Department of Transport and Communications

Bureau of Air Safety Investigation

MU-2 ACCIDENT INVESTIGATION

and

RESEARCH REPORT

Incorporating MU-2 accidents

VH-BBA near Leonora WA, 16 December 1988
VH-MUA at Meekatharra WA, 26 January 1990

January 1992

BASI
Bureau of Air Safety Investigation

Released by the Director of the Bureau of Air Safety Investigation
under the provisions of Air Navigation Regulation 283

ISBN 0 642 16354 5 January 1992

This report was produced by the Bureau of Air Safety Investigation (BASI), PO Box 967, Civic Square ACT 2608.

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CONTENTS

ABBREVIATIONS

AD	Airworthiness directive
ATC	Air traffic control
AUW	All-up weight
Avtur	Aviation turbine fuel
BASI	Bureau of Air Safety Investigation
bureau	Bureau of Air Safety Investigation
CAA	Civil Aviation Authority
CAO	Civil Aviation Order
CAR	Civil Air Regulation
CAS	Achieved cruise speed
CVR	Cockpit voice recorder
EAS	Equivalent air speed
EST	Eastern Standard Time
ELT	Emergency locator transmitter
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FDR	Flight data recorder
FL	Flight level
FOI	Flying Operation Instruction
FSI	Flight Safety International Inc
FSO	Flight service officer
FSU	Flight service unit
GA	General aviation
HF	High frequency
IAS	Indicated airspeed
ICAO	International Civil Aviation Organization
ICUS	In command under supervision
IF	Ice factor
IFR	Instrument flight rules
ISA	International standard atmosphere
ITT	Interturbine temperature

JCAB	Civil Aviation Bureau Japan
KCAS	Knots – calibrated airspeed
KIAS	Knots – indicated airspeed
lb	pounds weight
LH	Left hand
MAI	Mitsubishi Aircraft International
MCP	Maximum continuous power
MU-2	Generic term for all variants of MU-2B aircraft type
NTSB	National Transportation Safety Board
OAT	Outside air temperature
OKTAS	Meteorological measure of cloud, expressed in eighths
PIC	Pilot-in-command
POM	Pilots operating manual
ROC	Rate of climb
RPM	revolutions per minute
SCR	Special certification review
TAF	Terminal area forecast
TAS	True air speed
TOC	Top of climb
UTC	Universal Coordinated Time
VFR	Visual flight rules
VHF	Very high frequency
WST	Western Standard Time (UTC plus 8 hours)

CHAPTER 1

SYNOPSIS

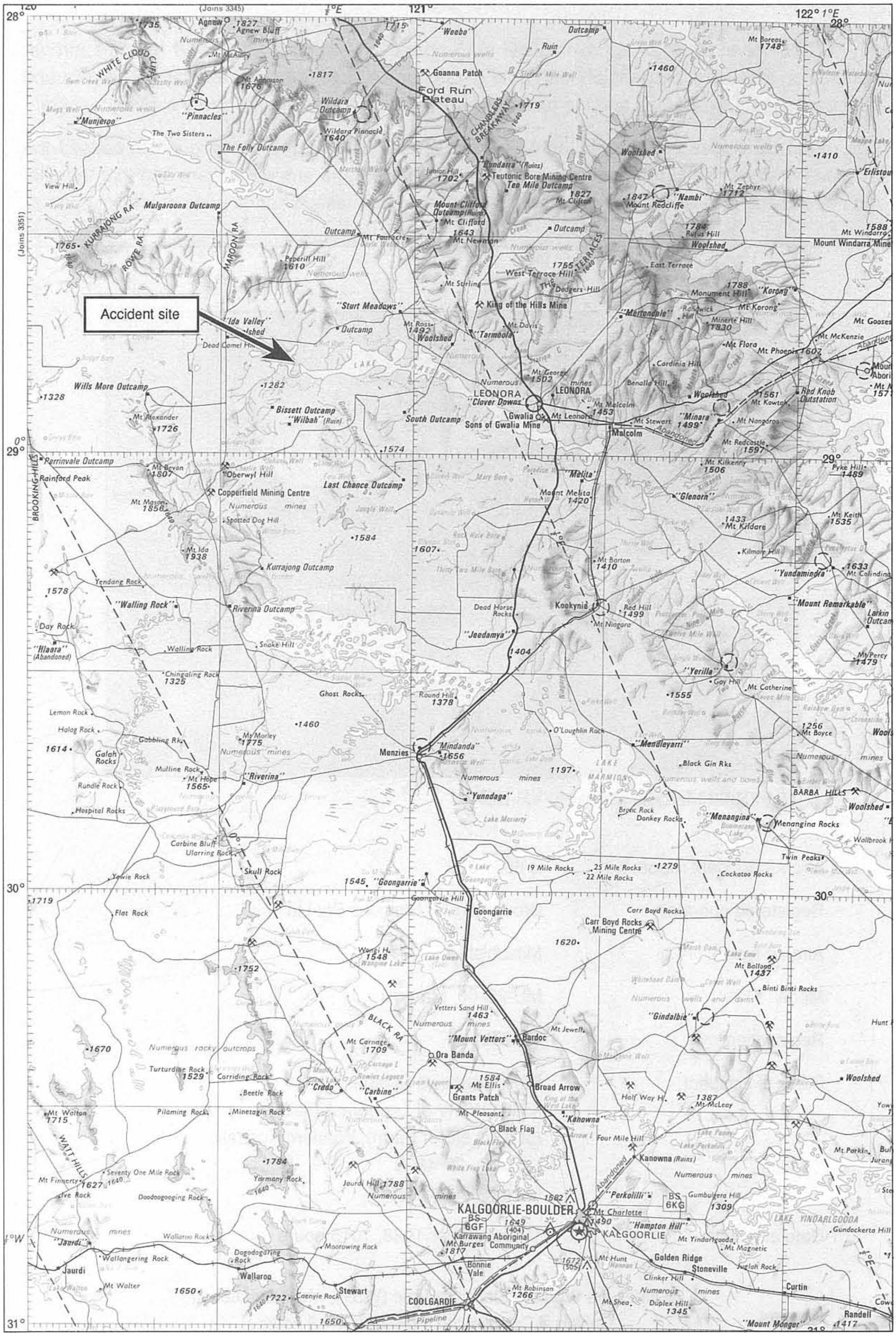
On 16 December 1988, at approximately 1015 hours, a Mitsubishi MU-2B-60 Marquis aircraft crashed on a pastoral property 55 km WNW of Leonora Airfield, Western Australia. The pilot and nine passengers were killed and the aircraft was destroyed by the impact and a subsequent fire.

The report concludes that the aircraft probably accrued icing on the airframe which caused the airspeed to decrease to the point where the aircraft stalled and entered a spin; and that the pilot did not become aware of the decreasing airspeed in time to take action to prevent loss of control.

MU-2B-60 Marquis similar to VH-BBA

Aircraft accident report:	B/885/1036
Registered operator:	Broughton Air Services Pty Ltd
Aircraft type:	Mitsubishi
Model:	MU-2B-60 Marquis
Registration:	VH-BBA
Place of accident:	Sturt Meadows Station 55 km WNW of Leonora Airfield (560 km NE of Perth), Western Australia Latitude 28°48' S Longitude 120°43' E
Date and time:	16 December 1988, 1015 hours

All times are Western Standard Time (WST), which equates to Universal Coordinated Time (UTC) + 8 hours



Relevant portion of Kalgoorlie 3352 WAC (World Aeronautical Chart)

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft had been chartered for a return flight from Perth to Bellevue Mine, Kalgoorlie and Nevoria Mine. The aircraft departed Perth on 15 December and arrived at Bellevue Mine after an uneventful flight.

The following morning the pilot telephoned Kalgoorlie Flight Service Unit (FSU) and obtained brief details of expected winds for the flight to Kalgoorlie, as well as a forecast of the weather for the aircraft's arrival. He then submitted details of the flight to the flight service officer (FSO), at the same time commenting that there was some adverse weather in the Bellevue Mine area. The flight plan indicated that the pilot intended to climb to flight level (FL) 195 after take-off, with a time interval of 27 min to pass Leonora and a further 22 min to reach Kalgoorlie. The flight plan was amended after take-off to include a brief stop at Leinster.

At 0940 hours the aircraft departed for Leinster, 5 km from Bellevue Mine. (This short flight was conducted to pick up passenger baggage.) At 0957 hours the pilot reported to the Kalgoorlie FSU that the aircraft had departed Leinster at 0955 hours and was climbing to FL 195. At 1008 hours he requested traffic information for a climb to FL 210 and, after being advised that there was no traffic, replied that he was climbing to that level. He also remarked that there were some big clouds in the area. No further communications were received from the aircraft.

At approximately 1015 hours the aircraft crashed on Sturt Meadows Station. The crash site was approximately 1200 ft above sea level.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	1	9	–
Serious	–	–	–
Minor/none	–	–	–
Total	1	9	–

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and the subsequent fire.

1.4 Other Damage

No other property was damaged during the accident sequence.

1.5 Personnel Information

The pilot-in-command (PIC) was aged 37 years. He held a current senior commercial pilot licence and a command instrument rating for multi-engine aircraft. His licence was appropriately endorsed for him to fly Mitsubishi MU-2 type aircraft.

The endorsement training was conducted in June 1988. During the endorsement process, the pilot flew on two night charter flights and the endorsing pilot considered that the pilot did not demonstrate a practical proficiency and understanding of high performance and high altitude operations. Following this training, the endorsing pilot advised the chief pilot that he considered that a further 20 hours of flight in command under supervision (ICUS) were needed before the pilot would be ready to act as PIC on commercial tasks.

The company chief pilot later observed the pilot's technique during a 3-hour flight, but did not discuss emergencies and only briefly discussed the operation of the aircraft. The additional ICUS flying was not completed and the chief pilot was later unable to recall the reason for this. No further checks or training were conducted with the pilot on the MU-2 prior to the accident.

The pilot's last proficiency check was conducted on 14 November 1988 when he underwent his command instrument rating renewal in a Beech 76 Duchess aircraft. He had previously completed a pilots' medical examination on 18 October 1988 and was considered fit to fly.

The MU-2 was the second twin-turbine powered aircraft type flown by the pilot. Up to 1985 he had also accumulated 175 hours flying a Cessna 441. At the time of the accident the pilot had 309 hours experience in twin-turbine and high-altitude aircraft and a total flying experience of 6249 hours, including 134 in the MU-2 aircraft. All of the 134 hours were accrued on VH-BBA, with 122 of these logged as PIC.

During the 90-day period preceding the accident, the pilot had flown 40 hours in VH-BBA. Five of these were in the 24 hours preceding the accident. He had not flown at all between 2 December and 15 December 1988.

The pilot had not exceeded prescribed duty times during his final duty period and had observed the mandatory rest periods. It was reported that on the evening of 15 December, the pilot retired between midnight and 0030 hours. He showed no signs of tiredness before departing Bellevue Mine for Kalgoorlie.

Witnesses described the pilot as an aggressive marketing manager who excelled in customer service. Flying operations were a secondary part of his employment responsibilities. He was known to be enthusiastic about the MU-2. The passengers in the right-hand pilot's seat on the three previous flights stated that he discussed the aircraft with them and showed them various instruments in the cockpit during the flight.

The pilot had no known medical problems which might have affected his ability to operate the aircraft safely. On the day before the accident the pilot was described as happy, relaxed and enthusiastic about the prospect of a family Christmas.

1.6 Aircraft Information

The Mitsubishi MU-2B-60 Marquis (serial number 782 SA) was issued with a US airworthiness certificate in May 1980. Examination of the aircraft log books current during its US operations (1980–1988) indicated that the aircraft was maintained in accordance with the manufacturer's inspection requirements and that airworthiness directives issued by the US Federal Aviation Administration (FAA) had been complied with.

The aircraft was imported to Australia from the USA during the early part of 1988. At the time of the accident, it was registered VH-BBA and was operated by Broughton Air Services Pty. Ltd. Australian certificates of registration and airworthiness were issued on 11 June 1988 and were valid at the time of the accident.

The aircraft was maintained in Australia in accordance with the Broughton Air Services maintenance system manual, as approved by the Civil Aviation Authority (CAA). Maintenance records indicate that the aircraft had been properly maintained and was in good condition.

A maintenance release had been issued on 19 November 1988 at 2747 airframe hours. It was valid at the time of the accident.

Examination of the engines and propellers revealed no defects which would have affected their normal operation prior to the accident.

At the time of the accident, the aircraft time in service was approximately 2827 airframe hours.

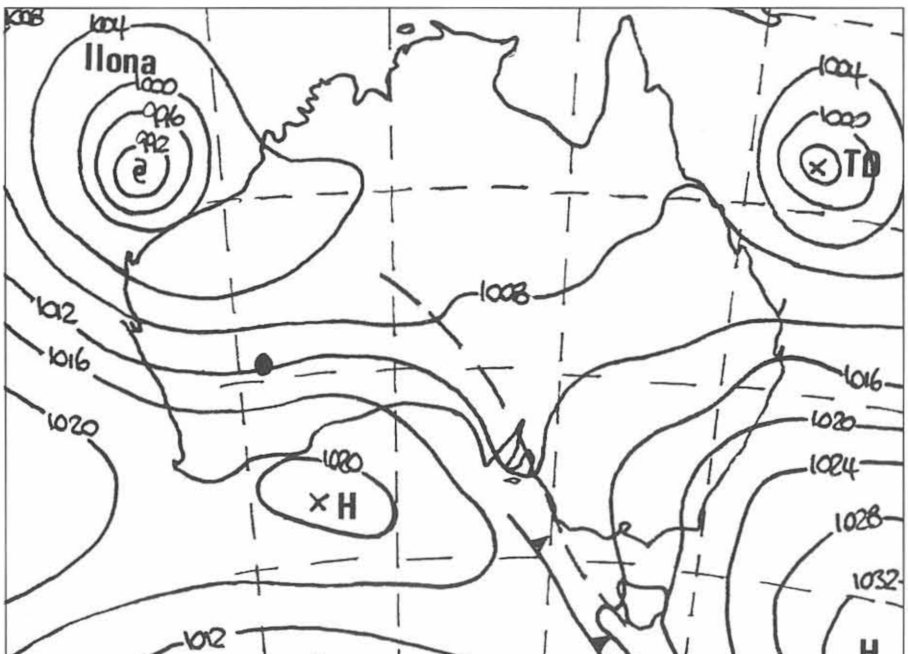
One defect existed in the aircraft oxygen system. A minor leak had been detected in the cockpit gauge/regulator but was considered by licensed aircraft maintenance engineers to be acceptable for continued operation. The oxygen supply had been turned off at the bottle some time prior to the accident flight. The investigation concluded that the oxygen system was not a contributing factor.

It was determined that the take-off weight and the centre of gravity of the aircraft were within the specified limits.

The aircraft fuel used was aviation turbine fuel (Avtur). There was no evidence that the fuel supplied to the aircraft had been contaminated.

1.7 Meteorological Information

Prior to take-off from Bellevue Mine, the pilot phoned Kalgoorlie FSU for a weather briefing. This brief consisted of the terminal aerodrome forecast for Kalgoorlie and en route wind descriptions at 10 000 ft, 14 000 ft and 18 500 ft.



Mean sea level analysis for 0900 hours 16 December 1988.
Leonora is marked with a dot.

While the brief did not give an overall picture of the weather situation, the pilot's comments indicate he was aware of thunderstorm activity in his area. The likelihood of icing was not raised in the telephone conversation and icing had not been forecast.

After advising the FSO on the radio of his intention to climb to FL 210, the pilot stated that there were some big clouds in the area. The accident area was at the edge of feeder cloud bands which lay NW/SE across the southern half of Western Australia and which were associated with tropical cyclone 'Ilona', located off the NW coast of the state. Witnesses reported two storms in the vicinity of the accident site: a large thunderstorm type cloud with rain SE of the accident site, and a smaller storm to the NW. Cloud base in the area at the time of the accident was 9000–11 000 ft.

The accident occurred during daylight hours.

1.8 Aids to Navigation

The availability and use of navigation aids were not relevant to this accident.

1.9 Communications

Whilst on the ground at Bellevue Mine and Leinster, the pilot could not contact Kalgoorlie FSU on high frequency (HF) radio.

Communications between the aircraft and Kalgoorlie FSU were otherwise normal. Very high frequency (VHF) communications between the aircraft and Kalgoorlie FSU were recorded on continuously running magnetic tape. An examination of the transcript of the tape indicates that all calls from the aircraft were made by the PIC. (For a transcript of appropriate radio calls see appendix 1, page 77.)

The electronic locator transmitter was thrown from the aircraft on impact and disintegrated. No emergency signal was received from the unit after the crash.

1.10 Aerodrome Information

Aerodrome and ground facilities were not a factor in this accident.

1.11 Flight Recorders

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

1.12 Wreckage and Impact Information

1.12.1 General

The aircraft had suffered massive destruction and a large portion of the right side was consumed by fire. The majority of the wreckage was confined to a relatively small area, with a large part of the centre section thrown forward some 30 m from the point of impact. The tail section was the least damaged section and lay along a line joining the imprints of the initial impacts of the two tip tanks. The horizontal stabiliser and rudder had become detached during the impact sequence and landed in a pile of wreckage containing the vertical stabiliser, right engine and right propeller. The fuselage lay in front of the tail section and was outlined by sections of aircraft skin, control cables and electrical cables. Some of these skin pieces were concertinaed to a fraction of their original length.

The right wing outboard section was 7 m ahead of the right propeller. The left engine lay in a shallow ditch, 3 m ahead of the horizontal stabiliser leading edge. The left wing outboard section, propeller and gear box were 5 m further ahead.

Wreckage with control surface in foreground and a propeller assembly in top left.

All aircraft extremities were identified as well as the control surfaces, trim tabs, doors and windows, suggesting that the aircraft did not suffer an in-flight break-up or control surface separation.

An intense, post-impact fire was confined mainly to the right side and had consumed most of the right wing and fuselage. The fire was fed by fuel from the ruptured fuel tanks.

It was established that the aircraft hit the ground in a nose-down attitude (probably at about 40°–50° below the horizontal), whilst spinning to the left.

1.12.2 Airframe

Fuselage

The fuselage shape was outlined by pieces of structure, control cables and electrical cables in a slightly elongated form. Very little of the fuselage structure remained intact, as most of it had burnt away or disintegrated. Parts of the skin from the bottom of the fuselage were to a large extent concertinaed. No such deformation was observed on skin from the top of the fuselage. As the wreckage was removed, a tree stump was discovered under the remains about 4 m rearwards of the cockpit wreckage. The nose landing gear, the radar dish and some avionics were found in the immediate vicinity of the stump. It appeared that while the bottom part of the fuselage was arrested by the stump, the top part travelled 4 m forward, shearing the fuselage at about the floor level.

Remains of the entrance and emergency door frames were found among the wreckage. The locking mechanisms indicated that the doors were locked at the time of impact. There was an abundance of windshield, door and cabin window glass fragments in the area. A significant amount of plexiglass had been destroyed by the fire, and nothing conclusive could be learnt by reassembling the recovered pieces.

Wings

The wing had split into three major sections consisting of the right and left outboard sections, which separated at the engine bay areas, and the centre section top panel containing both main spars.

Fire had consumed most of the upper skin and light structural elements of the right wing. The tip tank to wing attachments were severed and damaged by the fire. However, examination of the remains of the tank to wing attachments indicated that they were properly installed and secured.

The left wing sustained superficial fire damage to its leading edge area and tip tank. The tank remained attached at the front attachment point, while the rear attachment point had severed in overload.

The centre section panel consisted of the upper skin with fuel tank access doors and both spars. This section sustained only moderate fire damage.

The wing was laid out in a clear area adjacent to the accident site and the remains of its structure, plumbing, fuel caps and attachments were inspected. No fault was found. Both wings exhibited upward bending and shear consistent with the tip tanks impacting the ground. Ground impact marks on the wing commenced at the leading edge and continued rearwards. The deformation witnessed was consistent with gross overload.

Empennage

The horizontal stabiliser and the tail section had torn off at the vertical stabiliser bulkhead. It was essentially undamaged by the fire. The right stabiliser leading edge was crumpled and rolled upwards.

The vertical stabiliser had torn from the tail structure and lay ahead of the right horizontal stabiliser leading edge, and was slightly fire-damaged.

1.12.3 Landing gear

The landing gear was retracted at impact.

1.12.4 Flight controls

Both control yokes had the left horn broken off. No abnormalities were discovered in the remaining parts of the control columns.

The elevator remained attached to the horizontal stabiliser at the inboard hinges and the partially torn-off right outboard hinge. The left outboard hinge had torn off completely when the left balance weight dug into the ground. No fault was found in any of the hinges, quadrants, springs, pulleys or control runs. The elevator was in the full nose-up position at the time of impact.

Both elevator trims were undamaged and deflected approximately 6° nose-down. The trim jack chain links were broken, the push-pull rods were in good condition and the screw jacks moved freely in both directions. Subsequent engineering examination revealed that an accurate position for the trim tabs could be determined by examining the drum assembly for the rudder and elevator trim tab control system from behind the cockpit pedestal. It was concluded that the elevator trim tab was at 13.4° nose-up at impact. The difference between trim position and selected position is probably explained by the inertia and cable pull experienced by the control surfaces during the break-up sequence.

The tail boom interior and drain holes were examined and found free of any foreign matter, giving no indication of water accumulation or the possibility of such water accumulation in the tail boom freezing the control runs.

The rudder had been torn from the vertical stabiliser and its left side was extensively burnt. The hinges, quadrants and push-pull rods appeared to have been correctly assembled and secured. Examination of the burnt rudder and rudder trim tab established that the rudder was probably deflected 8° to the left and the trim tab near to the neutral position at impact.

The spoilers remained attached to the wing, but some of the hinges were torn off. Extreme travel in either direction was not indicated. No anomalies were found in the hinge points, push-pull rods or bellcranks and all fractures were in overload. It was later established from the cockpit quadrant, and from the position of the push-pull rods, that the spoilers were probably partly deflected in a right wing down selection at impact.

The right flaps and aileron trim tabs had been mostly burnt away and the left tabs had sustained substantial mechanical damage. As far as could be established, all hinges, push-pull rods and bellcranks were correctly attached and the fractures were caused by overload. The flaps were fully retracted at impact. Although equipped with spoilers for roll control instead of conventional ailerons, the MU-2 has roll trim control surfaces on each wing which are referred to as 'aileron trims'. The left aileron trim was 3.7° left control surface up and the right aileron was 3.7° right control surface down.

Control cable runs were traced from the cockpit to the individual control surfaces. Due to the amount of impact and fire damage it was impossible to trace any of the cable runs fully; however, no faults were found in the runs inspected. All of the failures discovered were determined to have been caused by overload at impact.

Three autopilot servos for the elevator, aileron and rudder were removed from the site for further examination. Some chains and control wires were severed by overload, but no evidence was found to indicate mechanical malfunction during flight. Specialist engineering examination indicated no pre-existing anomalies which could have contributed to the accident.

1.12.5 Systems

The extensive impact and fire damage precluded a complete examination of the aircraft systems. There had been a large quantity of fuel on board. The air-conditioning and pressurisation systems appeared to have been functioning correctly at impact. Inspections indicated that the pitot heat was probably operating at impact.

1.12.6 Engines and propellers

Both engines had been torn from their respective wing mountings and had broken just aft of the accessory mounting pad. Their control mechanisms and linkages were distorted and broken. The engine cores were entangled in deformed cowlings, having only their first stage centrifugal compressors partially exposed. The first stage compressor vanes were mostly missing or bent in a manner consistent with rotation at impact.

Propeller assembly

The propellers had both suffered extensive damage to their blades and mechanisms consistent with high rotational speed at impact.

An examination revealed that the engines and the propellers were fully serviceable and were operating at impact. The equivalent damage in both engines was matched by tachometer readings of about

97% RPM for each engine. Propeller pitch settings were also similar and were estimated to be approximately 30°. These are consistent with a climb or low speed cruise setting.

1.12.7 Instruments and avionics

Due to the extensive damage to the cockpit area, most of the instruments had disintegrated or burnt beyond the point of providing useful information. Evidence was found which indicated that electrical power had been available. Readings on the two airspeed indicators suggest that the indicated airspeed (IAS) at impact was in the order of 180 knots (kts).

1.12.8 Conclusion

No pre-existing defect or malfunction was discovered during the examination of the wreckage and impact area which could have contributed to the accident. There was neither an in-flight structural failure nor a loss of propulsion. While the investigation found that the systems on board the aircraft were working at the time of impact, the degree of damage precluded any definite conclusions as to the selections of these systems.

1.13 Medical and Pathological Information

A detailed pathological investigation was not possible because of the extreme nature of the injuries received during the impact sequence.

There was no evidence from the pilot's history or from the post mortem to suggest that he was in other than good health immediately prior to the accident.

Insignificant traces of carbon monoxide were detected in the bodies of some of the occupants, including the pilot.

The pathological examination determined that there had not been a fire on board prior to impact.

A chemical analysis of the filter from the air-conditioning system and pieces of fibreglass insulation from the cockpit area did not reveal any traces of hydrocarbon residues or any other residues which could have been debilitating to the aircraft occupants.

1.14 Fire

There was no evidence that fire had occurred in flight.

An intense fire developed at impact and consumed a large proportion of the right side of the aircraft. The extent of the fire was due to the large quantity of fuel in the tanks, which were ruptured as the aircraft disintegrated on impact.

1.15 Survival Aspects

The accident was not survivable.

1.16 Tests and Research

Early in the investigation the bureau was advised by operators of the aircraft that, due to the MU-2's aerodynamic soundproofing, it was possible for the airspeed to decrease whilst operating on autopilot, without the pilot being alerted by aerodynamic noises. A number of reports were also received from pilots stating that if ice accrued on the body of the aircraft or in other areas not de-iced by the pneumatic de-icing system, the aircraft could stall at higher than normal airspeeds.

Enquiries concerning similar documented accidents worldwide established areas of concern in the high-altitude flight regimes of the aircraft. Interest was focussed on significant losses of airspeed at high altitude, unusual experiences at or near the stall, rapid ice accretion on the airframe (particularly in non de-iced areas) and finally, in endorsement procedures.

1.16.1 Performance

To determine the altitude of the aircraft when control was lost, a study of the MU-2 climb performance was conducted.

The CAA-approved flight manual for the MU-2 does not contain performance charts for the climb. If performance charts from Flight Safety International (FSI) are used, it can be shown that the aircraft should have just reached the planned altitude of FL 195. However, FSI performance charts assume a best rate-of-climb speed of around 130 kts indicated airspeed (KIAS), whereas the operator's pilots used a climb profile involving an initial climb speed of approximately 200 kts IAS, followed by a speed reduction to approximately 150 kts IAS by FL 180. It is not known whether the pilot adhered to the operator's technique, but there was evidence to indicate that he may have used 140 kts as a reference climb speed, and used the rate-of-climb function of the autopilot.

View of de-icing boots on propellers, wings, vertical and horizontal stabilisers.

A passenger who had regularly flown with the pilot (also a pilot with experience in high-performance aircraft) advised that the pilot usually used the autopilot from early in the flight until well into the descent phase. This passenger believed that the pilot used 140 kts as his reference climb speed, because he noticed that the speed seemed to oscillate around this value during the climb.

Although the aircraft's achieved rate of climb cannot be established, any variation from the best rate of climb speed would have produced a lower rate of climb than the FSI profile. It is probable that the aircraft was still climbing towards the planned altitude of FL 195 when the pilot communicated his intention to continue the climb to FL 210. The aircraft impacted the ground 7 min after that call, indicating that the aircraft probably did not reach the amended cruise level before control was lost.

The details of other test and research programs are given in chapter 3 of this report.

1.17 Additional Information

1.17.1 Stall warning

The MU-2 is fitted with a stall warning system which activates stick shakers as the aircraft approaches the stall. It could not be determined if the stick shakers activated before the pilot lost control; however, information provided during the research phase of the investigation indicated that significant loss of speed and stalling can occur in icing conditions without the stick shaker activating. (See chapter 3 for further information.)

1.17.2 Witness information

A witness reported that he saw the aircraft fly overhead in a westerly direction toward a small storm. He indicated that the aircraft was in straight and level flight below the cloud base which he estimated to be around 5000 ft. He then observed the aircraft entering a descending left turn. The turn tightened and the descent rapidly increased. The 'spiral turn' continued until the witness lost sight of the aircraft behind trees. A short time afterwards a fireball appeared from the vicinity of the last sighting.

1.17.3 Spin aspects

The identification of a spin and the initiation of a successful recovery are dependent on a pilot's experience with spinning and his knowledge of the spin characteristics of each particular aircraft.

There is no evidence that the pilot in this accident had done any spin recovery training since his student pilot days. The pilot had no recent exposure to spins and had no known knowledge of the MU-2 characteristics. It was also established that no official data existed about the spin characteristics of the MU-2; however, anecdotal information from the USA suggested that the MU-2 can have a violent, oscillatory spin, with the nose attitude varying from about 30° below the horizon to beyond 90° below the horizon. (See chapter 3 for further information.)

The MU-2 is not approved for spinning.

1.17.4 Criminal allegations

Although several witnesses reported that death threats had been made against one of the passengers, inspection of the wreckage gave no indication of sabotage.

The pilot normally used the autopilot throughout most of the flight and was known to converse freely with passengers. As a marketing manager, he was apparently keen to maintain a high standard of passenger comfort.

He had no known medical condition which might have affected his ability to safely operate the aircraft. He was evidently in a relaxed frame of mind.

If, during the climb-out, the aircraft accrued some icing on the airframe without the pilot being aware of the situation, it is possible that the airspeed was allowed to decrease to the point where the aircraft stalled and control was lost. Once the aircraft entered a spin, it is unlikely that the pilot had sufficient knowledge or experience to regain control.

2.4 The Accident Sequence

Whilst the precise cause of the accident remains undetermined, the most likely explanation is that the accident resulted from the following events:

(i) The aircraft climbed into clouds and accrued airframe icing.

(ii) The pilot possibly was not aware of the ice formation.

(iii) The airspeed decreased, unobserved by the pilot, or was observed but not considered to be significant.

(iv) The autopilot trimmed the elevator trim nose-up as the airspeed decreased to the point of stall. This stall speed was considerably higher than the normal clean stall speed (see chapter 3).

(v) The aircraft stalled with the autopilot still engaged, and entered an uncontrolled descent which culminated in the aircraft impacting the ground in a left spin.

Close-up of propeller and wing de-icing boots

2. ANALYSIS

2.1 Flight Status Prior to Impact

Evidence from the recorded conversations between the pilot and the FSO, a study of the climb performance of the aircraft and the fact that both engines and propellers were operating at impact at about 97% RPM indicate that the aircraft was probably climbing to an amended cruise altitude of FL 210 when it diverged from normal flight.

There was no evidence available to support the witness information that the aircraft was flying in level, controlled flight at an altitude below 10 000 ft.

The witness may have seen the aircraft as it oscillated to its peak nose-up position during the spin, which could give the impression of level flight. It is also possible that the pilot recovered from the initial spin only to re-enter a spin due to somatogyral and oculogyral illusions. These illusions are well documented and can cause a pilot to re-enter a spin after recovery because the vestibular system senses the commencement of rotation in the opposite direction to the original motion. A pilot's attempts to prevent this perceived new rotation can actually return the aircaft to a spin. If the pilot did effect recovery and then re-entered the spin, it may have occurred as the witness looked up.

Since the pilot normally used the autopilot from early in the flight until well into the descent phase, it is probable that the autopilot was engaged when control was lost.

