. *Human Factors*, *33*, 205-232.

36 Stokes, A. F., & Wickens, C. D. (1988). Aviation displays. In E. L. Wiener & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 387-431). San Diego, CA: Academic Press.

37 Wogalter, M. S., Kalsher, M. J., & Racicot, B. M. (1993). Behavioural compliance with warnings: effects of voice, context, and location. *Safety Science*, *16*, 637-654.

38 Stanton, N. A., & Edworthy, J. (Eds.) (1999). *Human factors in auditory warnings*. Aldershot, UK: Ashgate.

39 Wheale, J. L. (1983). Evaluation of an experimental central warning system with a synthesised voice component. *Aviation, Space and Environmental Medicine*, 54, 517-523.

40 Doll, T. J., & Folds, D. J. (1985). Auditory signals in military aircraft: Ergonomic principles versus practice. In R. S. Jensen & J. Adrion (Ed's.), *Proceedings of the Third International Symposium on Aviation Psychology*. Columbus, OH: Ohio State University Press.

41 Munns, M. (1971). Ways to alarm pilots. *Aerospace Medicine*, *42*, 731-734.

2.3.2.5. CASA surveillance

2.3.2.5.1. Operations surveillance

A reduction in the number of 'Don't Know' annotations made in the AOC STIs demonstrated improved CASA familiarity with the operator over the year prior to the occurrence. Concurrently, the STIs indicated that the operator's potential level of risk increased markedly over that period.

The primarily subjective nature of the interaction of the STI with other surveillance planning information sources precludes consistent interpretation by inspectors of the need for additional surveillance of an operator in response to identification of increased organisational stressors. In addition, there is the potential for a lack of, or subjective interpretation and response to, industry intelligence, or a large number of 'Don't Knows' annotated on an STI form to dilute the relevance of an STI result when surveillance planning.

The lack of formalised 'triggers' within the surveillance - resource allocation methodology further diminishes the likelihood of an objective, reliable response by inspectors to: an increasing rate of change in perceived operator risk identified within successive STIs; or consolidated STI returns, trending information, or other integrated surveillance information. In that case, the lack of a CASA district office response to the operator's increased rate of change in perceived risk that was identified in the previous year's STI's, while potentially less than desirable, was understandable.

By not taking the opportunity to conduct additional surveillance of the operator, CASA denied itself the opportunity to fully understand any possible safety implications for the air taxi operation resulting from the identified increasing number of organisational stressors, or from any additional hazards not identified by the 22 April 2002 STI. The potential hazards to the air taxi operation that may have been identified by additional CASA surveillance over the period from completion of the second April STI to the day of the occurrence, included the:

- Chief Pilot's reported high flying rate
- management – Chief Pilot disparity in understanding of the company's induction training requirement, and, ultimately its application in the case of the occurrence pilot
- existence and varying interpretation and application by company pilots of a number of informal air taxi aircraft operating procedures
- limited opportunities for fatigued air taxi pilots to gain relief from air taxi flying operations
- increased management guidance required for the air taxi operation as a result of the number of recent changes of Chief Pilot.

Had CASA inspectors carried out additional surveillance, organisational risks resulting from identification of those potential hazards may have been evaluated, and consideration of the need for possible risk treatments may have been proposed to the operator.

The relevance of the CASA response in the development of the occurrence could not be quantified, and the evidence was not sufficient to find that it was a factor. However, the lack of some form of desk-top tool to assist inspectors to objectively assess STI data and other intelligence was considered by the investigation to be a shortcoming in the CASA approach to AOC surveillance. As a result of the recently announced delay in the development of CASR Part 119, and the potential duration of the transitional AOC period associated with the introduction of that Part, there is the potential for the existing approach to AOC surveillance to remain in place until mid 2011.

2.3.2.5.2. Engineering surveillance

The low number of 'Don't Know' annotations in the three COA STIs indicated that Airworthiness Inspector knowledge of the engineering operation remained high throughout the year prior to the occurrence. While the level of risk identified by the COA STI process remained relatively constant over that period, the number of engineering non-compliances reduced, and application of supporting documentary processes within the company was noted to improve. That was considered indicative of the inspectors maintaining a sound understanding of the issues affecting the operator's engineering element, and of diligently following up those issues. The investigation concluded that the improvement in the engineering element had, at least in part, resulted from the CASA inspectors' input.

2.3.3. Weather

The weather conditions were not considered a factor in the development of the occurrence.

2.4. Aircraft

2.4.1. Airworthiness Issues

The investigation established that the engine installation, prior to purchase by the operator, was contrary to the TCDS. The lack of appropriate documentation to authorise the installation of a converted engine in the occurrence aircraft meant that the aircraft was technically not airworthy.

Notwithstanding the regulatory issues, the advice from CASA and the engine manufacturer was that, practically, the installed engine should have been capable of producing the power expected from that specified in the TCDS. Furthermore, operation of the engine in the occurrence aircraft for 126.2 hours with no reported abnormalities affecting engine power output indicated that the engine should have been capable of consistently producing the required power. On that basis, the investigation concluded that there was no evidence that the configuration of the engine contributed to the development of the occurrence.

2.4.2. Aircraft systems

Although two passengers reported an aircraft vibration on the third sector prior to the occurrence flight, the investigation was unable to confirm the source, nature and implications for aircraft performance of that vibration. In addition, the lack of any reported vibration, or degradation in aircraft performance on the two sectors prior to the occurrence, further restricted the ability of the investigation to determine the implications of any vibration as a factor in the development of the occurrence engine abnormality.

Apart from a reduced valve clearance of the number-2 cylinder exhaust valve, there was no evidence of any defect or anomaly detected during the engine disassembly. However, subsequent examination of the disassembled engine components required additional consideration.

The lack of any reported engine roughness after recent start-ups meant that there was no perceptible evidence of a developing sticky valve. Furthermore, the absence of collateral damage to the valve train meant that there was no visible evidence that the valve had stuck. Accordingly, the investigation concluded that it was doubtful whether valve stickiness, if present, was sufficient to adversely affect engine performance to the extent reported by the witnesses.

Although it was likely that the blocked fuel injector nozzles resulted from the post-impact fire, the symptoms reported by the witnesses were not inconsistent with the possibility of pre-impact obstruction of one or more nozzles. However, on the available evidence, there was nothing to confirm that pre-impact blockage of one or more nozzles had been a factor in the occurrence.

Although it was likely that the fouled number-4 cylinder lower spark plug resulted from pre- impact engine operation, the investigation determined that it would not have had a significant influence on engine performance to the extent reported by witnesses.

Apart from establishing the structural integrity of the impulse coupling, the results of the examination of the magnetos was inconclusive. However, the relatively minor effect on engine power output of a magneto failure meant that, had such a failure occurred, it was unlikely that the performance of the aircraft would have been influenced to the extent reported by witnesses.

While exhaust muffler outlet blockage was a possibility, and may have conceivably resulted in symptoms consistent with those reported by the witnesses, the damage to the exhaust system prevented a comprehensive assessment of that hypothesis.

2.4.2.1. Fuel quality and status

Fuel sample test results indicated that the fuel supplied to the aircraft was of the required specification, of the correct grade and was free from contamination. The investigation concluded that the quality of the fuel had not been a factor in the occurrence.

The examination of the fuel system components that were not destroyed by the post-impact fire revealed that there was no evidence of pre-impact contamination of those components. More than sufficient fuel was carried for the planned flight. The aircraft had been flown for more than 85 minutes since it was last refuelled.

2.4.2.2. Aircraft take-off roll

The investigation considered an extensive range of factors that could have contributed to the apparent extended take-off roll that was about 2,950 ft (899.2 m) longer than predicted. However, as there were no known witnesses to the aircraft's take-off roll, and the results from the audio analysis of engine performance were inconclusive, the investigation was unable to determine the presence of an abnormality prior to the aircraft lifting off from the runway.

Given the pilot's general flying experience and recency in the Cherokee Six and its operation from Hamilton Island, the pilot should have been able to recognise a developing extended take-off roll. In that case, the investigation considered it unlikely that the pilot continued the takeoff with the knowledge that the aircraft was performing abnormally. On that basis, the investigation considered whether the aircraft might have sustained a performance degradation able to be rectified by the pilot on the runway, or that cleared of its own accord.

There was no indication from examination of the aircraft components retrieved from the aircraft wreckage to explain any possible performance degradation during the take-off roll. However, because of the recency of the previous right cabin door insecurity to the occurrence flight, the investigation considered whether the door might have become unlatched during the aircraft take-off run. While the pilot was reported to have been satisfied with the functionality of the right cabin door prior to the occurrence flight, this was the first flight after the repair and the in-flight serviceability of the repair had yet to be verified. Had the door 'popped' while the aircraft was on the runway, the pilot might have rejected his takeoff and secured the door before recommencing the takeoff from that position advanced down the runway. That may have given the appearance of an extended take-off roll.

Damage from the post-impact fire precluded detailed examination of the right cabin door and latching mechanism to determine its pre-impact functionality.