There are known cases of aircraft accidents resulting from a situation known as 'runaway elevator trim.' Typically, the trim runs to the full nose-up or full nose-down position, leading to loss of control and/or failure of the structure. The MU-2 aircraft, however, does not have a history of this type of accident and the upward deflection of the elevator trim tab at impact was less than half of the deflection available.

Although there had been reports of death threats made against one of the passengers, no evidence was found to indicate that sabotage was a factor in the accident. Nor was any evidence found to indicate that the pilot, or any of the passengers, had contemplated suicide.

The reported health of the pilot prior to the accident as well as post-mortem evidence make it unlikely that the pilot was incapacitated during the flight.

2.2 Meteorological Conditions

With thunderstorms in the area, a cloud base of 9000–11000 ft and an ambient temperature of –14°C at FL 195, the aircraft would have been operating in icing conditions. There was, therefore, a high probability of accretion of rime and/or clear ice on the airframe when operating in cloud.

2.3 The Pilot

There is evidence that the pilot's endorsement training was inadequate and that certain deficiencies identified during the training had not been rectified through post-endorsement ICUS operations or recurrent training.

The endorsing pilot considered that a further 20 hours of flight under supervision were needed before the pilot would be ready to act as PIC on commercial tasks. This additional training was not undertaken. It is therefore probable that the pilot had not been exposed to all of the aircraft's operational characteristics before operating on his own. It is unlikely that any deficiencies in his training would have been rectified without recurrent training and study. There was no evidence that either had taken place. It is therefore unlikely that the pilot had achieved a skill and knowledge level needed to operate an aircraft such as the MU-2 in an emergency situation.

3. CONCLUSIONS

3.1 Findings

3.1.1 The pilot was correctly licensed.

3.1.2 The MU-2 type endorsement training of this pilot was not adequate. The lack of understanding of high altitude and high performance operations identified during endorsment training was not rectified because the 20 hours of ICUS flying recommended by the endorsing pilot was not carried out.

3.1.3 As marketing manager for the company, flying was not the pilot's main reponsibility.

3.1.4 There is no evidence that recurrent training was conducted which could have rectified the identified training deficiencies. (See 3.1.2)

3.1.5 There was no evidence that the pilot suffered any sudden illness or incapacity which might have affected his ability to safely control the aircraft.

3.1.6 The aircraft had been maintained in accordance with the approved maintenance schedules, and there was nothing to suggest that it was not capable of normal operations.

3.1.7 The gross weight and centre of gravity of the aircraft were estimated to be within the limits specified in the approved flight manual.

3.1.8 No evidence of sabotage was discovered.

3.1.9 The provision of air traffic services was not a factor in the accident.

3.1.10 The pilot reported large clouds in his area as he advised his intention to climb above his planned cruise altitude to FL 210. Ground observers also reported thunderstorms in the general vicinity of the accident site.

3.1.11 The meteorological conditions during the latter stages of the climb were conducive to the formation of rime and clear ice.

3.1.12 The aircraft entered an uncontrolled descent and impacted the ground in a left spin.

3.1.13 It was not determined if the pilot momentarily effected recovery during the descent or if the descent continued unchecked to impact.

3.2 Relevant Events and Factors

3.2.1 It is probable that the pilot did not have an adequate understanding of the operations of the MU-2B-60 aircraft at high altitude.

3.2.2 The meteorological conditions were conducive to the formation of ice on aircraft flying in cloud above the freezing level.

3.2.3 It is probable that loss of control occurred above the freezing level on climb to an amended altitude of FL 210.

4. SAFETY RECOMMENDATIONS

The safety recommendations resulting from the investigation into the circumstances surrounding this accident have been combined with those resulting from the subsequent investigation into the accident involving VH-MUA, on 26 January 1990. Recommendations from both investigations appear in chapter 6 of this report.

CHAPTER 2

SYNOPSIS

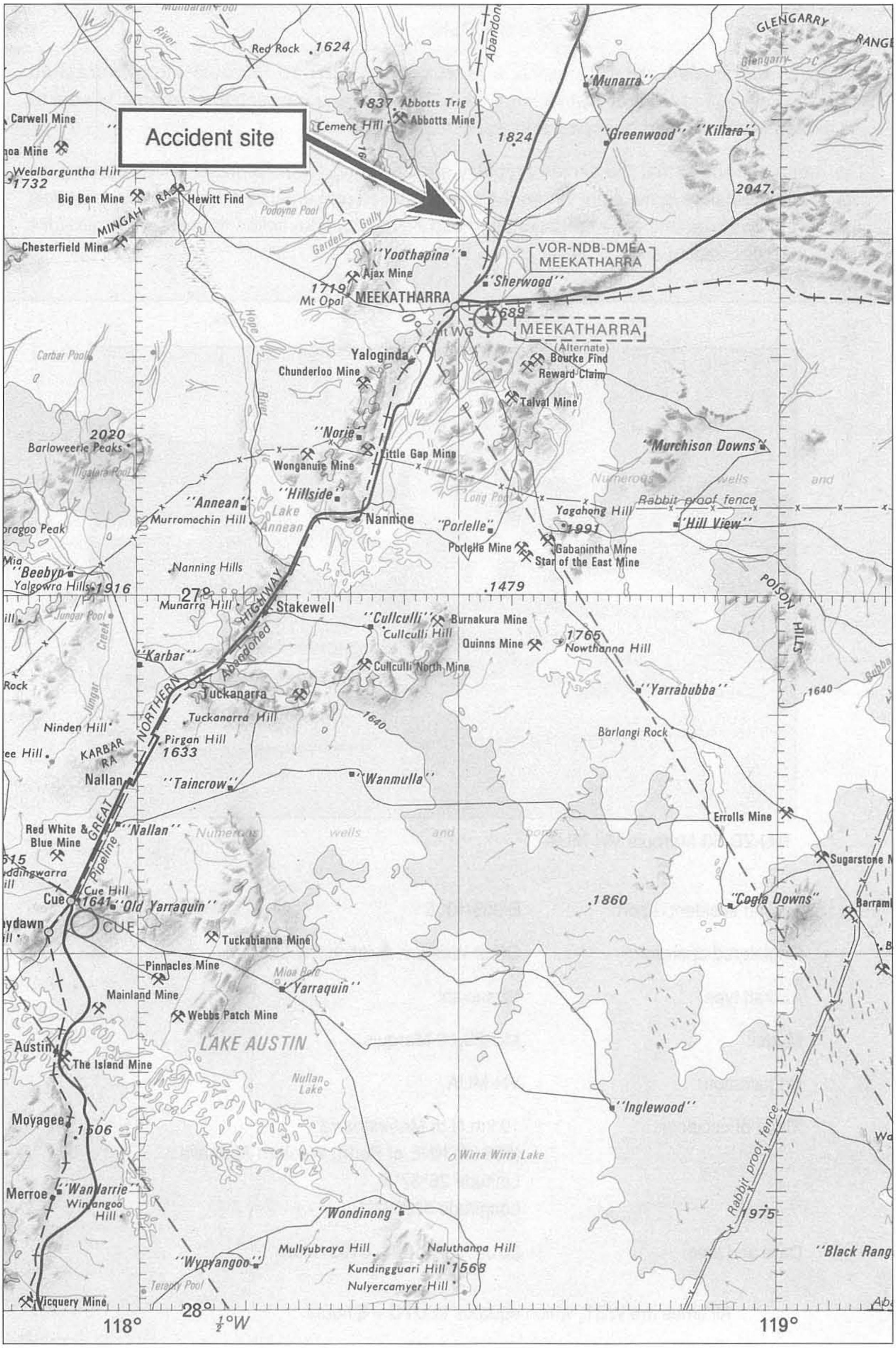
On 26 January 1990 at 0105 hours, a Mitsubishi MU-2B-60 Marquis aircraft crashed approximately 10 km NNE of Meekatharra, WA. The pilot and passenger were both killed and the aircraft was destroyed by impact and a subsequent fire.

The report concludes that the aircraft probably accrued icing on the airframe which caused the airspeed to decrease to the point where the aircraft stalled and entered a spin; that the pilot was not previously aware of the ice formation; and that he did not take action to prevent the aircraft's speed from decreasing.

MU-2B-60 Marquis VH-MUA

Aircraft accident report:	B/905/1005
Registered operator:	Great Western Aviation Pty Ltd
Aircraft type:	Mitsubishi
Model:	MU-2B-60 Marquis
Registration:	VH-MUA
Place of accident:	10 km N of Meekatharra (555 km NNE of Perth) Western Australia Latitude 26°37' S Longitude 118°32' E
Date and time:	26 January 1990, 0105 hours

All times are WST, which equates to UTC + 8 hours.



Relevant portion of Meekatharra 3346 WAC (World Aeronautical Chart)

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft had been chartered for a flight from Perth to Port Hedland. The pilot arrived at the aircraft at 2210 hours on 25 January, and after a short inspection of the aircraft, attended the CAA flight planning office for air traffic control and meteorology briefing. The briefing included information about a tropical cyclone off the NW coast of Australia and its potential effects on the proposed flight. After the flight plan was submitted, the pilot returned to the aircraft at 2315 hours as the loading was being completed, and conducted a preflight inspection of the aircraft and its load.

The aircraft departed Perth at 2339 and commenced a climb towards Ballidu, the first turning point, over which it passed at 0003 hours. Subsequently, the aircraft passed over Mt Singleton at 0020, Mt Magnet at 0040 and Meekatharra at 0102 hours. After Ballidu, the aircraft climbed from FL 170 to FL 190 and climbed further to FL 210 after Mt Magnet.

While over Meekatharra, the passenger (also a licenced pilot) gave the position report. One minute later, the pilot radioed that the aircraft was out of control and descending. He called again 30 seconds later and advised that the aircraft was in ice and spinning down through 8000 ft. No further communications were received from the aircraft. (Appendix 2, page 85 contains a transcript of all radio communications.)

Twenty-three seconds later, at 0105.10, the pilot of another aircraft in the area advised that he had witnessed the impact of the MU-2.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	1	1	–
Serious	–	–	–
Minor/None	–	–	–
Total	1	1	–

1.3 Damage to Aircraft

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

1.4 Other Damage

No other property was damaged during the accident sequence.

1.5 Personnel Information

The PIC was aged 51 years. He held a current commercial pilot licence (CPL) and a command instrument rating for multi-engine aircraft. His licence was appropriately endorsed for him to fly Mitsubishi MU-2 type aircraft.

The pilot had a total of 51.7 hours on the MU-2 at the time of the accident. During the endorsement training (December 1989 in Adelaide), the pilot flew 5.2 hours of dual instruction and a further 16 hours ICUS. The endorsing pilot believed that the pilot tended to fall behind during the asymmetric section of the training. The company chief pilot subsequently flew with the pilot and concluded that the endorsement was inadequate and that the pilot needed further flight under supervision before he could command flights in company aircraft. The pilot disagreed with this assessment, but agreed to fly under supervision for a further period. Prior to his subsequent departure on leave, the chief pilot briefed his replacement, who agreed with the inadequate training assessment.

Although he was not an instructor the acting chief pilot flew with the pilot on a number of flights, pointing out various aspects of the MU-2 operation but not carrying out any instruction. He merely flew as a supervising pilot. After 23.7 hours of ICUS, the pilot was considered to be ready for company command operations. The accident flight was the pilot's first flight as PIC of an MU-2 on a commercial operation.

The pilot first obtained his CPL in 1957, and in the ensuing 33 years had accumulated 11 030 hours flying a variety of aircraft, including helicopters and gliders. After a 15-year absence from full-time flying, he recommenced commercial flying in April 1989.

In July 1989, the pilot completed a pilot's medical examination and was considered fit to fly, with a restriction that he wear corrective lenses.

The accident flight route was familar to the pilot. For the 6 months prior to the accident he had conducted night freight tasks to various ports in the NW of Western Australia, including Port Hedland, in a Beech Queenair aircraft. After completing the MU-2 endorsement, he had flown to Port Hedland ICUS in VH-MUA with the company's acting chief pilot. This 6-month period of flying was his first exposure to commercial and general aviation for more than 25 years.

On the day of the accident flight, the pilot was relieved of duties associated with his employment for about 9 hours. At the commencement of the flight, he had rested/slept for a maximum of 9 hours in the previous 42 hours, and had told an associate, some weeks before the flight, that his sleeping patterns were being disturbed by the night flights he was flying. Prior to his MU-2 endorsement, during a night freight familiarisation flight in an MU-2, the pilot removed his headset at about 0100 hours and slept for an hour, stating to the aircraft captain that this was his low time.

The pilot was a former aircraft accident investigator and was aware of pilot performance degradation resulting from fatigue. He was also aware of the MU-2's icing potential and the dangers of such conditions.

On the accident flight, the passenger who sat beside the pilot, was a flying instructor with a senior commercial pilot's licence and a multi-engine command instrument rating. He had a total of 1525 flying hours but was not endorsed to fly MU-2 type aircraft.

1.6 Aircraft Information

The Mitsubishi MU-2B-60 Marquis (serial number 746 SA) was issued with a US airworthiness certificate in mid-1979. Examination of the US aircraft log books revealed that in December 1979 the left wing of the aircraft was broken inboard of the left engine nacelle during a landing accident in Italy. The aircraft was subsequently dissassembled and shipped to the USA for repairs. These repairs were complicated and the aircraft was not flown again until July 1982, when it began low-frequency operations which continued until it was exported to Australia in July 1988. By this time the aircraft had logged 624.7 flying hours.

The Australian certificate of registration was issued on 5 August 1988 and the certificate of airworthiness on 9 August 1988. Both certificates were valid at the time of the accident. The aircraft was registered VH-MUA and was operated by Great Western Aviation Pty Ltd.

The aircraft was withdrawn from service in February 1989 after accumulating 600 hours of operations in Australia. The withdrawal was due to the discovery of major problems in the wing areas repaired previously in the USA. The entire wing was consequently replaced and major repairs made to the lower fuselage structure.

The aircraft next flew in June 1989 and re-entered service for the operator with a total of 1285 hours on the airframe.

The aircraft was maintained in Australia in accordance with the Great Western Aviation maintenance system manual, as approved by the CAA. Maintenance records indicate that the aircraft had been properly maintained and was in good condition.

An appropriate maintenance release had been issued on 23 January 1990 at 1887 airframe hours. It was valid at the time of the accident.

The investigation did not disclose any defects or outstanding maintenance requirements in the engines, propellers, airframe or accessories which could have been factors in the accident. Similarly, examination of the practices and procedures followed during the two rebuilds of the aircraft failed to disclose any element likely to have contributed to the accident.

At the time of the accident, the aircraft had accumulated a total of 1902 hours.

The maximum permissible take-off weight for the aircraft was 5250 kg. The actual weight for the aircraft at take-off is estimated to have been 151 kg above this limit at 5401 kg (including 1145 kg of fuel and 822 kg of cargo). The aircraft's centre of gravity is estimated to have been located centrally within the fore and aft limits.

At the time of the accident, the estimated aircraft weight had reduced to 5017 kg, also within centre of gravity limits.

The aircraft fuel used was Avtur. No fuel sample was available from the wreckage; however, analysis of a sample taken from the tanker which refuelled the aircraft confirmed that the fuel was free of contaminants and met the appropriate product specifications.

1.7 Meteorological Information

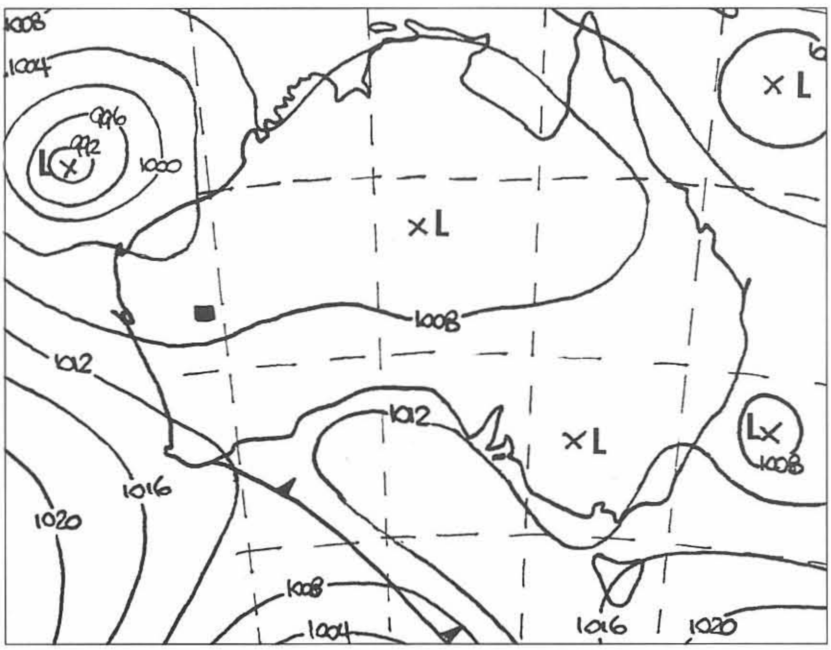
At his flight planning weather briefing, the pilot was supplied with a route forecast along with a terminal area forecast bulletin and the FL 185 and FL 235 grid winds.

The pilot was appraised of the synoptic situation which was dominated by the presence of tropical cyclone 'Tina' off the NW coast of Australia. A band of cloud associated with the outflow from 'Tina' extended from the Learmonth–Carnarvon coastal area SE across Meekatharra and Mt Magnet towards Kalgoorlie and the S coast.

Meteorological information issued at the Perth Weather Service Office shows that expected weather on the route to Meekatharra involved:

1. broken layers (between 5 and 7 OKTAS) of middle-level cloud with lowest base of FL 140, the most probable cloud being altocumulus and altostratus types, with nothing to suggest any areas of strong convection;
2. no significant precipitation;
3. 40 km visibility;
4. the possibility of moderate icing in the middle level cloud layers above the freezing level (approximately FL 155); and
5. nil significant turbulence.

While post-accident analysis confirmed that the wind forecasts were accurate and that layers of cirrus-type cloud overlaid the area of the accident to FL 300 in some parts, there was no evidence of cumulonimbus clouds. It was confirmed that altostratus, or weakly advective altocumulus tops, were present over some parts of the area at levels above FL 150.



Mean sea level analysis for 0900 hours 26 January 1990. Meekatharra is marked with a square.

Air temperature at the aircraft's altitudes after Ballidu was between -8°C and -12°C. The presence of supercooled, middle-level moisture of tropical origin in the atmosphere over the route flown provided conditions conducive to the formation of airframe icing.

1.8 Aids to Navigation

The availability and use of navigation aids were not relevant to this accident.

1.9 Communications

VHF communications between the aircraft and Perth FSU were recorded on continuously running magnetic tape. The tape recording indicates that all calls were made by the PIC, with the exception of the position report made over Meekatharra which was made by the passenger.

The recording did not reveal any background aircraft noises to indicate a deviation from normal aircraft operations.

1.10 Aerodrome and Ground Facilities

These were not a factor in this accident.

1.11 Flight Recorders

The aircraft was not equipped with a FDR or a CVR, nor was either required by regulation.

1.12 Wreckage and Impact information

1.12.1 General

The wreckage was badly fragmented with a splay around a bearing of approximately 310° and was confined to a relatively small area of 200 m by 140 m.

The aircraft impacted the ground in a near-vertical attitude and much of the forward section of the aircraft had penetrated the ground to a depth approaching 1 m. The vertical attitude was confirmed by forward-to-aft compression buckling of the wings along with the impact damage to the left tip tank. A lot of soil had been displaced by the impact and a crater approximating the head-on profile of the aircraft was created. Most of the wreckage lay in the crater and its immediate vicinity. At either end of the crater were imprints of both tip tanks and the imprints indicated left rotation at impact.

Some of the rear fuselage had been torn away from the forward section of the aircraft and was thrown approximately 30 m back along the 310° bearing.

Smaller pieces of wreckage had been ejected mainly along two lines, creating an angle of approximately 45–50° to either side of the aircraft's axis.

All of the aircraft extremities were identified as well as the control surfaces, trim tabs, doors and windows, suggesting that the aircraft did not suffer an in-flight break-up or control-surface separation.

1.12.2 Airframe

Fuselage

The aircraft's vertical impact had totally destroyed the fuselage structure, leaving only the empennage essentially intact. The main door and parts of the locking mechanism indicated that the door had been properly locked. Nothing conclusive could be learnt from the plexiglass remains.

Wings

Remains of both wings were found with parts of the engine, cockpit and fuselage in an area between the crater and the empennage.

The wings had both been concertinaed back to the rear spar, indicating that both had failed due to gross overload at ground impact.

Marks on the edge of the crater indicated that the leading edge of the left wing had hit the ground in a left rotation.

The left-wing tip tank was found approximately 8 m to the rear of the left tip tank impact point, it was ascertained that the aircraft impacted the ground in a nose-down attitude of 90°–95° while rotating to the left with the left wing slightly down. A spin was suggested by the vertical attitude and the airspeed at impact, which was later determined as being 175 kts.

Empennage

Damage to the empennage indicated that it had rolled or cartwheeled to its resting place after detaching from the main fuselage at the rear pressure bulkhead. It was found 25 m to the rear of the crater.

1.12.3 Landing gear

The landing gear was retracted at impact.

1.12.4 Flight controls

All flight controls were located at the impact site. The spoilers were found with the left retracted and the right up indicating a bank to the right was selected at impact.

Examination of the rudder and its detached counterweight indicated that the rudder was selected to the left at impact.

While the rudder trim tab was found to be deflected to the full nose-left position, this was not considered to be relevant, since the tab was cable-operated and it was possible for the cable to be tensioned at impact such that one side of the cable would break first and allow the tab to move from its selected position after impact.

Extensive damage to the elevators was consistent with impact forces and rendered any determination of their position at impact impossible.

Examination of the elevator trim capstan established that the range of tab deflection at impact was 14°–21° nose-up. It was determined that the most likely position of the elevator trim tab was a deflection of approximately 17° nose-up trim, over half of the 30° available.

Operating cables and rods for the flight controls were traced as far as possible. No pre-existing deficiencies were discovered which would have prevented normal operations.

1.12.5 Systems

Little could be learnt from the system components recovered. On-site evidence that the engines had been operating at impact indicated that fuel was capable of being fed to the engines from the tanks.

Nothing could be learnt about the operational status of the air-conditioning or pressurisation systems.

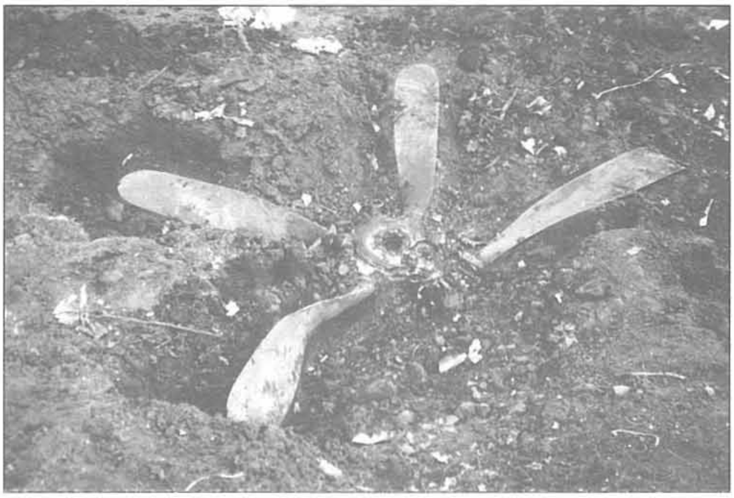
Examination of various components from the electrical and pneumatic anti-icing and de-icing systems failed to discover any pre-impact defects preventing normal operation of those components if selected. Whether the systems had been armed, or selected to operate, could not be determined.

The rudder/yaw damper servo was not present although the servo mounting pad and its associated capstan and cables were installed. The motor attachment bolts were in place with the nuts tightened firmly onto spacer washers. This was consistent with the motor not being installed when the aircraft departed Perth.

It was established that the rudder trim servo motor had not been electrically connected at the time of impact.

1.12.6 Engines and propellers

Only the power sections of the engines remained intact. The gearbox assemblies yielded individual gears, pieces of bearings and pieces of engine accessories. Examination of engine damage indicated engine rotation at the time of impact. No pre-existing defects were found in either engine that would have interfered with normal operation.



Each propeller had separated from its engine. The propellers were driven almost 1 m into the ground and their blades were detached. Workshop inspection concluded that both propellers were rotating in excess of 800 RPM at nearly identical power settings. At impact, the blade angle of both propellers was at least 29° with power settings approximating flight idle. No pre-existing defects were found in either propeller that would have prevented normal operation.

It was determined that the right power lever was slightly forward of the FLIGHT IDLE position and the right condition lever at the TAKE-OFF LAND position (100% RPM). The respective positions of the left power and condition levers could not be determined.

Metallurgical examination of the engine jet pipes showed a temperature of at least 400°C at impact, which indicated that the engines were emitting hot gases at impact. This is a further indication of engine operation at impact.

1.12.7 Instruments and avionics

Impact and fire damage prevented conclusive analysis of the instruments recovered. Readings obtained by inspection of the components were of minimal value. An airspeed indicator gave a reading of 175 kts and the left RPM indicator showed 100% RPM.

1.12.8 Summary of wreckage and impact examination

It was determined that the aircraft hit the ground in a left spin with a 90°–95° nose-down attitude. The aircraft was intact when it impacted and the engines were delivering approximately flight-idle power with the propellers rotating at 100% RPM. No pre-existing defects were found in the systems and components examined, to suggest that the aircraft lost control after an inflight failure of one of these components. The extent of the destruction prevented recovery and examination of all components, thus precluding a definitive statement on the basis of the wreckage examination.

1.13 Medical and Pathological Information

Impact injuries to both occupants prevented a detailed pathological investigation.

There was no evidence from the pilot's history to suggest that he was in other than good health immediately prior to the accident.

Traces of carbon monoxide found in both bodies were considered to be the result of post-mortem muscular absorption of combustion products.

1.14 Fire

The aircraft exploded on impact and an intense fire developed. The fire was fuelled by the large quantity of fuel in the tanks which were ruptured during the impact.

There was no indication that the aircraft was burning prior to impact.

1.15 Survival Aspects

The accident was not survivable.

1.16 Tests and Research

1.16.1 Pilot Profile

The pilot was experienced and a prominent member of the Western Australian aviation community. Six months before the accident he had recommenced flying duties on a commercial basis after an absence of 15 years. During those years he had been an aircraft accident investigator, and had maintained an active involvement in aviation as a recreational pilot.

Contrary to the prevalent impression that he was meticulous and 'by-the-book', investigation revealed that the pilot tended to be less rule-bound and sometimes casual in attitude. This attitude was exhibited by the pilot after his MU-2 endorsement and was partly responsible for the company chief pilot's assessment of the endorsement being inadequate.

After rejoining the commercial aviation industry, the pilot had some difficulty in achieving a proficient standard. This manifested itself both during command instrument rating training and the subsequent MU-2 endorsement.

Although the pilot had extensive aviation experience, he did not have recent experience in high altitude operations in pressurised aircraft, nor could the majority of the previous types flown by the pilot be considered to have similar performance capablilities of the MU-2.

Prior to the accident flight, the pilot had not flown the MU-2 for six days, but had flown 11 hours in a Beech Queenair, an aircraft of lesser performance characteristics than the MU-2.

The pilot had attended an evening function on the night prior to the accident flight. The assessment of friends' descriptions of the pilot at that function indicated that he may have been affected by cumulative fatigue. It is not known why the pilot conducted an overweight take-off from Perth on the accident flight.

1.16.2 Radar Analysis

The radar data recorded in Perth, which followed the progress of VH-MUA from Perth to the end of radar coverage, was analysed.

The analysis indicated that the aircraft became airborne at Perth International Airport at 2336.52 hours on 25 January 1990. After take-off radar picked up the aircraft at 300 ft and followed it during its climb to FL 170 and to overhead Ballidu. The aircraft was seen to pass Ballidu at 0002.58 hours on 26 January 1990 and commenced a climb to FL 190 at 0004.53 hours. The radar returns ceased at 0018.52 hours when the aircraft was approximately 6 nm S of its Mt Singleton position and still at FL 190.

It was seen that the aircraft initially climbed at 190 kts calibrated airspeed (KCAS) and reduced to 175 KCAS at FL 170. After levelling at FL 170, it accelerated and stabilised for a short period at 202/204 KCAS before again accelerating to a cruise speed of 220 KCAS. The temporary speed stabilisation at FL 170 was consistent with a short-term power reduction.

At an all-up weight (AUW) of 5210 kg, a temperature of -12.5°C and an altitude of FL 170, the cruise data in the Mitsubishi-supplied pilot operating manual (POM) indicated a cruise speed of 207 KCAS at the recommended cruise power of 96% RPM and 650°C interturbine temperature (ITT). To achieve the higher cruise-speed of 220 KCAS at the AUW of the aircraft, an increased power setting would have been required. It is possible that maximum continuous power (MCP) of 100% RPM and 650°C ITT may have been needed.

During the climb to FL 190, the airspeed decreased to a minimum of 174 KCAS. The aircraft levelled off at FL 190 and accelerated to 210 KCAS, which was 12 kts higher than the airspeed expected using the recommended cruise-power settings. This suggested that the engines were again set at more than the recommended cruise-power setting.

In the 5 min before the aircraft left radar coverage, a small-amplitude airspeed oscillation with a 2 min period was observed. As there was no corresponding altitude change, it was assumed that the oscillation was confined to airspeed. Possible explanations for the oscillation are: variations in engine power; a build-up and the shedding of ice; or an exercising of the de-ice system.

The recorded radar data showed that during the cruise phases to Mt Singleton, the aircraft had maintained altitude precisely and had not varied from the planned and reported altitudes. The precise maintenance of altitude is an indication that the autopilot was engaged and that the altitude-hold mode was selected.

After the aircraft passed beyond radar coverage, position reports were given at Mt Singleton, at Mt Magnet and at Meekatharra. From the elapsed time intervals it was determined that the aircraft cruised at an average achieved cruise speed (CAS) of 198 kts between Mt Singleton and Mt Magnet at FL 190, and 191 kts between Mt Magnet and Meekatharra at FL 210.

After taking into account fuel usage and temperature changes, it was calculated from the POM that the aircraft should have cruised at 199 KCAS between Mt Singleton and Mt Magnet, if recommended cruise power was selected. It was also calculated that the aircraft should have cruised at 190 KCAS between Mt Magnet and Meekatharra with recommended cruise-power set.

The average airspeed for the Mt Singleton–Mt Magnet segment was approximately the same as the speed calculated from the POM, which indicated that the pilot probably was able to reduce power to the recommended setting, as fuel had been used on the previous segment and the aircraft performance was slightly improved. It is also possible that the pilot left the higher power setting in place and encountered a drag increase, such as ice, which slowed the aircraft from the 210 KCAS determined from the radar replay during the previous segment.

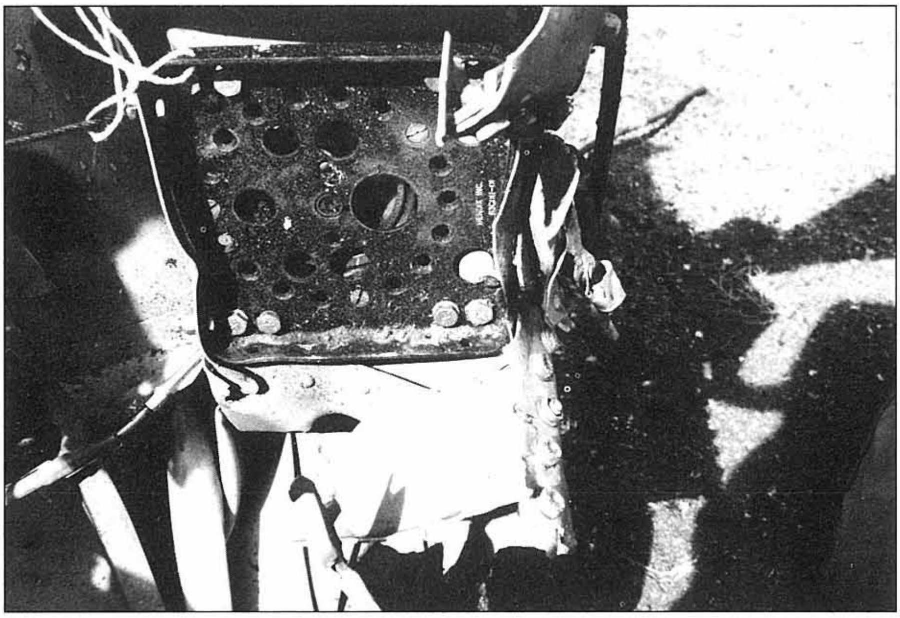
On the Mt Magnet–Meekatharra segment, the average airspeed for the segment again approximated the calculated speed from the POM. However, the position of some engine controls and instruments in the wreckage indicated that MCP had been used on this segment and should have resulted in a cruise speed in the order of 12 kts higher. The fact that MCP was used for the entire flight whilst under radar control, and that MCP was evident at impact, increases the probability that the final segment was flown with the higher power setting selected.

A probable explanation for the lower airspeed in spite of the higher power setting is that the aircraft suffered additional drag in the form of airframe ice which slowed it to the airspeed which the POM suggests should normally be achieved with the recommended power settings

1.17 Additional Information

1.17.1 Effect of non-connection of servos

During the inspection of the wreckage, it was noted that the yaw-damper servo was missing. It was determined that this component was not in the aircraft before the flight left Perth, i.e. it had not become detached during the impact sequence. It was also noted that the rudder servo was electrically disconnected before the flight commenced and the plug had been tied back away from the servo attachment area.



Yaw-damper servo attachment bracket

Investigations revealed that the servos had probably been removed from the aircraft prior to its arrival in Australia in July 1988. There was no evidence that they had been refitted to the aircraft prior to the accident flight.

The autopilot fitted to VH-MUA was certified in the MU-2 as a three-axis autopilot, which included the yaw-damper/rudder servos. Unless the operator gained approval from the CAA to operate the aircraft without the three-axis autopilot, the autopilot was required to be fully functional for flight on commercial operations, or alternatively, two endorsed pilots would be required on each flight.

The autopilot manufacturer stated that the autopilot was certified for three-axis operations and there has been no reason for the manufacturer to accrue test data for operations of the autopilot with only two axes. The manufacturer was reluctant to speculate on how the aircraft would respond without the rudder and yaw-damper servos connected to the system.

A number of autopilot specialists were consulted and generally agreed that if the yaw-damper and rudder trim servos were disconnected from the autopilot, a pilot would probably see a slight slip as the aircraft turned. The degree of unbalance could not be determined, but it was considered that with a 30° bank turn, the skid-ball would indicate a definite displacement from the central trimmed position.

The investigation concluded that any out of balance condition caused by the absence of the trim servos would be masked by the larger aerodynamic effects introduced by ice accretion.

Other pilots who flew the aircraft were unaware of the disconnection. The technique used by the pilots in the preflight check of the autopilot would not have detected a yaw-damper unserviceabilty prior to take-off.

A light on the autopilot panel adjacent to the yaw-damper illuminated when the autopilot or the yaw-damper systems were selected ON. This light merely indicated that power was available to the yaw-damper and did not indicate that the yaw-damper was working or its state of serviceability. The pilots probably saw the light illuminate when the yaw-damper was selected ON and assumed that the yaw-damper was working. During manual flight the rudder and the manual rudder trim would have worked normally.

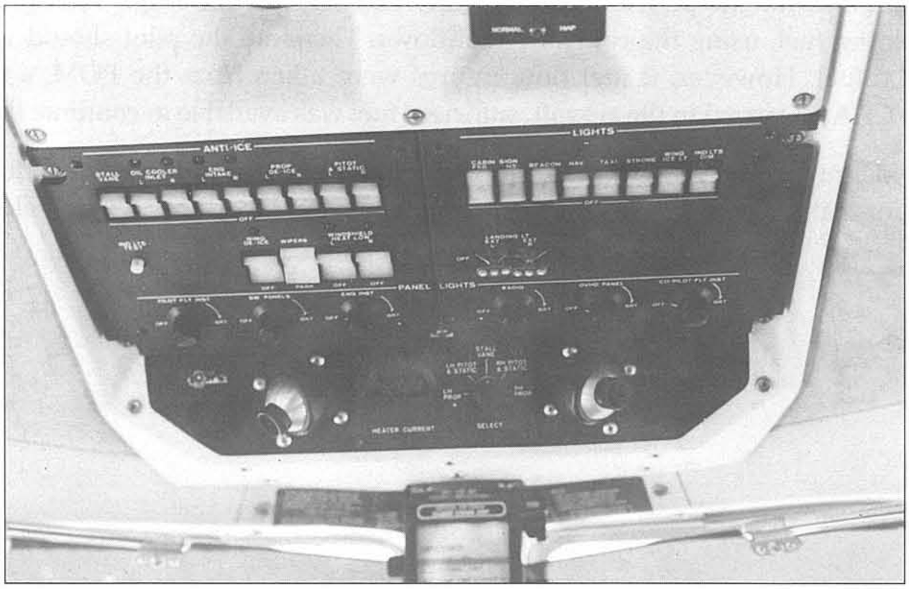
1.17.2 Radio calls

The second-last radio transmission from the aircraft (see appendix 2, page 85) indicated that the pilot had lost control of the aircraft and was descending. The last call was made with the pilot under obvious physical stress. Although the transmission stated that the aircraft was in ice, it was considered that he meant that ice was present before control was lost, since when the transmission was made the aircraft was at 8000 ft, i.e. at an altitude well below the freezing level.

In previous MU-2 accidents involving loss of control, there had been speculation as to whether the aircraft had been spinning or was in a spiral dive. The final transmission in the present accident stated that the aircraft was spinning. The purpose of this statement by the pilot was probably to clarify the type of descent and the reason for the loss of control

1.17.3 Icing effects

Evidence obtained during the research carried out by the bureau indicates that ice can form quickly on the airframe of MU-2s and the reductions in airspeed can be sudden (see chapter 3). Moreover, the aircraft can stall at airspeeds far in excess of the uncontaminated aircraft stall speeds.



Cockpit overhead panel showing anti-ice equipment switches

The route being followed by VH-MUA required the aircraft to turn through 23° and adopt a new track of 357° magnetic.(see appendix 3, page 89) The autopilot would most probably have selected a rate-one turn for the track change, and the aircraft would have used approximately 25°–30° of bank for the turn. The resultant loss in the lift from this angle of bank in the turn would have caused the aircraft to descend. However, the evidence indicates that the autopilot was set to altitude-hold mode, and with this setting, the autopilot would have applied more nose-up elevator trim to increase the attitude of the aircraft to hold the altitude. The added drag from the increased attitude would have caused the airspeed to decrease. The absence of autopilot yaw functions may have also contributed to an uncoordinated turn.

The proximity of the Meekatharra position report and the initial loss of control report indicates that control of the aircraft was probably lost as it entered the turn onto the new heading. This would indicate that the aircraft had accrued some ice en route to Meekatharra and that the added loss in airspeed from the turn caused the aircraft to stall.

1.17.4 Pilot licensing aspects

While the bureau recommended that the CAA implement new minimum-experience levels for MU-2 pilots as interim recommendations in July 1989, the CAA did not revise the minimum experience levels for MU-2 pilots until after the VH-MUA accident. This accident arguably may have been avoided if the revised levels were incorporated earlier. The pilot did not meet some of the new requirements at the time of the accident.

1.17.5 Flight plan

An examination of the flight plan, submitted by the pilot, revealed that the aircraft had insufficient fuel for the planned flight to Port Hedland, if the company fuel planning figures were used. The pilot had changed the figures on the flight plan to indicate that there was sufficient fuel for the flight. He probably had the intention of reviewing the fuel situation en route, prior to Meekatharra. Using the fuel flows recommended by his company, the pilot should have planned to stop at Meekatharra for fuel.

A number of experienced MU-2 pilots expressed the opinion that they thought that the pilot had planned to climb too high too early. They thought that the aircraft may not have been ready to climb to FL 210 until at least Meekatharra.

It was determined that when the aircraft passed Meekatharra, there was probably insufficient fuel remaining in the tanks for the pilot to complete the remainder of the flight with appropriate fuel reserves and holding fuel, using the company fuel flows. Therefore the pilot should have landed at Meekatharra to refuel. However, if fuel flow figures were taken from the POM, a document not approved by the CAA or carried in the aircraft, sufficient fuel was available to continue the flight.

There was no evidence to show that the pilot was under any pressure to complete the flight within any time constraints, or that the pilot was discouraged from landing at Meekatharra to refuel.

2. ANALYSIS

2.1 Flight Status Prior to Impact

Evidence from the recorded conversations between the pilot and the FSO indicates that the aircraft had passed the Meekatharra turning point; was in ice before control was lost, and descended in a spin.

Consistent with the pilot's final transmission are:

(1) the known weather conditions in the accident area, which were conducive to the formation of airframe icing above FL 155; and

(2) the evidence of the airframe wreckage, which indicated that the aircraft hit the ground in a nose-down attitude of 90°–95° in a left spin.

No other aspects were identified that were likely to have contributed to the inflight loss of control.

2.2 Meteorological Conditions

The circulation from tropical cyclone 'Tina' produced a strong inflow of moisture across the southern section of SW Australia, resulting in bands of altostratus and altocumulus clouds across the intended path of VH-MUA. Analysis of the atmospheric conditions likely to have been encountered by the aircraft after the Ballidu position indicated that the conditions were conducive to the formation of airframe icing, and that the type of ice would probably have been rime ice or a mixture of rime and glaze ice. Accretion of airframe ice would probably have been steady and subtle as there were no prominent areas of strong advection.

2.3 The Pilot

The pilot was experienced with a reputation of being meticulous and enthusiastic about flying. However, it was shown that he sometimes exercised a casual approach to rules and regulations. This attitude was clearly demonstrated by the pilot electing, in contravention of company operating procedures, to continue beyond Meekatharra when calculations using the company's fuel flow figures indicated insufficient fuel to cover the remaining portion of the flight with the required reserves.

The investigation also found that the pilot experienced some difficulty in mastering operational aspects of the MU-2 during his endorsement. The company chief pilot considered that the pilot was inadequately endorsed and required further flight exposure in the form of ICUS flights, before allowing the pilot to command the MU-2 on operational tasks. The accident flight was flown at flight levels which were considered to have been too high for optimum performance, suggesting that gaps in his operational expertise still existed.

At the time of the accident the pilot had accumulated 51.7 hours on type. The accident flight was his first commercial operation in the MU-2 as PIC, and apart from a small solo flight after the Adelaide endorsement, it was also the first occasion he had flown the high-performance, high-altitude aircraft on his own.

There is evidence that the pilot was fatigued on the night of the accident. Existing cumulative fatigue, combined with the resumption of erratic shift work with the attendant circadian desynchronisation, the lack of sleep associated with the previous 42 hours' activities, and the decision to fly at a time acknowledged by the pilot as his 'low' time, could explain how an ice accumulation on the airframe and the associated loss in airspeed and attitude increase went unnoticed. While his accident investigation training should have alerted him to his tiredness, he may have accepted the situation due to his enthusiasm for the aircraft and the prospect of commanding his first flight.

2.4 Accident Sequence

The accident probably resulted from the following events:

(a) The aircraft encountered icing conditions somewhere along the route to Meekatharra, probably on the last leg from Mt Magnet.

(b) The pilot did not become aware of the ice formation or the associated airspeed reduction prior to loss of control.

(c) As the airspeed reduced, the autopilot trimmed the aircraft nose-up to maintain altitude.

(d) The pilot selected the new heading over the top of Meekatharra for the next leg to Port Hedland.

(e) The aircraft entered a turn to the left.

(f) As the aircraft turned, the airspeed decreased and the contaminated wing stalled.

(g) Before the pilot realised that the aircraft had stalled with the autopilot engaged, the aircraft entered a spin.

(h) With the aircraft spinning, the pilot could not physically recover control unless the high nose-up elevator trim position were reduced. (See chapter 3 for more information about control forces in the spin.)

(i) The aircraft impacted the ground spinning to the left in a near-vertical attitude.

3 CONCLUSIONS

3.1 Findings

3.1.1 The pilot was correctly licensed to conduct the flight.

3.1.2 The initial endorsement of the pilot was considered to be inadequate and a further period of flight exposure was required. The extra flying was conducted under the supervision of a pilot who was not an instructor. The supervising pilot did not teach new techniques or procedures but merely supervised a series of operational tasks.

3.1.3 The pilot had not previously flown high-performance, general aviation aircraft such as the MU-2.

3.1.4 The pilot had not flown in high-altitude aircraft for over 15 years, nor had he been involved in regular flight operations for the same period until he rejoined the aviation industry 6 months prior to the accident.

3.1.5 Certain aspects of the pilot's planning and attitude towards the operation of the MU-2, indicated the pilot did not take sufficient account of the operational characteristics of this aircraft type.

3.1.6 The pilot did not possess some of the experience levels and recency requirements placed on MU-2 pilots immediately after the accident.

3.1.7 The pilot's recent and long-term history suggest that he was subject to cumulative fatigue which could have impaired his environmental awareness.

3.1.8 There was no evidence that the pilot suffered any sudden illness or incapacity which might have affected his ability to control the aircraft.

3.1.9 The aircraft was correctly certified for the flight.

3.1.10 Two servos from the autopilot system had been removed from the system's operation. The non-operation of these servos was not considered to have contributed to the loss of control.

3.1.11 The weight and centre of gravity were estimated to have been within the limits specified in the approved flight manual at the time the pilot lost control.

3.1.12 The meteorological conditions at the aircraft's cruise altitudes were conducive to the formation of ice on an aircraft's airframe.

3.1.13 In his final radio transmission the pilot reported that the aircraft was in ice.

3.1.14 The pilot lost control and the aircraft entered a spin at FL 210 and impacted the ground in a left spin.

3.1.15 The aircraft did not break up in flight.

3.2 Relevant Events and Factors

3.2.1 The pilot did not have recent experience in high-performance, high-altitude aircraft except for the 51.7 hours gained in the MU-2.

3.2.2 The pilot did not possess some of the experience levels and recency requirements placed on MU-2 pilots immediately after the accident by the CAA.

3.2.3 The pilot did not take sufficient account of the operational characteristics of this aircraft type.

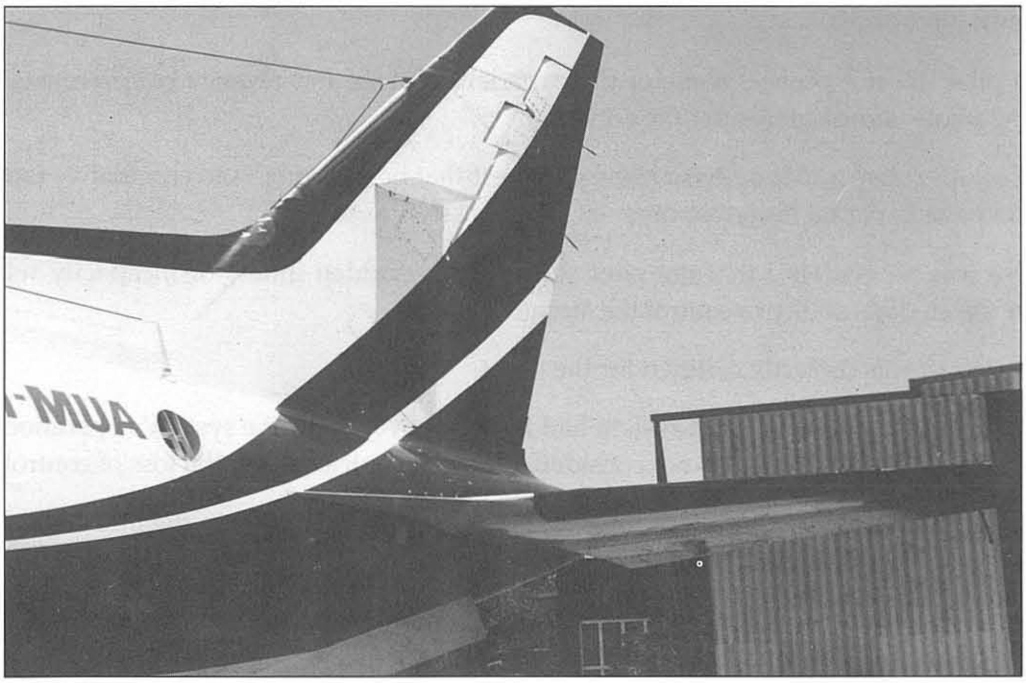
3.2.4 The pilot's situational awareness was probably impaired during the flight, because of the combination of pre-existing cumulative fatigue, and insufficient sleep in the previous 42 hours.

3.2.5 The meteorological conditions were conducive to the formation of airframe icing on an aircraft flying in cloud along the flight planned route.

3.2.6 It is probable that control was lost as the aircraft banked to the left over Meekatharra, to change track towards Port Hedland.

3.2.7 The pilot reported that the aircraft was in ice during his last radio transmission.

3.2.8 The pilot was unable to recover from the spin before the aircraft hit the ground.



VH-MUA empennage showing vertical and horizontal stabiliser de-icing boots

4 SAFETY RECOMMENDATIONS

All safety recommendations resulting from the investigation into the circumstances surrounding this accident have been combined with those resulting from the parallel investigation into the accident involving VH-BBA, on 16 December 1988. Recommendations from both investigations appear in chapter 6 of this report.

CHAPTER 3 RESEARCH AND ANALYSIS

SYNOPSIS

Chapters 1 and 2 examined the VH-BBA and VH-MUA accidents in their immediate context. The present chapter broadens the focus to explore the likely event sequence involved in other MU-2 occurrences of this type. Individual events contributing to the sequence are isolated and interventions proposed to prevent the events and break the sequence chain.

1. PROBABLE SEQUENCE OF EVENTS

1.1 Database Analysis

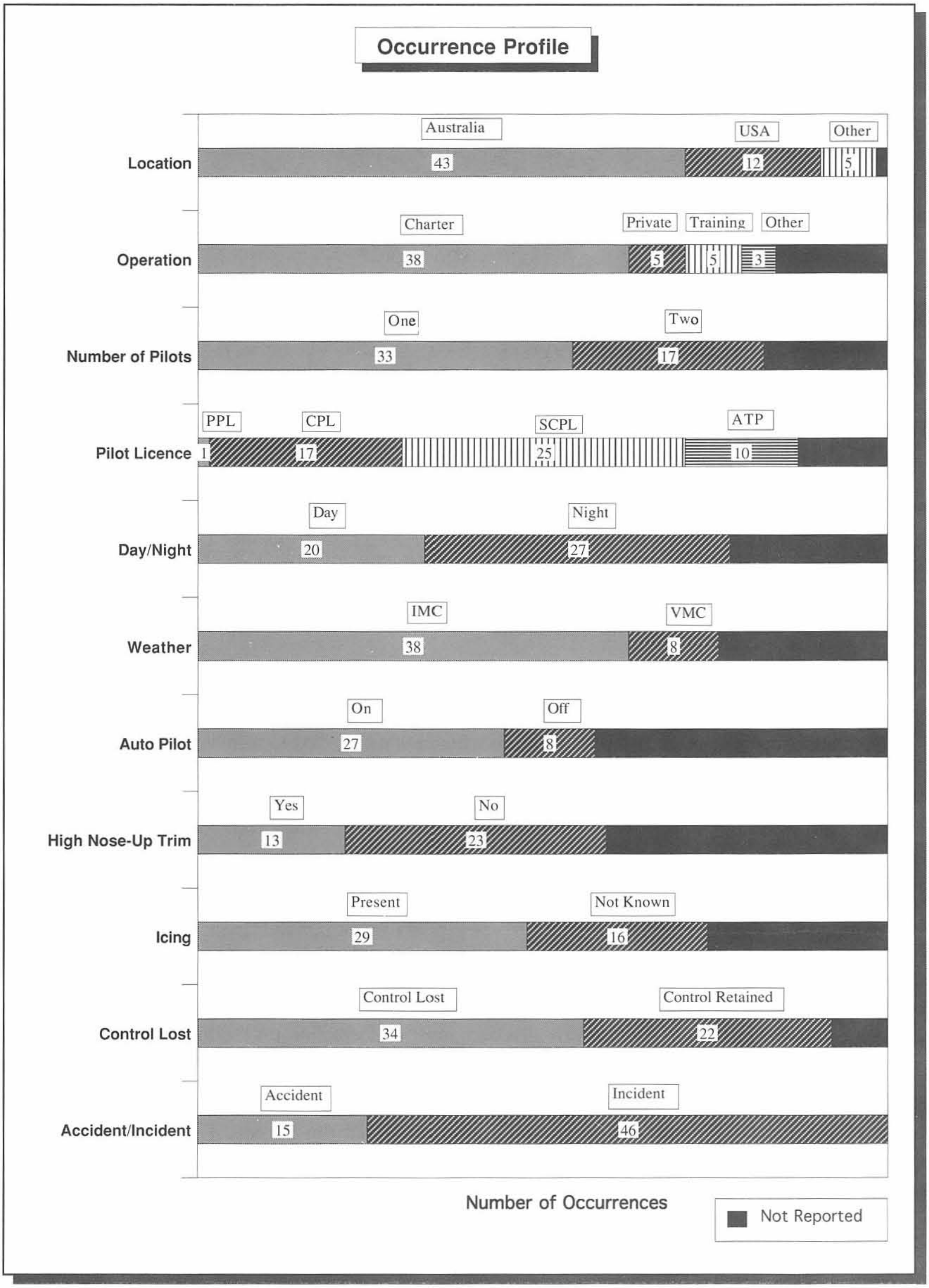
Each of the two accidents involved the following events:

- Weather conditions were conducive to the formation of airframe ice on an aircraft flying through the area above the freezing level. (See appendix 4, page 90 for pictorial comparison.)
- The aircraft probably accrued airframe icing which may not have been visible to the pilot.
- The airspeed decreased and the autopilot attempted to maintain attitude, rate of climb or altitude by applying nose-up trim inputs.
- The airspeed continued to decrease to the point of stall, which probably was considerably higher than the normal clean stall speed for the aircraft.
- The aircraft probably entered a spin from which the pilot failed to recover.
- Both pilots had inadequate training on the aircraft.

Beyond these general observations, it is difficult to reconstruct either accident in much detail. But events occurring in other accidents and incidents may offer some further clues.

Alerted by a number of unsolicited reports concerning MU-2 incidents (control loss in cruise or climb), the bureau initiated a nationwide survey of MU-2 pilots, operators and others, requesting data about the aircraft's handling characteristics in the upper levels of its flight regime. The survey invited details of any unusual events which may have occurred whilst the aircraft was climbing to, or cruising at, levels above FL 150. Of particular interest were instances of loss of control, icing encounters accompanied by significant reductions in airspeed, and ice formation on the airframe. Details of the pilot's flight experience, endorsement training and recurrency training were also requested.

Accident and incident reports from safety organisations worldwide were also assembled, along with information supplied by pilots and operators who contacted the bureau. The resulting database contained 15 accident and 46 incident reports.



Occurrence Profile
Location
Australia
43
USA
12
Other
5
Operation
Charter
38
Private
5
Training
5
Other
3
Number of Pilots
One
33
Two
17
Pilot Licence
PPL
1
CPL
17
SCPL
25
ATP
10
Day/Night
Day
20
Night
27
Weather
IMC
38
VMC
8
Auto Pilot
On
27
Off
8
High Nose-Up Trim
Yes
13
No
23
Icing
Present
29
Not Known
16
Control Lost
Control Lost
34
Control Retained
22
Accident/Incident
Accident
15
Incident
46
Number of Occurrences
Not Reported

TABLE 1

Table 1 profiles the occurrences. It should be noted that although 61 entries were made in the database, not all of the entries related to each category examined. Throughout the database analysis, reference will only be made to that part of the sample for which status is known. It can be seen that:

- Most operations were charter operations. This reflects the typical use of MU-2s, at least in Australia.
- Two-thirds of the cases involved single-pilot operations, again reflecting the nature of operations involving this aircraft.
- Pilots generally held commercial or senior commercial licences, with a significant number also holding air transport licences. (Pilot endorsements and training are described in greater detail below.)
- Slightly over half the occurrences were at night, and most took place in instrument meteorological conditions.
- The autopilot was engaged in most aircraft at the time of the occurrence.
- One-third of the aircraft were in a high nose-up trim condition at the time of the occurrence
- Aircraft icing was reported in a significant number of occurrences.
- Control of the aircraft was lost in 34 cases, and resulted in 15 accidents.

The most common type of incident involved rapid speed loss at altitude due to ice. In some of the reported incidents the pilot took appropriate action, generally by descending, and did not lose control of the aircraft. For example:

> *Reporter was cruising at night in ice. He had all anti-ice equipment operating, and had just cycled the de-ice boots manually. He looked down to do some paperwork. When he looked up after approximately 3–4 minutes, the IAS had reduced from about 200 kts to 145 kts. He noticed that the elevator trim had been selected to a high value by the autopilot. He disengaged the autopilot and descended.*

While the information available from the accidents was generally less revealing, the pilot's final radio broadcast from VH-MUA indicated that ice was present, and the manner of his call underscored the importance of this factor.

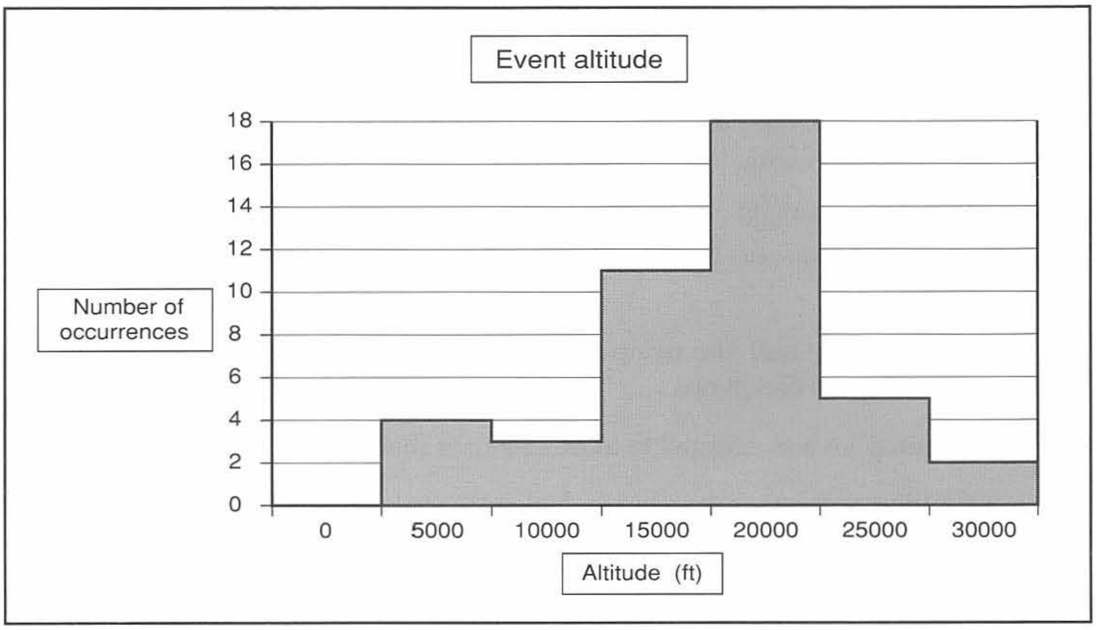
As described earlier, many of the occurrences and all of the accidents in the database involved a loss of control. Roughly half of the incidents recorded involved a loss of control from which the pilot was able to recover.

TABLE 2

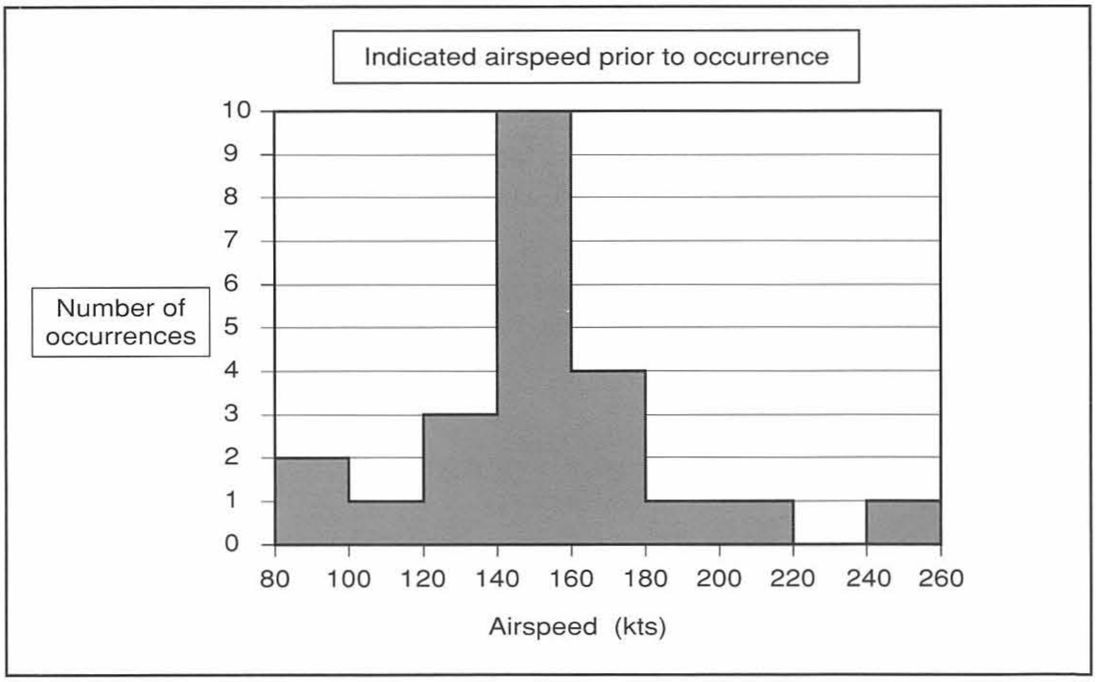
	Accident	Incident	TOTAL
Control lost	15	19	34
No control loss	0	22	22
TOTAL	15	41	56

Analysis of the database revealed information patterns about the environment in which the occurrences took place, aircraft configurations and flight characteristics. These are described below:

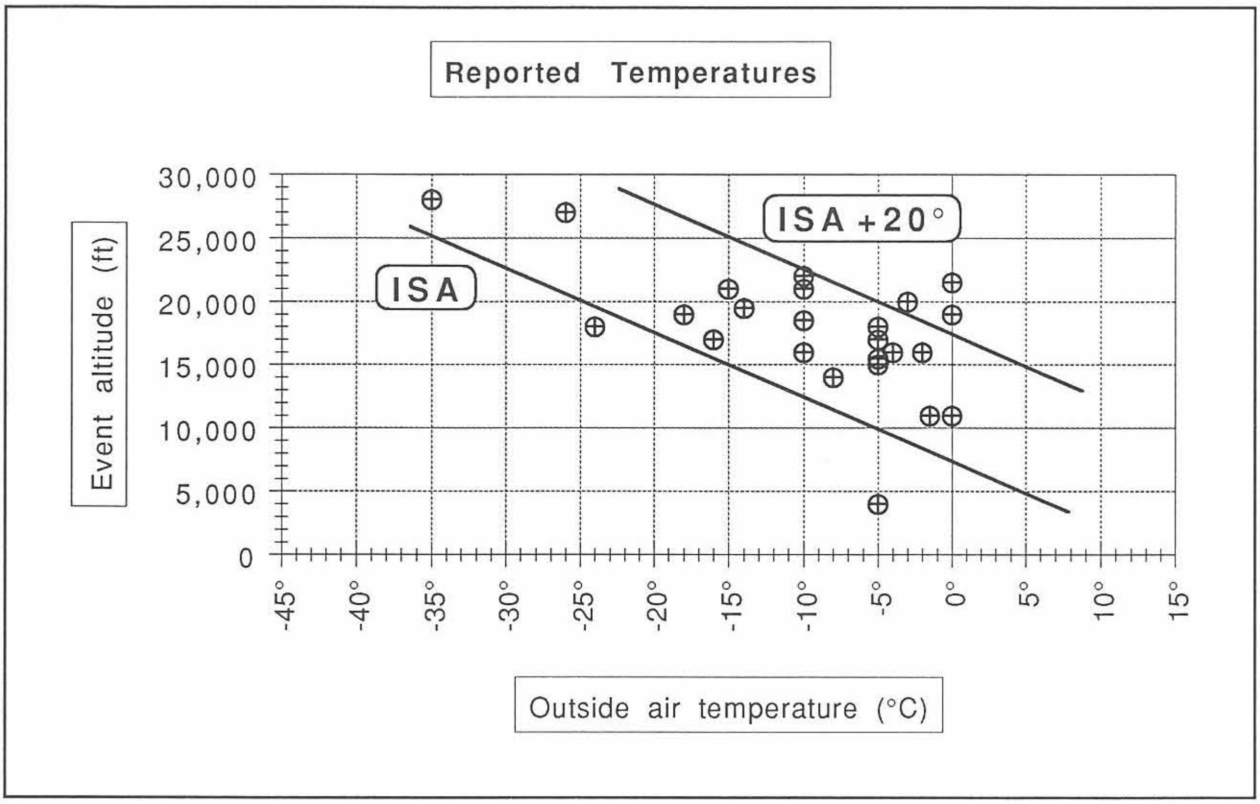
Altitude: The focus of this research is on occurrences over 15 000 feet. The distribution of altitudes reflects this focus.