2.4.2.3. Post lift off from the runway

Extensive examination of the aircraft systems, and consideration of the aircraft history, did not reveal any evidence of pre-existing anomalies that might have adversely impacted on the post lift off performance of the aircraft engine to the extent reported by witnesses. The investigation determined that a mechanism that might have resulted in the symptoms reported by the witnesses was fuel supply-related.

As described in section 2.4.2.1, there was sufficient fuel of the correct specification onboard the aircraft for the planned flight. Therefore, the investigation focussed on the possibility that delivery of fuel to the engine may have been compromised.

The fuel indicated in the aircraft Flight Record as remaining in each main fuel tank meant that selection of either main tank for the occurrence flight would have resulted in minimal risk of manoeuvre-related uncovering of a main tank fuel outlet during a normal takeoff.

The lack of any record by the pilot of fuel remaining in the aircraft tip tanks and impact damage prevented determination of the amount of fuel in the tip tanks at the commencement of the occurrence flight. However, based on the informal company tip tank use policy, the investigation concluded that there was probably a maximum of 5-10 L of fuel in each tip tank. In that case, the low quantity of fuel in the tip tanks meant that selection of either tip tank would have exposed the aircraft to an increased risk of fuel starvation. Any aircraft manoeuvre, such as a takeoff had the potential to modify the timing and symptoms of such starvation.

The position of the fuel selector control on the cockpit floor increased the risk of either the pilot or front seat passenger inadvertently knocking the control from its intended selection when entering or exiting the cockpit area. If, during the Takeoff Checks, the pilot visually checked correct fuel tank selection, without confirming the selection by detent 'feel', a possibly unintended fuel selector control position may have remained unnoticed. In that case, there was the potential that an inadvertent or intermediate fuel tank selection could have been made.

The investigation determined that any intermediate fuel tank selection that resulted in fuel being drawn from a combination of the LEFT and RIGHT main tank positions would have been of no consequence for the occurrence flight.

However, a partial tank selection, that included drawing fuel from either of the left or right tip tanks, would have meant the tip tank outlet could become uncovered, and an indeterminate fuel-air mixture result at some time after that selection was made. That would have resulted in the delivery of fuel to the engine being compromised, resulting in temporary power loss. That was consistent with the witness reports of abnormal engine performance shortly after takeoff.

Irrespective of whether the pilot recognised that the abnormal engine operation was fuel supply-related, and immediately rectified any fuel selection anomaly, engine power may not have been regained until up to 10 seconds later. Overall, the possible temporary nature of any compromise in the engine fuel supply may have explained the finding that, at ground impact, there was power being delivered to the propeller in response to the resupply of fuel.

2.5. Human factors

2.5.1. Analysis of pilot performance

The analysis of pilot performance will consider the significance of the toxicological findings in terms of their potential contribution to the occurrence. Authorised specialist toxicologist laboratories provided those findings to the ATSB. Discussion of the scientific and medical aspects of drug and alcohol impairment, and its effect on human performance, draws from the specialist aviation medical research conducted for the ATSB as part of the investigation.

Other factors to be considered include fatigue, environmental factors and the nutritional and hydration status of the accident pilot.

2.5.1.1. Alcohol[42]

The estimated 8.5-hour period between the pilot's last observed alcoholic drink and commencing duty, satisfied the requirements of the existing Civil Aviation Regulations (CAR 256). If he consumed more alcohol after returning to his room, the 8 hour bottle-to-throttle rule specified in CAR 256 may have been infringed. However, there was no evidence to indicate that was the case.

[42] Includes analysis based on the content of the ATSB discussion paper titled *Alcohol and Human Performance from an Aviation Perspective: A Review*.

Any analysis of the role of alcohol in this occurrence must take into account the issue of post-alcohol impairment (PAI) or hangover effects. This is defined as impairment of function, even after the blood alcohol concentration (BAC) has returned to zero. There was the possibility that the occurrence pilot may have had a degree of PAI, even if he had observed the 8 hour bottle-to-throttle rule. This could not be discounted because the full extent of alcohol intake the night before the occurrence was unknown. It must also be remembered that a person's ability to determine accurately their level of alcohol impairment is generally poor.

Alcohol is known to interfere with the function of the human vestibular system, which is of critical importance for normal orientation. Vestibular dysfunction can significantly increase the risk of spatial disorientation in pilots, which can, in turn, lead to inappropriate control inputs, potentially leading to loss of control and increased risk of an accident.

The occurrence involved a low-level turn in good weather during daylight. Any head movement by the pilot during the turn may have produced a degree of disorientation because of the combination of Coriolis and G-excess phenomena, with any associated nystagmus amplifying the disorientation.

Nystagmus induced by Coriolis stimulation can be accentuated and prolonged by alcohol for up to approximately 34 hours post-ingestion. Furthermore, if the level of +Gz acceleration is greater than +1 Gz, nystagmus can be produced some 48 hours after alcohol ingestion. In this particular occurrence, it could be reasonably assumed that the pilot would have been moving his head during the turn, which was made at a high +Gz level.

The G-excess illusion is a particular form of vestibular disorientation that results in a false sensation of body tilt (pitch or roll) when the G environment is greater than the normal +1 Gz situation. The occurrence pilot was reported to have conducted a turn in excess of 60 degrees angle of bank, or a +2 Gz turn. Had the pilot looked into the turn with his head elevated, or out of the turn with his head depressed, he may have experienced an apparent underbank of at least 10 to 20 degrees. A perceived underbank by the pilot could have resulted in a pilot control input leading to an unrecognised, pilot-induced overbank, with subsequent loss of altitude and/or stall and, possibly, descent into terrain.

The presence of constituents of a well-known headache medication in the pilot's blood (discussed later) could have been consistent with remedial action taken to treat the effects of a hangover, which, in turn, would be indicative of a recent significant alcohol intake. This would have made the likelihood of PAI in this pilot more probable.

2.5.1.2. Cannabis[43]

If the pilot used cannabis in the days leading up to the occurrence, that may have reduced his ability to effectively deal with the emergency situation with which he was confronted. As little as a single dose of cannabis can adversely affect human performance of complex cognitive tasks for up to 24 hours after intake. Similarly, the

[43] Includes analysis based on the content of the ATSB discussion paper titled *Cannabis and its Effects on Pilot Performance and Flight Safety: A Review*.

psychomotor and performance-reducing effects of cannabis are dose-dependent, and may well depend on the complexity of the task being performed. The more difficult the task required of the pilot, the more likely that carry-over effects of cannabis will result in impaired performance of the flying task. Thus, the combination of possible recent cannabis use, and increased task difficulty due to the reported in-flight engine problem, could have resulted in a degree of performance impairment in the occurrence pilot.

It has been suggested that subtle cognitive impairment could develop in chronic users of cannabis over several years. Research has suggested that long-term cannabis use may impair the efficient processing of information.[44] *(see Discussion Paper)* The extent and pattern of cannabis use by the pilot could not be clearly established.

The finding that the pilot was a cannabis user was a cause for concern, but there was insufficient evidence to draw a positive conclusion regarding the contribution of cannabis use in this particular occurrence.

2.5.1.3. Opiates

It was unlikely that use of an analgesic preparation containing paracetamol and codeine directly contributed to degraded pilot performance. Rather, it was indicative of other problems. The fact that the pilot had analgesic substances in his blood, and was reported to have been drinking an unknown quantity of alcohol the night before the occurrence, were findings consistent with the requirement for self-treatment of an alcohol-induced hangover. However, while that possibility existed, the supporting evidence was again circumstantial, and could not be reliably proven one way or another.

2.5.1.4. Nutritional state

Evidence suggested that the occurrence pilot had probably not eaten during the day of the occurrence. The lack of food intake may have suggested a level of gastric upset, secondary to alcohol hangover and may have resulted in alcohol-induced hypoglycaemia, and attendant poor cognitive functioning. The evidence for this phenomenon in the occurrence pilot was inconclusive. This factor was, on the balance of evidence, unlikely to have played a major role in the occurrence sequence.

2.5.1.5. Fatigue

Based on the occurrence pilot's telephone records, it was apparent that, on the night prior to the occurrence, the pilot retired to bed no earlier than about 0042. That, and the report that the pilot arrived at Shute Harbour on the day of the occurrence at 0725 meant that, in all likelihood, the pilot would have achieved no more than six and a half hours sleep that night. In addition, any difficulty sleeping experienced by the pilot would have further decreased the pilot's total sleep on the night prior to the occurrence.

Therefore, it was possible that the pilot could have started the duty day with a degree of fatigue as a result of an insufficient amount of sleep the previous night. The alcohol

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[44] Newman, D. G. (2004). *Cannabis and its effects on pilot performance and flight safety: A review*. Canberra, ACT: Australian Transport Safety Bureau.

ingested by the pilot that night would have degraded the quality of that sleep. Fatigue may have reduced the pilot's ability to effectively deal with the in-flight emergency.

The operational tempo and nature of the air taxi operations were of greater intensity than the pilot had previously experienced. Any fatigue experienced by the pilot would have reduced his capacity to cope with that increased workload.

2.5.1.6. Environmental factors

The potential for thermal stress was more likely, given that the accident occurred towards the end of the day, after the pilot had spent many hours in the warm and relatively moist environmental conditions. He may have become progressively dehydrated during the course of the day. However, the pilot had sufficient breaks between short sectors to minimise the potential for thermal stress. Nonetheless, the diuretic effects of the previous night's reported alcohol intake may have made him relatively more dehydrated than normal at the beginning of the duty day. That would have become progressively worse during the day, particularly if his fluid intake was inadequate.

There was insufficient evidence regarding the pilot's fluid intake on the day of the occurrence for the investigation to be able to establish if dehydration was a factor.

2.5.1.7. Human performance summary

From an aeromedical perspective, the pilot autopsy and toxicological findings were somewhat inconclusive. However, the adverse effects on pilot performance of post-alcohol impairment, recent cannabis use and fatigue could not be discounted as contributory factors to the occurrence. In particular, the possibility that the pilot experienced some degree of spatial disorientation during the turn as a combined result of the manoeuvre, associated head movements and alcohol-induced vestibular dysfunction could not be discounted.

2.5.2. Drug and alcohol testing regimes

2.5.2.1. Introduction

No Australian study has comprehensively examined the prevalence of illicit drug or alcohol use in the Australian aviation industry. The precise dimensions of the drug and alcohol problem in the Australian aviation industry remain, therefore, largely unknown. Based on the prevalence of drug and alcohol use in the wider community, it is statistically probable that a proportion of Australian aircrew and other safety sensitive personnel will be users and/or mis-users of alcohol and/or illicit drugs.

2.5.2.2. Current regulations

Current aviation regulations do not adequately address some important issues relating to the effects of illicit drugs and alcohol. PAI is known to result in impaired human performance at skilled tasks such as flying well beyond the prescribed 8 hour bottle-to-throttle rule, and for many hours after BAC has returned to zero.[45, 46, 47, 48, 49] Similarly, cannabis has been shown to have residual effects that can also persist well beyond eight hours.[50, 51] There is therefore much evidence to suggest that 8 hour bottle-to-throttle rules by themselves are inadequate.[52, 53, 54]

In addition, under CAR 256, aircrew must self-determine their fitness to fly. If they can satisfy the 8 hour rule, and consider themselves to not be impaired by drugs or alcohol, then they are legally able to fly an aircraft. However, the weight of scientific evidence suggests that human beings are, in general, unable to accurately determine their level of performance impairment due to alcohol.[55, 56] The same is probably true of illicit drugs. Also, PAI and residual drug effects may only become apparent during high cognitive workload situations, such as the emergency confronting the occurrence pilot. Therefore, it is possible that, under the current regulations governing alcohol and drug use, some pilots may be flying, whether knowingly or unknowingly, with some level of impairment. This should be regarded as a serious flight safety issue that warrants attention.

There are also significant limitations to the regulatory requirement for pilots and other designated aviation personnel to disclose either a problematic history, or current use of drugs and alcohol during their annual medical examination. Specifically, medical applicants may fear the adverse consequences that such disclosure may have on their livelihood and future career prospects, before considering the consequences of non-disclosure. Therefore, it is also possible that, under the current CARs governing medical certification, some pilots may not be disclosing their drug and alcohol use accurately. That appears to have been the case with the occurrence pilot.

2.5.2.3. Drug and alcohol testing for Australian aviation industry personnel

In Australia, there is personal responsibility on the part of safety-sensitive employees in relation to observing CAR 256. This regulation is not overly prescriptive and, while generally reflective of ICAO guidelines, it does put the onus on aircrew, with the added risk that they will either deliberately or inadvertently violate the regulation. CAR 256 does not adequately protect or deter against the use of illicit drugs, nor does it provide

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[45] Cook, C. C. H. (1997). Alcohol and aviation. *Addiction, 92*, 539-555.

[46] Gibbons, H. L. (1988). Alcohol, aviation and safety revisited: A historical review and a suggestion. *Aviation, Space & Environmental Medicine, 59,* 657-660.

[47] Modell, J. G., & Mountz, J. M. (1990). Drinking and flying – the problem of alcohol use by pilots. *New England Journal of Medicine, 323*, 455-461.

[48] Yesavage, J. A, Dolhert, N., & Taylor, J. L. (1994). Flight simulator performance of younger and older aircraft pilots: effects of age and alcohol. *Journal of the American Geriatric Society, 42,* 577-82.

[49] Yesavage, J. A, Leirer Von, O., Denari, M., & Hollister, L. E. (1985). Carry-over effects of marijuana intoxication on aircraft pilot performance: A preliminary report. *American Journal of Psychiatry, 142,* 1325-1329.

[50] Leirer Von, O., Yesavage, J. A., Morrow, D. G. (1991). Marijuana carry-over effects on aircraft pilot performance. *Aviation, Space & Environmental Medicine, 62,* 221-227.

[51] Yesavage, J. A, Leirer Von, O., Denari, M., & Hollister, L. E. (1985). Carry-over effects of marijuana intoxication on aircraft pilot performance: A preliminary report. *American Journal of Psychiatry, 142,* 1325-1329.

[52] Cook, C. C. H. (1997). Alcohol policy and aviation safety. *Addiction, 92*, 793-804.

[53] Gibbons, H. L. (1988). Alcohol, aviation and safety revisited: A historical review and a suggestion. *Aviation, Space & Environmental Medicine,* 59, 657-660.

[54] Yesavage, J. A, Dolhert, N., & Taylor, J. L. (1994). Flight simulator performance of younger and older aircraft pilots: effects of age and alcohol. *Journal of the American Geriatric Society, 42,* 577-82.

[55] Cook, C. C. H. (1997). Alcohol and aviation. *Addiction, 92*, 539-555.

[56] Yesavage, J. A, Leirer Von, O. (1986). Hangover effects on aircraft pilots 14 hours after alcohol ingestion: a preliminary report. *American Journal of Psychiatry, 143,* 1546-1550.

grounds for ‘on suspicion’ or post-occurrence testing of safety sensitive aviation employees. Clearly, the current lack of any drug or alcohol test regime, which might support the existing regulations, prevents those regulations from posing a sufficient level of deterrence.

The introduction of a drug and alcohol testing program for the Australian aviation industry is a complex and emotive issue and has generated a considerable degree of controversy in the industry. Implementation of a drug and alcohol testing program assumes that there is the potential threat of drug and alcohol use in the aviation environment, a view recognised by ICAO. Random testing acts as a deterrent. If individuals perceive a likelihood of being detected with subsequent punitive consequences, then they may choose not to engage in the prohibited activity.[57] ‘On suspicion’ testing also acts as a deterrent, with the additional benefit that it can lead to the immediate prevention of an incident or accident.

Regulatory authorities and operators have a responsibility to ensure that safety sensitive aviation personnel are free from impairment induced by alcohol, drugs or other disabling substances when performing their tasks.[58] Similarly, individual employees have an obligation to ensure they are capable of performing their duties to the best of their ability. Some operators, as well as employers in a wide variety of other industries, are very public in their support for drug and alcohol testing programs. Unions and employees, on the other hand, are generally wary and, at times, extremely vocal in their opposition. The introduction of a drug and alcohol testing program must carefully balance the duty of care to the travelling public against the personal privacy and other rights of employees. Notwithstanding, each Australian State police force conducts random breath testing of drivers, and the Victorian State government has recently instigated a trial of random cannabis testing of drivers. There is every reason to suggest that similar testing regimes should be considered for application to safety sensitive personnel in other transport modes, including aviation.

It would also be useful to specify a maximum BAC in the regulations. This would then provide a value against which to test. The value should be reasonable and achievable in the widest circumstances. A maximum BAC ensures that a pilot who has been drinking heavily, but then abstains for 8 hours in accordance with the regulations, will not be able to fly if his BAC is still above the prescribed amount. Such an outcome is not possible under existing legislation. A BAC of 0.04% as in the US policy appears too high, since impairment effects have been shown at this level. The JAA limit of 0.02% would appear to be more appropriate, and represents 40% of the Australian legal BAC limit for driving of 0.05%. However, one of the difficulties with this approach is that pilot performance has been shown to degrade after significant alcohol consumption even when the BAC has returned to zero.

The ability to perform ‘on suspicion’ testing of safety sensitive employees has considerable potential to enhance flight safety, and would be a natural adjunct to any random program. The instances of detection of pilots attempting to board their aircraft under the influence of alcohol, described in attachment D, serve as an example of the benefits of the adoption of an ‘on suspicion’ test regime.

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[57] International Civil Aviation Organization. (1995). *Manual on prevention of problematic use of substances in the aviation workplace (Doc. 9654-AN/945).* Montreal: ICAO.
[58] *Ibid.*

The currently available evidence strongly suggests that the majority of pilots who violate the alcohol regulations do so knowingly. This group of pilots requires a greater deterrent in order to modify their behaviour. A drug and alcohol testing program would offer more deterrent value than the current regulations. An education program, on the other hand, best serves inadvertent drink flyers, because the evidence suggests that their violation of the regulations regarding alcohol use is based on inadequate knowledge.