Airspeed: As can be seen from the distribution below, indicated air speed immediately prior to the events was most commonly around 150 kts.



Temperature: Although temperature and altitude data was not available for all reported occurrences, the temperatures fell mainly in the international standard atmosphere (ISA) to ISA +20°C range. This is shown graphically below.



In summary, the occurrences commonly took place above 15 000 ft, at speeds between 120 and 180 kts, and in the ISA to ISA+20°C temperature range.

Aircraft attitude: As discussed earlier, most of the occurrences took place during cruise, and most pilots were operating with the autopilot engaged. A number of pilot reports noted that, prior to the event, the autopilot had commanded a high nose-up elevator trim selection. Unfortunately, data on the selection of the autopilot and the trim position was not always available from the reports. However, the limited data which was available did support the observation that high nose-up trim values were closely related to the use of the autopilot (table 2). In eight out of the nine cases of high trim values where the status of the autopilot was known, the autopilot was ON. It should be noted that not all cases where the autopilot was engaged resulted in high nose-up trim settings.

The following is an example of high nose-up trim input:

The reporter was cruising at FL 140 on a night-freight run. He had his knee resting on the elevator trim wheel. The airspeed was decreasing due to ice build-up and the autopilot was slowly trimming nose-up as the IAS reduced. The autopilot suddenly wound back a full turn of the trim towards nose-up. The IAS rapidly reduced by 10 kts. The pilot disconnected the autopilot and descended.

TABLE 3

AUTOPILOT	HIGH TRIM SETTING Yes	No	TOTAL
Autopilot on	8	11	19
Autopilot off	1	4	5
TOTAL	9	15	24

There was some evidence that the presence of a high nose-up attitude was related to the severity of the control loss. In the table below, occurrences have been classified as control maintained, control lost but regained, and control losses resulting in accidents. The data suggests that most cases with high nose-up trim settings resulted in loss of control.

TABLE 4

HIGH TRIM SETTING	CONTROL LOSS Control maintained	Control lost & regained	Accidents	TOTAL
Yes	2	6	5	13
No	16	5	1	22
TOTAL	18	11	6	35

Icing: There is some indication that the presence of ice is associated with the aircraft attitude. As shown below the presence of ice was slightly more likely when there was a high trim setting than when trim settings were normal. It should be noted however that the observed patterns are not statistically significant at a high level.

TABLE 5

ICE	HIGH TRIM SETTING Yes	No	TOTAL
Ice present	7	8	15
Ice not present	4	9	13
TOTAL	11	17	28

A number of incident pilots reported icing on the aircraft body in areas which are not de-iced. Again there is some indication that this is related to a high nose-up attitude.

TABLE 6

BODY ICE	HIGH TRIM SETTING Yes	No	TOTAL
Body ice present or suspected	6	10	16
Body ice not present	3	13	16
TOTAL	9	23	32

Stall speed: A number of pilots reported that the aircraft stalled at a higher IAS than the stall speeds suggested in the flight manual. All told, there were eight pilots (who could recall the actual speed) who reported a high stall speed. For these occurrences the average speed at which stall occurred was slightly over 140 kts. This is very close to the speed at which the majority of the reported occurrences took place.

Several of the overseas accident investigation reports detail sequences of events which are similar to the two accidents investigated by the Bureau of Air Safety Investigation (BASI). A summary of one such example (from the National Transportation Safety Board [NTSB] files) is as below. (For a list of all overseas accidents examined during the investigation, see appendix 11, page 106.)

Three months before the accident, the pilot had accumulated 15 hours on the MU-2. The aircraft had departed on a private IFR flight. The aircraft disappeared from radar 20 minutes after take-off as it passed an altitude of FL 140 on its climb to FL 170. Moderate ice was forecast en route and the cloud tops were forecast to FL 170. The aircraft hit the ground in a nose-down attitude and the elevator trims were found jammed in the full nose-up position.

1.1.1 Analysis

The probable sequences of events established for the various occurrences from the database analysis and the available physical evidence appear to have a number of factors in common:

- encounters with ice
- altitudes above FL 150;
- speeds between 120 and 180 kts with a peak of 150 kts and a suggested stall speed of over 140 kts;
- atmospheric temperatures in the ISA to ISA+20°C range;
- ice formations on the airframe in positions which are not de-iceable; and
- abnormally high nose-up elevator trim inputs.

In a number of the incidents reported, the critical steps in this sequence occurred rapidly while the pilot was distracted and therefore unaware of developments. In particular, the speed loss due to ice; the autopilot selection of higher nose-up settings; and the possible entry to an incipient stall condition are reported to have occurred without the pilot being aware of them. In addition, in cases where the pilot reported possible airframe icing, this was not generally recognised until after the event.

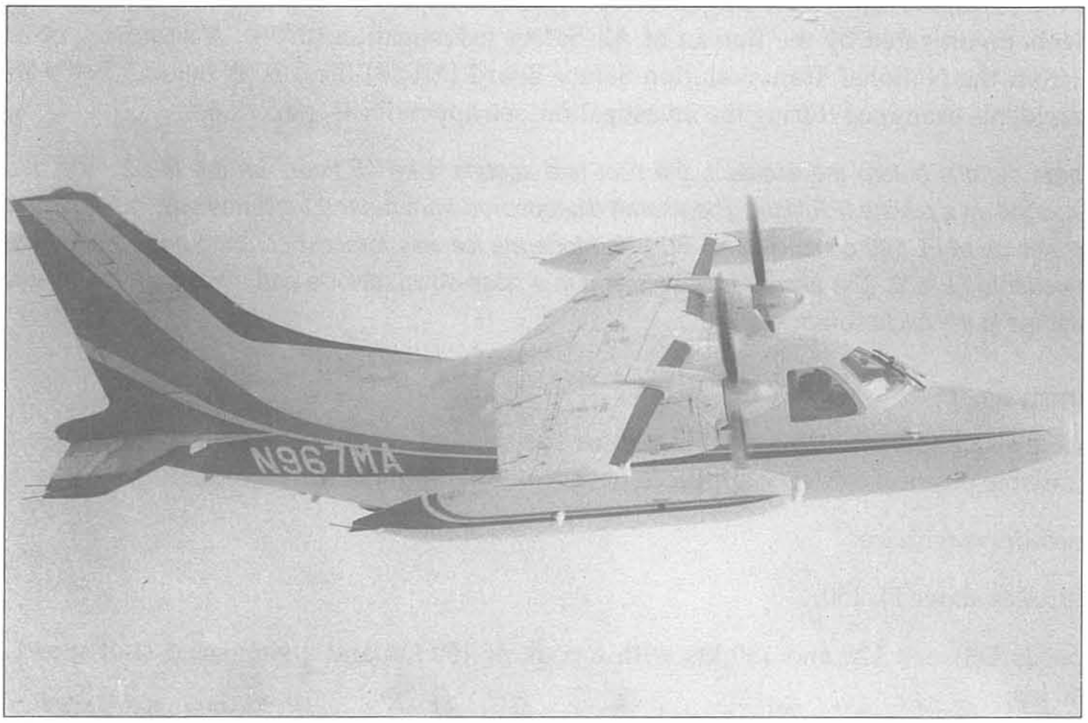
It seemed appropriate to explore ways in which pilots might be alerted to these situations as they developed in order to break the chain of events. Three possible areas were examined:

- ice detection, specifically airframe icing;
- high trim warnings; and
- stall warnings.

1.2 Ice Detection

1.2.1 Discussion

No ice-warning device is fitted to the MU-2 aircraft. Moreover, the FAA-approved flight manual, the CAA-approved flight manual and the manufacturer's POM do not advise how to detect ice formation. While the notes for the ground-school course conducted by FSI in the USA advise that the 'wing de-ice' should be activated when approximately 1/4 inch (6 mm) of ice is seen to have formed on the wing leading edge, no advice is provided about how this thickness should be gauged. Thus, those pilots who have FSI documentation will know that when they see 1/4 inch of ice on the wings they should activate the wing de-ice equipment; but they are still not advised on how to estimate how much, if any, ice has formed on other parts of the airframe.



MU-2 aircraft showing commencement of ice accretion on leading surfaces

Interviewed pilots spoke of the difficulty of determining ice formation, even in areas normally visible to the pilot. When glaze ice forms, it is virtually transparent during the daytime and almost impossible to detect on the wing leading edges at night. They advised that determining ice thickness on the wings was reduced to guesswork, especially at night. Some pilots use the formation of ice on the windscreen wiper as an indication that ice is forming on the wings and that the de-icing system should be activated.

Various reports described events attributed to unseen ice forming along the lower part of the fuselage. Performance degradation experienced was attributed to ice accretion on the airframe, with little or no ice on the wing leading edges or windscreen wipers providing advance warning of the ice formation.

The following describes an instance of suspected ice accumulation on the undersurface:

> *The aircraft was cruising at FL 150 at night. It entered a line of cumulus-type cloud and immediately started to accumulate ice. As the pilot watched the leading edges for a suitable amount of ice to form before he activated the de-ice boots, he noticed that the autopilot was slowly trimming the nose up. Noticing that the airspeed had decreased to 120 kts, he activated the boots immediately and there was a slight increase in airspeed. The attitude remained very nose-up, so he descended. As the aircraft passed FL 130, he felt 'a great sheet of ice slide off the airframe from underneath' and the airspeed increased to normal.*

The MU-2 cruises in a nose-up attitude which is dependent on aircraft weight, altitude and centre of gravity. If a heavy aircraft is cruising in its higher flight regime, it is reasonable that the aircraft could have an attitude relative to the airflow high enough to allow ice to form on the undersurfaces of the fuselage. It is also conceivable that this could occur without the pilot's knowledge.

The presence of ice on the airframe can cause performance degradation and pilots should be aware of its formation promptly so that appropriate actions are taken. A rapid airspeed reduction should not be the first warning to a pilot that ice may have formed on the airframe.

1.2.2 Recommendation

It is recommended that the CAA liaise with the aircraft manufacturer to develop a detector which can be fitted to the MU-2 to warn pilots that ice is forming or has formed on the airframe.

1.3 Elevator Trim Warning

1.3.1 Discussion

During the VH-BBA investigation it was found that the elevator trim was probably set at about 13° nose-up at the time of impact. Inspection of the wreckage of VH-MUA revealed a nose-up trim value of 17–21° at the time of impact. Subsequent research revealed that 13 of the 61 occurrences included in the MU-2 database had a higher than normal nose-up trim setting. Many of the reporters could not quantify the amount of nose-up trim but specified that a higher than normal value was seen.

A number of accident reports from the NTSB are similar to those appearing in chapters 1 and 2 of this report. In one such case it was found that the elevator trim was selected to 12° nose-up trim prior to impact; in another, the elevator trim was determined to have been set at the 10° nose-up trim position.

In the MU-2 accident at Bargo NSW in 1983 (see appendix 11, page 106), it was discovered that the elevator trims were at full nose-up deflection. The investigators suggested that the position of the trims was not conclusive because it was likely that the trim motors had moved significantly during the impact sequence due to their construction and mode of operation. During inspection of another of the NTSB files, a similar result was seen and a similar conclusion reached. It should be noted here that the trim position can be fairly accurately determined if the elevator trim capstan from the cockpit centre pedestal is recovered and inspected.

In 1983 the NTSB recommended in safety recommendation A-83-56 that the FAA conduct a special certification review (SCR) of various aspects of the MU-2's flight operations. (See 2.2.4, page 65.) As part of that review, the team performed flight tests to check on the adequacy of the warnings of an approaching stall in the aircraft. These checks were done in both the short and the long-body variants of the MU-2. Notes taken during these flights show that when the aircraft was flown towards a stall in a clean configuration with the autopilot ON, the elevator trim was driven to a high nose-up position. The short body had its trim driven to 12° nose-up by the time the aircraft had reached the stall speeds of 92 kts (power ON) and 101 kts (power OFF). The notes for the long-body Marquis indicate that the trim was driven to full nose-up trim as the aircraft approached the stall speed. (Note: the elevator trim tab in the MU-2 has a movement range of 10° nose-down to 30° nose-up, with minor variations depending on model.) During other SCR tests, the Marquis was taken towards the stall speed with an engine shut down. The notes show a 15° nose-up elevator trim position at the stall.

To ascertain the normal distribution of elevator-trim movement, two MU-2 operators were asked to record trim-travel parameters for a number of flights in which the pilots did not fly outside their normal operating limits. It was found that the upper limit of 'normal' elevator-trim travel was 7° which occurred when the flaps were set at 40° and the aircraft was on its final approach to the runway. The results were recorded for a limited range of weights and centre of gravity conditions.

1.3.2 Conclusion

There is evidence to suggest that the elevator-trim tab can be driven beyond the normal operating range of nose-up elevator trim by the autopilot as airspeed decreases in an icing encounter. If the pilot fails to see the airspeed loss or the high trim input (a real possibility according to survey responses), the pilot may lose control of the aircraft as it stalls. Also, if there is a large amount of nose-up elevator trim, the pilot will probably be unable to overcome the high stick forces on the control column to effect recovery until the trim is moved towards NEUTRAL and the high nose-up forces are removed from the elevator (refer 1.5.1). If an alert was attached to the trim system which warned that the trim was outside the normal operating range, the pilot should be able to disconnect the autopilot and take actions to prevent the situation from deteriorating to a loss of control.

1.3.3 Recommendation

It is recommended that:

1. the CAA liaise with Mitsubishi Heavy Industries America Inc or any future company responsible for product integrity of the MU-2 aircraft to develop an aural (headphones and cockpit speakers) and visual system to warn pilots when the elevator trim has exceeded the normal operating range, particularly in the nose-up direction; and
2. the CAA require all operators of MU-2 aircraft in Australia to install the above trim position warning system on their aircraft.

1.4 Stall Warning

1.4.1 Discussion

Stall angles of attack in the MU-2 are sensed by an electrically heated lift transducer in the leading edge of the right wing. Signals from the transducer and flap-position switch are electronically evaluated. At 4–9 kts above the stall speed at each flap position, the system activates a control-column shaker.

The adequacy of the MU-2 stall-warning system in icing conditions can be challenged on several grounds.

1. A 'caution note' in section 5 of the FAA-approved MU-2B-60 flight manual warns: 'Ice accumulation on the wing de-ice boot may disrupt air flow over the stall vane *and prevent the system from providing accurate stall warning*' [italics ours].
2. The present investigation has shown that the MU-2 may stall *without any warning whatsoever*.

   In both accident investigations (see chapters 1 and 2), it could not be determined if the stick shaker activated before the aircraft entered the spin. Pilots whose control loss followed an event sequence similar to that proposed for these two accidents reported that the aircraft stalled at significantly higher than normal clean-stall speeds, and that the stick shaker did not activate. In one incident, an experienced pilot departed from normal operations at FL 220 and 160 kts. He reported that the aircraft stalled, or very nearly stalled, at 160 kts, and that the stick shaker did not activate.

   Nine of the 61 records in the bureau's MU-2 database mentioned an observed stall speed exceeding that described in the flight manual. In 18 instances it could not be determined if there was a higher than normal stall speed. Although stick-shaker activation was not mentioned in the survey questionnaire, sufficient responses detailing non-activation of the stick shaker were received to indicate an area of concern.

3. (i) *It is known that ice can form rapidly on the MU-2.* This is evident from the bureau's database: of the 44 reporters who could say whether or not there was a rapid formation, 23 reported a high accretion rate. This conclusion is also supported by the bureau's computer performance modelling (see page 53).

(ii) It is also known that *ice on the wing can substantially increase stalling speed.* According to one authority, 'an ice deposit of one-half inch at the leading edge of an airfoil will reduce the lifting power of the airfoil by up to 50% and increase drag by an equal amount. The result: substantially higher stalling speeds' (Robert I. Stanfield, *Flight Safety Foundation Prevention Bulletin*, October 1988).

(iii) The interaction of factors (i) and (ii) with the MU-2's autopilot mechanism is potentially hazardous. If airspeed is lost due to ice-contaminated wings, and the autopilot attempts to maintain altitude by increasing the angle of attack, *it is possible that the aircraft will reach a stall angle of attack before the stall warning activates.*

1.4.2 Recommendation

It is recommended that the CAA investigate the adequacy of the stall warning system in the MU-2, particularly in icing conditions.

1.5 Spin Recovery

1.5.1 Discussion

The CAA-approved flight manual for the MU-2B-60 states that intentional spins are prohibited manoeuvres and should be avoided. The POM states:

> Should an inadvertant spin be encountered, the following recovery procedure should be employed.
>
> 1. Retard both power levers to FLIGHT IDLE.
> 2. Apply full rudder opposite to the direction of rotation and hold.
> 3. Push control wheel briskly forward.
> 4. When rotation stops, neutralise controls and pull out of the dive by applying steady back pressure on the control wheel.

A warning adds that most of the unsuccessful spin recoveries result from not waiting long enough for the controls to become effective.

The above procedure incorporates spin recovery actions which are applicable to most aircraft.

While the manufacturer could provide only limited information about the MU-2's spin characteristics, anecdotal evidence suggests that the spin can be violent and unstable, with the nose oscillating between -30° and -90° to the horizontal and an extremely high descent rate.

If there is a high nose-up trim input, the stick forces required to recover from the spin may well exceed the pilot's capability unless trim is first reduced. The control-stick forces to apply nose-down elevator (as required in the stall and spin recoveries) were estimated over a range of forward speeds and elevator trim tab positions*. The estimated forces were not excessive for normal flight and stall recoveries. However high nose-up trim conditions required very large stick forces (approx. 180 kg stick push) which would probably exceed the capability of most pilots.

In the absence of flight and wind tunnel test data, the engineer's conclusions must remain tentative. It is perhaps significant that 13 out of 36 control-loss occurrences in the bureau's MU-2 database involved known instances of high nose-up trim and that a number of MU-2 control-loss accidents involved suspected high nose-up trim at the control-loss point.

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*Aeronautical Engineers Australia: *Mitsubishi MU-2B-60 Preliminary Investigation for Bureau of Air Safety Investigation,* 13.3.90, AV 1381/2

1.5.2 Recommendation

The MU-2 has largely unknown spin characteristics, but it is at least known that a high rate of descent is experienced along with possible violent oscillations. It has been estimated that the stick forces needed to recover from a spin, if there is a high nose-up trim input, could well be beyond the pilot's capability, unless the trim input is first reduced.

It is therefore recommended that:

> the CAA incorporate into the MU-2 flight manual, or other appropriate document, a recommendation that the pilot neutralise elevator trim as part of the spin-recovery procedure.

1.6 Summary

The event sequence postulated for the VH-MUA and VH-BBA accidents has been shown to have occurred (even to the point of control-loss) in several earlier instances both in Australia and abroad. In some of these occurrences, however, control was recovered.

A number of factors apparently common to the accidents and incidents were identified by the bureau. It is believed that if one or more of these factors could be eliminated from the typical sequence of events leading to loss of control of the aircraft, the sequence would be broken and the pilot enabled to take action sufficiently early to prevent the situation from developing to the point of loss of control.

2. AIRCRAFT PERFORMANCE IN HIGH-LEVEL ICING ENCOUNTERS.

The MU-2's safety performance in high-level icing situations is considered to have serious limitations. Beyond these limits, performance degradation can be swift and catastrophic. Although the aircraft is certified with approval for flight in icing conditions, appropriate testing to determine the limits of safe flight has not been done.

2.1 Computerised Performance Model

2.1.1 Discussion

No quantitative data was available to study the reaction of an MU-2 aircraft to an icing encounter. There were subjective reports available, but these did not provide the hard data required to analyse how a relatively heavy MU-2 reacts to severe icing at the higher reaches of its performance envelope. (Australia-specific data was also needed, since atmospheric temperatures in Australia are typically higher than the ICAO standard atmosphere.)

A computer model was therefore developed to simulate an icing encounter and its effect on the MU-2's performance.

The model computed aircraft drag, propeller thrust and allowed for parameters such as residual jet thrust, bleed-air power loss etc. The data to compute drag and engine power was provided by Mitsubishi Aircraft International, and Hartzell Propellers provided the data used to compute propeller efficiency.

The model was controlled by selecting the engine power setting and controlling either the attitude or speed in a climb to compute the climb profile, or engine power and cruise altitude to compute the cruise speed. Aircraft weight and outside air temperature could be varied to cover the full range of likely conditions.

To simulate icing conditions, allowance was made for application of an ice factor (IF). This was expressed as a percentage increase in the profile drag coefficient as well as a smaller increase in the lift-dependent drag coefficient

The manner in which the drag coefficient varied with the IF was calculated to be:

$$CD = (1+IF)\, CD_o + (1+IF/2.5)KC_L{}^2$$

where
- IF = ice factor
- CD = total drag coefficient
- CD_o = zero lift drag coefficient (clean aircraft)
- K = lift dependent drag parameter (clean aircraft)
- C_L = lift coefficient.

Ice accretion could be introduced at any stage during the running of the program to simulate the aircraft climbing through the freezing level or encountering conditions conducive to the formation of ice during climb or cruise. The following table demonstrates the conditions approximated by the IF

IF	APPROXIMATE SIMULATION
0.0	Clean aircraft
0.3 (30 %)	Aircraft with residual ice
1.0 (100%)	Moderate icing with de-ice systems off
2.0 (200%)	Severe icing with de-ice systems off

A full derivation and explanation of the IF is found in appendix 8 on page 97.

2.1.2 Model Validation

The accuracy of the model without icing was checked against performance data contained in the POM for the MU-2B-60. The climb-out times to various pressure altitudes for different take-off weights were compared to the POM figures, as were the CASs at various altitudes and outside air temperatures. Some difficulties were experienced in extracting data from the POM charts because of the scales used, and, in some instances, errors in interpretation of those charts may have introduced exaggerated differences between the POM figures and the results from the model.

It was shown that the model closely simulated the flight manual cruise performance figures for an aircraft cruising at 96% power, in ISA conditions ranging from ISA-10°C to ISA+20°C. The agreement between figures was better at the higher cruise speeds, that is, above 200 kts CAS. However, at lower cruise speeds, which occur for a heavy aircraft at high temperatures, a lesser agreement was reached. For example, the largest difference of 7 kts (4.3%) was at 5216 kg AUW, 23000 ft and ISA + 20°C. This configuration would not be common in practice, because the aircraft would not be operating in an efficient and effective manner, due to a low cruise speed and a high nose-up attitude.

The table below contains the results from a series of computer simulations of cruise conditions.

Program cruise CAS versus POM cruise CAS for ISA + 20°C Conditions
96% power and bleed air on for various altitudes and weights

Altitude (ft)	RPM (%)	Weight (kg)	POM CAS (kts)	Program CAS (kts)	Difference (%)
15000	96	4309	212	213	+ 0.5
		4763	208	209	+ 0.5
		5216	204	204	0.0
17000	96	4309	205	206	+ 0.5
		4763	200	202	+ 1
		5216	195	196	+ 0.5
19000	96	4309	197	200	+ 1.5
		4763	191	195	+ 2.1
		5216	185	189	+ 2.2
21000	96	4309	189	192	+ 1.6
		4763	182	187	+ 2.2
		5216	174	179	+ 2.9
23000	96	4309	180	185	+ 2.8
		4763	172	178	+ 3.5
		5216	162	169	+ 4.3

NOTE 1. '+' Difference — Program CAS is faster than POM CAS
2. '–' Difference — Program CAS is slower than POM CAS

The comparison between the model and the POM data for the times to climb had to be performed using 98% power, due to the lack of other data in the POM. In general, it was found that the model took longer to reach the altitudes than predicted in the POM, and the table below summarises the differences.

Average difference in climb times for 98% power

Altitude (ft)	Weight (kg)	Time Difference (%) ISA	ISA+20°C
5000	4309	+ 2.9	+ 2.4
to	4763	+ 4.2	− 3.4
15 000	5216	+ 7.7	+ 8.1
5000	4309	+ 1.9	+ 3.6
to	4763	+ 4.8	+ 6.1
19 000	5216	+ 4.5	+ 4.9
5000	4309	+ 4.8	− 1.4
to	4763	+ 4.0	+ 0.1
23 000	5216	− 0.9	+ 1.7

NOTE 1. '+' Difference — Program time is longer than POM time

Data for the rate of climb at 100% power was also available in the POM, and was compared with the results from the model. In all cases, the model achieved a lower rate of climb than predicted in the POM. Over the altitude, weight and temperature ranges considered, the differences varied from −76 ft/min (−4.5%) at 15 000 ft, ISA and 5216 kg, and to +31 (+2.9%) ft/min at 23 000 feet, ISA and 4763 kg.

Comparison rate of climb versus program rate of climb for
ISA +20°C conditions and 100% RPM

Altitude (ft)	Weight (kg)	Climb EAS (kts)	POM ROC (ft/min)	Model ROC (ft/min)	Difference ROC (%)
15 000	4309	148	1770	1754	− 0.9
	4763	152	1410	1397	− 0.9
	5216	156	1110	1095	− 1.4
17 000	4309	146	1560	1531	− 1.9
	4763	150	1220	1196	− 1.9
	5216	154	950	936	− 1.5
19 000	4309	143	1350	1316	− 2.5
	4763	148	1010	1016	− 0.6
	5216	153	740	726	− 1.9
21 000	4309	141	1170	1151	− 1.6
	4763	146	850	828	− 2.6
	5216	151	560	546	− 2.9
23 000	4309	139	960	956	− 0.1
	4763	144	650	642	− 1.2
	5216	149	380	373	− 1.8

NOTE 1. '−' Difference — Program ROC is less than POM ROC

Summary of Validations

The model was validated by checking its flight results against data contained in the POM and generally good agreement was obtained over the full flight envelope range of altitude, weight, engine power setting and atmospheric temperature range. In particular, the cruise and rate-of-climb figures demonstrated differences of less than 5% and the time-to-climb figures showed a maximum discrepancy of less than 9%. Considering the quantity of data available to program the computer model and the accuracy of the POM graphical presentation, it was concluded that these differences were acceptable and that the model presented an acceptable match.

2.1.3 Aircraft Flight Simulations

After the accuracy of the model had been validated, it was used to recreate the flight profiles of four MU-2 flights for which radar data recordings were available. The four flights were:

Case 1: Climb accident, VH-MLU at Bargo NSW, on 23 May 1983;

Case 2: Normal climb, VH-MIU from Sydney, on 23 May 1983, (23 minutes after VH-MLU);

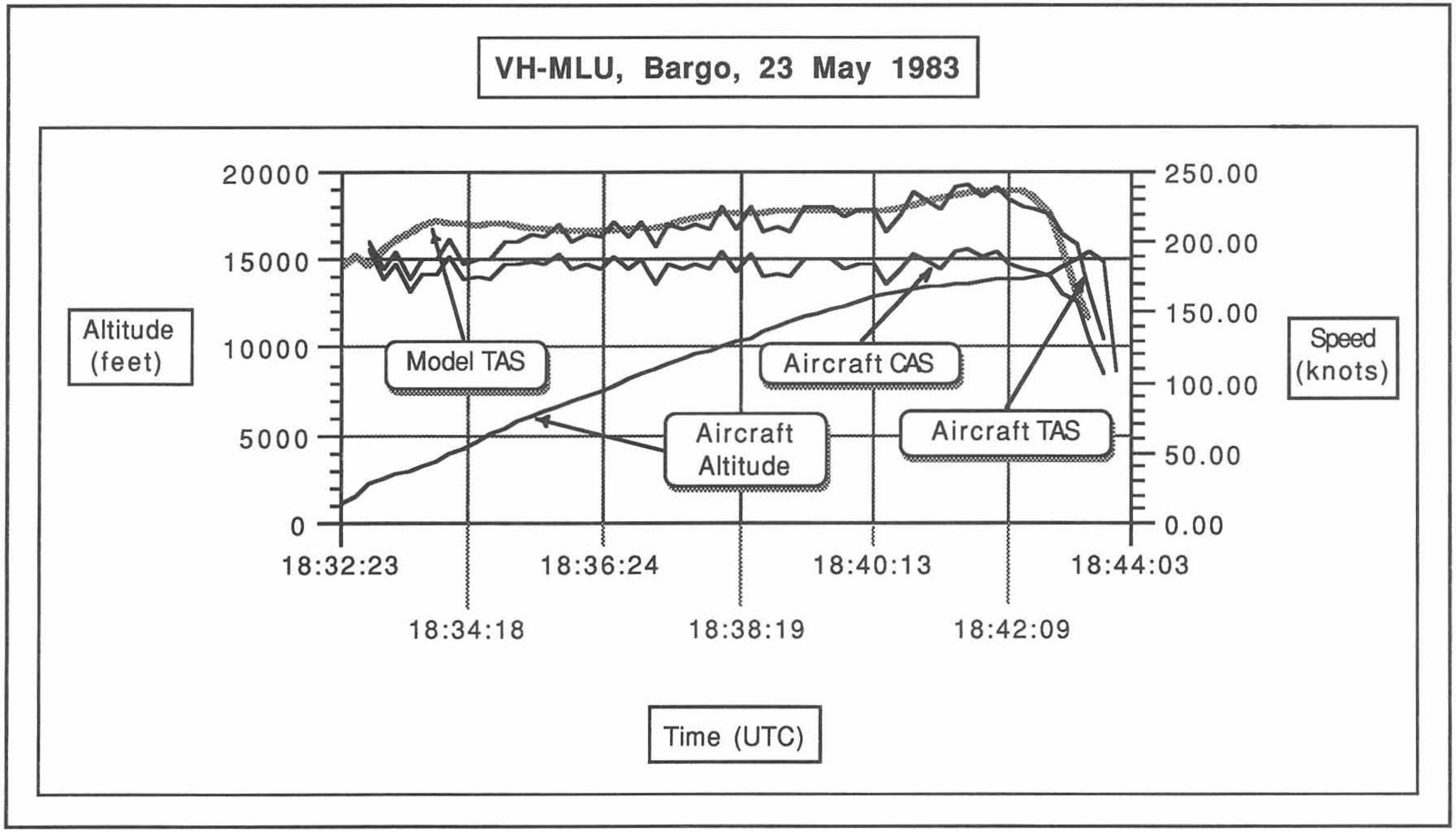
Case 3: Normal climb and cruise, VH-MUA from Perth, on 25 January 1990, (initial portion of final flight);

Case 4: Cruise accident, N300CW, at Putnam, Texas, 14 February 1990, (final part of flight).

The four flight profiles were reproduced by the model and were compared with the radar data, in an attempt to provide indications of the attitudes and power settings used, and any indications of icing which occurred during the accident flights. Meteorological information from the appropriate day provided the temperature/altitude profiles used to simulate the actual flights. The climb profiles were simulated by adjusting the attitude at a fixed power setting so that the model produced similar altitude and time profiles to the radar data and for the cruise profiles, the power setting and/or IFs were adjusted to reproduce the radar data.

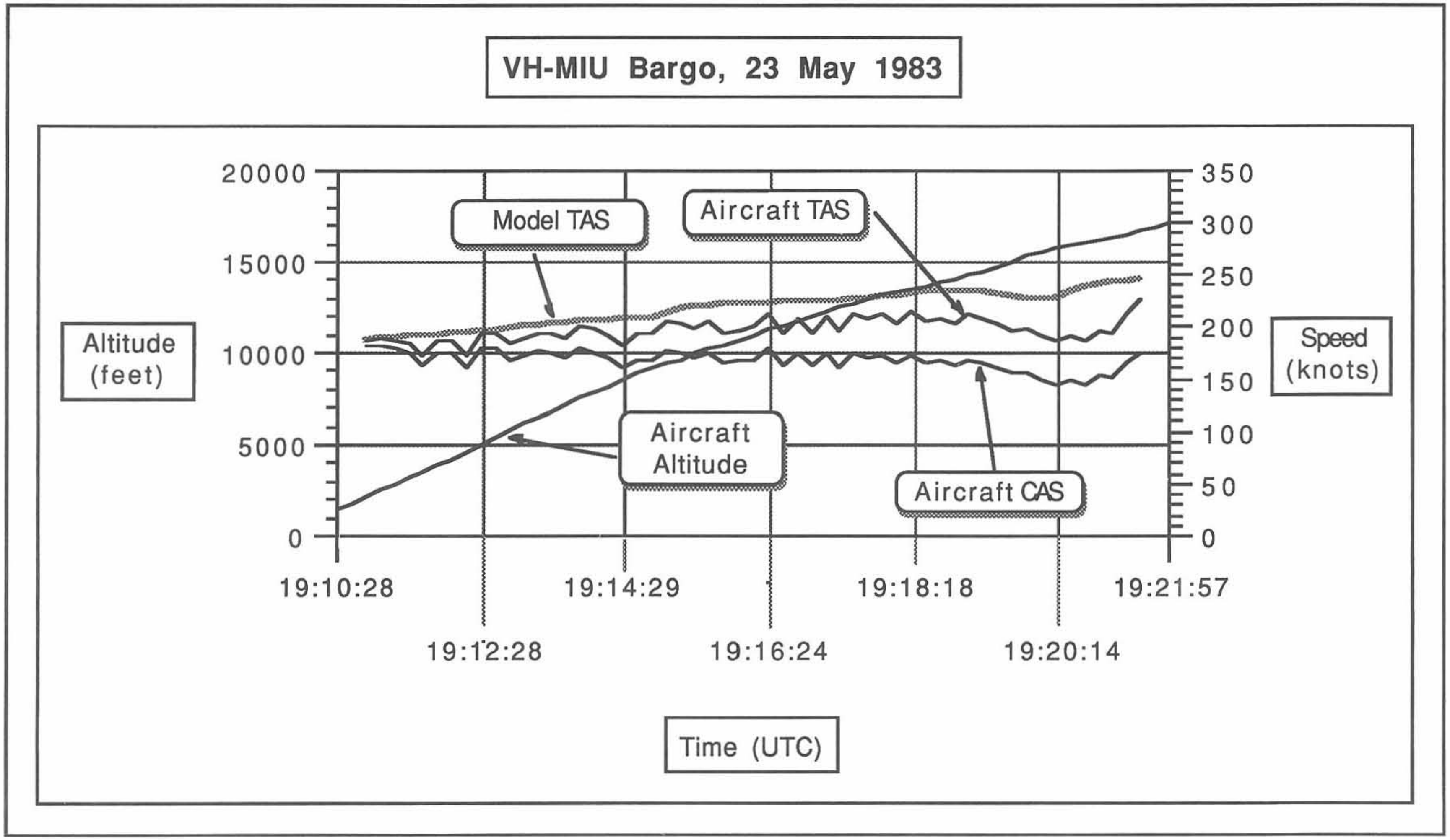
Copies of the simulated profiles and brief summaries of the icing simulations are as follows:

CASE 1

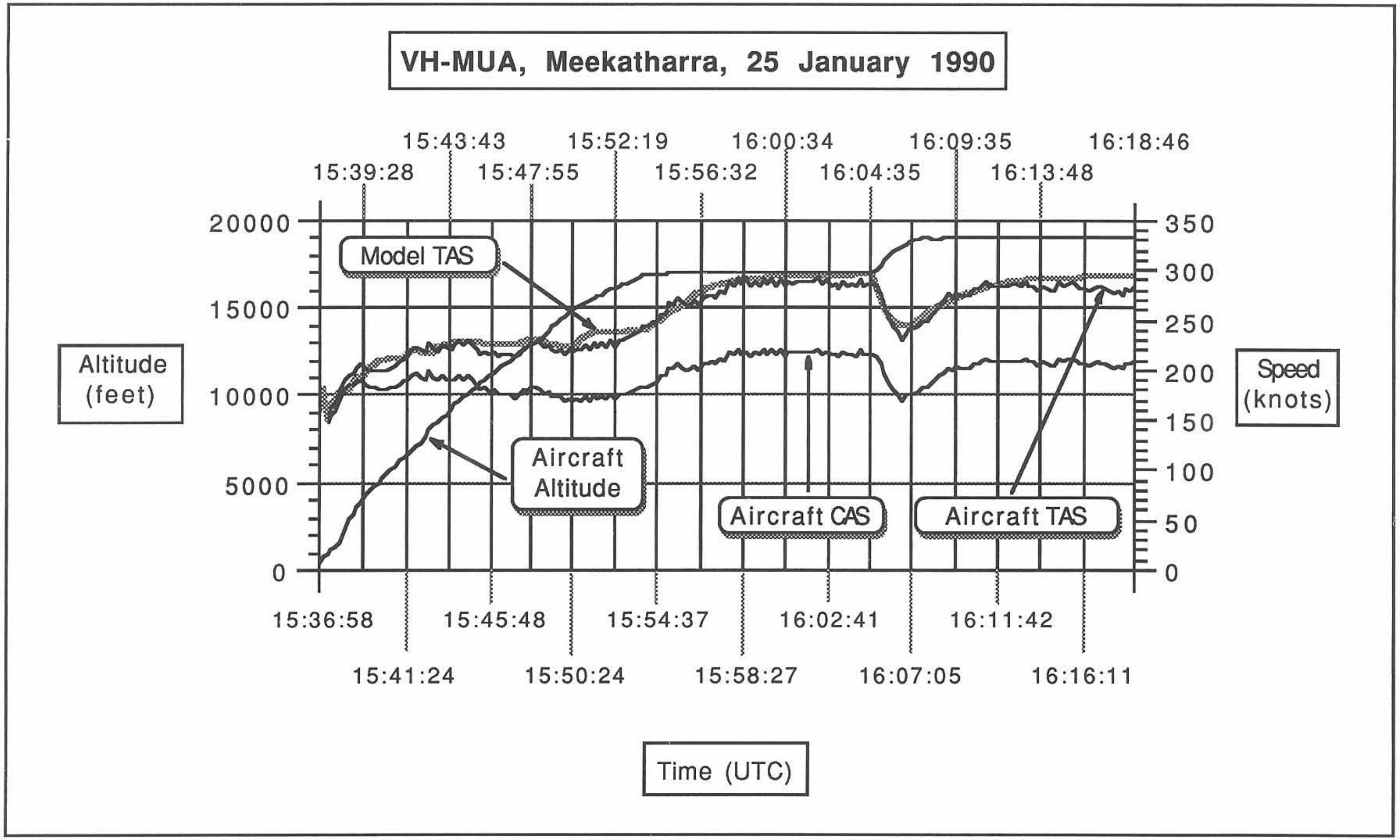


VH-MLU: The model was able to approximate the climb profile to 12 900 ft using MCP and small changes in attitude only. The resultant TAS profile appeared to be a smoothed version of the averaged radar data. An average icing factor of 40% was required to be applied to the model to simulate the reduced rate of climb between 12 900 ft and 14 250 ft. The final deceleration of the aircraft to the loss of control speed was simulated by a combination of a further increase in icing to 85%, and a large increase in attitude to produce a similar TAS and altitude profile to that of the aircraft. At the loss of control altitude of 15 500 ft, the averaged aircraft TAS was 164 kts (131 kts CAS) compared with the model 158 kts TAS.

CASE 2

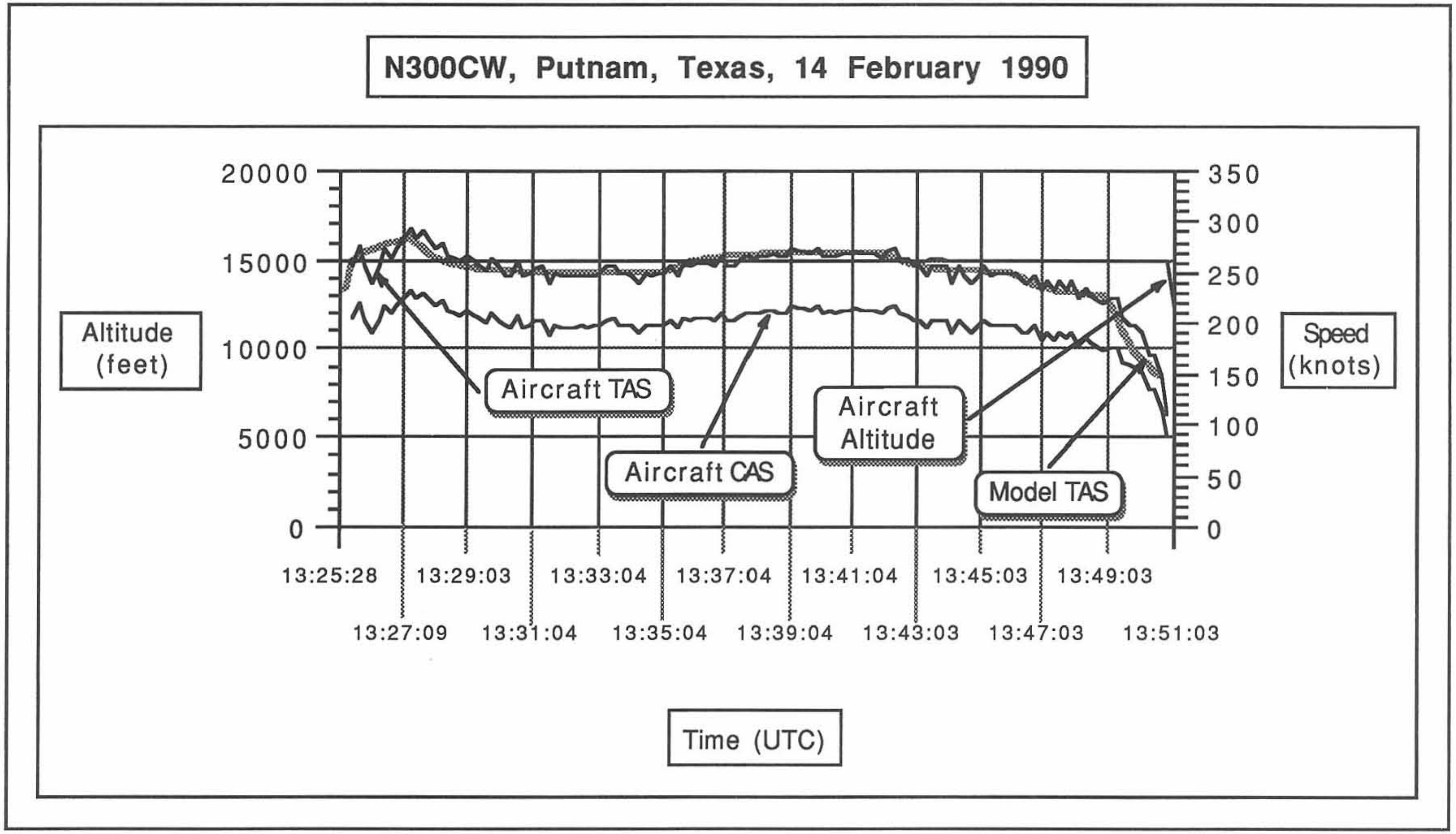


VH-MIU: The climb for this aircraft was modelled by using MCP and changes in aircraft attitudes but without the addition of any icing factors. The model produced good agreement with the recorded data to 9 400 ft, and then diverged from the recorded data and climbed faster than the aircraft to the top of climb. No explanation was determined for this observation.



VH-MUA: The model was used to reproduce the radar flight profile for this aircraft from shortly after take-off until the end of the recorded radar data at 160 nm from Perth. Using MCP, the model produced a good likeness to the recorded data, except for the latter stages of the initial climb, where the model outclimbed the aircraft. By reducing the power at the top of both the initial and en route climbs, the model was able to reproduce the step in airspeed seen in the recorded data at the commencement of both cruise segments. No IFs were introduced during the flight comparisons and the simulations indicated that MCP was most probably used during the recorded cruise segments. No attempt was made to reproduce the speed variations seen towards the end of the recorded data due to the unknown nature of the variations and their frequency.

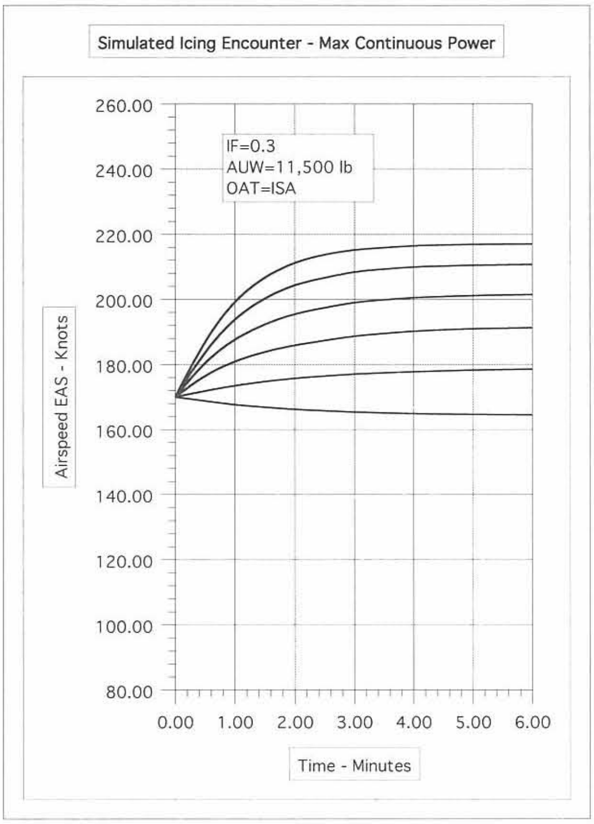
CASE 4

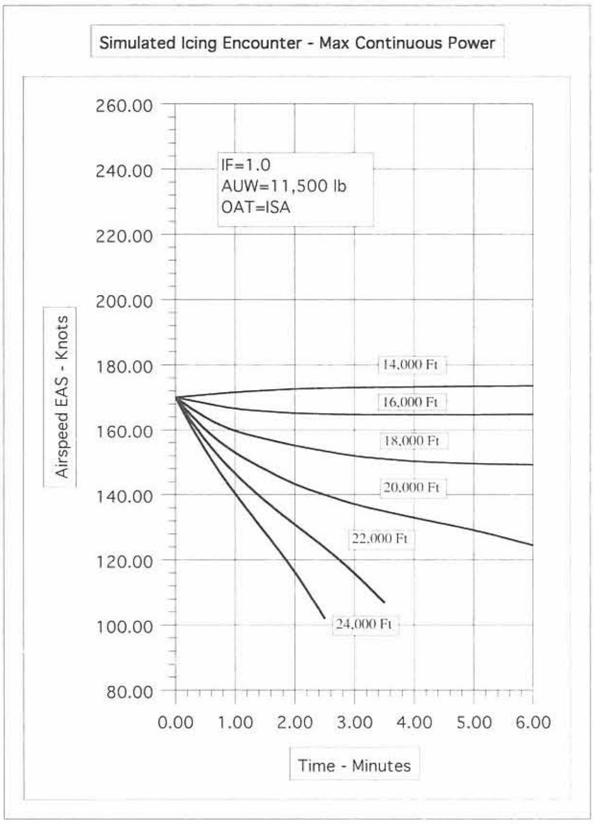


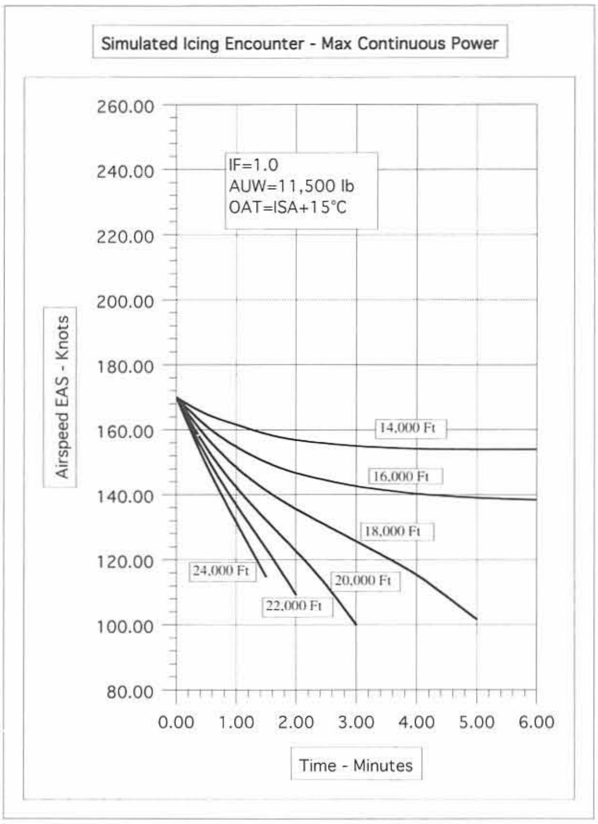
N300CW: The model produced an excellent likeness to the recorded data provided by the NTSB investigation team. The accelerations and decelerations seen in the data were simulated assuming an accumulation and shedding of ice. Throughout the simulations, 100% power was used and IFs were progressively added to reproduce the actual flight. The recorded data showed that control was apparently lost at a TAS of 146 kts (116 kts CAS), and the model simulated the final deceleration to a TAS of 155 kts with an approximate icing factor of 1.85 (185%).

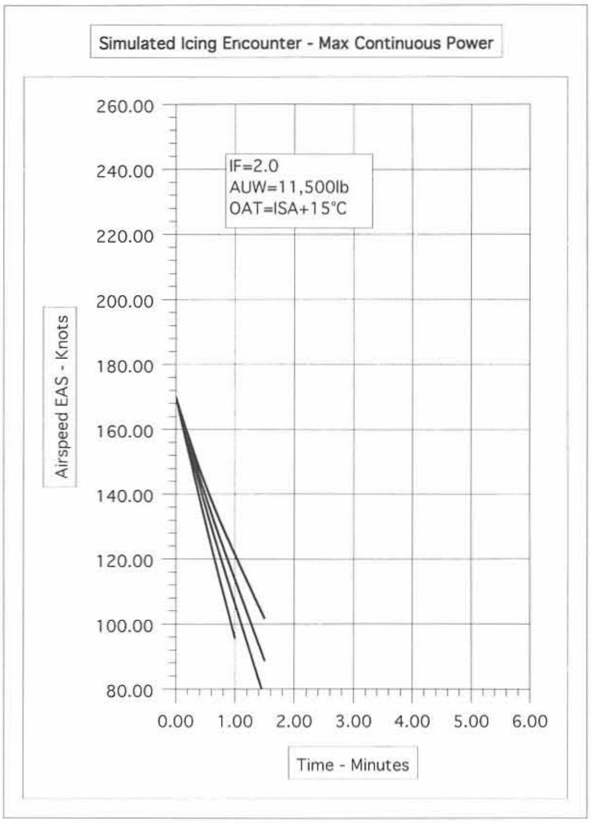
Performance Simulation

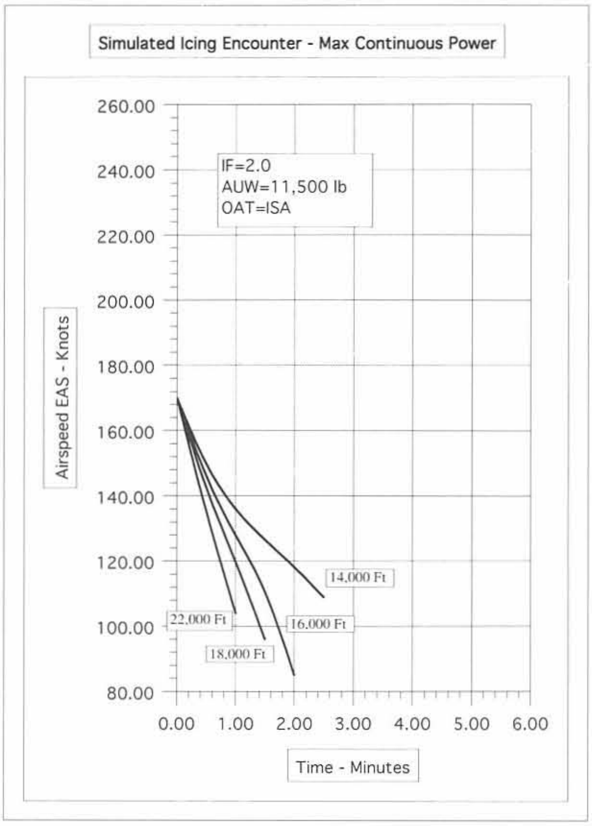
Simulation of the performance of the MU-2 in ice at high altitudes, particularly when the encounter is with moderate or severe ice, indicates a very high rate of speed loss. For example, at the altitude (21 000 ft) and temperature (ISA+12°C) at which VH-MUA was operating, the results indicate that decelerations of about 40 kts/min for moderate icing (IF=1.0), and about 90–100 kts/min in severe icing (IF=2.0), could be experienced. Such decelerations would require a very rapid response from the pilot if a stall was to be avoided, particularly if the autopilot was engaged in the altitude-hold mode. The graphs below show the results of the simulations.

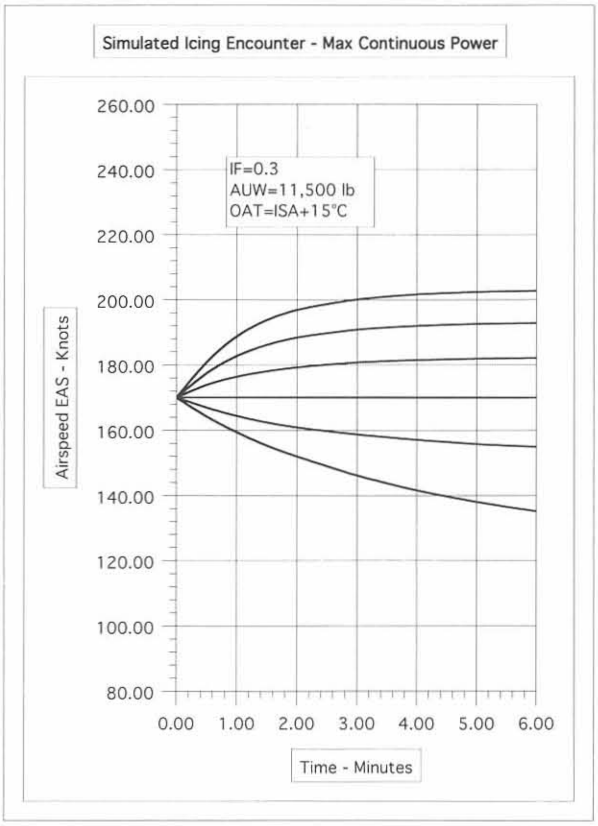





Simulated Icing Encounter - Max Continuous Power
IF=1.0
AUW=11,500 lb
OAT=ISA+15°C
14,000 Ft
16,000 Ft
18,000 Ft
20,000 Ft
22,000 Ft
24,000 Ft
Airspeed EAS - Knots
Time - Minutes


Simulated Icing Encounter - Max Continuous Power
IF=2.0
AUW=11,500lb
OAT=ISA+15°C
Airspeed EAS - Knots
Time - Minutes


Simulated Icing Encounter - Max Continuous Power
IF=2.0
AUW=11,500 lb
OAT=ISA
14,000 Ft
16,000 Ft
18,000 Ft
22,000 Ft
Airspeed EAS - Knots
Time - Minutes


Simulated Icing Encounter - Max Continuous Power
IF=0.3
AUW=11,500 lb
OAT=ISA+15°C
Airspeed EAS - Knots
Time - Minutes

Similar rapid speed losses have been reported by some of the pilots in the survey. For example:

> *The reporter had the autopilot on whilst in the climb and had his head down flight planning for the next leg. After a very short period he noticed that the control column was vibrating and that the IAS was decreasing through 130 KIAS. The aircraft had a high nose-up attitude. The pilot disconnected the autopilot and pushed forward on the control column. At this stage it was noticed that the IAS was decreasing through 110 KIAS and the column was still shaking. The pilot attained a nose-low attitude and the speed remained at 90 KIAS for a lengthy period before regaining normal speed. The aircraft lost 3 000–4 000 ft during this episode. Prior to the incident the pilot had noticed only a small amount of ice on the wiper blade and on the leading edges of the wing.*

2.1.4 Summary

BASI developed a computer model of the MU-2B-60 aircraft which had the capability of simulating an icing encounter and the effects such an encounter would have on the performance of the aircraft.

The model was checked against performance data contained in the POM and generally good agreement was obtained over the full altitude, weight, engine power setting and atmospheric temperature range. The model was also verified against known MU-2 flights, including accident flights. With reasonable assumptions, the model was also able to fairly accurately reproduce the profiles of these flights.

Research with the model indicated that the MU-2 aircraft can experience rapid speed losses when exposed to moderate ice encounters at higher altitudes when reasonably heavy. The results were entirely consistent with the known characteristics of loss of control occurrences in this flight regime.

2.2 Certification for Flight In Icing Conditions

2.2.1 Certification history

The FAA certification of the MU-2B was originally accomplished under the provisions of the Bilateral Airworthiness Agreement between the USA and Japan dated 1 February 1963. In accordance with Part 10 of the Civil Air Regulations (CAR), currently Section 21.29 of the Federal Aviation Regulations (FAR), FAA Type Certificate A2PC was issued for the MU-2B on 4 November 1965. The applicable regulations were cited as CAR Part 3 dated 15 May 1956, including Amendments 3-1 through 3-8, plus special conditions stated in FAA letter to Civil Aviation Bureau Japan (JCAB) dated 14 May 1965. The special conditions were later modified by FAA letters to JCAB dated 25 January 1968 and 12 May 1971.

The aircraft were manufactured in Japan and shipped to the USA as completed airframe assemblies. Engines and other accessories were then added and the aircraft were test-flown and released. Interior furnishings, additional avionics and instruments were usually added after the aircraft was released by Mitsubishi's USA representative. Mitsubishi models MU-2B, MU-2B-10, -20, -25, -26, -30, -35 and -36 were approved under the import criteria of Part 10 of the CAR.

On 12 September 1973, Mitsubishi Aircraft International (MAI) submitted an application for type certification of the MU-2B under the provisions of Part 21.21 of the FAR. The effect of this was to place control of the type design with MAI at San Angelo, Texas, and to place direct responsibility for specific approval of type design, and changes thereto, with the FAA rather than through JCAB and the bilateral agreements. Exemption number 1951 was granted on 4 February 1974 to permit use of the same certifying regulations as were used for aeroplanes manufactured under Type Certificate A2PC.

Type Certificate A10SW was subsequently granted on 20 January 1976 for the MU-2B-25 and -35 models. Later, approval was granted for the -26, -26A, -36, -36A, -40 and -60 models to be added as part of Type Certificate A10SW.

2.2.2 Ice protection certification

The ice protection system was certified in accordance with CAR 3. Paragraphs 3.652 and 3.712 were the basis for the system functional and installation testing. Paragraph 3.652 related to the engine intake de-icing which is not pursued here. Paragraph 3.712 is headed 'De-icers' and, in total, states:

> When pneumatic de-icers are installed, the installation shall be in accordance with approved data. Positive means shall be provided for the deflation of the pneumatic boots.

Report NA-9813-A, entitled 'Method of Substantiation of Conformity to Airworthiness Requirements for Model MU-2B-25 Aircraft', dated 14 September 1973, was issued by Mitsubishi Heavy Industries Ltd., Nagoya Aircraft Works. The document listed the various reports submitted in the certification data package when type certification for the aircraft was requested. This report was apparently the Mitsubishi data reference for the issue of Type Certificate A10SW.

Report NA-9813-A listed reports YET 65232 and NMU 0877 as detailing the results of the functional and flight testing of the ice protection system. These tests were carried out to show conformance with CAR 3 paragraph 3.712. These two documents formed part of Substantiation Code *B YET 69123 indicating that the testing was carried out on the original MU-2B aircraft, but not on any of the subsequent variants.

NMU 0877, dated 1 July 1965, detailed the flight tests carried out on the system. The document showed that only one flight was conducted, the main emphasis being on the aircraft flight characteristics with the de-icer boots inflated. Flights in icing conditions, and flights with accrued ice, were not flown.

YET 65232, dated 8 November 1965, described the de-icer boots inflation and sequencing ground testing, and concluded that the system operated satisfactorily.

Before Type Certificate A10SW was issued, MAI supplied Engineering Report MR0149 entitled 'Icing Flight Test Report'. MRO149 contains the statement: 'This report shows a history of MU-2B flight test into known icing conditions far in excess of that normally flown for certification testing'. Under the heading 'Flight Test Data' is the statement: 'The following data are 46 accounts of Mitsubishi flight test into icing conditions ranging from light to severe at temperatures from –54° F to +32° F'.

Assessment of the data disclosed that 21 accounts took the form of 'Icing Encounter Reports' compiled in a survey conducted between 29 January and 16 February 1976. Pilots answered a series of pro-forma questions about their experience in icing. Some of the accounts related to events up to 7 years prior to the survey. The other 25 accounts are pilot reports of ice encounters covering the period 1966 to 1976.

All these reports would more properly be labelled 'pilot testimonials' rather than 'flight tests' in that the latter, if they were to be considered in a certification context, would need to be:

- approved by the manufacturer and/or certification authority;
- carried out to a schedule that addresses the certification requirement;
- supported by a flight-test plan that stipulates the conditions surrounding each test, e.g. weight and balance, flight parameters etc.; and
- supported by a detailed report recording all facets of the flight.