However, even with the fully operational random drug and alcohol testing program in the United States, a small number of positive test results are still being reported. This indicates that there is still a small, yet determined group of offending pilots who are flying in defiance of promulgated regulations. The consequences of a positive test result in these pilots can lead to either a change of behaviour through rehabilitation or, removal from safety sensitive employment in intractable cases.

2.6. Survival aspects

The fire and emergency response was in accordance with the Airport Emergency Plan.

3. CONCLUSIONS

3.1. Findings

Aircraft

1. The aircraft had a valid Certificate of Airworthiness in force at the time of the occurrence.

2. The aircraft had a valid Certificate of Registration in force at the time of the occurrence.

3. The aircraft had a valid Maintenance Release in force at the time of the occurrence.

4. Aircraft documentation indicated that, in accordance with the regulations, the aircraft was not airworthy. There was no evidence to suggest that the aircraft's lack of airworthiness was a factor in the occurrence.

5. The aircraft weight and balance was within limits at the time of impact.

6. On takeoff, the aircraft was reported to lift off from the runway later than predicted by the manufacturer's performance data.

7. Fuel quality was not a factor in the occurrence.

   – Examination of the fuel system components that were not destroyed by the post-impact fire revealed that there was no evidence of pre-impact contamination of those components.

   – The aircraft had been flown for more than 85 minutes since it was last refuelled.

8. There was sufficient fuel onboard the aircraft to complete the planned flight.

9. Based on the available evidence, the investigation was unable to identify any pre-impact engine condition that might have resulted in abnormal engine performance to the extent reported by witnesses to the occurrence.

Flight Crew

1. The pilot held a Commercial Pilot (Aeroplane) Licence.

2. The pilot held class and design feature endorsements relevant to the operation of the Cherokee Six aircraft type.

3. The pilot satisfied the recent experience requirements of the CARs and was certified competent in the execution of flight crew emergency procedures in accordance with the CAOs.

4. The induction training provided to the pilot by the operator recognised the normal and emergency flight manoeuvre familiarity requirements of CAO 40.1.0.

5. The approach taken by the operator to the provision of the pilot's induction training left responsibility for integrating that training into the necessary Cherokee Six emergency skills with the pilot.

6. The induction training provided to the pilot did not meet that understood by management to have been afforded the pilot.

7. The operator's in-aircraft Normal and Emergency Checklist did not include the actions in the event of a power loss after takeoff.

8. The induction training and check to line most likely prevented the pilot from fully appreciating the nature of, and operational tempo and risks inherent in the air taxi operation.

9. There was no evidence that a pre-existing medical disease contributed to the circumstances of the occurrence.

10. There was no conclusive evidence that the pilot had contravened the requirements of CAR 256 when he commenced duty on the day of the occurrence.

11. The pilot may have been suffering from the cumulative effects of post-alcohol impairment and fatigue at the time of the occurrence.

12. Evidence indicated that the pilot had used cannabis within the few weeks prior to the occurrence. That evidence did not necessarily indicate that the pilot was affected by use of cannabis at the time of the occurrence.

13. The pilot may have experienced the G-excess illusion, with any associated nystagmus amplifying pilot spatial disorientation.

14. As a result of the G-excess illusion, the pilot may not have recognised a rapidly developing overbank situation.

15. There was insufficient evidence to establish whether pilot dehydration was a factor in the occurrence.

Other findings

1. There was no evidence that the ambient weather conditions contributed to the circumstances of the occurrence.

2. The emergency response was in accordance with the Airport Emergency Plan.

3. The maximum height achieved by the aircraft during the takeoff and right turn was likely to have been about 250-300 ft AMSL.

4. At takeoff, the aircraft probably had about 84 L of fuel on board.

5. The aircraft was intact at the time of impact with the ground. Due to high impact forces, the accident was not survivable.

6. The lack of a desk-top tool to support the CASA AOC STI surveillance methodology decreased the likelihood of an objective and consistent response by inspectors to increasing potential operator risk.

7. A drug and alcohol testing regime affecting safety-sensitive personnel was not in-place in the Australian aviation industry at the time of the occurrence.

3.2. Significant factors[59]

1. Based on witness reports, the aircraft's engine commenced to operate abnormally shortly after lift off from the runway.
2. The pilot initiated a steepening right turn at low level.
3. The aircraft stalled at a height from which the pilot was unable to effect recovery.

[59] That is, an element in the circumstances of an occurrence, without which the occurrence would not have occurred.

4. SAFETY ACTION

4.1. Recommendations

4.1.1. Drug and alcohol testing

The following paragraphs provide a summary of the drug and alcohol testing programs in the Australian and international transport industries.

4.1.1.1. Australian road, rail and marine industries

- All Australian State and Territory police conduct random breath testing of motor vehicle drivers
- Victorian State police are trialing a random cannabis testing regime for motor vehicle drivers, which commenced in 2003
- The NSW State Rail Authority has broadened its initial 'on suspicion' blood alcohol testing regime for application to its safety-sensitive personnel to include random drug and alcohol testing
- The Australian Maritime Safety Authority has developed draft legislation to allow its marine surveyors, under certain conditions, to conduct breath testing of mariners.

4.1.1.2. International aviation

- In the US, 49 Code of Federal Regulations (CFR) Part 40A promulgates the procedures for transportation workplace drug and alcohol testing programs for all regulated US transport modes, and Federal Aviation Regulations[60] stipulate drug and alcohol testing of aviation safety-sensitive personnel
- In the UK, the Railways and Transport Safety Act 2003 permits 'on suspicion' drug and alcohol testing of safety-sensitive personnel in the aviation industry.

4.1.1.3. Australian aviation

- Proposed Civil Aviation Safety Regulation (CASR) Part 43 introduces human factors standards relating to drug and alcohol use by aircraft maintenance personnel. That Part includes subjective conditions under which an aircraft maintenance person can be 'conclusively presumed to be significantly impaired' by alcohol or other psychoactive substances

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[60] For example 14 CFR Part 121

- There is no existing drug and/or alcohol testing program applicable to Australian aviation safety-sensitive personnel,[61] or intention by the Civil Aviation Safety Authority to include such a program within CASR Part 91 – Flight Operations.

Recommendation 20040039

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, in conjunction with the Department of Transport and Regional Services, establish the safety benefits of the introduction of a drug and alcohol testing program to the Australian aviation industry for safety-sensitive personnel. Where possible, this program should harmonise with existing and evolving national and international regulations.

Recommendation 20040040

The Australian Transport Safety Bureau recommends that the Department of Transport and Regional Services, in conjunction with the Civil Aviation Safety Authority, establish the safety benefits of the introduction of a drug and alcohol testing program to the Australian aviation industry for safety-sensitive personnel. Where possible, this program should harmonise with existing and evolving national and international regulations.

4.1.2. Drug and alcohol education

Recommendation 20040041

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority revise the content of the pilot Day VFR Syllabi to include contemporary aviation medical knowledge regarding the effects of alcohol and illicit drugs use on human performance, and disseminate that information to qualified pilots via a comprehensive education program.

4.1.3. Surveillance planning

Recommendation 20040042

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority review their Safety Trend Indicator process, including with a view to developing a methodology to assist in objectively assessing potential at-risk organisations. That should include formal ‘triggers’ that enable the consistent prediction of the requirement for additional surveillance until Civil Aviation Safety Regulations Part 119 takes full effect.[62]

4.2. Safety advisory notices

Safety Advisory Notice 20040043

[61] This includes but is not limited to pilots, cabin crew, air traffic control personnel, maintenance personnel, loading and dispatch personnel and security personnel.
[62] CASA estimates that transitional AOCs could be issued for up to six years.

The Australian Transport Safety Bureau suggests that the Civil Aviation Safety Authority, through its industry publications, inform operators and pilots of Cherokee Six aircraft that a fuel selector control visual indication might not ensure selection of the intended fuel tank. In that case, actual fuel tank selection may be incorrect or partial, and result in the possibility for inconsistent engine fuel supply. Pilots should confirm correct visual fuel tank selection by detent 'feel'.

Safety Advisory Notice 20040044

The Australian Transport Safety Bureau suggests that the Civil Aviation Safety Authority, through its industry publications, should inform operators that a pilot's induction program should reflect the risks inherent in the proposed operation, and take account of the pilot's competencies, recency and proficiency relative to those risks.

4.3. Local safety actions

The operator has advised that it has completed a review of all areas of its operation. The following actions were reported as having been taken as a result of that review:

- Retraining of all company pilots, including briefings and discussions on engine failure technique in single and multi-engine aircraft, with particular attention to engine failure in single-engine aircraft over water. The briefings included in-depth discussions on water landings with regard to sea conditions
- Establishing the use of the full length of the runway for all takeoffs, regardless of the length of the runway
- Review and amendment of the operations manual where required
- Review and establishment of a pilot fatigue management system, including altered daily work schedule.