For a test flight to meet the above requirements, it would be expected to include operations:

- at maximum cruising altitudes;
- with weights up to maximum gross at take-off;
- throughout a range of icing conditions; and

- with exploration of controllability and stall margins resulting in records of the lateral, directional and longitudinal stability of the aircraft at high and low speeds, with assessments of the period, damping, divergence and force gradients encountered.

BASI is not aware that such tests were carried out.

Two compliance reports were raised to add the -26A/-36A and the -40/-60 to Type Certificate A10SW after it was issued in 1976, as these variants were later developments. Neither of the reports listed any data to show conformity with CAR 3.712. Therefore, these later models were accepted on the basis of the data from the original MU-2B testing.

2.2.3 Certification flight testing

CAR 3, paragraph 3.16 details general requirements for flight testing and calls for 'a comprehensive and systematic check... in flight... of all components to determine... they perform their intended function' and that 'sufficient testing and supplementary experience... be obtained and evaluated to give reasonable assurance that the airplane... should continue to function properly in service'. Paragraph 3.16 (4) states 'All components of the airplane should be intensively operated... under all operating conditions expected in service'.

Specifically in regard to testing of the aircraft for approval of flight into known icing conditions, BASI is not aware of 'comprehensive and systematic checks' and 'sufficient testing' having been carried out, although it is recognised that pilot testimonials could be considered 'supplementary experience'.

2.2.4 Special certification review (SCR)

On 24 August 1983 NTSB Safety Recommendation A-83-56 was sent to the FAA for consideration, following a number of unexplained MU-2 accidents. The recommendation read as follows:

> The National Transportation Safety Board recommends that the Federal Aviation Administration: Conduct a special certification review of Mitsubishi MU-2 airplanes relative to the engines, fuel system, autopilot, and flight control systems; flight in known icing conditions; engine inoperative characteristics; and handling characteristics during IMC landing approaches; and take the appropriate action to correct any deficiencies identified (Class II, Priority Action, A-83-56). (For SCR conclusions see appendix 5, page 92.)

The 'flight in known icing conditions' sections of the SCR Report indicated that the FAA team reviewed the pilot testimonials and the engineering reports and concluded that the MU-2B icing protection system did comply with the CAR 3 requirements which were valid at the time of the type certification. However, the team added that the documentation for the ice protection system would be inadequate for certification under 1984 rules for flight in known icing conditions.

The SCR team conducted a limited flight evaluation of the MU-2B-20 in icing conditions. The objectives of the icing flights were to determine that handling qualities did not deteriorate with a reasonable residual ice accumulation and that all icing protection equipment performed the intended function. The SCR team found no discrepancies or items for concern.

Only two icing evaluation flights were conducted, both in the short fuselage -20 aircraft. No evaluation flights were made in the long fuselage -60 aircraft. On both ice evaluation flights in the -20 aircraft, the aircraft was well below the maximum take-off weight and neither flight operated above 11 000 ft above mean sea level.

The SCR team complied with the terms of the NTSB Recommendation A-83-56 in that they reviewed the certification of the MU-2 in relation to flight in known icing conditions. However, the team did not test the flight-in-icing performance of the aircraft throughout the full range of operating conditions expected in service. In particular, flights at high altitude and high weights were not included.

If the MU-2 were submitted for type certification under present-day regulations, FAR 23 at paragraph

23.1419 would require that the aircraft be flight tested in an icing situation which deposited a predetermined amount of ice on the aircraft, over a set distance and at normal operating altitudes and weights for the aircraft. In light of the evidence presented in this report on the limits for safe operation of the aircraft at high altitudes and weights, and given that the aircraft is commonly operated in these circumstances, application of flight testing per FAR 23 paragraph 23.1419 to the MU-2 would seem entirely appropriate.

2.2.5 Summary

The MU-2 ice protection system was certified under CAR 3. Functional and flight tests of the performance of this system were conducted prior to certification.

In respect of general flight testing for flight in icing conditions, available documentation describes a series of pilot reports. There is no evidence of systematic flight testing of the aircraft in icing conditions. In particular, performance in icing conditions, at high altitudes (above 15 000 ft), and at high weights, was apparently not the subject of rigorous flight testing. This is not necessarily to imply that such testing was required for certification at that time, simply to point out that this aspect of the aircraft's performance was not so tested.

A subsequent SCR did include some flight tests in icing conditions. However, these tests were limited to altitudes below 11 000ft and in aircraft at well below maximum take-off weight. In addition, the tests were conducted only on the short-fuselage version of the MU-2.

2.2.6 Analysis

Similar to many aircraft of the same generation, certification of the MU-2 did not include a full flight test program in icing conditions. The requirements of CAR 3 were assessed by means of pilot reports detailing the observed performance in icing conditions. At that time such evidence was considered adequate for certification.

However, subsequent experience with the aircraft as documented in this report suggests that there are serious limitations to safe flight in icing conditions, particularly at high altitudes and weights. Furthermore, computer simulation of the MU-2's performance under these conditions supports the observations made by pilots that performance degradation can be rapid, sometimes leading to loss of control.

In light of the demonstrated problems with the MU-2, the **unlimited** certification of the aircraft for flight in icing does not appear appropriate. To clearly determine the limits of safe flight, a properly constructed program of flight tests as currently applied under FAR 23 would be required. As detailed above, it appears that, to date, such a program has not been conducted for the MU-2.

This is not to suggest that the certification for flight in icing conditions, of other aircraft certified in the same manner as the MU-2, is necessarily inadequate. Simply that, with its accident and incident history, the true performance limitations of the MU-2 in particular are not known.

2.2.7 Recommendations

BASI therefore recommends:

1. that the CAA withdraw approval for the MU-2 aircraft to be flown in known icing conditions until flight testing is performed to determine the operational limits of safe flight in these conditions. Such flight testing should include icing encounters at aircraft weights near maximum take-off weight and altitudes at the upper limit of the operating band.
2. that the CAA liaise with the FAA to ensure that the FAA is aware of the withdrawal of approval for the MU-2 aircraft type to operate in known icing conditions in Australia.

3. PILOT TRAINING

3.1 Discussion

There is reason to believe that the endorsement training process for pilots of MU-2-type aircraft is inadequate and that a more in-depth training and recurrency program is required.According to the Air Navigation Orders (ANOs) in force at the time of the VH-BBA accident a pilot who wished to be endorsed to fly the MU-2 was required to undergo training and pass tests of his knowledge of the operating limitations of the type of aeroplane and tests of his ability to perform all normal and emergency flight manoeuvres in the particular aircraft. For a pilot who expected to fly the aircraft under instrument flight rules (IFR) and/or on charter tasks, the minimum flight time the regulatory authority would accept for endorsement was 10 hours. This flight time was to include dual instruction and route flying ICUS.

Before the VH-BBA accident the holder of a flying instructor's rating who had more than 50 hours total multi-engine experience and more than 10 hours of command time on the MU-2 was permitted to train and to endorse a pilot onto the MU-2. The instructor was not required to demonstrate competence in operating the aircraft, or knowledge of the aircraft's systems and performance, apart from the normal requirements of a pilot endorsement.

3.2 Pilot Endorsements

During the investigation of the VH-BBA accident, it was ascertained that the pilot had flown a little more than the minimum required. A number of the pilots who were still flying the MU-2 after the accident had also achieved only a few hours more than the minimum required during their endorsement flying. Others had not met the minimum.

Discussions with FAA representatives revealed that there were no legal requirements for pilots in the USA seeking endorsement onto the aircraft. A pilot with a multi-engine approval could legally fly the aircraft without specific type training. This situation was generally recognised as inadequate within the US aviation industry and both the manufacturer and many insurance companies had taken steps to ensure that pilots were trained to an adequate level.

The manufacturer had subsidised further training courses for pilots working for companies which had purchased new aircraft. These subsidies were sometimes extended to second-hand aircraft purchasers. The subsidised courses commenced after the SCR (see 2.2.4 page 65) of 1983/4, and continued until MU-2 production ceased in 1986. According to the manufacturer, the MU-2 accident rate within the USA had decreased noticeably after introduction of the training courses.

Many insurance companies within the USA had recognised that pilots of MU-2 aircraft needed to be trained adequately and had advised prospective clients that before their pilots could be insured, they would need to meet specified experience and training levels. A typical requirement placed on one corporate charter operator was that pilots must have 500 hours ICUS before being allowed to command flights for that operator. The same operator was required to send his pilots to a recognised MU-2 training school to have valid insurance. The minimum experience levels of pilots dictated by the insurance companies in the USA were far greater than the 10 hours ICUS stipulated for Australian endorsements.

Discussions with experienced MU-2 pilots both in Australia and overseas confirmed survey information to the effect that the MU-2 is a complex, high-performance aircraft, and pilots who fly it need to use techniques sometimes different from those used in similar turboprop aircraft. A message often repeated in the information-gathering stage of the investigation was that the aircraft needed to be accurately flown within specified limits and that the margins for error were less than for similar types of aircraft.

Many experienced pilots expressed the need for regular recurrency training to ensure that critical sequences were practiced under supervision on a regular basis.

Analysis of the database showed that pilots involved in the reported occurrences had a wide range of overall flying experience. Total hours ranged from 1500 to 15 000 with a mean of slightly over 7000 and no peaks in the distribution. Turbine engine experience averaged slightly over 2000 hours.

In general, pilots involved in these MU-2 occurrences had recorded less than 1000 hours on the MU-2.

In terms of training for the MU-2, most pilots had logged less than 8 endorsement hours. About one-third had recorded 8–15 hours. On average, pilots had flown some 27 hours ICUS, ranging from under 10 hours to over 50. (The foregoing figures are based on those pilots for whom data was available.)

Pilot experience was very clearly related to the outcome of the occurrences. As can be seen in the table below, accident pilots were less experienced overall, had less turbine engine experience and considerably less MU-2 experience than did incident pilots.

TABLE 7

	Pilot experience (average)		
	Total hours	Turbine hours	MU-2 hours
Accident pilots	4912 (11)	961 (5)	151 (11)
Incident pilots	7869 (36)	2220 (30)	1026 (37)

(Figures in brackets are the base numbers for averages)

While both experienced and inexperienced pilots had been involved in control-loss occurrences, the former had a better chance of regaining control, as shown in table 8

TABLE 8

Pilot experience and control loss

Pilots who:	Average MU-2 hours
Maintained control	959 (21)
Lost control	785 (24)
— Regained control	1237 (14)
— Failed to regain control	151 (10)

(Figures in brackets are the base numbers for averages)

3.3 Design and Flying Characteristics

Many experienced MU-2 pilots interviewed regarded the aircraft as different from others in the below 5700 kg utility category of twin-engine aircraft. Some of the differences easily quantified are:

- roll control by spoilers rather than ailerons;
- low aspect ratio;
- high wing loading;
- special handling techniques needed at speeds lower than 150 kts, especially in the engine failure after take-off situation;
- the use of propeller slipstream lift generation and full-span, double-slotted fowler flaps.

Special handling techniques were dictated because the features above gave the aircraft a 'jet-like' feel. For example, the aircraft could quickly develop an excessive sink rate when the power was reduced and appropriate preventative measures had not been taken. Also, an engine failure after take-off required type-specific techniques which needed to be emphasised during endorsement and practised by pilots in their recurrent training.

3.4 Analysis

The MU-2 is a unique and complex GA aircraft. Many experienced pilots expressed the view that future pilots of the MU-2 should be better trained than is currently required in Australia and that they should have regular recurrent training on the type.

Pilots involved in occurrences recorded in the database had very few endorsement hours (generally less than 8) or ICUS hours (average 27). Furthermore the data shows that experience, particularly on type, closely correlates with the pilot's chance of survival following loss of control.

3.5 Recommendations

Requirements for the training of MU-2 pilots in Australia appear inadequate. In the USA, the accident rate to MU-2 type aircraft in USA reduced following the introduction of the higher levels of training.

BASI recommended to the CAA:

1. that the CAA acknowledge that the MU-2 is a high-performance aircraft, and for the purpose of aircraft type endorsement, should be treated in the same context as aircraft above 5700 kg, as per Civil Aviation Order/Air Navigation Order (CAO/ANO) 40.1.0 paras 6.2 and 6.3;
2. that the CAA set minimum experience levels for pilots seeking an MU-2 endorsement;

3. that the CAA require that MU-2 endorsement approvals be given only to pilots who have completed a course similar to the FSI training course, who have CAA-set minimum experience levels on the aircraft, and who are current on the aircraft;
4. that the CAA require MU-2 operators to have an MU-2 supplement in their operations manual as a prerequisite for inclusion of the MU-2 aircraft on their air service licence (air operators certificate), and that this supplement include a 6-monthly MU-2 recurrent training check for pilots;
5. that the CAA consider setting minimum ICUS levels for pilots before they are approved for operations as PIC .

It was revealed during the investigation of the VH-BBA accident that the pilot had recently renewed his instrument rating in a twin-engine aircraft which was greatly below the performance capability of the MU-2. This is believed to be a common practice in the GA industry, partly due to the costs involved. It is inappropriate that an instrument rating should be renewed in a low-performance aircraft if the pilot normally flew aircraft of higher performance such as the MU-2, since emergency situations in the latter are considerably more complex. It is therefore recommended:

6. that the CAA consider requiring MU-2 pilots to renew their instrument rating on the MU-2 or an aircraft of comparable performance.

Endorsement requirements for the MU-2 were also applicable to similar aircraft operating in the same flight regimes with similar engines. Many pilots interviewed added that aircraft similar to the MU-2 (e.g. King Air, Cessna Conquest and Piper Cheyenne) were also complex and, while not possessing the MU-2's peculiar characteristics, had similar training requirements. It is therefore recommended:

7. that the CAA consider the application of recommendations 1–6 above to similar, high performance GA aircraft which operate in the same flight regime.

CHAPTER 4 CAA RESPONSE TO RECOMMENDATIONS

BASI submitted recommendations 1–7 (see page 69) to the CAA in July 1989 as interim recommendations. These were endorsed by the Perth coroner (17 October 1989) following the VH-BBA coronial inquiry.

The CAA acknowledged receipt of the bureau's interim recommendations on 21 July 1989 and on 18 August 1989 advised the bureau of a paper to be prepared in consultation with BASI and aviation industry representatives which would define the MU-2's problems and identify suitable solutions. To date (October 1991), no other formal replies have been received from the CAA concerning actions taken in response to the recommendations. The following paragraphs list a number of actions which have come to the attention of BASI from a variety of sources.

In October 1989, the CAA produced a paper titled 'MU-2 Operations in Australia'. Its aim was 'to examine the MU-2 situation to determine whether or not unique training requirements are necessary' for continued safe operation. The paper discussed some of the unusual design and flying characteristics of the aircraft as well as various techniques specific to the training required for flying the aircraft. Also discussed were some problems reported to both BASI and the CAA with regard to general operations. Finally, the paper considered various overseas training requirements.

The paper concluded that the MU-2 is a 'reasonably complex high-performance aeroplane with some unique handling characteristics' and that 'some of the endorsement training being conducted by the industry is not adequately covering all of these characteristics'. Specific training requirements were viewed as a possible solution to some of the concerns about MU-2 operations in Australia.

The paper recommended that:

1. the CAA recognise the MU-2 as an aeroplane requiring specific endorsement and operational training requirements;
2. the CAA determine which legislative mechanism would best enable implementation of new training requirements;
3. the CAA circulate proposed training requirements to CAA type specialists and industry operators before implementation of new procedures.

A conference was held on 28 November 1989 by the CAA to discuss MU-2 operations. Participants included the authority's examiners of airmen (from each state), major operators of MU-2 aircraft nationwide, various representatives from the authority's central office and BASI.

Following lengthy discussions of MU-2 operations and comparisons with other aircraft, a series of recommendations emerged from the conference for consideration by the CAA. According to the minutes of the conference (30 January 1990), it was recommended that:

1. endorsements be completed in accordance with a detailed syllabus of ground and air training to be approved by the CAA;
2. the syllabus of training be based on the Flight Safety International MU-2 course and include a 'closed book' engineering examination;
3. the aircraft endorsement form list systems covered, certifying the satisfactory completion of an engineering examination and detail flying time for the endorsement;
4. the air training include a minimum of 20 hours ICUS post-endorsement training before a pilot is appointed to a command;

5. MU-2 endorsement training be carried out only by graded flight instructors specifically approved by the CAA and by approved persons within a check and training organisation;
6. instructors and other persons be approved to carry out endorsement training only after they have demonstrated to an examiner of airmen that they have a required level of knowledge and skill;
7. an examiner of airmen complete the Flight Safety International MU-2 endorsement course to enable him to competently assess and approve endorsement training in Australia;
8. pilots engaged in passenger-carrying commercial operations be required to undergo an annual proficiency check on the aeroplane;
9. the annual proficiency check be carried out by a pilot approved to do endorsement training;
10. pilots already endorsed on type and who are engaged in commercial operations be required to complete a proficiency check within 3 months of a requirement being promulgated;
11. a common approval process be put in place for flight instructors and persons nominated for endorsement approval;
12. a standardisation conference involving CAA and industry personnel be held annually;
13. Airworthiness Branch (of the CAA) be tasked to carry out a check on the serviceability and documentation of all aeroplanes;
14. for endorsement purposes, there be a class of aeroplane described as 'below 5700 kg multi-engine gas turbine'; and
15. any endorsement and proficiency check requirements applied to the MU-2 be applied to the below 5700 kg multi-engine gas turbine class of aeroplane.

In the early hours of 26 January 1990, VH-MUA crashed. Later that day the CAA issued a number of requirements, via telex, governing the continued operations of MU-2 aircraft. An additional requirement was added the following day. Various changes to content and format of the operational restrictions appeared over the next 4 months until the CAA issued Airworthiness Directive AD/MU-2/45 Amdt 3, which updated and superseded all previous requirements for MU-2 operations. The AD was effective from 16 May 1990.

The CAA informally advised the bureau that by the close of 1990, recommendations 1, 2, 4, 5, 6, 7, 8, 9 and 11 from the above list had been implemented, as had recommendations 8 and 9 with an increased frequency of 6-monthly checks. By the end of the year the airworthiness branch of the authority had completed the check described in recommendation 13 and the CAA had commenced a review of standards for aircraft mentioned in recommendations 14 and 15.

In February 1991, the CAA issued a Flying Operation Instruction (FOI) covering training and checking for the MU-2. This answered the first 5 of the BASI recommendations sent to the CAA in July 1989. The FOI also adjusted some of the minimum experience levels required under AD/MU-2/45 Amdt 3 of May 1990, while FOI requirements for a 6-monthly proficiency check partly addressed recommendation 6 (see page 70).

The requirements of the telexes dated 26 and 27 January 1990, the AD/MU-2/45 Amdt 3 and the FOI are reproduced in appendices 6, 7 and 8 of this report.

CHAPTER 5 SUMMARY

The two MU-2 accidents in Western Australia initiated a major BASI investigation to establish possible causal factors for these and other unresolved MU-2 accidents.

The MU-2 is a complex aircraft with higher performance capabilities than other aircraft operating in the same flight regimes. Analysis showed that a number of incidents had occurred in Australia and overseas involving encounters with ice whilst climbing to altitude or whilst cruising at altitudes mainly above FL 150. Patterns emerging from the analysis indicated that many of these encounters resulted in a rapid loss of airspeed, sometimes to the point of stall and loss of control.

A computer-based performance model developed at BASI demonstrated that an MU-2 aircraft operating at altitudes above FL 150 and encountering light to moderate ice could rapidly lose a significant amount of airspeed. This loss could suddenly reduce the airspeed to below 150 kts, which was shown to be the average speed at which pilots had experienced a stall and loss of control.

In respect of general flight testing for flight in icing conditions, available documentation describes a series of pilot reports. There is no evidence of systematic flight testing of the aircraft in icing conditions. In particular, performance in icing conditions at high altitudes (above 15 000 ft), and at high weights, was apparently not the subject of rigorous flight testing. This is not necessarily to imply that such testing was required for certification at that time, simply to point out that this aspect of the aircraft's performance was not so tested.

A subsequent SCR did include some flight tests in icing conditions. However, these tests were limited to altitudes below 11 000ft and in aircraft at well below maximum take-off weight. In addition, the tests were conducted only on the short-fuselage version of the MU-2.

Experience with the aircraft as documented in this report suggests that there are serious limitations to safe flight in icing conditions, particularly at high altitudes and weights. Furthermore, computer simulation of the MU-2's performance under these conditions supports the observations made by pilots that performance degradation can be rapid, sometimes leading to loss of control. In light of the demonstrated problems with the MU-2, the **unlimited** certification of the aircraft for flight in icing does not appear appropriate. To clearly determine the limits of safe flight, a properly constructed program of flight tests as currently applied under FAR 23 would be required. As noted above, it appears that, to date, such a program has not been conducted for the MU-2.

This is not to suggest that the certification for flight in icing conditions, of other aircraft certified in the same manner as the MU-2, is necessarily inadequate. Simply that, with its accident and incident history, the true limitations of the MU-2 in particular are not known.

Having examined appropriate regulations and the experience levels of pilots involved in its database occurrences, the bureau formulated certain recommendations concerning pilot training standards in Australia. These focused on increasing the required hours of endorsement training and on raising the required experience level of both the endorsing pilot and the endorsee. The CAA has acted on most of the recommendations and Australian MU-2 pilots now have better training and higher overall flight experience than previously.

However higher training standards are not the complete answer to the problem. In December 1990, 10 months after the CAA introduced the first MU-2 operating restrictions, the following incident occurred. The pilot involved in this incident met the new CAA experience requirements and was confident that he knew the problems associated with flight in ice in the MU-2.

The ARFOR indicated ISOL CB well to the S with no cloud above FL 140 in my area. At FL 180, 175 KIAS, *0°C indicated OAT I entered very light thin (broken) stratus. Apart from a light frosting on screen, spinner and LH wing there was no significant visible ice. With little or no turbulence and no more than 1–2 minutes since inspecting the wing, airframe vibrations began (autopilot engaged). I was doing the flight log at the time. I looked up to see IAS at 125 KIAS, 60° bank to left IAS decreasing at about 2 kts/sec. I disconnected the autopilot and had the feeling that the tail was trying to overtake me. Wings were levelled and I pushed forward till 160 KIAS. I eased back gently and stalled (additionally prior to this, roll rate was about 5°/sec). All anti-ice, de-ice and igniters were selected as per the flight manual. I unstalled at 170 KIAS and 1000 ft low. I was recleared at FL 160 without problems. Total reaction time available to me was about 5 seconds. Beyond 5 seconds I would have been inverted, and stalled, judging by the roll and IAS reduction rates.*

Until appropriate flight testing takes place to establish the safe limits of flight for the MU-2 in icing conditions, the potential for pilots to encounter similar problems will continue.

CHAPTER 6 RECOMMENDATIONS

6.1 Recommendations emerging from this report are listed below. (For further information, see chapter 3.)

It is recommended that:

1. the CAA withdraw approval for the MU-2 aircraft to be flown in known icing conditions until flight testing is performed to determine the operational limits of safe flight in these conditions—such flight testing should include icing encounters at aircraft weights near maximum take-off weight and altitudes at the upper limit of the operating band;
2. the CAA liaise with the FAA to ensure that the FAA is aware of the withdrawn approval or any other action taken to restrict operations of MU-2 aircraft in known icing conditions in Australia;

Subject to the results of the certification test flying recommended in 1, recommendations 3–6 may well be addressed as a matter of course.

3. the CAA liaise with Mitsubishi Heavy Industries America Inc. and any future company responsible for product integrity of the MU-2-type aircraft to investigate the development of an aural (headphones and cockpit speakers) and visual system to warn pilots when the elevator trim has exceeded the normal operating range, particularly in the nose-up direction;
4. the CAA consider requiring all operators of MU-2-type aircraft in Australia to install the above trim-position warning system on their aircraft;
5. the CAA investigate the adequacy of the stall warning system in the MU-2, particularly in icing conditions;
6. the CAA liaise with the aircraft manufacturer to investigate the development of a detector which can be fitted to the MU-2 to warn pilots that ice is forming or has formed on the airframe;
7. the CAA consider incorporating into the MU-2 flight manual, or other appropriate document, a recommendation that the pilot neutralise elevator trim as part of the spin-recovery procedure;
8. the CAA review training requirements and strengthen them as appropriate to reflect that the MU-2 is a high-performance aircraft. The CAA consider whether, for the purpose of aircraft type endorsement, the MU-2 should be treated in the same context as aircraft above 5700 kg, as per CAO (ANO) 40.1.0 paras 6.2 and 6.3;
9. the CAA set minimum experience levels for pilots seeking an MU-2 endorsement;
10. the CAA consider a requirement that MU-2 endorsement approvals be given only to pilots who have completed a course similar to the Flight Safety International training course, who have CAA-set minimum experience levels on the aircraft, and who are current on the aircraft;
11. the CAA consider a requirement that MU-2 operators have an MU-2 supplement in their operations manual as a prerequisite for inclusion of the MU-2 aircraft on their air service licence (air operators certificate), and that this supplement include a 6-monthly recurrent training check for pilots;
12. the CAA consider setting minimum ICUS levels for pilots before they are approved for operations as PIC ;

13. the CAA consider requiring MU-2 pilots to renew their instrument rating on the MU-2 or an aircraft of comparable performance; and
14. the CAA consider expanding recommendations 8–13 above to similar, high-performance aircraft which operate in the same flight regime.

6.2 Further Investigation Areas

6.2.1 Emergency locator transmitter (ELT)

The ELTs fitted to both VH-BBA and VH-MUA were extensively damaged on impact and did not operate. Fortunately, there were witnesses to both accidents and the accident sites were quickly located. Had there been no witnesses, SAR costs would have been unnecessarily high. Had there been survivors but no witnesses, the failed ELTs might have jeopardised the survivors' chances of being rescued.

In April 1985, a new Technical Standard Order for ELTs (TSO C91a) was introduced which was intended to increase the reliability of ELTs following impact. BASI intends to examine the suitability of ELTs subject to TSO C91a for carriage in aircraft similar to the MU-2.

6.2.2 Flight recording equipment

The MU-2 is not required to carry either a FDR or a CVR.

In 1983, BASI proposed that CVRs be fitted to certain categories of aircraft below 5700 kg maximum take-off weight. Industry opposition limited the requirement to pressurised, multi-turbine powered aircraft capable of carrying more than 11 people, thus excluding the MU-2.

Investigations of Australian MU-2 accidents have been frustrated by the absence of FDR and CVR data.

In recent years, ICAO and the FAA have introduced new requirements for the installation of CVRs in aircraft carrying two pilots and six passengers.

BASI is currently examining FDR requirements.

6.2.3 Actions to be completed

From the list of recommendations above, the CAA has satisfactorily addressed numbers 8–12, and number 13 may have been actioned by FOI 13-4, Issue 1. Number 14 is still under consideration. Recommendations 1–7 are still to be considered by the CAA.

APPENDIX 1

TRANSCRIPT OF RECORDED COMMUNICATIONS

Concerning MITSUBISHI MU-2 Aircraft VH-BBA
during the periods
8812152330 TO 8812152400 UTC,
and
8812160030 TO 8812160230 UTC.

LEGEND

BBA	–	Mitsubishi MU-2 aircraft: VH-BBA
TYG	–	Cessna C210 aircraft: VH-TYG
FMW	–	Cessna C210 aircraft:VH-FMW
RFDS	–	Royal Flying Doctor Service radio operator
KG1	–	Flight Service Sector 1 (Kalgoorlie)
KG2	–	Flight Service Sector 2 (Kalgoorlie)
PH	–	Flight Service Sector (Perth)
CD	–	Flight Service Sector (Ceduna)

SYMBOL DECODE

?	–	Unidentified source
(—)	–	Unintelligible word(s)
// //	–	Explanatory note or editorial insertion
( )	–	Word(s) open to other interpretation
*	–	Expletive deleted
....	–	Significant pause (one dot per second)

1. Telephone call from the pilot of VH-BBA to the Flight Service Operator at Kalgoorlie FSU.

Time	From	To	Text
2339:56	KG2	BBA	Flight Service Kalgoorlie
2340:00	BBA	KG2	good morning it's Kevin Fitzmaurice calling from Bellevue here
2340:04	KG 2	BBA	yes Kev

Time	From	To	Text
2340:05	BBA	KG 2	who's that
2340:06	KG 2	BBA	Mike
2340:07	BBA	KG 2	good day Mike how are you
2340:08	KG 2	BBA	oh pretty good
2340:09	BBA	KG 2	good ahm we've got some weather here what have you got down there
2340:13	KG 2	BBA	one OKTAS at three thousand all the rest is above er ten
2340:16	BBA	KG 2	right there is a bit of a thunderstorm cooking around the place at the moment I don't know if it's anything off the tail end of the cyclone but it could be
2340:20	KG 2	BBA	have you
2340:21	BBA	KG 2	yeah ..... that's early ..... *
2340:25	BBA	KG 2	yes it's it's all around
2340:26	KG 2	BBA	ahm nice one
2340:28	BBA	KG 2	ahm anyway mate I need ah we'll be getting airborne here at ah about nine o'clock local but I'll just get some weather off you first if I can
2340:30	KG 2	BBA	ok where are you off to
2340:32	BBA	KG 2	ahm just TAFS for ahm weather and TAFS for ah sixty-one what are we sixty-one out here aren't we
2340:34	KG 2	BBA	ahm you're just in ah sixty-one
2340:36	BBA	KG 2	sixty-one will do I'm coming down to KAL first port of call anyway
2340:38	KG 2	BBA	ok no worries
2340:40	BBA	KG 2	and ah TAFS for ah just the TAF for Kalgoorlie I can plan the rest when I get there I think
2340:45	KG 2	BBA	ok mate hang on
2341:11	KG 2	BBA	ahh Kalgoorlie ah is going for one twenty at fourteen with one OKTAS at four thousand
2341:19	BBA	KG 2	one twenty at fourteen one OKTAS at one four thousand
2341:22	KG 2	BBA	four thousand
2341:23	BBA	KG 2	four thousand
2341:24	KG 2	BBA	top temp is twenty-nine

Time	From	To	Text
2341:26	BBA	KG 2	twenty-nine degrees
2341:29	KG 2	BBA	ahm the winds upstairs one four thousand two nine zero at forty
2341:31	BBA	KG 2	yep
2341:32	KG 2	BBA	one zero thousand is two seven zero two zero
2341:36	BBA	KG 2	twenty at ten was it
2341:35	KG 2	BBA	yeah
2341:39	BBA	KG 2	ah have you got any grid wind there at all
2341:40	KG 2	BBA	no eighteen and a half two nine zero at forty
2341:42	BBA	KG 2	eighteen five two nine zero at forty well that's just the same isn't it ah well it's only what it's one ninety miles won't be much above that anyway
2341:52	KG 2	BBA	yeah the next one is twenty three and a half thousand so
2341:57	BBA	KG 2	yeah ok all right mate ahm do you want to take some details now then
2342:02	KG 2	BBA	yep I'll just take short details and write it on a strip
2342:04	BBA	KG 2	ok I just realised I haven't done any bloody time intervals so it's not going to be much help to you
2342:07	KG 2	BBA	ahm what are you BBA aren't you
2342:10	BBA	KG 2	ahm BRAVO BRAVO ALPHA single pilot charter
2342:12	KG 2	BBA	it's alright I'm not going to take all that wind
2342:13	BBA	KG 2	alright
2342:15	KG 2	BBA	just em ewe two charter Bellvue Kalgoorlie ahm you want to get away about zero one hundred endurance
2342:34	BBA	KG 2	endurance ex here will be two hundred
2342:35	KG 2	BBA	POB
2342:36	BBA	KG 2	POB will be eleven
2342:39	KG 2	BBA	ahm level any ideas
2342:41	BBA	KG 2	ahm track is one six six what does that make me
2342:43	KG 2	BBA	one six six ahm
2342:47	BBA	KG 2	it's evens isn't it sorry it's odds

Time	From	To	Text
2342:49	KG 2	BBA	odds plus
2342:54	BBA	KG 2	odds plus five so lets call it ahm one nine five
2342:55	KG 2	BBA	ok
2343:00	BBA	KG 2	if I get that high
2343:01	KG 2	BBA	yeah
2343:02	BBA	KG 2	might only go to one seven five and if you'll just bear with me for a moment ah hang on I'll give you I'm going my first reporting point is abeam Leonora
2343:06	KG 2	BBA	oh you are going to report are you
2343:07	BBA	KG 2	yeah
2343:08	KG 2	BBA	ok
2343:09	BBA	KG 2	oh * yeah
2343:11	BBA	KG 2	eighty-six divide ahm I'm going to get about two maybe two two forty eighty-six on that first leg twenty-seven minutes
2343:18	KG 2	BBA	yep
2343:19	BBA	KG 2	and then we've got to KAL from there divide er two nine five times sixty er twenty-two same again
2342:29	KG 2	BBA	ok
2343:30	BBA	KG 2	and then we're going to marble lock
2343:33	KG 2	BBA	are you going to replan
2343:36	BBA	KG 2	yeah I'll replan I think when I get there because the weather could have changed by then
2343:38	KG 2	BBA	yeah ok mate I haven't taken a full plan that's all so
2343:40	BBA	KG 2	we're not getting away until midday anyway so ah
2343:43	KG 2	BBA	yeah I've just written this out on a strip
2343:45	BBA	KG 2	ok LIMA X-RAY first aid rations water you know all the rest
2343:47	KG 2	BBA	yep
2343:49	BBA	KG 2	ok talk to you at nine o'clock what four six eight four this morning
2343:52	KG 2	BBA	four six or six five ah you can get us ahm above two thousand at Bellvue

Time	From	To	Text
2343:58	BBA	KG 2	ok mate see you when I get there
2344:01	KG 2	BBA	ok Kev ta ta

2. The second part of the transcript deals with the radio calls made about the operations of VH-BBA after take off at Bellevue until its crash is reported.