ATTACHMENTS

Attachment A: Analysis of the pilot's speech

A.1 Overview

During the investigation, the ATSB requested an independent analysis of the pilot's speech before and during the occurrence flight. A consultant forensic phonetician undertook auditory and acoustic analyses of voice recordings of the pilot's radio transmissions. *Auditory* analysis provided a qualitative assessment of observations of the voice of the pilot. *Acoustic* analysis provided a quantitative assessment of the pilot's voice using measures such fundamental frequency,[63] formant or F-pattern[64] and speech and articulation rates. The forensic phonetician had previous experience in conducting voice analyses during investigations.

The consultant was provided with copies of the following radio communications, all made by the occurrence pilot, when flying the occurrence aircraft:

- those made on the Mandatory Broadcast Zone (MBZ) frequency on the day of the occurrence, including the occurrence flight
- those with air traffic control earlier on the day of the occurrence
- those transmitted on flights conducted on 20 and 22 September 2002.

The consultant was tasked with conducting a comparative analysis of the pilot's speech on the day of the occurrence with equivalent flights, in the same aircraft and at similar times of day, on 20 and 22 September 2002. Auditory and acoustic analyses had the potential to detect differences in the pilot's voice between recordings made on the days prior to the occurrence and recordings made on the day of the occurrence.

A.2 Introduction to Speech Analysis[65]

Speech analysis holds promise as a technique for detecting changes in the psychological and/or physiological state of a speaker that may be associated with fatigue, hypoxia, alcohol intoxication, drug impairment, physical exertion, workload demand, emotional stress, and fear (Belan, 1994; Brenner & Cash, 1991; Brenner, Shipp, Doherty & Morrisey, 1985; Johnson, Pisoni, & Bernacki, 1990; National Transportation Safety Board, 1990).

Speech analysis analyses a whole pattern of voice information and related behaviour to identify possible factors affecting individuals involved in an occurrence. This will generally involve measurement of variables such as fundamental frequency (pitch), speech rate (number of syllables per second), intensity (or loudness), speech errors, response time, and aspects of the speech quality. The data is then compared with carefully selected samples (generally from the same person under normal conditions).

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[63] *Fundamental frequency* is the rate at which the vocal cords of the larynx open and close during speech releasing puffs of air. A fundamental frequency of 150Hz indicates that the vocal cords open and close 150 times per second. Listeners normally perceive the fundamental frequency as the pitch of the speaker's voice.

[64] The *formants* are frequencies at which the vocal tract above the larynx, acting as a filter due to its natural modes of vibration, will allow maximum energy to pass from the sound produced by the vocal cords. The formant frequencies determine many aspects of perceived speech. Formant dispersion refers to the relative spacing between successive formants.

[65] The following introduction is based on material developed by Dr Mike Walker at the Australian Transport Safety Bureau.

Due to its imprecise nature, any information obtained needs to be combined with other information before making any overall conclusions regarding the existence or influence of a particular condition.

Speech analysis has been successfully employed to examine the influence of a variety of factors on human performance. In particular, speech analysis has been used extensively by Dr Alfred Belan of the Commonwealth of Independent States (CIS), where over 300 aircraft accident investigations have employed speech analysis techniques to augment investigations. Dr Malcolm Brenner and others have also conducted research at the US National Transportation Safety Board (NTSB). The main factors successfully examined included:

- **Stress and Workload.** Increase in pitch, intensity and speaking rate, and decrease in the number of syllables in an emergency (Brenner, Doherty & Shipp, 1994; Mayer, Brenner & Cash, 1994; Ruiz, Legros, & Guell, 1990)
- **Alcohol.** Decrease in speaking rate, misarticulation of specific difficult sounds (e.g. ‘r’ to ‘l’, ‘s’ to ‘sh’, ‘ez’ to ‘es’) and speech errors (Brenner & Cash, 1991)
- **Hypoxia.** Decrease in the speed of response and speech rate, failure to speak, imprecise pronunciation and incomplete responses (e.g. ATSB Aviation Safety Report 200003771, Beech Super King Air 200 VH-SKC, 4 September 2000)
- **Medical Events** (e.g. NTSB analysis for Piper Arrow accident, 9 August 1991, FTW-91-FA-144)

Although the measurements of many of these variables can be conducted with relatively inexpensive software, specialists in forensic phonetics and other areas of linguistics are generally needed to conduct a thorough and valid analysis.

A.3 Speech data examined

The pilot’s radio transmissions from 1200 until completion of the pilot’s duty period on 20 and 22 September 2002 was labelled baseline data. The pilot’s radio transmissions from 1200 until closure of the air traffic control tower on the day of the occurrence was labelled occurrence day data. Both data sets were analysed. The pilot’s transmissions were made from the same aircraft on each day and were recorded on the same recording medium. Those transmissions provided an adequate and comparable sample of the pilot’s voice at corresponding times.

A.4 Auditory analysis

The baseline data indicated that the occurrence pilot’s voice was of average pitch for a male speaker, and that voice quality was generally modal. There was no evidence of either ‘harsh’ or ‘creaky’ voice from the pilot.[66, 67]

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[66] Voice quality has been shown to have acoustic correlates. Laver suggests its characteristics fall into three categories: (1) modal and falsetto, (2) creaky and whispery and (3) harsh or breathy. Any of these features can occur independently within a speaker’s voice, or they can occur in various combinations. Modal voice represents the neutral mode of phonation, with the glottis opening and closing fully. The vocal folds vibrate regularly and there is no audible friction in voiced sounds. Whispery voice occurs when there is incomplete closure of the glottis, so that air flows continuously across the vocal folds, causing the characteristic lack of phonation. Harsh voice occurs when phonation is present, but there is some irregularity in the cycle-to-cycle variations both of fundamental frequency and of amplitude, giving a characteristic ‘rough’ auditory quality to the voice. Creaky voice occurs with a low frequency vibration of relatively thick and short vocal folds. This is often accompanied by irregularity in periodicity. In this attribute, creaky and harsh voice are similar, with creaky voice occurring at fundamental frequencies below about 100 Hz, and harsh voice occurring at fundamental frequencies above 100 Hz.

[67] Laver, J. (1991). *The gift of speech* (p. 198). Edinburgh: Edinburgh University Press.

The occurrence day data indicated that the quality of the pilot's voice was observably 'harsher'. In addition, the pilot had a tendency towards 'creaky' voice, particularly towards the end of speaking turns. Furthermore, the pitch of the pilot's voice appeared, on average, to be somewhat lower when compared to his voice on the two baseline days. Overall, the *auditory* analysis identified some small differences in the pilot's voice on the day of the occurrence compared to the previous baseline recordings.

Changes in the pilot's breathing patterns, lung capacity and/or involuntary muscular control over the breathing apparatus could explain the high incidence of both 'harsh' and 'creaky' voice on the day of the occurrence, when compared to the two baseline days.

A.5 Acoustic analysis

The *acoustic* analysis identified that the fundamental frequency (F0) of the pilot's voice on the occurrence day was, on average, 9 Hz lower than the combined average F0 on the two baseline days. However, that difference was not statistically significant.

Pilot voice F-pattern was measured at seven points that could be readily identified on the waveform and spectrogram of transmission of the call sign, *Mike Alpha Romeo*. F2 was found to be the only formant, which remained viable for the comparison of baseline and occurrence day data. There were no statistically significant differences between the baseline and occurrence day data for each set of F2 measurements.

Speech and articulation rates are both durational measurements expressed in terms of the number of syllables per second. Speech rate is calculated by dividing the duration of the entire utterance, including any pauses, by the total number of syllables in the utterance. Articulation rate is calculated in a similar way, except that those silent pauses within the utterance are not included in the calculation.

Different speech sounds are typically articulated with different time frames, that is, some speech sounds take longer to articulate than others. To maintain comparability when calculating articulation rates over relatively small quantities of data, such as short utterances, it is preferable to calculate articulation rate over linguistically equivalent items. Transmission of the call sign, *Mike Alpha Romeo*, was selected as the basis for that measurement. The comparative analysis determined that the pilot's speech and articulation rates were slightly faster on the day of the occurrence compared to the baseline days. However, those differences were not statistically significant.

A.6 Summary of voice analysis

The *auditory* analysis suggested that there were some differences in the pilot's recorded voice on the day of the occurrence, when compared to recordings of transmissions made on the baseline days. In particular, on the day of the occurrence, the pilot's voice demonstrated a slightly 'harsh' quality that became 'creaky' when he lowered the pitch of his voice, particularly at the end of intonational phrases.

Acoustic analysis suggested that the pilot's voice was probably lower in pitch and slightly faster on the occurrence day compared to the other two days.

There were some limitations with the data and transmission medium, which precluded the development of more conclusive findings. Nonetheless, there were some minor but observable differences in the pilot's voice on the occurrence day compared to the baseline days. Those differences were observed through *auditory* analysis and were supported to some extent by *acoustic* analysis. However, the observable differences were not statistically significant.