0137:17	BBA	KG 1	Kalgoorlie BRAVO BRAVO ALPHA six five
0137:25	BBA	KG 1	Kalgoorlie BRAVO BRAVO ALPHA six five seven five
0137:38	KG 1	BBA	BRAVO BRAVO ALPHA go ahead
0137:53	KG 1	BBA	BRAVO BRAVO ALPHA go ahead
0137:58	TYG	KG 1	// MOVEMENT REPORT //
0138:04	KG 1	TYG	// ACKNOWLEDGEMENT OF MOVEMENT REPORT //
0138:39	KG 1	BBA	BRAVO BRAVO ALPHA go ahead
0139:00	PH	KG 1	standby
0139:09	PH	KG 1	taxies BRAVO BRAVO ALPHA did you copy details
0139:15	KG 1	PH	negative
0139:20	PH	KG 1	he's taxiing Bellvue for amended destination Leinster at six thousand five hundred time hundered time interval five ten persons on board on four six eight four
0139:25	FMW	KG 1	// MOVEMENT REPORT - OVER INTERCOM EXCHANGE //
0139:28	KG 1	PH	standby standby one standby
0139:29	KG 1	FMW	// MOVEMENT REPORT //
0139:30	KG 1	PH	roger can you tell me those details again
0139:36	PH	KG 1	roger he's taxiing Bellvue for Leinster BRAVO BRAVO ALPHA six thousand five hundred five minute time interval ten POB on four megs
0139:42	KG 1	PH	roger BRAVO BRAVO ALPHA
0139:55	CD	KG 1	// INTERCOM EXCHANGE REFERENCE DEPARTURE HSZ //
0140:07	KG 1	FMW	// REQUEST FOR MOVEMENT REPORT //
0140:15	FMW	KG 1	// MOVEMENT REPORT //
0140:20	KG 1	FMW	// MOVEMENT ACKNOWLEDGEMENT //

Time	From	To	Text
0143:07	BBA	KG 1	BRAVO BRAVO ALPHA 118.4 do you read
0143:09	KG 1	BBA	BRAVO BRAVO ALPHA go ahead
0143:14	BBA	KG 1	roger ah we're on descent from 4500 to Leinster this time departed Bellvue at 40 circuit ah Leinster at ah 44 cancel SAR
0143:28	KG 1	BBA	BRAVO BRAVO ALPHA Leinster Sarwatch terminated
0143:32	BBA	KG 1	what's your primary HF we haven't been able to get you yet
0143:36	KG 1	BBA	roger I heard you on 65 try 8822
0145:40	PH	KG 1	// INTERCOM EXCHANGE // did you get ah BRAVO BRAVO ALPHA ok
0145:41	KG 1	PH	roger affirmative

//Non relevant radio traffic until 0150:15//

Time	From	To	Text
0150:15	PH	KG 1	BRAVO BRAVO ALPHA taxiing Leinster for KAL flight level 195 revised time interval abeam Leonora 18 remainder unchanged
0150:36	KG 1	PH	roger BRAVO BRAVO ALPHA no traffic
0150:38	PH	KG 1	BRAVO BRAVO ALPHA

//More non relevant radio traffic//

Time	From	To	Text
0157:15	BBA	KG 1	Kalgoorlie BRAVO BRAVO ALPHA VHF
0157:18	KG 1	BBA	BRAVO BRAVO ALPHA go ahead
0157:21	BBA	KG 1	roger departed Leinster at 55 tracking 169 on climb to flight level 195
0157:29	KG 1	BBA	BRAVO BRAVO ALPHA

//More non relevant radio traffic//

Time	From	To	Text
0208:43	BBA	KG 1	BRAVO BRAVO ALPHA any traffic ah amended two one zero
0208:49	KG 1	BBA	BRAVO BRAVO ALPHA no traffic
0208:51	BBA	KG 1	roger climbing amended two one zero
0208:57	KG 1	BBA	BRAVO BRAVO ALPHA
0209:00	BBA	KG 1	some big clouds out here

//More non relevant radio traffic//

Time	From	To	Text
0217:43	KG 2	RFDS	Flight Service KAL
0217:44	RFDS	KG 2	Flight Service
0217:46	KG 2	RFDS	yeah
0217:47	RFDS	KG 2	Flying Doctor Base
0217:48	KG 2	RFDS	yeah John
0217:49	RFDS	KG 2	right just had a report of an aircraft crash
0217:50	KG 2	RFDS	go ahead
0217:51	RFDS	KG 2	fifteen miles west of Sturt Meadows Station
0217:55	KG 2	RFDS	yep
0217:56	RFDS	KG 2	I cannot read the fellow he's very weak he reckons that a twin engined aircraft I think he said the colour was blue // KG 1 COMMENCED CALLING BBA //
0218:02	KG 1	BBA	BRAVO BRAVO ALPHA have you passed abeam Leonora
0218:04	RFDS	KG 2	// CONTINUATION OF 0217:56 EXCHANGE // and I believe he said that the aircraft had gone into a steep dive
0218:12	KG 2	RFDS	yeah yeah
0218:15	RFDS	KG 2	and he does not feel there would be any survivors. he is not on the scene he is going to the scene now
0218:22	KG 1	BBA	BRAVO BRAVO ALPHA Kalgoorlie
0218:25	RFDS	KG 2	now his signal is about strength less than strength one
0218:30	KG 2	RFDS	yeah
0218:31	RFDS	KG 2	I really can't you know absolutely confirm what he has said but I believe and said 'roger' that that is the situation
0218:37	KG 2	RFDS	ok John ahm I'll get back to you in about ok as soon as I have been onto the soc and our guys I will get straight back to you
0218:38	KG 1	BBA	BRAVO BRAVO ALPHA Kalgoorlie
0218:42	RFDS	KG 2	no problem
0218:43	KG 2	RFDS	thanks ta ta
0219:09	KG 1	BBA	BRAVO BRAVO ALPHA BRAVO BRAVO ALPHA Kalgoorlie

Time	From	To	Text
0219:36	KG 1	BBA	BRAVO BRAVO ALPHA BRAVO BRAVO ALPHA Kalgoorlie
0220:00	KG 1	BBA	BRAVO BRAVO ALPHA BRAVO BRAVO ALPHA Kalgoorlie

APPENDIX 2

TRANSCRIPT OF RECORDED COMMUNICATIONS

Concerning MITSUBISHI MU-2 Aircraft VH-MUA
during the period
9001251541 to 9001251718 UTC

LEGEND

MUA – Mitsubishi MU-2 aircraft: VH-MUA
ECH – Mooney M20-J aircraft: VH-ECH
MWJ – Beech B70 aircraft:VH-MWJ
FS – Flight Service (Perth)
ADC – Aerodrome Controller (Perth)
Sector – Sector Controller (Perth)

SYMBOL DECODE

? – Unidentified source
(—) – Unintelligible word(s)
// // – Explanatory note or editorial insertion
( ) – Word(s) open to other interpretation
* – Expletive deleted
.... – Significant pause (one dot per second)

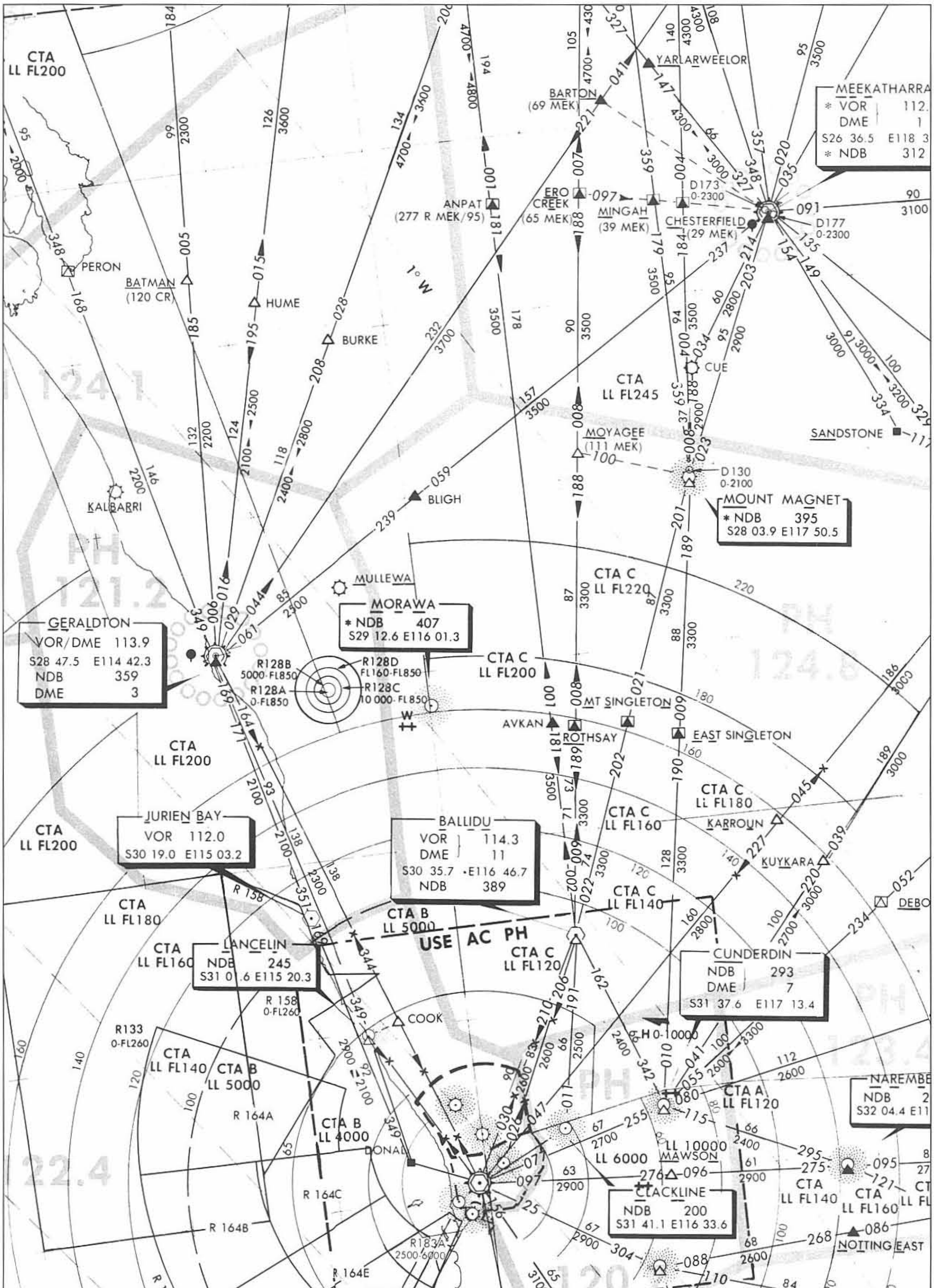
Time	From	To	Text
1541:15	FS	ADC	speak to me
1541:16	ADC	FS	yes departure MIKE UNIFORM ALPHA Perth for Hedland at three niner
1541:18	FS	ADC	roger
1603:46	FS	ADC	go ahead
1603:48	ADC	FS	position is MIKE UNIFORM ALPHA was Ballidu zero three flight level one seven zero Mount Singleton one six

Time	From	To	Text
1603:58	SECTOR	FS	MIKE UNIFORM ALPHA
1604:40	FS	SECTOR	go ahead
1604:41	SECTOR	FS	change of level MIKE (.....) MIKE UNIFORM ALPHA
1604:44	SECTOR	FS	change of level one seven zero
1604:44	SECTOR	FS	correction flight level one niner zero
1604:50	FS	SECTOR	one nine zero
1604:50	SECTOR	FS	he's at flight level one nine zero is he
1604:51	FS	SECTOR	roger thanks
1604:53	SECTOR	FS	on climb at
1604:54	FS	SECTOR	roger
1616:52	???	???	Perth (seven)
1616:53	SECTOR	FS	(revised) estimate UA Mount Singleton one niner
1616:54	FS	SECTOR	MIKE UNIFORM ALPHA
1621:12 to :23	MUA	FS	Perth MIKE UNIFORM ALPHA good evening we're Mt Singleton at two zero maintaining flight level one nine zero and Magnet at three nine
1621:26	FS	MUA	MIKE UNIFORM ALPHA good evening
1640:03	MUA	FS	Perth MIKE UNIFORM ALPHA was Magnet four zero maintaining flight level one nine zero Meeka on the hour and do you have any traffic at flight level two one zero
1640:17	FS	MUA	MIKE UNIFORM ALPHA no traffic
1640:21	MUA	FS	MIKE UNIFORM ALPHA is climbing to flight level two one zero
1640:25	FS	MUA	MIKE UNIFORM ALPHA
1645:13	FS	MUA	MIKE UNIFORM ALPHA contact one two two decimal six
1645:17	MUA	FS	MIKE UNIFORM ALPHA
1645:43	MUA	FS	Perth MIKE UNIFORM ALPHA'S maintaining flight level one two zero
1645:48	FS	MUA	MIKE UNIFORM ALPHA
1703:09	MUA	FS	Perth this is MIKE UNIFORM ALPHA Meeka zero two maintaining flight level two one zero Mount Sandford three two

Time	From	To	Text
1703:21	FS	MUA	MIKE UNIFORM ALPHA
1704:09	MUA	FS	Perth MIKE UNiFORM ALPHA'S out of control going down
1704:14	FS	MUA	MIKE UNIFORM ALPHA
1704:39	MUA	FS	MIKE UNIFORM ALPHA we are in ice and we are spinning down through eight thousand
1705:02 to :08	ECH	FS	Perth um ECHO CHARLIE HOTEL we've just ah witnessed MIKE UNIFORM ALPHA crash
1705:11	FS	ECH	roger approximate position thanks
1705:13 to:22	ECH	FS	ah gee's six point two DME and we're right on the three three five zero radial
1705:23	FS	ECH	roger thanks
1705:43	MWJ	ECH	ECHO CHARLIE HOTEL this is MIKE WHISKY JULIET what is the weather situation out (like that) have your got any turbulence
1705:50 to :58	ECH	MWJ	no there's absolutely no turbulence ah there doesn't appear I can't see clouds so there may be some upper layer cloud
1706:01 to :04	MWJ	ECH	oh you didn't see him fly in or out of any thunder storms or anything
1706:05	ECH	MWJ	ah negative there is didn't appear to be any thunder storms at all now I I south of Meeka I flew though flew through some rain thats about light showers
1706:18	MWJ	ECH	roger
1706:19 to :26	FS	ECH	ECHO CHARLIE HOTEL ah from operations can you hold over the crash site thanks. did you actually see the aircraft go in
1706:26 to :34	ECH	FS	ECHO CHARLIE HOTEL oh roger we saw him spin in when he made that eight and a half ah foot call and we saw him go all the way down
1706:35	FS	ECH	roger thanks
1706:52 to :57	FS	ECH	and ECHO CHARLIE HOTEL when you get to the crash site if you could just confirm it was six point two DME three five zero radial
1706:59	ECH	FS	ECHO CHARLIE HOTEL roger
1710:06 to :16	ECH	FS	Perth ECHO CHARLIE HOTEL that position is on the ah three five five radial and its just about spot on six miles Meeka

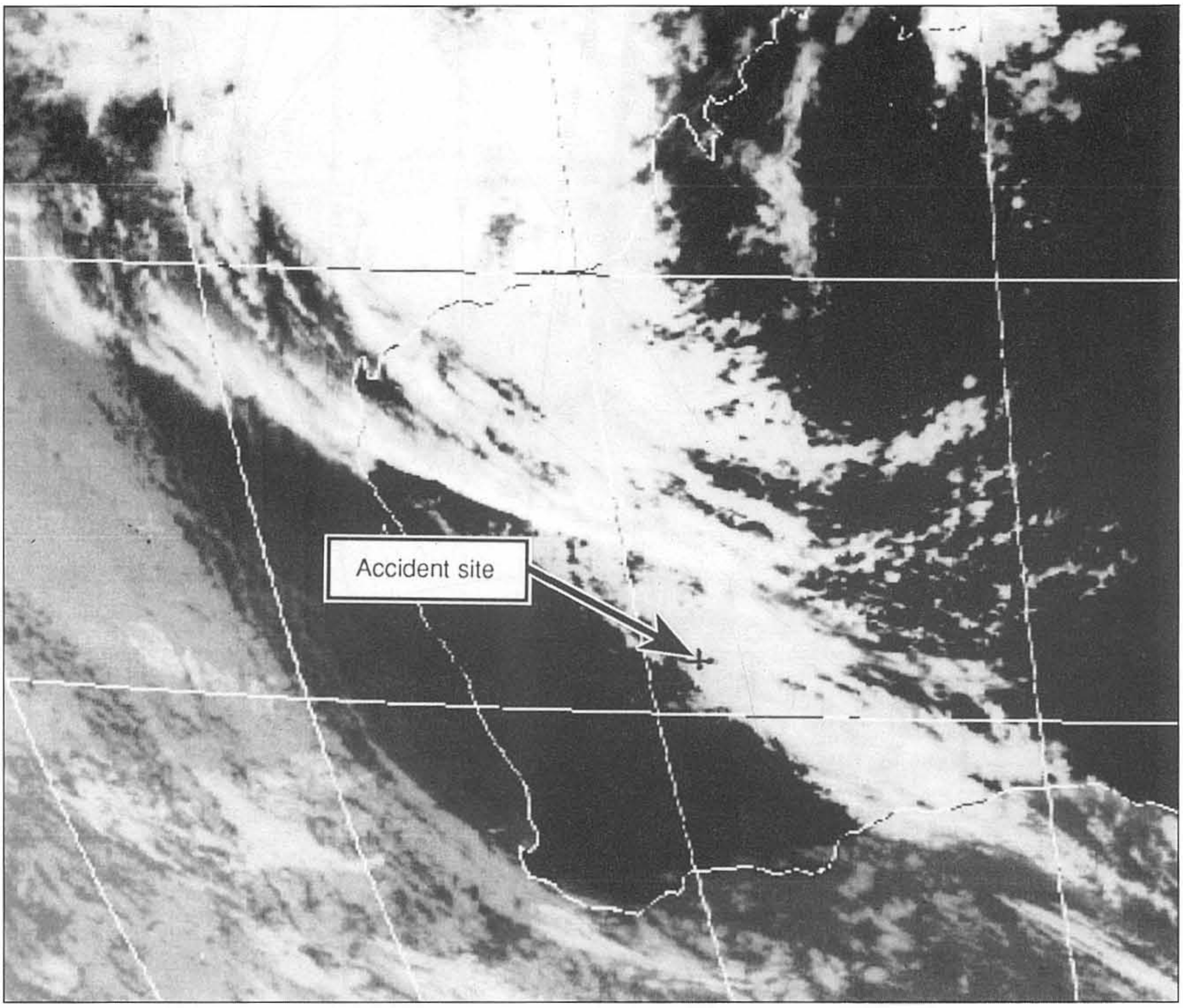
Time	From	To	Text
1710:18	FS	ECH	roger thankyou
1710:20	ECH	FS	and I'll be continuing on to Portland
1710:26 to :31	FS	ECH	ah ECHO CHARLIE HOTEL from Senior Operations Controller can you just stay in that position momentarily we will advise
1710:33	ECH	FS	ECHO CHARLIE HOTEL roger will do
1710:51	FS	ECH	ECHO CHARLIE HOTEL ah could you see any fire
1710:55	ECH	FS	affirm there's quite a big fire here
1711:08 to :11	FS	ECH	ECHO CHARLIE HOTEL request you hold your position call me again at time three zero
1711:13	ECH	FS	echo charlie hotel roger

APPENDIX 3

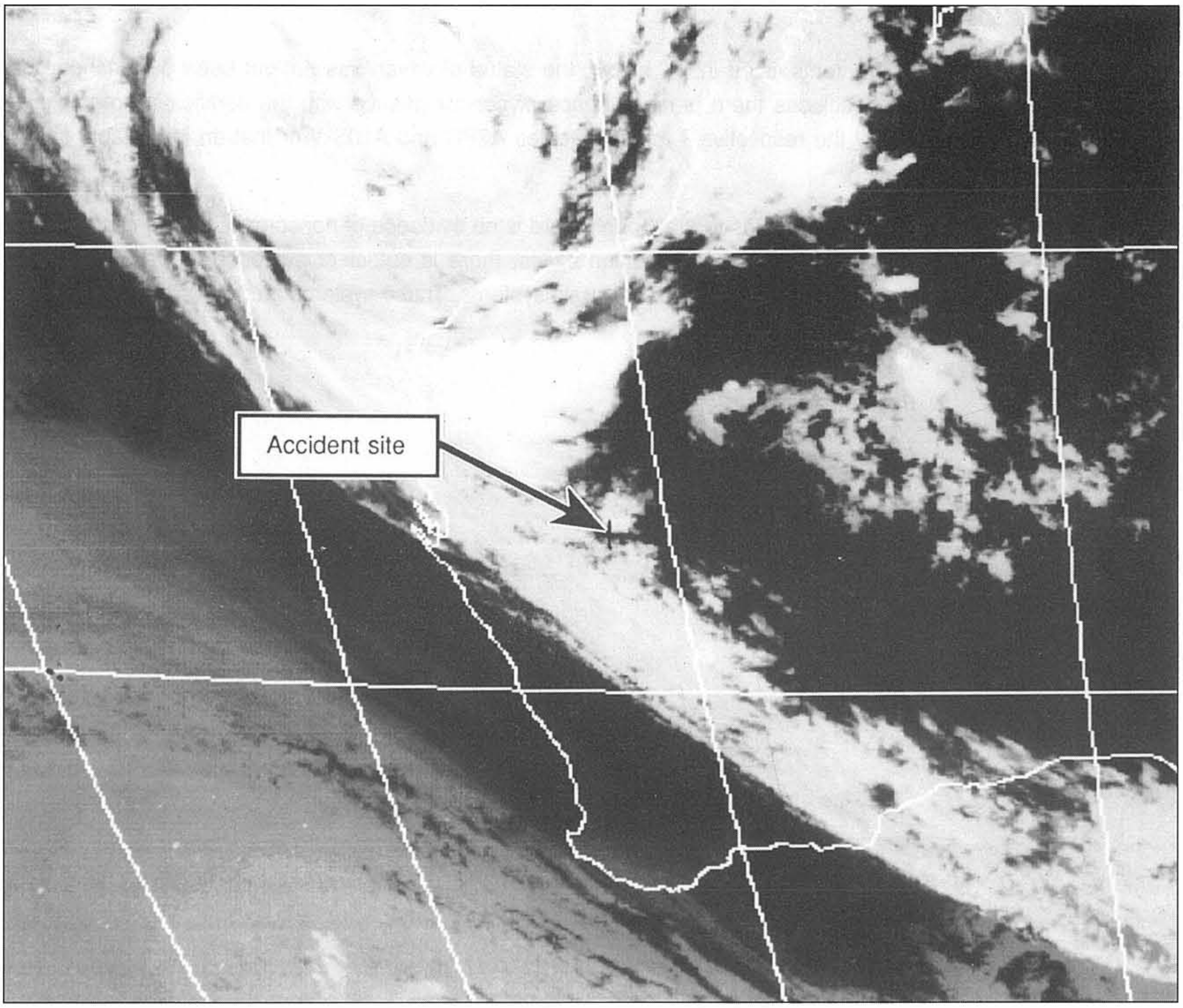


En route chart for Perth–Meekatharra

APPENDIX 4



Weather situation 45 min after the Leonora accident involving VH-BBA



Weather situation 2 hrs 5 min before the Meekatharra accident involving VH-MUA

APPENDIX 5

Extract from Special Certification Review, 28 March 1984:

Conclusions

A. Except for the items listed in "B" below, the status of which has not yet been determined, the SCR Team concludes there is no evidence of noncompliance with the certificating regulations established by the respective Type Certificates A2PC and A10SW or that an identifiable safety hazard exists.

B. The SCR Team concludes that although there is no evidence of noncompliance with certificating regulations or that an unsafe condition exists, there is sufficient evidence to warrant a more detailed review, analysis and tests of certain systems. These systems are:

1. Ice protection systems.
2. Pitot and static system.
3. Electrical system.
4. Environmental system turbine.

APPENDIX 6

The following is a copy of part of a telex sent throughout the CAA network, alerting the CAA regional offices to requirements for the MU-2 aircraft. The telexes were sent at 1757 Eastern Standard Time (EST) on 26 January 1990. The message read as follows:

Please pass urgently the following message to all MU-2 operators within yr (your) area.
Quote Until further notice the following operating limitations have been imposed on all MU-2 aircraft for all operations.

1. *Autopilot not to be engaged*
2. *two pilots endorsed on MU-2 required.*
3. *Pilot-in-command minimum experience – 2500 hrs total – 1000 hrs multi-engined – 500 hrs command or AICUS on MU-2 Unquote*

The message included a list of known MU-2 registrations and was signed by the Group General Manager (Safety Regulations) A.E.Higgen.

A correction to the above telex was distributed at 0906 EST on 27 January 1990. The correction read:-

Please pass urgently the following message to all MU-2 operators within yr area.

Quote Until further notice the following operating limitations have been imposed on all MU-2 aircraft for all operations.

1. *Autopilot not to be engaged.*
2. *Two pilots endorsed on MU-2 required.*
3. *Pilot-in-command minimum experience – 2500 hrs total – 1000 hrs multi-engined – 500 hrs command or AICUS on MU-2.*
4. *No operations in known icing conditions. Unquote.*

The message included the same list of known MU-2 registration numbers and was also signed by A.E.Higgen

APPENDIX 7

The following is a copy of an AD issued as part of the Schedule of Airworthiness Directives contained in Civil Aviation Orders, Part 105. It was issued as part of AL 7/90 and was effective from 16 May 1990.

The AD read as follows:

AD/MU-2/45 Amdt 3	OPERATIONAL RESTRICTIONS 7/90 DM
Applicable to Aircraft:	All MU-2 series aircraft.
Requirement:	The following Flight Manual statement is required. A copy of this message is required to be inserted into the Flight Manual at the appropriate pages until a formal approved amendment is issued through the responsible Field Office of the CAA.

1. Except when specifically exempted from the restriction by the specialist MU-2 Examiner of Airmen, Safety Regulation Group, the pilot in command shall not operate the aircraft in known or forecast icing conditions.

2. Except with the specific approval of the Assistant General Manager Operations Branch, Safety Regulation Group, the pilot in command shall have the following minimum experience:

   - 2500 hours total
   - 1000 hours multi-engine
   - 500 hours command of turbine powered aeroplanes of which 200 hours must have been accrued during the past two years.
   - 100 hours as PIC or AICUS of MU-2 aircraft.

Compliance:	Effective 16 May 1990.
Background:	This action has been taken as a precautionary measure following a number of accidents to the type in Australia and overseas. Amendment 2 removed the requirement for the auto-pilot not to be engaged, removed the requirement for a minimum crew of two pilots and varied the pilot experience requirements. Amendment 3 permits operation in known or forecast icing conditions subject to the approval of the Authority's specialist MU-2 Examiner.

APPENDIX 8

The following is a copy of CAA Flying Operations Instruction No. 13-4, Issue 1, dated 21 December 1990. This FOI superseded and updated all previous CAA operational requirements for the MU-2 aircraft type. The FOI reads as follows:

MITSUBISHI MU-2 – TRAINING AND CHECKING

CONTENTS

1 – DEFINITION

1.1 – In this instruction MU-2 means any model of the Mitsubishi MU-2.

2 – INTRODUCTION

2.1 – The MU-2 is a complex aeroplane with a high wing loading and an unusual control system. Although it can be operated safely in all weather conditions it requires a higher level of pilot training and recency than most other aeroplanes weighing less than 5700 kg.

3 – PILOT QUALIFICATION AND EXPERIENCE

3.1 – There are no special qualifications required to fly the MU-2.

3.2 – Operators are to be encouraged to select pilots with a total of 2000 hours minimum aeronautical experience and 500 hours minimum on multi-engined aeroplanes for endorsement training.

4 – PILOT ENDORSEMENT TRAINING AND EXAMINATIONS

4.1 – Endorsement training is to be carried out only by CAA approved pilots and operators in accordance with an approved course of ground and air training. Applicants for approval are to be assessed by the CAA MU-2 Type Specialist Examiner.

4.2 – The ground engineering course, including an approved examination, is to be a minimum of 20 hours duration.

4.3 – The flying course is to include a minimum of 5 hours dual instruction.

5 – REQUIREMENTS FOR AIRCRAFT CAPTAIN

5.1 – Endorsed pilots are to fly the following minimum hours AICUS before qualifying as captain on the MU-2:

(a) Pilots with less than 50 hours in command of turbine engined aeroplanes – 50 hours.

(b) Pilots with 50 hours or more in command flying turbine engined aeroplanes – 30 hours.

6 – PILOT CHECKING AND RECENCY

6.1 - To operate as pilot-in-command of MU-2 aircraft, pilots are required to have:

(a) within the last 6 months, satisfactorily complete a proficiency check in the MU-2 conducted by an approved pilot or organisation; and

(b) within the last 90 days, completed 1 hours flying and 3 landings in the MU-2.

7 - OPERATIONS MANUAL REQUIREMENTS

7.1 - Pilots and operators approved to conduct MU-2 endorsement training in accordance with this FOI are required to provide in their operations manuals:

(a) detailed syllabuses of ground and flight training; and

(b) guidance material for the 6-monthly proficiency check.

8 - REFERENCES / SPONSOR

8.1 - References : File F90/1482

8.2 - Sponsor: Manager, Flight Crew Licensing and Training, Operations Branch.

The FOI was distributed to the CAA Field Offices at the end of February 1991.