The observed changes in the pilot's voice quality and pitch, and speech and articulation rates recorded on the day of the occurrence, compared to his recorded voice on the baseline days was consistent with the hypothesis that the pilot may have been experiencing some physiological problem on the day of the occurrence.

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Attachment B: Proposed Part 121B of the Civil Aviation Safety Regulations

Notice of Proposed Rule Making (NPRM) 0307OS of July 2003 was part of the ongoing process in the development of the proposed Part 121B of the Civil Aviation Safety Regulations (CASR). The NPRM affected persons involved in the conduct of passenger transport operations in small aeroplanes.[68]

CASR 121B.945 proposed requiring an operator to ensure that a pilot, when changing operator, completed an operator's conversion course before commencing supervised or unsupervised line flying with that operator. The proposal included that the conversion course should include, amongst other requirements:

- ground training and checking, including aeroplane systems and normal, abnormal and emergency procedures;
- line flying under supervision and a line check; and
- if the pilot had not previously completed an operator's conversion course, and applicable to the proposed operation, ditching procedures training.

CASR 121B.961 outlined proposed supervisory requirements for a pilot in command of an aeroplane engaged in line operations. In the case of a pilot with equivalent experience to the occurrence pilot, that would have required supervision for 25 hours of flight time with the operator. In order for a pilot to be supervised, the pilot was required to be briefed before, and de-briefed after, each series of flights in a tour of duty by an appropriate person (as defined). Components to those briefs included: the route(s) to be taken, the aerodrome(s) to be used, weather forecasts and conditions, aeroplane loading, take-off and landing performance of the aeroplane, fuel requirements and possible contingencies.

At the completion of the proposed period of supervision, a pilot was to undertake a line check. That check was to be in accordance with CASR 121B.965(6), and would have applied to the appointment of the occurrence pilot. The aim of the line check was to confirm competency in carrying out normal line operations described in a company's Operations Manual.

Recurrent checking and training of pilots was proposed in CASR 121B.965, and included the requirement for an annual Operator Proficiency Check. That check was to confirm pilot competence in carrying out normal, abnormal and emergency procedures to the standard set out in the Manual of Standards. Units and elements of the flight check proposed under CASR Part 121B included, but were not limited to: entry to, and recovery from a stall; turn the aeroplane steeply; manage an engine failure after takeoff and manage an abnormal situation.

[68] Aeroplanes were described as 'small' when their authorised maximum take-off weight was not above 5,700 kg.

Attachment C: Relevant aeronautical knowledge and experience

C.1 Day VFR Syllabus Aeroplane – Student, Private and Commercial Pilot Licences

The Day VFR Aeroplane – Student, Private and Commercial Pilot syllabi detailed the progressive flying and ground training requirements relevant to the Student, Private and Commercial Pilot Licences for aeroplanes. A pilot licence candidate was also required to satisfy promulgated Associated Training and Aeronautical Knowledge requirements for the award of either the Private or Commercial Pilot Licence –Aeroplane Theory Examination.

Associated Knowledge was that knowledge that must be known by the pilot completely, and that related directly to the safety of the aeroplane. That knowledge included:

- the adverse effects associated with alcohol and over the counter and prescription drugs use
- the ability to recall the emergency actions listed in the pilot's operating handbook and after an engine failure after takeoff (EFATO)
- the use of the aircraft flight manual to extract take-off and landing distances required
- describing the symptoms when approaching, characteristics of, and recovery from the stall
- being able to state why power must be applied to maintain speed in a level turn
- being able to state why an aeroplane tends to overbank in level and climbing turns
- being able to state the effect on stall speed of a change in bank angle when conducting a level turn.

Each flying training syllabus requirement included performance standards that applied to the practical flying phases of the respective pilot licences. In the case of the Commercial Pilot Licence – Aeroplane (CPL(A)), the standards ensured that, prior to an attempt to fulfil the requirements of the CPL(A) flight test, pilots demonstrated a high level of proficiency when conducting certain exercises when under pressure. Included amongst those exercises were:

- level turns at bank angles no less than 45°, maximum rate and minimum radius
- stalling and spinning
- EFATO and elsewhere in the circuit
- partial engine failure/malfunctions
- flap, brake, and other airframe malfunctions
- unlatched cowl/canopy/door/hatch.

C.2 Flight Instructor's Manual

The *Flight Instructor's Manual*[69] was written as a reference for trainee flight instructors, and to assist the newly qualified flying instructor. Included among the exercises within the manual were:

- Exercise 12, Take-off and Climb to Downwind Position. The manual required the instructor to:
  - ensure student consideration of the factors affecting the length of the take-off run and initial climb

[69] Campbell, R.D. (1994). *Flight Instructor's Manual* (Amended and reprinted). Surrey, England: The Campbell Partnership.

- ensure that the student monitored the engine Ts&Ps and checked the RPM, air speed and, where applicable, fuel pressure or flow after the application of full power. That action was noted as having the potential of alerting a pilot of the need to reject the takeoff, or of decreasing the likelihood that an after take-off emergency might occur at low height following the takeoff
- discuss and simulate a minor emergency, such as a 'popped' cabin door or window during or shortly after takeoff
- demonstrate the abandoned take-off procedure from during the take-off run
- demonstrate and allow practice by the student of an EFATO. That exercise stressed that the pilot should '…select the most suitable obstruction free area for use as a landing path' and 'turn the aircraft no more than is necessary to set up the approach path'

- Exercise 14, First Solo and Consolidation. In that exercise, the manual required the instructor to ensure that the student was proficient in the execution of a rejected takeoff, EFATO and other emergencies prior to being certified safe solo.

C.3 Private and Commercial Aeroplane Pilot Competency Standards

The units of competency to be achieved for the Private and Commercial Pilot's Licence Qualifications – Aeroplanes, Day VFR comprised the skills and knowledge required to fly an aeroplane according to the day VFR. Aside from a Commercial Pilot Licence unit of competency involving flight by reference to limited instrument panel, the units of competency were common to both licences. However, in the case of the Commercial Pilot Licence, the performance levels for a number of units of competency indicated the requirement for increased levels of management and evaluation of processes and the establishment of principles and criteria by the pilot licence aspirant.

Unit 17 of the Commercial Pilot competency standards included the requirement to take off an aeroplane. Included among the underpinning knowledge and skills to that competency was a knowledge of the factors affecting take-off distance and initial climb performance. Evidence of a pilot's ability to satisfy the competency standards affecting taking off an aeroplane included:

- performing a pre-take-off safety brief
- checking and reacting to engine instruments during the take-off run.

Unit 20 of the competency standards referred to the execution of advanced manoeuvres and procedures and included recovery from an aircraft stall and incipient spin and turning an aeroplane steeply. The assessment guide for those competencies included the following evidentiary requirements:

- the effect of airframe buffet is observed and felt through the control column
- visual or aural stall warning indicators are observed
- stall departure from intended flight path is observed
- recovery is made from stall during a turn
- awareness of height loss is maintained
- entry is made to an incipient spin
- entry and maintenance of a steep turn at up to 45 or 60 degrees angle of bank
- awareness of increased stalling speed in turns is demonstrated.

Unit 21 of the list of competencies included the requirement to manage abnormal situations. An element of that unit of competency was the management of an EFATO or other abnormal engine malfunction. Among the underpinning knowledge and skills to that competency was an understanding of the height loss during a 180 degree gliding turn. The supporting Assessment Guide included the requirement for the pilot candidate to perform EFATO or other abnormal situation checks and actions as evidence of ability to meet the licensing standards.[70] Evidence of a pilot's ability to meet the licensing standards associated with managing an EFATO included the pilot:

- minimising turns
- having an action plan that included not turning back towards the airfield after engine failure unless above a safe altitude.

[70] The checks and actions in that guide were advisory. Checks and actions in approved checklists, placards, Flight Manual/POHs, or Operations Manuals had precedence and were to be complied with.

Attachment D: Drug and alcohol testing regimes[71]

D.1 Aviation regulations relating to drugs and alcohol

Aviation is a safety-critical industry involving safety-sensitive employees. 'Safety-sensitive employees' are defined by the International Civil Aviation Organization (ICAO) as 'persons who might endanger aviation safety if they perform their duties and functions improperly' (15). Pilots are defined as safety-sensitive employees, as are other employee categories such as cabin crew, maintenance personnel, air traffic controllers and aviation security screening personnel. In order to ensure that these employees operate safely, various legislative instruments and regulations have been developed and implemented in many countries across transport modes to address drug and alcohol use by safety-sensitive personnel.

Countries, such as Australia, that are signatories to the Convention on International Civil Aviation and are member states of ICAO by and large incorporate ICAO guidance, standards and recommended practices into their own domestic legislative and regulatory framework. The adoption of ICAO standards and recommended practices (SARPs) is reflected in the aviation regulations that exist in member states. As such, the majority of regulations in member states will be similar, and contain essentially common elements in order to conform to ICAO SARPs as much as possible.

In Australia, Schedule 1 of the Civil Aviation Regulations (CAR) 1988 specifies that an applicant for a medical certificate must have no established history or diagnosis of alcoholism or drug dependence or the use of illicit drugs.

CAR 256 concerns the use of alcohol and drugs by the crew of an aircraft. Specifically, CAR 256 (1) to (3) mandate that:

- A person shall not, while in a state of intoxication, enter any aircraft
- A person acting as a member of the operating crew of an aircraft, or carried in the aircraft for the purpose of so acting, shall not, while so acting or carried, be in a state in which, by reason of his or her having consumed, used, or absorbed any alcoholic liquor, drug, pharmaceutical or medicinal preparation or other substance, his or her capacity so to act is impaired
- A person shall not act as, or perform any duties or functions preparatory to acting as a member of the operating crew of an aircraft if the person has, during the period of 8 hours immediately preceding the departure of the aircraft, consumed any alcoholic liquor.

As part of the public consultation process during the development of Civil Aviation Safety Regulations (CASR) Part 91 – Flight Operations, respondents to Notice of Proposed Rule Making 0101OS of January 2003 called for:

> tighter control over the use of both alcohol and other drugs, particularly recreational drugs.

In its response to that call, the Civil Aviation Safety Authority (CASA) indicated that:

[71] Prepaired by the ATSB with the assistance of Dr David Newman MB, BS, DAvMed, PhD, MRAeS, MAICD, AFAIM, an independent aviation medical specialist.

> Enabling legislation is under consideration for more precise measurement and random testing of pilots in line with other industries in Australia and the US. Requirements will be in CASR Part 67 Medical Standards.[72]

CASA indicated that there was no proposed change to the current draft Part 91 regulation, effectively reflecting the requirements of CAR 256, at that time. CASA estimates that CASR 91 should be introduced in the second quarter of 2005.

CASR Part 43 includes regulatory proposals pertaining to every person or organisation carrying out maintenance in Australia, on Australian or foreign aircraft. That maintenance can include the repair, inspection, overhaul and modification of aircraft or aeronautical products. Part 43 introduces human factors standards relating to drug and alcohol use by the maintainer, and to management of maintainer fatigue.[73,74] Relevant sub-parts include:

- Part 43.265, which defines the subjective conditions under which a person can be conclusively presumed to be significantly impaired by alcohol or substance use. The sub-part includes no objective test in order to confirm that qualitative judgement
- Parts 43.270, 43.275 and 43.280, outlining the offences for performing work when significantly impaired, and when significantly impaired by fatigue or by psychoactive substance.[75]

Canada, another ICAO member state, has a regulation for alcohol and drug use in aircrew that is broadly similar to CAR 256. Specifically, Canadian Aviation Regulation 602.03 states that no person shall act as a crewmember of an aircraft:

- within 8 hours after consuming an alcoholic beverage
- while under the influence of alcohol
- while using any drug that impairs the person's faculties to the extent that the safety of the aircraft or of persons on board the aircraft is endangered in any way.

Neither the Australian CAR 256 nor the Canadian CAR 602.03 specifies a particular maximum permissible blood alcohol concentration (BAC). However, in Europe, the Joint Aviation Authorities (JAA) regulations covering the use of alcohol and drugs are relatively more prescriptive. JAR–OPS Part 1 details operating requirements for civil aircraft involved in commercial air transport in JAA member states. JAR–OPS 1.085 (d) and (e) give specific requirements relating to crew responsibilities in terms of drugs and alcohol, as follows:

- JAR-OPS 1.085 (d). A crew member shall not perform duties on an aeroplane while under the influence of any drug that may affect his faculties in a manner contrary to safety
- JAR-OPS 1.085 (e). A crew member shall not:
  - consume alcohol less than 8 hours prior to the specified reporting time for flight duty or the commencement of standby
  - commence a flight duty period with a blood alcohol level in excess of 0.2 promille[76] (equivalent to 0.02% BAC)

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[72] At the time of this report, there was no indication of any random testing requirement in CASR Part 67.

[73] Reflects the overall government direction for safe work places and work practices.

[74] Internationally, the considerations of fatigue and substance abuse have been recognised to contribute highly to unsafe conditions in many industries. CASA has indicated that it considers aviation to be no different, and that the provisions of Part 43 reflect current best practice requirements and individual responsibility.

[75] Places a responsibility on the individual to recognise their limitations when impaired, and the safety risk they are creating.

[76] The most commonly used measurements of BAC are grams of ethanol per millilitre of blood in the United States (also expressed as % BAC) and milligrams of ethanol per millilitre of blood used in much of Europe (also expressed as promille).

- consume alcohol during the flight duty period or whilst on standby.

The only practical and significant difference between CAR 256, Canadian CAR 602.03 and JAR-OPS 1.085 is that the JAA regulation specifies a maximum permissible blood alcohol concentration of 0.2 promille.

The United States Federal Aviation Administration (FAA) has very prescriptive regulations concerning drug and alcohol use in pilots and other aviation personnel. These are contained within Federal Aviation Regulations (FARs) that specifically cover airline operations (known as Part 121 operations) and air taxi, commuter or on-demand operations (known as Part 135 operations).

FAR 121.458 and FAR 135.253 both specify that pilots or other personnel performing safety-sensitive functions for these classes of air carrier must not have a blood alcohol concentration of 0.04% or greater. Under these regulations, employees must not report for duty or remain on duty requiring the performance of safety-sensitive functions while having an alcohol concentration of 0.04% or greater. This maximum permissible BAC level was established in 1985 (14, 33). The regulations also state that no employee shall use alcohol while performing safety-sensitive functions, and that no employee shall perform flight crewmember or flight attendant duties within eight hours after using alcohol. The regulations give a 4-hour mandatory time interval for employees performing safety-sensitive functions other than flight crewmember or flight attendant duties (that is, maintenance personnel, air traffic control, etc).

In terms of illicit drug use, FAR 121.455 and FAR 135.249 specify that pilots and other personnel performing safety-sensitive functions must not perform those functions for the certificate holder (the air carrier) while that person has a prohibited drug in their system. There are five such illicit drugs - marijuana, cocaine, opiates, phencyclidine (PCP), and amphetamines.

The relevant CARs, Canadian CARs, JARs, and FARs share some similarities, but also exhibit some significant differences. In terms of alcohol, all are notably different with respect to prescribed maximum permissible BACs. In Australia and Canada, a maximum BAC is not specified, whereas in Europe the maximum permissible BAC is half that detailed in the US regulations. Only in the United States are specific illicit drugs mentioned.

D.2 Drug and alcohol use by pilots

The relevant CARs, Canadian CARs, JARS and FARs described above are designed to prevent pilots operating aircraft while under the well-established adverse influences of alcohol or illicit drugs. The available scientific literature indicates that there are serious performance impairments associated with drug and alcohol use, and that this impaired performance can lead to a significant reduction in flight safety (3, 7, 8, 16, 18, 19, 20, 22, 23, 31, 34, 35, 36).

D.3 The international experience

Despite regulatory attempts to modify pilot crew behaviour with regards to drug and alcohol use, there have been numerous, well-publicised cases where pilots have attempted to fly or actually flown aircraft whilst under the influence of either illicit drugs and/or alcohol (1, 2, 5, 7, 27, 35). Alcohol has been associated with approximately 10% to 30% of fatal general aviation accidents in the US, and has been implicated in airline accidents (22, 25). In the UK, a fatal aviation accident occurred in which amphetamine use was reportedly involved (7).

Most airlines have some sort of alcohol policy to cater for those personnel who develop alcohol problems (9, 11, 13, 32). This reflects the perceived magnitude of the problem in the airline industry (9). According to ICAO, the rate of loss of licence for alcohol problems is approximately one in 5,000 (15). The data on illicit drug use in pilots is far less extensive (6, 20, 28). One study reported that among a group of 1,169 pilots with FAA licences, 4.4% admitted to being cannabis users (28).

Several studies have examined the attitudes of pilots to drinking and flying. These studies show that most pilots find it very difficult to assess their BAC after drinking (14, 29). Widders and Harris found that 24% of British pilots surveyed could not determine when their BAC had fallen to 0.02%, and that this might lead them to infringe the regulation. This group was described as 'inadvertent drink-flyers' (33). A further group felt that they were safe to fly before their BAC had dropped to below 0.02%, the so-called 'non-believers'. Both groups could potentially infringe the regulations, albeit for different reasons. In this particular survey, 42% were non-believers and 8% were inadvertent drink-flyers. Holding an Air Transport Pilot Licence was found to be more likely to place that person in the non-believer group. This finding contrasts with other studies which show that most pilots believe that alcohol is more a problem in general aviation than in commercial airline operations (29).

That study concluded that pilots suffered from a lack of knowledge of the rate at which BAC declines over time following a drinking session. Furthermore, 5 years after the 0.04% BAC level was introduced in the US in 1985, only 37% of pilots were even aware of it (30). In another study, 50% of respondents felt that they had or may have flown with a BAC in excess of 0.02% (21). Almost 4% of US pilots involved in one survey admitted to having flown an aircraft shortly after consuming alcohol (10).