APPENDIX 9

1. SIMULATED ICING ENCOUNTER

An aircraft encountering icing suffers a loss in performance due to some or all of the following:

1. an increase in drag due to airflow disturbance;
2. an increase in weight;
3. a decrease in engine power when the de-icing equipment is operated;
4. an increase in wing and empennage drag if the de-icing boots are inflated;
5. a power loss due to combustion instabilities if excessive free moisture or ice is ingested; and
6. an increase in stall speed due to both weight increases and airflow disturbance.

There is no specific information available to quantify these effects on the MU-2 aircraft. Some references (particularly FAA Technical Report ADS-4 – Engineering Summary of Airframe Icing Technical Data) contain specific data useful to the designer in providing a satisfactory anti-icing or de-icing system. There is, however, only limited data on aircraft performance losses. Figure 1 (a copy of figure 3-29 from Report ADS-4) gives measured drag increases for a Russian IL-14 aircraft during a glaze icing encounter. The drag was measured for the de-icing system operating and not operating. The data is for a glaze ice of 1.38 inches on a standard indicator and is considered to represent a moderate to severe encounter.

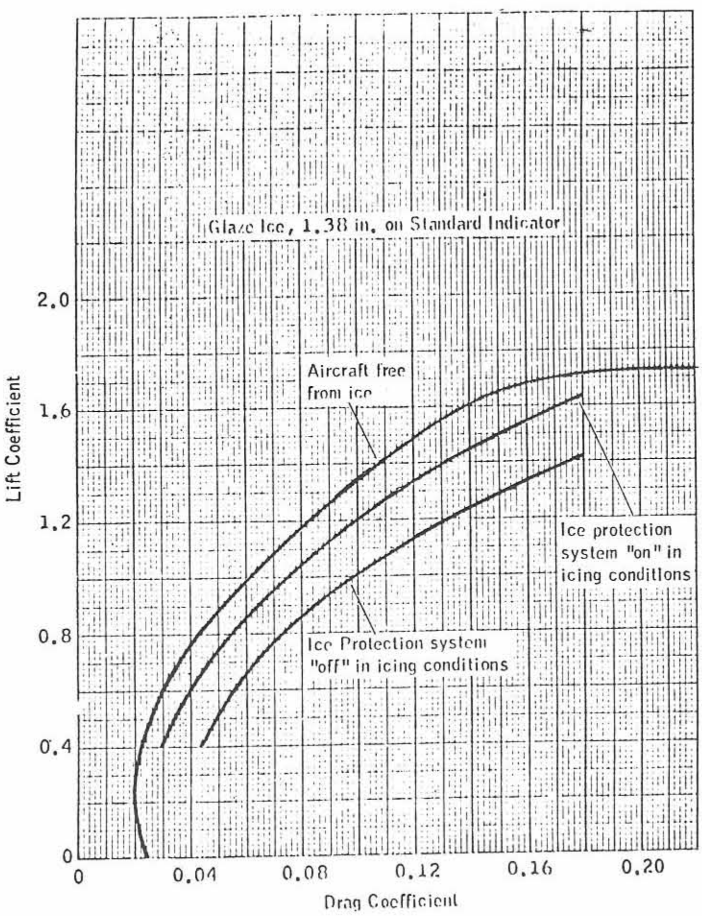


Figure 3-29. Drag Polars of USSR IL-14 During Glaze Ice Encounter (Ref. 3-17).

Figure 1

The IL-14 is a twin-engine aircraft similiar to a Douglas DC-3. It is an earlier technology aircraft than the MU-2, having piston engines and a lower wing loading, and, consequently, lower minimum drag and stall speeds. However, the trend of increasing drag as ice accumulates should be similiar. Given the lack of data specific to the MU-2 aircraft, the shape of the drag polar will be based on the IL-14 data.

2. DRAG POLAR WITH ICE

The drag coefficient (CD) provided by the manufacturer for the MU-2B-60 aircraft has the following form:

$$CD = CDo + KCL^2$$

where CD = total drag coefficient
CDo = zero lift drag coefficient
K = lift dependent drag parameter
CL = lift coefficient

Analysing the data of figure 1 according to this expression we obtain the following:

Table 1

	Derived coefficients		% increase	
	CDo	K	CDo	K
Clean aircraft	0.013	0.0484	–	–
Protection system on in icing	0.020	0.0575	54%	19%
Protection system off in icing	0.029	0.0740	123%	53%

The data in the table indicates that the increase in the zero-lift drag is far greater than the increase in the lift-dependent drag. The rates are:

De-ice 'on' in icing = 54/19 = 2.84
De-ice 'off' in icing = 23/53 = 2.32
mean = 2.58

The zero-lift drag increase is therefore approximately 2.5 times the lift dependent drag increase.

The drag coefficient, when simulating icing in the performance model, is therefore calculated as follows:

$CD = (1 + IF)\ CDo + (1 + IF/2.5)\ KCL^2$ where IF is an icing factor.

The icing factor will have values ranging from zero for a clean aircraft with de-icing systems off to 2.0 or even greater for severe icing with de-icing systems off. Comparing the result with the IL-14 data, we see that an icing factor of approximately 0.5 would represent the data for flight in icing with the de-icing systems on and 1.25 would represent the data for flight in moderate to severe icing with the de-icing systems off. Note that the IL-14 data represents glaze ice with 1.38 inches of ice on a standard indicator and is considered to be a moderate to severe icing encounter.

Since no two aircraft responses to icing will be identical, the way the drag increase is simulated in the performance model can only be treated as an approximation of the way the MU-2B-60 aircraft drag might increase.

3. OTHER FACTORS

The drag increase discussed in the preceding section is only one of the factors which degrade aircraft performance in icing conditions. Others are:

- weight increase;
- power lost to de-icing equipment;
- power loss due to combustion instabilities; and
- increase in stall speed.

Lack of data prevents consideration of these factors. The simulation of an icing encounter is therefore only to the first order, and takes into account only the most important factor, namely, the increase in drag. Actual aircraft performance may, therefore, be degraded more than is indicated by the model.

4. RESULTS

Constant-altitude encounters were simulated over the range of ISA to ISA+20°C from 14 000 to 24 000 ft. The initial aircraft weight was 11 500 lb and MCP (100% RPM 100% torque or 650°C ITT) was set. The speed at the commencement of each run was 170 kts equivalent air speed (EAS) and the speed was allowed to stabilise over 6 min. The computation was truncated if the speed approached the stall speed. In some cases the speed had not stabilised after 6 min but continued to decay slowly.

Four icing factors were used and these approximated the following conditions:

Table 2. Icing Factors

Icing factors	Approximate Simulation
0.0	Clean aircraft
0.3	Aircraft with residual ice
1.0	Moderate icing, de-icing systems OFF
2.0	Severe icing, de-icing systems OFF

Figures 1a to 1f show the aircraft accelerating (or decelerating) from 170 kts at MCP. The results indicate that the aircraft can only maintain altitude and a reasonable flying speed at very light icing conditions below about 18 000 ft. Under moderate (IF=1.0) or severe icing (IF=2.0) the speed decays, sometimes at alarmingly high rates. For example, a severe encounter (IF=2.0) could cause the speed to decay to the stall speed in about 1 min or less for all altitudes above 14 000 ft.

The speed at which the aircraft will stabilise in level flight and MCP is shown in figure 2. Note that no data is shown for IF=2.0. This is because the aircraft speed would not stabilise under any of the combinations of altitude and outside air temperature (OAT).

Even under moderate icing conditions (IF=1.0), a reasonable flying speed could only be maintained at temperatures close to ISA standard and relatively low altitudes of approximately 14 000 ft.

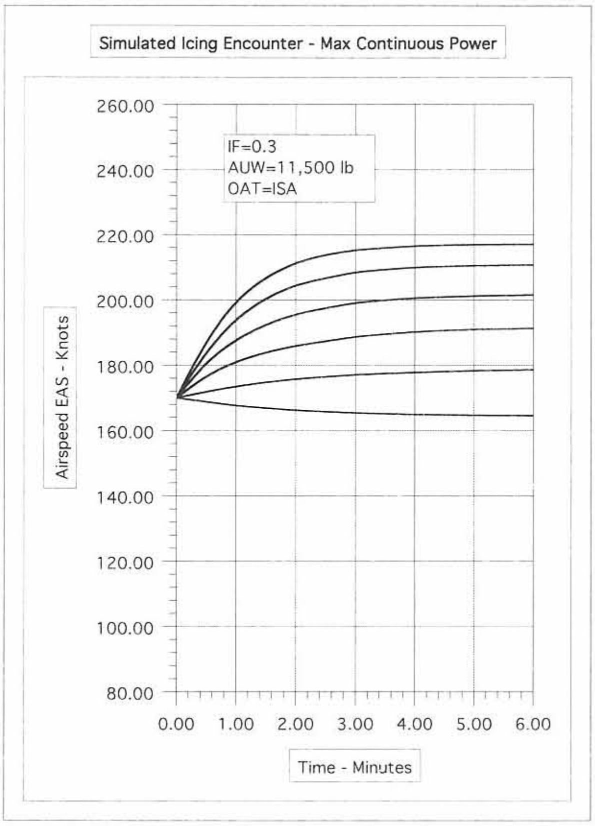


Figure 1a

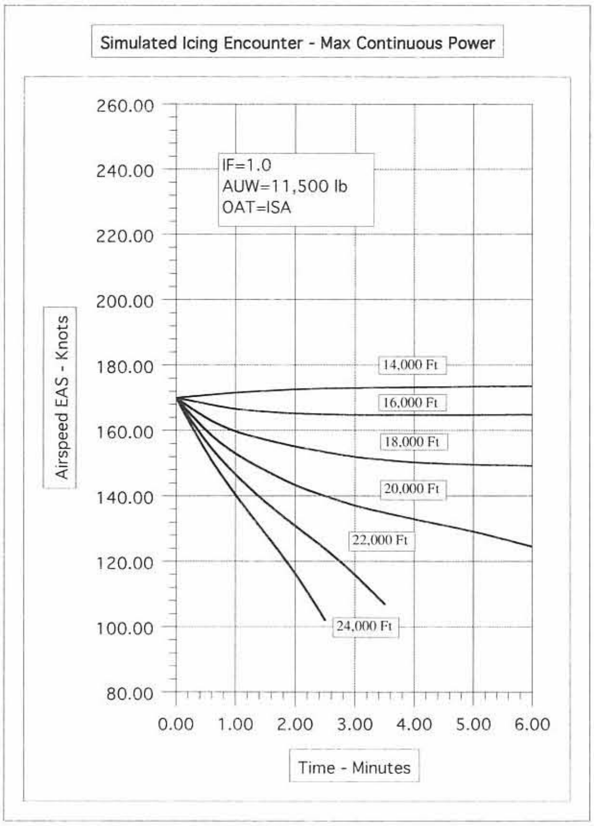


Figure 1b

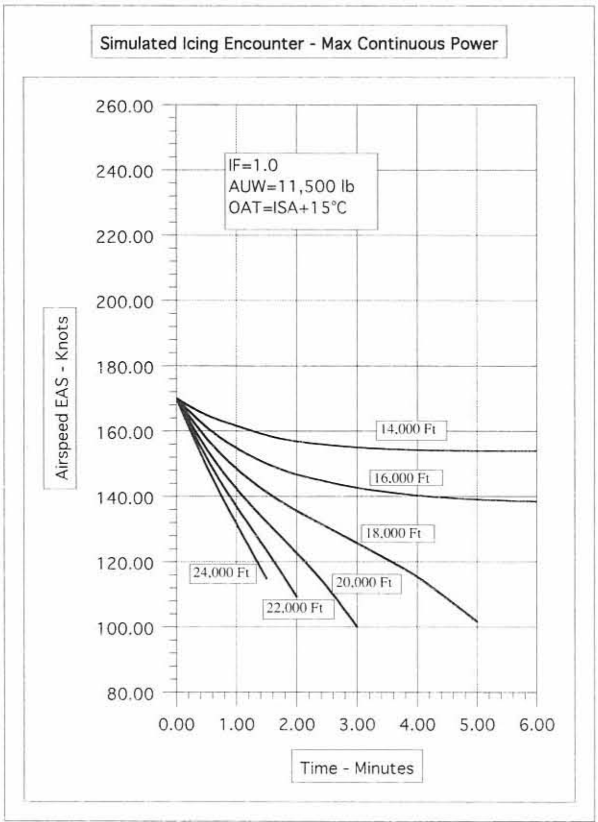


Figure 1c

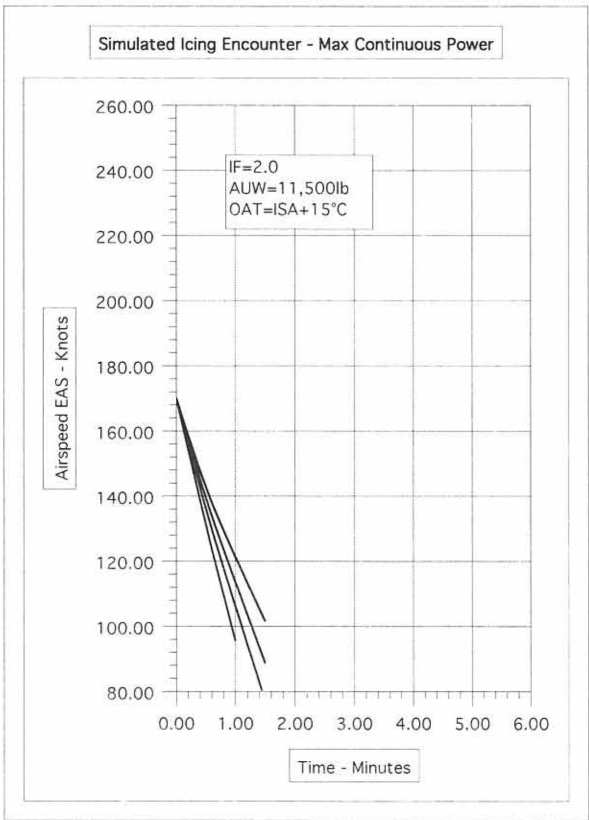


Figure 1d

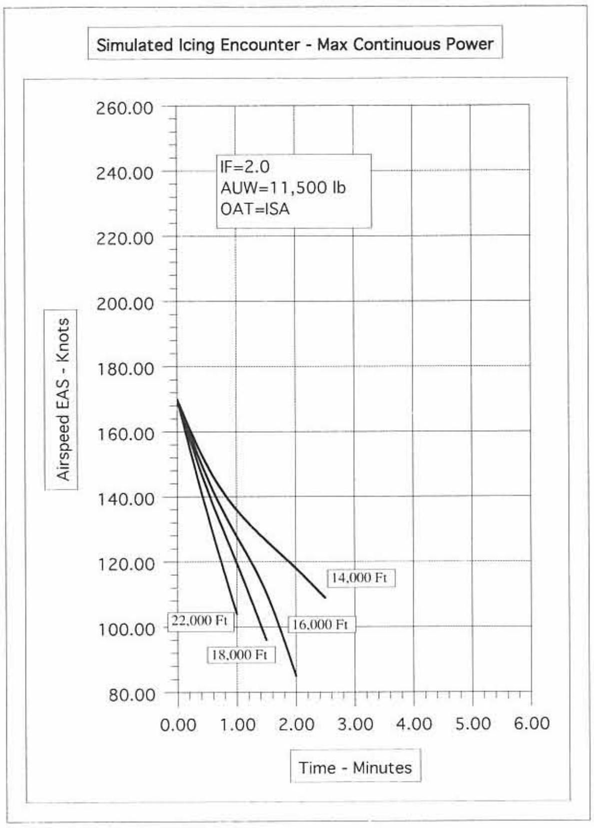


Figure 1e

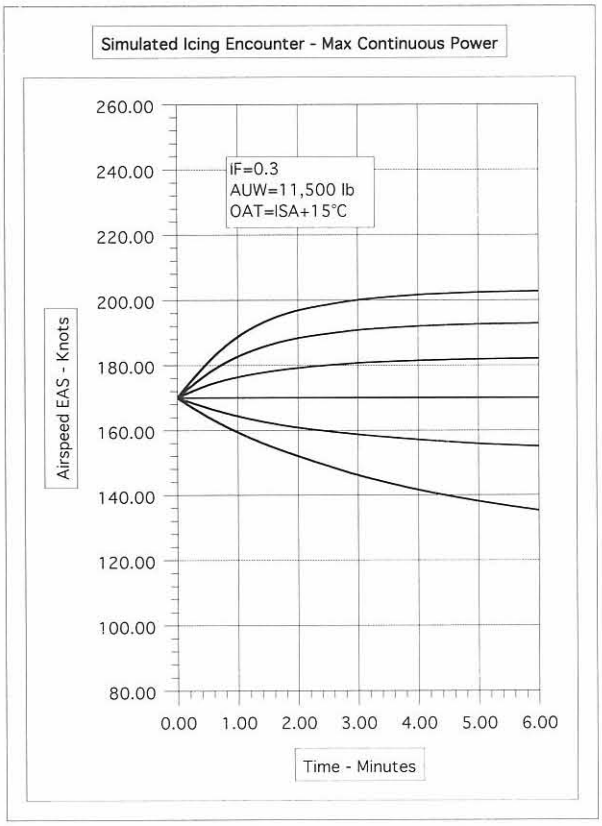


Figure 1f

Finally, figure 3 shows the rate of speed loss as the aircraft accelerates or decelerates through 170 kts EAS. The aircraft weight is 5216 kg and MCP is selected. Temperatures range from ISA to ISA+20°C and icing factors of 0.0, 1.0 and 2.0 are used. The data indicates that the clean aircraft performs quite well at all conditions except high altitudes and high temperatures. However, when icing (either moderate or severe) occurred, the rate of speed loss was very high. For example, at the altitude and temperature VH-MUA was operating (21 000 ft and ISA+12.5°C), decelerations are of the order of 40 kts/min for moderate icing (IF=1.0) and about 90–100 kts/min for severe icing (IF=2.0).

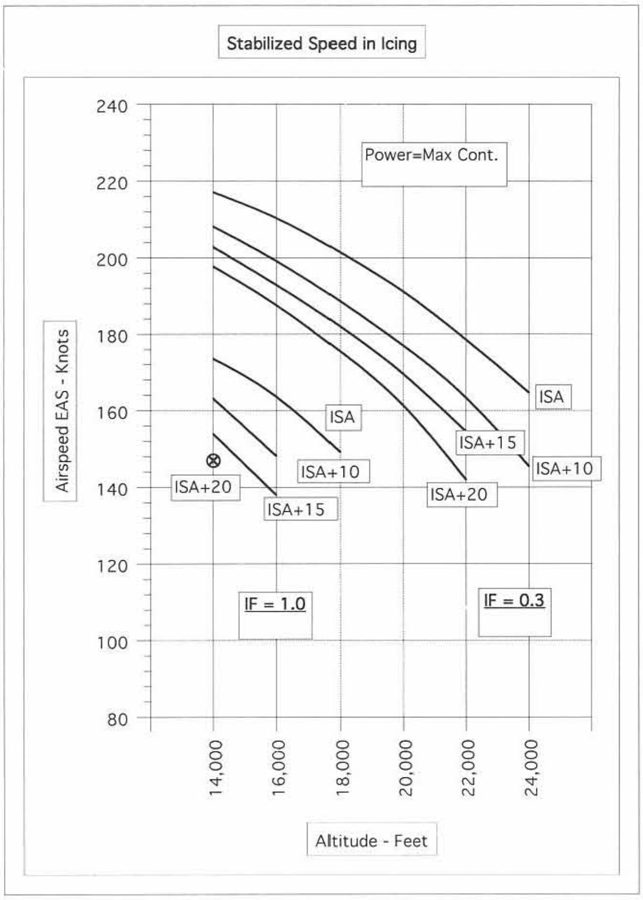


Figure 2

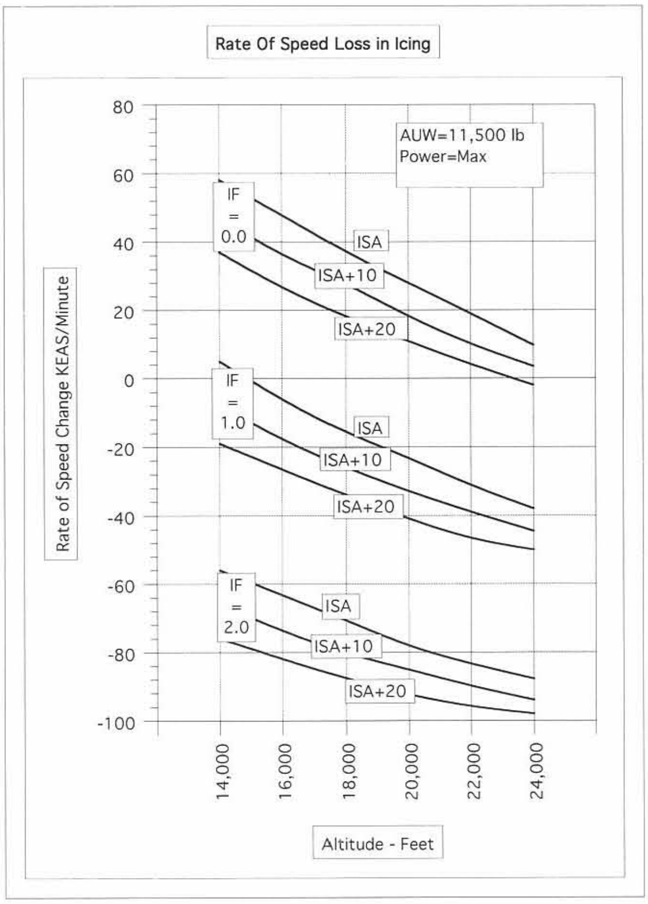


Figure 3

APPENDIX 10

The performance model was used to reproduce the sector times of VH-MUA immediately prior to the accident by simulation flight in icing conditions.

Icing Simulations for VH-MUA.

The following position reports were made from VH-MUA:

– passed Mt Singleton at	1620 UTC
– passed Mt Magnet at	1640 UTC
– passed Meekatharra at	1702 UTC

Thus the first leg (Mt Singleton–Mt Magnet), a distance of 87 nm, took 20 min and the second leg (Mt Magnet–Meekatharra) (95 nm) took 22 min. For the first leg the aircraft maintained its cruise altitude of 19 000 ft. However, for the second leg, a climb to 21 000 ft was made shortly after leaving Mt Magnet. Temperatures averaged ISA+12.5°C and the winds were 330/15, giving a headwind component of about 10 kts. The estimated AUW at the start of each leg was:

Mt Singleton – Mt Magnet:	11 494 lb
Mt Magnet – Meekatharra:	11 294 lb

All these conditions were simulated on the model. Further, 3 different engine power settings were used as follows:

recommended cruise	96% RPM and 100% torque or 650°C ITT
maximum cruise	98% RPM and 100% torque or 650°C ITT
maximum continuous	100% RPM and 100% torque or 650°C ITT

Each simulation was commenced at a cruise speed consistent with no icing and the engine power selected for that simulation. However, for the climb after Mt Magnet MCP was used in all cases.

Results:

The results are tabled below. Two approaches were adopted.

(i) A small fixed amount of icing was simulated over the cruise part of the leg, i.e. for the complete first leg and for the second leg after top of climb (TOC) was reached.

(ii) An icing factor (IF) of 0.5 was simulated for increasing time periods. In all cases the icing was applied towards the end of the leg. An IF of 0.5 was chosen because it approximated flight in icing with de-icing systems operating. Derivation of the IFs and their significance is contained in appendix 9.

Table 1. Icing simulation Mt Singleton–Mt Magnet (19 000 ft). Time reported by VH-MUA: 20 min.

RPM %	Start speed KEAS	Start of icing min:sec	Icing factor	Total time min:sec	Time in icing min:sec	Finish* speed KEAS
96	194	N.A	Nil	19:27	Nil	194.8
96	194	0:00	0.05	19:54	19:54	190.0
96	194	0:00	0.10	20:21	20:21	185.4
98	198	N.A	Nil	19:05	Nil	198.2
98	198	0:00	0.05	19:30	19:30	193.6
98	198	0:00	0.10	19:56	19:56	189.2
100	207	N.A	Nil	18:10	Nil	208.3
100	207	0:00	0.15	19:27	19:27	193.6
100	207	0:00	0.20	19:52	19:52	189.2
100	207	0:00	0.25	20:22	20:22	184.1
96	194	17:00	0.50	19:46	2:46	158.6
96	194	15:00	0.50	20:19	5:19	151.5
98	198	17:00	0.50	19:20	2:20	165.2
98	198	15:00	0.50	19:49	4:49	159.0
98	198	13:00	0.50	20:19	6:19	158.0
100	207	17:00	0.50	18:16	1:16	183.2
100	207	15:00	0.50	18:42	3:42	167.1
100	207	13:00	0.50	19:13	6:13	163.1
100	207	11:00	0.50	19:46	8:46	162.4
100	207	9:00	0.50	20:22	11:22	162.2

Table 2. Simulation Mt Magnet–Meekatharra (21 000 ft). Time reported by VH-MUA: 22 min.

RPM %	Start speed KEAS	Start of icing min:sec	Icing factor	Total time min:sec	Time in icing min:sec	Finish* speed KEAS
96	194	NA	Nil	21:45	Nil	187.2
96	194	3:05 (TOC)	0.05	22:12	19:07	182.4
96	194	3:05 (TOC)	0.10	22:40	19:35	177.7
98	198	NA	Nil	21:24	Nil	190.6
98	198	2:55 (TOC)	0.05	21:48	18:53	186.0
98	198	2:55 (TOC)	0.10	22:14	19:19	181.6
100	207	NA	Nil	20:33	Nil	199.6
100	207	2:35 (TOC)	0.10	21:26	18:51	189.4
100	207	2:35 (TOC)	0.15	21:54	18:19	184.7
96	194	20:00	0.50	21:59	1:59	155.7
98	198	21:00	0.50	21:25	0:25	179.5
98	198	20:00	0.50	21:31	1:31	163.0
98	198	19:00	0.50	21:44	2:44	155.2
98	198	18:00	0.50	22:00	4:00	151.7
100	207	19:00	0.50	20:43	1:43	167.8
100	207	17:00	0.50	21:13	4:13	155.5
100	207	15:00	0.50	21:50	6:50	151.9
100	207	14:00	0.50	22:10	8:10	151.5

*In some cases where the time in the simulated icing was short, the speed was still decreasing and had not stabilised at the end of the leg.

Discussion

Tables 1 and 2 show that only a small amount of ice is required to achieve the recorded times between the reported positions if the IF is applied for the complete leg. However, in these simulations, the speed at the end of the leg is comparatively high (180–190 kts EAS), and a low-speed control loss is unlikely. Therefore, the aircraft probably encountered intermittent icing.

In the second series of simulations, using an IF of 0.5 for part of the leg, the speed decreased rapidly and stabilised at about 150–160 kts EAS for MCP (slower for the lower power settings). If the aircraft stall speed is also raised by the ice, then this speed may not provide an adequate margin for maneouvres, such as normal turns, to be safely accomplished.

Note that an IF of 0.5 probably represents the aircraft in moderate icing with de-icing systems in use.

APPENDIX 11

Accidents examined during investigation process

1. N233MA, MU-2B-25, 2 September 1981, near McLeod, Texas USA. The aircraft had been level at FL 210 for approximately 10 min and had just begun a climb to FL 230. The aircraft had reached FL 212 before it descended. In 31 seconds it had descended to 1900 ft, where radar contact was lost. The aircraft was seen in a spin prior to impact. Moderate ice was forecast over the aircraft's planned route but the pilot was not briefed about it.

2. N3ED, MU-2B-10, 6 September 1981, near Riverton, Wyoming USA. The aircraft had departed on an IFR flight plan when it disappeared from radar approximately 20 min after take-off at an altitude of 14000 ft. It was determined that there was icing in the area during this flight and that the pilot had accepted the aircraft for the flight with known unserviceabilities of the wing boots, propeller boots and windscreen de-icing systems.

3. N750MA, MU-2B-40, 19 November 1981, near Jacksonville, Florida USA. Approximately 25 min after the aircraft departed on a VFR training flight, it was seen in a descending right turn. Radio queries of the aircraft as to its present altitude were not answered. The aircraft crashed into the water and was destroyed.

4. N72B, MU-2B-60, 24 March 1983, near Jeffersonville, Georgia USA. The aircraft cruised at FL 180 and was cleared to descend to FL 110. No acknowledgement was received and shortly thereafter, the radar target disappeared from the screen. Light rime ice was reported as having been present between 10000 ft and FL 220 in clouds. The SCR was initiated as a result of the recommendation from this accident investigation.

5. VH-MLU, MU-2B-60, 24 May 1983, near Bargo, New South Wales. The aircraft climbed on track at an average rate of 1300 ft/min until FL 130. The rate of climb increased to 1800 ft/min. At FL 160 the aircraft entered a near-vertical descent and radar contact was lost 1 min later at 3100 ft. The aircraft impacted the ground in a near-vertical attitude.

6. N513DC, MU-2B-60, 5 March 1986, near Eola, Illinois USA. The aircraft was flying on the fifth of 6 planned flight legs. The aircraft was to fly 30 nm at 4000 ft. After take-off on this fifth leg, the aircraft was given a number of vectors to fly by ATC. Approximately 5 min after the last heading change, the pilot reported that he was descending in an uncontrollable spin. The freezing level was 1100 ft and icing was reported in the area.

7. N8CC, MU-2B-35, 2 June 1986, at Bartlett, Texas USA. The pilot was on an IFR flight plan; however, VFR conditions prevailed. The pilot reported level at 9000 ft and shortly thereafter reported that his autopilot was stuck in the descent mode and he could not disconnect it. He also reported a 6000 ft/min rate of descent. The aircraft impacted the terrain in a 45° nose-down and inverted attitude.

8. N184MA, MU-2B-??, 18 June 1987, near Coral Springs, Florida USA. The aircraft departed without a filed flight plan and the wreckage was discovered early next morning. No further details were available.

9. F-GERA, MU-2B-36A, 16 April 1988, Saint-Just-Saint Rambert, France. The pilot had filed an IFR plan and approximately 8 min after the pilot had acknowledged a clearance to continue climbing to FL 170, the ATC noticed that the radar target had disappeared from the screen. The freezing level was at 8500 ft and other aircraft from the same area reported light icing.

10. VH-BBA, MU-2B-60, 16 December 1988, near Leonora, Western Australia. Aircraft was seen to impact the ground in a left turn, with an extreme nose-down attitude. The last radio report indicated that the pilot intended to climb above his flight-planned level to an amended level of FL 210. Large clouds were in the area and were reported by the pilot. The conditions were conducive to the formation of airframe icing. (See chapter 1 for more details.)

11. VH-MUA, MU-2B-60, 26 January 1990, near Meekatharra, Western Australia. Aircraft was seen in a spin which continued to ground impact. The pilot reported that he was in ice and was spinning down through 8000 ft in his last radio communication. Conditions on the sector prior to the loss of control were assessed as being conducive to ice formation. (See chapter 2 for more details.)

12. N300CW, MU-2B-60, 14 February 1990, near Putnam, Texas USA. The aircraft was in cruise at FL 150 and the pilot requested a descent to FL 130. ATC was unable to clear the aircraft to that level due to conflicting traffic, and instead cleared it to FL 140. The clearance was not acknowledged and no further radio transmissions were received. Radar contact was lost at FL 148. Instrument meteorological conditions prevailed and an IFR flight plan had been filed. The aircraft was destroyed by impact and post-impact fire.

Information contained in numbers 1–4, 6–8 and 12 above was extracted from reports supplied by the NTSB. Requests for a further seven reports from the NTSB were not granted.