D.4 The Australian experience

A search of the ATSB's occurrence database for the period 1972-2002 was conducted to help ascertain some indication of the possible prevalence of drug and alcohol use in the aviation occurrences[77] reported to the ATSB over that period. The data provided an incomplete picture, because it was possible that various drug and alcohol-related events were not reported, or were not identified during an investigation. For example, the ATSB does not have the legal authority to compel surviving safety-sensitive operational personnel to undertake breath analysis and/or blood tests in order to determine the presence of alcohol or illicit drugs.

The data comprised 31 reported occurrences where alcohol and/or drugs were present. Of the 31 reported occurrences, 29 involved aeroplane crew and two involved helicopter crew. Fourteen of the occurrences involved fatalities. The majority of the occurrences involved general aviation aircraft conducting non-commercial operations. Of the occurrences reported during non-commercial operations, 26 cases involved the use of alcohol and seven cases involved the use of marijuana, heroin, or prescription drugs. Two of those cases involved the use of both drugs and alcohol, one of which was fatal. There was one fatal commercial operation involving the use of alcohol by the pilot. One instance of alcohol use by an Australian airline crew was reported that had the potential to affect the safety of operations.

[77] Accidents and incidents are collectively known as occurrences.

Overall, it was not possible to accurately determine the full extent of inappropriate drug and alcohol use in the Australian aviation industry. All of the above reported occurrences involved inappropriate substance use by pilots. The ATSB database did not reveal any reports involving inappropriate substance use by other current safety-sensitive personnel, such as air traffic control personnel or aircraft maintenance engineers. However, there was an historical exception of one report of a Flight Service Officer under the influence of alcohol when on duty. That employment category no longer exists in the aviation industry. Further research is needed in order to obtain a contemporary picture of inappropriate substance use by safety-sensitive employees in the Australian aviation industry.

D.5 Drug and alcohol testing programs

Police conduct random breath testing in all Australian States and Territories in order to detect whether motor vehicle drivers are driving under the influence of alcohol. The States have moved from initially disparate BAC limits, to a uniform national limit of 0.05%, and the Transport Workers Union has indicated its qualified support for compulsory drug and alcohol testing of truck drivers. In addition, Victoria has recently introduced a trial random cannabis testing regime for motor vehicle drivers. Other States and Territories have indicated that they will closely monitor that trial for application in their own jurisdictions.

In NSW, the rail authority introduced a random drug and alcohol testing program for rail safety sensitive employees in October 2003. That testing regime expanded that authority's previous program of 'on suspicion' and post-accident testing. The many issues involved in implementing such a program are still being negotiated with the relevant authorities and industry stakeholders, such as unions.

There is presently no legislated blood alcohol test regime in place in the Australian maritime industry. However, in at least one recent incident, onboard alcohol consumption by a ship's master and chief engineer was noted in the development of the occurrence, and the responsible State Water Police conducted 'on suspicion' blood alcohol testing of those persons as a result.[78] The Australian Maritime Safety Authority has recently drafted changes to its legislation to allow its marine surveyors to conduct breath testing of mariners under certain conditions. Those proposed regulatory changes are presently with the maritime industry for comment.

Australia does not have a mandatory drug and alcohol testing program for its aviation industry. That is the case despite the potential, as in the other transport modes, of dire consequences of safety-sensitive personnel performing tasks under the influence of alcohol, PAI or an illicit substance. A major Australian airline has publicly stated its desire to implement a proposed random drug and alcohol testing program for its 38,000 staff, although it has experienced significant resistance from staff and unions because of privacy concerns.

It is therefore reasonable to suggest that, given the application of alcohol testing amongst the nation's road, rail and marine transport modes, and the trial of a cannabis testing regime amongst Victorian drivers, such testing should be considered for extension to pilots and other safety-sensitive personnel in the Australian aviation industry.

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[78] ATSB Marine Safety Investigation Report 169 of March 2003.

In Europe, the JAA currently has no plans to introduce a mandatory drug and alcohol testing program. However, in December 2003, the UK Parliament enacted the *Railways and Transport Safety Act 2003*, which authorised ‘on suspicion’ drug and alcohol testing of aviation employees by uniformed police constables (17). A maximum BAC is prescribed in that legislation.

The United States has a formalised system of random drug and alcohol testing for all regulated transportation modes, including aviation.[79] The drug testing program for certain aviation industry workers was introduced in 1989, and later expanded in 1995 to include alcohol testing. Under the legislation, specified aviation entities are required to develop and implement drug and alcohol programs in accordance with the FAA-mandated policy. Those specified aviation entities include airlines, air taxi, commuter and on-demand air transport operations (Part 121 and Part 135 certificate holders).

In general, the FAA regulations require testing of safety-sensitive personnel including:

- flight crewmembers
- flight attendants
- flight instructors
- aircraft dispatchers
- aircraft maintenance or preventive maintenance personnel
- ground security coordinators
- aviation screening personnel
- air traffic controllers.

The program only covers the testing of a specified list of substances. Those substances are:

- marijuana
- cocaine
- opiates
- PCP
- amphetamines
- alcohol.

A urine specimen is collected for the purposes of testing for the five different drugs, while breath testing is used for alcohol screening. The testing can be conducted under a variety of specified circumstances, such as pre-employment, post-accident, reasonable cause or suspicion, return to duty, and random testing.

The drug and alcohol policies are promulgated in 14 CFR Part 121 Appendix I (Drug Testing Program) and 14 CFR Part 121 Appendix J (Alcohol Misuse Prevention Program).

The random testing programs for both illicit drugs and alcohol as promulgated in those appendices stipulate that there is a minimum annual percentage test rate for the random alcohol and drug testing of covered employees. With some exceptions, that minimum annual rate is set at 25% of all safety-sensitive personnel. The minimum level can be modified by the FAA Administrator to either a higher or lower level, depending on the violation rate among covered employees for the preceding 2 years.

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[79] The legislative basis for that system of testing is US Code of Federal Regulation Part 40 – PROCEDURES FOR TRANSPORTATION WORKPLACE DRUG AND ALCOHOL TESTING PROGRAMS

The minimum annual percentage rate for random drug and alcohol testing for the forthcoming calendar year is published each year in advance. For the 2003 calendar year, the published minimum annual percentage rate for drug testing was 25% of safety-sensitive personnel, based on the violation rate for 2002 and 2001 being less than 1%. However, the published minimum annual percentage rate for alcohol testing during 2003 is 10%, based on the violation rate for 2002 and 2001 being less than 0.5%.

The random drug and alcohol testing programs have a number of additional requirements that must be adhered to by the employer. Those requirements include the appointment of:

- A Medical Review Officer (MRO), who is responsible for reviewing and reporting the test results and verifying any positive results. The qualifications and detailed responsibilities of the MRO are promulgated in 49 CFR Part 40, Subpart G
- A Substance Abuse Professional (SAP), who has responsibility for making recommendations concerning education, treatment, follow-up testing and aftercare of employees who have violated the drug and alcohol regulations. Qualifications and detailed responsibilities are promulgated in 49 CFR Part 40, Subpart O
- Urine Collectors, Breath Alcohol Technicians and Screening Test Technicians. Those persons must be appropriately qualified, and meet their responsibilities as specified in the relevant sections of 49 CFR Part 40 (Subparts C-E, I, J-N). These tasks and responsibilities are quite detailed, and specify the procedures to be followed when collecting and processing samples under the testing programs in order to safeguard the chain of custody.

The requirements also include:

- The establishment of an employee assistance program (EAP). The EAP is designed to provide education and training, as well as a telephone hotline service for employees to use
- The need to follow the administrative guidelines for record keeping, reporting and documentation (listed in 14 CFR Part 121 Appendix I, VI.A and Appendix J, IV.A) as well as quality assurance
- The need to include details within the program of what is prohibited conduct under the regulations, and what the consequences are for violation of the regulations. Strategies for returning employees to work who have violated the regulations must also be incorporated.

Under these regulations, a positive urine drug test result must be subjected to confirmatory testing. This testing is performed via gas chromatography analysis with mass spectrometry. Although expensive, this technique is reported to be virtually error-free with a positive result (15).

Under the policy guidelines, a company is also able to set up its own program, which may or may not be more stringent. However, there are specific requirements for such cases, and the company must make employees aware of the separate and distinct nature of the in-house program from the FAA-mandated program.

By 1991, the FAA drug-testing program had screened over 230,000 personnel. Of those tested, 0.4% were positive for 1 or more of the 5 specified drugs. Of the positive drug tests, 59% were for cannabis and 38% were for cocaine (7). Those two illicit drugs are also the most commonly detected illicit drugs among job applicants to airlines (7, 32). Among pilots who were tested under this program, 42 were positive in 1991, but of the sample tested in 1994, the number had declined to 16. The overall proportion of positive drug tests has remained at less than 1% (7).

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